Milk Supply Response in California: Effects of Profitability Variables and Regional Characteristics

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This article discusses supply response for milk in California with the emphasis on the impact of profitability of milk production. Profitability variables are specified as profit margin per cow due to the availability of cost of production data. California production is disaggregated into five regional response equations for market (Grade A) milk and an equation for manufacturing milk (Grade B). Econometric results for larger, more specialized dairies indicate very inelastic responses and long production lags. Results for smaller, less specialized dairies indicate elastic responses and somewhat shorter lags.

An important factor in formulating dairy policy is the reaction of producers to changes in the profitability of producing milk. Although considerable knowledge is available on the topic, many questions remain concerning the magnitude and the timing of the response. This article considers milk supply response in California with emphasis on the response to changes in the profitability of producing milk. The use of California data has two advantages which provide a unique opportunity to investigate the profitability question. First and most important, costs of production data are available; second, the distribution of size and type of dairies is predominately regional, facilitating the comparison of response by size and type of dairy operation.

Previous studies have used single and multi-equation specifications to measure milk supply response. Single equation estimates have been obtained by Halvorson, Wipf and Houck, and Hammond using the partial adjustment hypothesis and by Chen, Courtney and Schmitz using the Almon polynomial lag. Zepp and McAlexander, Wilson and Thompson, and Prato have simultaneously estimated production per cow and cow numbers. Building upon simple accounting equations outlined by Frick and Henry, Elterich and Johnson, Jackson, and Hallberg have estimated recursive models of the milk producing sector based on biological as well as economic considerations. In all of these studies the profitability of producing milk has been specified by separate variables for milk price and feed prices or by milk price divided by a feed price variable. All studies except Chen, Courtney and Schmitz used annual data.

In this study, bimonthly (six per year) observations for 1958-1973 are used to obtain single equation estimates of milk supply response for six California regions.[1] The availability of cost of production data and the large number of observations facilitate the specification of return over variable costs as the measure of profitability and a detailed analysis of the lagged response to profitability of milk production. In addition the disaggregation of production makes possible a comparison of the response to profitability among the distinct regions and between California market (Grade A) and manufacturing (Grade B) producers.[2]

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[1]The bimonthly time period was selected to be consistent with the data collected and used by the State of California.

[2]The results in this article are part of an econometric

Model Specification

Regional Production Areas

Although milk is produced in all parts of California, production is centered near the large metropolitan areas of Los Angeles and San Francisco and in the Central Valley. In this study production is separated into market (Grade A) milk production in five regions and statewide manufacturing (Grade B) milk production. Market milk dairies in the Southern California, the Southern San Joaquin Valley, and the Northern San Joaquin and Sacramento Valley regions are typically large, with hundreds and even thousands of cows per dairy, and specialized with many dairies purchasing nearly all feed inputs and replacements. Dairies in the Southern California region are typically the largest and most specialized. Both total production and average farm size are increasing most rapidly in the Southern San Joaquin Valley Region.

Market milk dairies in Mountain Areas and North Coast and manufacturing milk dairies are much smaller and less specialized; these dairies are not too different from dairy farms in other major U. S. milk producing areas, such as the Northeast and the Lake States. Market milk producers in the Central Coast region are a mixture of the two extremes just mentioned. In this region the movement and dispersal of dairies due to urban expansion are important factors.[3]

model of the California dairy industry developed to provide the California Director of Food and Agriculture and other decision-makers additional economic input in establishing the price that distributors pay milk producers. In addition to the supply response equations, estimates are obtained for manufacturing milk price, marketing margins, and consumer demand. Simulations to 1985 are performed (Milligan 1975 and 1978).

[3]The Mountains and North Coast region now produces less than one percent of the market milk in California. South San Joaquin Valley and North San Joaquin and Sacramento Valleys are regions of increasing production. Manufacturing milk production has been decreasing; it now is less than ten percent of California milk production.

Factors Affecting Milk Supply Response

Even though the emphasis of this article is on profitability variables, other variables that influence the quantity of milk produced must be included in the estimating equations. Factors other than profitability fall into three categories: (a) economic forces that represent the profitability of the viable alternatives available to dairymen, (b) forces affecting the gradual improvement in technology, management, and genetic ability that characterize milk production, and (c) seasonality of milk production. Three variables are specified to represent alternatives to producing milk: (1) beef price, (2) index of land prices in California, and (3) an interest rate lagged two years. The percentage of cows on DHI test is included to reflect improvement in management; a time variable is included to capture trends reflecting the gradual improvement in management, technology, and genetic ability. Seasonality of milk production is specified by dummy variables for all but the January-February period.

Profitability Variables

In the five market milk equations, the profitability measure specified is short-run profit margin per cow, specified as milk price minus variable costs per hundredweight multiplied by production per cow.[4] This specification is used for two reasons. First, a profitability measure reflects the return to dairymen net of variable costs and likely is a stronger determinant of supply response than is milk price alone. Moreover, a profitability measure implies that input substitutions due to price changes have already occurred. For most of the studies mentioned above, a profitability specification was not a viable alternative due to absence of cost of production data. The second reason is that the separate specification of variables for prices received and costs of production gave inferior econometric

[4]Variable costs include feed, marketing, labor, and operating expenses. Fixed costs are not included due to data limitations and the difficulties encountered in deriving fixed cost per hundredweight.

results, including frequent occurrence of incorrect signs. Although this result is surprising from a theoretical viewpoint and somewhat inconsistent with results reported in the literature (although Hammond discarded all feed cost variables), the problem may relate to State milk control procedures since these same cost of production figures are employed as a basis for determining class 1 prices. Consequently, a causation problem is created, and the ambiguous results may be the consequence.

Margin per cow rather than per hundredweight of milk is used since limits on dairy capacities and most management decisions utilize the cow as the unit of measurement. In the manufacturing milk equation the forces affecting profitability are specified by including variables for milk price received and the price of corn because a cost of production data series is unavailable.

Due to the long production cycle of the dairy cow and the large fixed investments required for dairy systems, current production levels are a response to profitability for several previous years. Although little guidance is provided by the literature for selecting a lag structure on margin per cow with bimonthly observations, it is known that dairymen execute three types of responses to alterations in the margin they are receiving: a short-run response, a long-run response, and a decision to dispose of the herd. Adjustments in feeding levels and culling rates affect production for a period of one to two years. Decisions to increase capacity are not reflected in production for two or more years due to delays in choosing milking, feeding, and housing systems, in construction of new facilities, and in acquiring replacements. The disposal decision has both short-run and long-run impacts but is infrequent in California.

In developing a lag structure, it was expected that these responses would affect aggregate production differently in areas with specialized dairies (market milk equations for Southern California and the Valley regions), than in areas with smaller, more diversified dairies. Southern California dairies and market milk dairies in the Central Valley seldom are liquidated, and feeding and culling adjustments are minor because the degree of specialization dictates that the dairies are run at or near full capacity. In fact, many authorities in the dairy industry argue that some producers feel they must generate an approximately constant income stream to meet fixed costs and debt payments. This course of action by some producers results in a weak aggregate short-run response that may even be the opposite of what an economist would expect. Consequently, in the specialized dairy areas of California most of the response to profitability could be in the third and fourth lagged year. In the less specialized areas, response was hypothesized to be stronger and to occur sooner due to more exits from the industry and short-run responses facilitated by diversification.

Final Form of the Regional Supply Equations

The equation for each market milk region is specified as follows:[5]

$$(1)\quad q_t^{aj} = f(m_n^{aj}, m_{n-1}^{aj}, m_{n-2}^{aj}, m_{n-3}^{aj}, p_{tt}^{r}, p_{tt}^{bf}, p_{tt-2}^{i}, dhi_{tt}, TM, S_t^1, S_t^2, S_t^3, S_t^4, S_t^5, u_t^j)$$

where q^{aj} = Daily hundredweight of market milk production in region j, where j = 1: Southern California, 2: South San Joaquin Valley, 3: North San Joaquin and Sacramento Valleys, 4: Central Coast, and 5: Mountain Areas and North Coast; t = The bimonthly observation; tt = The simple average of bimonthly observations t through t−5; tt−2 = The simple average of bimonthly observations t−12 through t−17 (two years ago); n−i, (i= 0, 1, 2, 3) = The average value of the variable lagged 1, 2, 3 and 4 years, calculated by averaging bimonthly observations t−1 −(6 * i) through t−6 −(6 * i); m^{aj} = Profit margin

[5]The major data source is California Crop and Livestock Reporting Service. References and all transformations for each variable are contained in Appendix A of Milligan 1978.

per cow for market milk in region j; p^r = Index of land prices in California; p^{bf} = Price per hundredweight received for beef in California; p^i = Interest rate in percent; dhi = Percent of all dairy cattle in California on DHI test; TM = Time trend: January-February 1961 = 1, 2, . . .; S^i = Dummy variables to measure seasonal effects; and u^j = Disturbance term for region j.

In the manufacturing milk equation (q^b_t), the margin variables are replaced by milk price (p^b_n, p^b_{n-1}, p^b_{n-2}) and the price of corn (p^{corn}_t).

Estimation Procedure

Each of the five market milk and the manufacturing milk equations was estimated by generalized least squares using the two step first-order autoregressive scheme suggested by Theil (p. 254). Due to the complexities of price determination, the actual price received is unknown to the producer for nearly two months. Consequently, the current period's price is not specified in the estimating equation and a single equation technique is appropriate. Generalized least squares is used because of autocorrelation resulting from the short time period. A second-order autoregressive scheme was tried with inferior results.

Several distributed lag schemes were investigated to specify the lagged effects of profitability. These effects were not approximated by any of several formulations of the partial adjustment hypothesis [Nerlove 1958a, 1958b] or the polynomial lag [Almon and Chen, Courtney, and Schmitz]. More significant and theoretically reasonable coefficients were obtained when the profitability variables were specified as the average profit margin per cow lagged one, two, three, and four years. Based on expected sign, significance, and explained variation, this specification was better than other lag specifications containing margin and price variables. The inclusion of milk price and input price variables rather than margin variables resulted in incorrect sign and low significance levels.

Multicollinearity was not an insurmountable problem because of the large number of observations and the relatively low correlation in the lagged time series for profit margin per cow. The correlations between the four margin time series were 0.6 to 0.7 whereas correlations between similar time series for price alone were 0.9 and above.

The Results

Each supply response equation contains a subset of the variables specified in equation (1). Some variables were excluded because they were not relevant to the region; others were deleted in the estimation process. Criteria used in eliminating variables include theoretical correctness of the signs, statistical significance, and expected importance in projecting the future direction of production. Profitability variables were deleted only when they had almost no significance, except in the Central Coast region where other specifications were less desirable theoretically than that in Table 1. It is recognized that this procedure limits the statistical relevance of the statistics presented in Table 1.

The elasticities derived from the coefficients on the profitability variables are summarized in Table 2. The margin elasticities are the percentage change in milk supply from a one percent change in short-run margin. Since even a small change in milk price or variable cost creates a large proportionate change in margin, the margin elasticities are very small. In order to provide a comparison with price elasticities, a measure of the percentage change in production from a margin change created by a one percent change in the milk price must be calculated. This measure is labeled "estimated" price elasticity and is obtained as follows. One percent of the price (average value or most recent value) is multiplied by the production per cow, divided by the average margin per cow, and converted to a percent to give the percentage change in margin created by a one percent change in price. This percentage is then multiplied by the margin elasticity to derive a value that can be compared with price elasticities.

TABLE 1. Regional Market Milk Supply Response Coefficients for California, 1961-1973

Dependent Variable	Constant	Coefficients for Predetermined Variables																	
		m_n^{aj}	m_{n-1}^{aj}	m_{n-2}^{aj}	m_{n-3}^{aj}	p_{tt}^{r}	p_{tt}^{bf}	p_{tt-2}^{i}	dhi_{tt}	TM	S_t^1	S_t^2	S_t^3	S_t^4	S_t^5	$\hat{\rho}$	D-W[b]	$\bar{R}^2$
q_t^{a1c}	101076		−45	227		−357	−115			387	2694	3372	617	389	−744	.53	1.31	.82
	(8.82)[a]		(−0.64)	(3.74)		(−2.50)	(−0.93)			(4.57)	(7.41)	(7.61)	(1.33)	(0.87)	(−1.99)			
q_t^{a2d}	53687		75	103	127	−579		−641	533	634	2723	5153	5380	3440	267	.50	1.29	.97
	(3.33)		(1.08)	(1.64)	(1.92)	(−4.05)		(−1.34)	(1.74)	(5.26)	(8.16)	(12.82)	(12.83)	(8.55)	(0.80)			
q_t^{a3d}	7651	−64	−122	295	239				759	142	3685	6595	6082	3089	−159	.51	1.10	.93
	(0.59)	(−0.68)	(−1.18)	(2.66)	(2.17)				(1.95)	(1.22)	(8.88)	(13.17)	(11.63)	(6.16)	(−0.38)			
q_t^{a4c}	28603	−54					−223		73	66	1519	1619	1092	410	−150	.62	1.21	.76
	(5.98)	(−1.91)					(−5.04)		(0.54)	(2.07)	(12.11)	(10.41)	(6.65)	(2.62)	(−1.16)			
q_t^{a5d}	2530	19		12	19		−51	−101	24		516	875	642	303	54	.54	1.20	.88
	(6.77)	(2.25)		(1.47)	(2.21)		(−4.04)	(−1.95)	(2.07)		(15.32)	(21.40)	(15.00)	(7.41)	(1.59)			
		p_n^b	p_{n-1}^b	p_{n-2}^b	p_{tt}^{corn}													
q_t^{bc}	73020	9416	10581	6533	−2598	−1465					6809	10781	9544	4105	597	.49	0.91	.89
	(16.68)	(3.20)	(3.43)	(2.24)	(−1.86)	(−14.06)					(11.59)	(15.20)	(12.89)	(5.76)	(0.99)			

[a]t-values are in parentheses. Since only large sample properties are applicable for generalized least squares, significance is determined by a standard normal table.

[b]At the one percent level of significance all D-W values except the 1.10 and the 0.91 are in the indeterminacy region.

[c]Transformed observations from March-April 1961 through November-December 1973 ($n = 77$) are used. The January-February 1961 observation is utilized for the autoregressive transformation and observations from 1958-1960 are used for the lagged variables.

[d]Transformed observations from January-February 1962 through November-December 1973 ($n = 72$) are used. Values for 1961 are used as lags since m_{n-3} is included. Rather than lose a degree of freedom from the autoregressive process, m_t for November-December 1957 is set equal to m_t for January-February 1958.

TABLE 2. Margin and Price Elasticities for Milk Produced in California.

Area of Production, Time Period, and Equation	Margin Elasticity: Mean Values	Margin Elasticity: Nov-Dec 1973 Values	Price Elasticity: Mean Values	Price Elasticity: Nov-Dec 1973 Values	"Estimated"[a] Price Elasticity: Mean Values	"Estimated"[a] Price Elasticity: Nov-Dec 1973 Values
Southern California						
n−1	−.011	−.015			−.066	−.086
n−2	.050	.067			.323	.370
Total	.040	.052			.257	.284
South San Joaquin						
n−1	.016	.031			.141	.160
n−2	.018	.042			.186	.201
n−3	.017	.046			.217	.218
Total	.051	.119			.543	.579
North San Joaquin						
n	−.019	−.020			−.119	−.154
n−1	−.033	−.060			−.214	−.260
n−2	.068	.136			.496	.587
n−3	.046	.094			.390	.423
Total	.062	.140			.552	.596
Central Coast						
n	−.031	−.032			−.200	−.306
Mountains						
n	.124	.291			.630	1.334
n−2	.068	.184			.377	.740
n−3	.093	.289			.566	1.054
Total	.285	.764			1.573	3.128
Manufacturing Milk						
n			1.315	3.242		
n−1			1.424	3.219		
n−2			.852	1.941		
Total			3.591	8.402		
All Milk						
n			.425	.522		
n−1			−.460	−.511		
n−2			.252	.283		
n−3			.706	.781		
Total			.924	1.075		

[a]See text for calculation procedure.

The above transformation assumes no change in variable costs and production per cow when price changes. The assumption of no change in costs is no problem, but some reaction in production per cow might be expected; however, Prato and Wilson and Thompson did not find such a relationship. Both derived insignificant coefficients; one had a negative value and one a positive value. The bias from these assumptions would therefore appear to be minimal.

The expected differences between equations representing primarily large, specialized "industry-like" dairies and those representing primarily smaller, more marginal, more diversified producers are very apparent in the regression results and in the elasticities. As hypothesized, there is little short-run response in the regions with primarily specialized dairies as indicated by insignificant coefficients on the first two margin variables and by the corresponding small elasticities. The occurrence of negative coefficients even with questionable significance is, however, rather surprising. In order to be certain that the negative signs are not a function of the particular specification used, a series of alternative specifications, particularly on the lag structure, were investigated. The negative short-run coefficients appeared consistently in these specifications. Since most price changes in the time period considered (1958-1973) were small, it may be that the short-run constant income stream objective prevails for small price changes. It is unlikely this response would hold for large price changes.

The results in Tables 1 and 2 coincide well with the characteristics of dairies in the regions. The very inelastic but relatively more rapid adjustment in Southern California is not surprising since dairies there are the largest in the state; however, production increases in Southern California have been less rapid than in the Valley regions due to pressures from urban expansion. The more elastic but less rapid responses in the two Valley regions are reasonable since both regions have experienced larger production responses than the Southern California region. Although the absence of a long-run adjustment in the Central Coast region is unexpected, it may not be unreasonable since aggregate production has shown little change. Pressures from urban expansion are a predominant factor in production decisions in this region. Perhaps when margins increase, some producers increase production but others move to another region.

The Mountain Areas and North Coast market milk region and the manufacturing milk equations represent producers who are smaller, more marginal, and more diversified. The response results in these equations differ dramatically from other areas with larger, more specialized operations. The response to profitability of production is much more rapid and much larger. Both equations show a very significant response in the first year. The response to profitability variables also is quite elastic in both equations.

The elasticities labeled "total" in Table 2 seem reasonable when compared to the long-run elasticities obtained in other studies.[6] The elasticity for all California milk production of 0.924 is very close to that obtained by Hammond for the Pacific region. As indicated above, direct specification of profitability was superior to indirect specification using milk price and input prices for this set of data. Because profitability is a key decision variable in making farm decisions and because direct specification measures all cost of production changes rather than just those with specified input prices, the hypothesis that direct specification of profitability could improve the results for other milk production response equations seems acceptable.

Implications for Policy and Future Research

These results suggest that regions with large, specialized dairies exhibit very inelastic responses to profit margins while regions where the typical dairy is smaller and less specialized exhibit elastic responses to changes in profitability. The results further indicate that there is a two or four year lag before the major impact of the response occurs in regions with specialized dairies. Additional research is needed to determine to what degree the results of this study can be generalized to other milk producing regions.

The policy implications of these results are twofold. First, a reasonable hypothesis based on these results is that the aggregate response to profitability will become more in-

[6]The total or the sum of the elasticities for individual years is an approximation of the long-run elasticity. Since the individual elasticities are the percentage change in production for a one percent change in margin n−i years ago, the sum gives the total percentage change in production resulting from a one percent change in margin. This procedure is consistent with Wilson and Thompson for a finite series and with the procedure used to derive the long-run elasticity in the partial adjustment hypothesis.

elastic as a greater proportion of the milk is produced on larger, more specialized dairies. As the response becomes more inelastic, more precise policy decisions will be required to avoid adverse or inequitable consequences for consumers and producers since larger adjustments will be required to correct "errors."

The second policy implication originates from the long lag found in the specialized dairy areas. These results indicate that there will be an increasing time span between a change in profitability and the major response in aggregate production as dairies become larger and more specialized. In order to effectively react to this situation, policymakers will have to consider much more carefully the long-run implications of all policy decisions.

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