Cyclical Instability in the U.S. Dairy Industry without Government Regulations

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Abstract

Simulations of the U.S. dairy industry under a variety of conditions indicate that milk price variability would be considerably greater in the absence of price supports. Milk production would also be more variable, but significantly less than would milk prices. Summary statistics for the 1955-78 period, however, indicate that, in the absence of pricing programs, milk prices would have varied no more than did prices for corn, wheat, or hogs. A long-term price-production cycle does not appear to be inherent in the dairy industry.

Keywords

Milk pricing, Dairy instability, Dairy price programs

One of the aims of U.S. dairy policy over the last 50 years has been to provide stability to the dairy industry. Many argue, on the basis of fairly convincing evidence, that the instruments used to achieve this policy have been quite effective (*7*).[1] Some add that removal of the policy instruments would be accompanied by unacceptably high levels of instability in the industry (*1*, *2*). Others suggest, however, that the U.S. dairy industry is now sufficiently mature, sufficiently free from institutional barriers that foster inefficient pricing and allocation decisions, and sufficiently national in scope to make the existing regulatory machinery unnecessary (*8*).

In view of current concerns over Government regulation and of the debates on new food and agricultural policy direction and legislation, dairy policy merits careful consideration. Some important questions that need to be answered are: How much instability can be expected as a result of program removal? Is this expected level of instability tolerable? Who might suffer as a result of this level of instability, and by how much? Who might benefit from removal of the dairy programs, and in what ways?

An industry may be characterized as having high levels of instability if prices or production fluctuate frequently and widely about the trend of their respective market-clearing values. Instability is excessively high if it causes producers or consumers to misallocate resources in production or consumption or if it forces producers or consumers to incur excessive costs in obtaining market information.

Instability thus defined can arise from three principal sources: discriminatory or disruptive practices of milk buyers, seasonal fluctuations in supply and demand, and long-term cyclical variations in prices and supply. Each of these three sources of instability must be examined to fully assess the impacts of program removal. In this article we deal only with the third source.[2] A dynamic simulation model of the U.S. dairy industry is used to estimate the level and nature of cyclical instability that might be expected in the absence of existing dairy programs.

The Estimated Model

Cyclical instability, as defined here, is due to the behavioral characteristics of dairy farmers and consumers and to the biological lags inherent in milk production. The hypothesis to be tested is that removal of the existing regulatory machinery would be accompanied by intolerable levels of price instability because of the behavioral and biological characteristics of the dairy industry. Additional issues to be examined are: (1) When exogenous shocks disturb the system, what instabilities are introduced and over what time period do they persist? (2) Are price-production cycles of the magnitude of the beef cycle, for example, latent in the dairy industry?

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] An earlier report on the same subject suggested that, in the absence of existing dairy programs, instability due to the first two sources could be expected to be minimal (*5*).

The model formulated and estimated here follows closely that specified in a previous paper (*4*). The model is estimated from annual data over the 1955-78 period. It includes five equations—one identity and four behavioral equations—which determine total milk production. It also includes a fluid milk demand equation and a manufacturing milk demand equation. Closure is obtained with a supply-demand equilibrium identity, a nonlinear blend price relation, and a fluid-manufacturing price differential equation. There are 10 equations in all.

The behavioral equations of the model were estimated by ordinary least squares. The identities and estimated equations are given in table 1.

Table 1—Model equations

Equation number	Equation[1]
(1)	$COWS_t = COWS_{t-1} + REPLACE_{t-1} - CULLS_{t-1}$
(2)	$CULLS_{t-1}/COWS_{t-1} = 0.2239 + 0.8423REPLACE_{t-1} + 0.002256TIME_t - 0.007812PCAN_{t-2}$ (3.02) (4.93) (1.99) (2.83) $- 0.000284PMILK_{t-2} + 0.00001PCAN_{t-2}*PMILK_{t-2}$ (2.54) (2.22) $R^2 = 0.813$
(3)	$REPLACE_t = -2324.21 + 1.3182HEIFERS_{t-2} + 0.000227PMILK_{t-1}$ (7.01) (29.63) (2.85) $R^2 = 0.977$
(4)	$HEIFERS_t/COWS_{t-1} = 0.1354 + 0.002548PVEAL_{t-1} + 0.2495REPLACE_{t-1}/COWS_{t-1}$ (2.14) (3.20) (1.66) $R^2 = 0.877$
(5)	$OUTPUT_t/COW_t = 3.2753 + 0.2319TIME_t + 0.8071PMILK_{t-1}/PFEED_{t-1}$ (11.85) (52.67) (3.86) $R^2 = 0.995$
(6)	$DEMANDF_t/POP_t = 560.79 - 0.0427PFLUID_t/CPI_t + 262.65AGE45_t - 1538.18AGE50_t$ (1.57) (0.91) (3.25) (1.28) $- 2.4815TIME_t + 0.4325DEMANDF_{t-1}/POP_{t-1} + 0.01562INCOME_t/CPI_t$ (2.27) (2.23) (1.50) $R^2 = 0.995$
(7)	$DEMANDM_t/POP_t = 370.37 - 0.1380PMFG_t/CPI_t - 543.95AGE20_t - 0.6281TIME_t$ (3.72) (2.60) (4.29) (1.36) $+ 0.6799DEMANDM_{t-1}/POP_{t-1}$ (5.15) $R^2 = 0.965$
(8)	$OUTPUT_t = DEMANDF_t + DEMANDM_t + EXTRA_t$
(9)	$PMILK_t = w_{1t}PFLUID_t + w_{2t}PMFG_t$
(10)	$DIFF_t = PFLUID_t - PMFG_t$

[1] Student-*t* values for estimated coefficients are given in parentheses below their respective coefficients.

The variables used in the model are:

Endogenous variables

$COWS_t$ = cows on hand as of January 1 of year *t*, 1,000 head;

$REPLACE_t$ = dairy heifers 500 pounds or over on hand as of January 1 of year *t* and assumed to enter the herd during year *t*, 1,000 head;[3]

$CULLS_t$ = number of cows culled from the herd during year *t* (includes deaths), 1,000 head;

$HEIFERS_t$ = dairy heifer calves under 2 years of age on hand as of January 1 of year *t*, 1,000 head;[4]

$OUTPUT_t$ = milk produced during year *t*, 1 million pounds;

$PMILK_t$ = price received for all milk wholesale in year *t*, cents/hundredweight (cwt);

$PFLUID_t$ = price received for fluid eligible milk in year *t*, cents/cwt;

$PMFG_t$ = price received for manufacturing grade milk in year *t*, cents/cwt;

$DEMANDF_t$ = domestic consumption of fluid milk products in year *t*, 1 million pounds of fluid milk equivalent; and

$DEMANDM_t$ = domestic consumption of manufactured dairy products in year *t*, 1 million pounds of fluid milk equivalent.

Exogenous variables

$PCAN_t$ = price received for utility cows in year *t*, dollars/cwt;

$PVEAL_t$ = price received for choice veal calves at St. Paul in year *t*, dollars/cwt;

$PFEED_t$ = price paid for 16-percent dairy ration in year *t*, cents/cwt;

CPI_t = consumer price index for all food in year *t*, 1972 = 1.0;

$INCOME_t$ = per capita disposable income in year *t*, dollars;

$TIME_t$ = time variable having a value of 1 in year 1950, 2 in 1951, and so forth;

$AGE20_t$ = percentage of population less than 20 years of age in year *t*;

$AGE45_t$ = percentage of population between 20 and 45 years of age in year *t*;

$AGE50_t$ = percentage of population 46 years of age and older in year *t*;

POP_t = total U.S. population, millions;

$EXTRA_t$ = total noncommercial demand plus net additions to stocks plus net exports, 1 million pounds of fluid milk equivalent; and

$DIFF_t$ = differential between fluid and manufacturing milk price, cents/cwt.

Definitions

$$w_{1t} = DEMANDF_t/(DEMANDF_t + DEMANDM_t + EXTRA_t), \text{ and}$$

$$w_{2t} = 1 - w_{1t}.$$

Observations on all variables except CULLS and EXTRA were obtained from published U.S. Department of Agriculture (USDA) reports. Annual values of CULLS were calculated from identity (1). Annual values of EXTRA were obtained as a residual of total milk production less total domestic fluid and manufacturing milk consumption.

A complete model of the dairy industry would have additional equations explaining PVEAL, major portions of EXTRA, and perhaps PCAN and PFEED. I considered these variables exogenous here partly to keep the model as simple as possible, but more important because they do not appear strongly influenced by the domestic dairy sector. EXTRA would be expected to be largely determined by actions in the

[3] This series was initiated in 1965. Estimates of REPLACE back to 1955 were made by the Livestock Section of ERS.
[4] This series was discontinued in 1970. Equation (4) was thus estimated over the 1955-70 period and then used to generate HEIFERS for the 1971-78 period so the remaining equations could be estimated.

political arena, PCAN and PVEAL by events in the beef sector,[5] and PFEED by events in the feed-grain economy.

Several alternative specifications of equations (2) through (7) were estimated. The above specification was chosen because it produced coefficients that were generally acceptable in terms of signs and significance levels.[6] The demand equations were also estimated by two-stage-least-squares with results almost identical to those reported here. The remaining equations of the model have only exogenous or predetermined variables as independent variables and, thus, can justifiably be estimated by ordinary least squares.

Most of the estimated coefficients appear reasonable in sign and magnitude with the possible exception of the coefficients on PCAN and PMILK in equation (2). One would ordinarily expect the culling rate to be positively related to PCAN and negatively related to PMILK. The estimated relation, however, indicates that the culling rate is:

1. Positively related to PCAN only when PMILK is $7.81/cwt or above, and

2. Negatively related to PMILK only when PCAN is $28.41/cwt or below.

These rather peculiar results are somewhat difficult to explain. It should be noted, however, that the above critical values of PMILK and PCAN were not obtained until 1972. Hence, these results may simply reflect the fact that during the 1955-71 period, PMILK and PCAN were sufficiently stable so that dairy farmers did not base culling rate decisions on these factors, whereas in the seventies, high milk and cattle prices led dairy farmers to respond more actively to these factors.

The estimated demand relations yield the farm-level elasticities shown in table 2 at the 1955-78 means of the respective variables. These elasticities appear reasonable in view of previous estimates and recent trends in dairy product consumption.

When the fluid milk demand function was estimated over the 1951-78 period instead of the 1955-78 period, the estimated longrun price elasticity for fluid milk was greater (−0.501) than that for manufacturing milk (−0.373). This appears to be an unjustifiable result. It suggests that structural conditions in the early fifties (for example, the influence of the Korean War) grossly distorted the fluid milk demand picture. It also suggests that attempts to estimate the fluid milk demand relation must proceed with caution and that more innovative empirical work needs to be done in this area.

Simulations

The model outlined above was solved for equilibrium prices and quantities for the 1955-78 sample period under different assumptions as to the levels of DIFF and EXTRA (table 3). The purpose of this exercise was to simulate the operation of the U.S. dairy industry under a variety of policy alternatives, including that of no classified pricing of Grade A milk and no price supports.

Simulation 1 was designed to capture the essence of existing regulatory programs. The marketing order program is reflected by exogenously setting DIFF equal to the actual value of this variable in each year. The price-support system is reflected by permitting Government purchases and sales when the blend price would otherwise vary by more than the limits indicated in table 3; it is implemented in the model by allowing EXTRA to vary so that the indicated limits on price are satisfied. This simulation cannot be expected to reproduce precisely the realized prices and quantities over the sample

[5] The simple correlation between the deflated farm price of steers and the deflated farm price of utility cows is 0.69; and that between the deflated farm price of steers and the deflated farm price of choice veal calves is 0.72. A regression of the deflated price of veal calves on deflated per capita disposable income, per capita veal consumption, and time yielded an R^2 of only 0.57 and regression coefficients of questionable magnitude. Apparently, factors exogenous to the dairy sector largely determine PCAN and PVEAL.

[6] The coefficients of the equations reported here differ slightly from those reported earlier (*5*) because data revisions only recently available were incorporated and because a different series was used to represent REPLACE.

Table 2—Farm-level price and income elasticities for raw milk

Milk use	Price elasticities[1]		Income elasticities[1]	
	Shortrun	Longrun	Shortrun	Longrun
Fluid products	−0.0791	−0.1393	0.1437	0.2532
Manufactured products	− .1773	− .5540	[2]	[2]

[1] Calculated at the 1955-78 means of prices, incomes, and per capita consumption.
[2] The coefficient on per capita income was not significantly different from zero in this relation. When included, it produced a negative regression coefficient.

Table 3—Description of simulation runs

Simulation run	Policy variable assumptions	
	DIFF	EXTRA
1	Observed value	Variable[1]
2	Observed value	Observed value
3	4.25% of actual PMFG[2]	2% of OUTPUT
4	4.25% of actual PMFG[2]	4% of OUTPUT
5	4.25% of actual PMFG[2]	2% of OUTPUT[3]
6	4.25% of actual PMFG[2]	Variable[1]

[1] EXTRA set equal to its observed value so long as $0.95 \leq (PMILK_t/PMILK_{t-1}) \leq 1.1$. If this inequality does not hold, EXTRA is increased or decreased incrementally (by 5 percent) until the condition holds.

[2] This percentage level was chosen so that the 1974 value of DIFF would approximate the 1974 GradeA-Grade B cost differential of $0.27 estimated by Frank, Peterson, and Hughes (*3*).

[3] OUTPUT/COW reduced by 10 percent in 1979 to simulate an external shock.

period because the model neither accounts for random events in the real world nor reflects Government program intentions exactly. To the extent that this simulation is a fair approximation of existing program intentions, however, its results will serve as a base for comparing the results of subsequent simulations.

In simulation 2, both DIFF and EXTRA were assumed to take on their actual values during the 1955-78 period. There is no mechanism for supporting prices so as to limit price variation. Here prices are free to be determined by the economic conditions of the industry (as captured by the model), subject to actual values of DIFF and EXTRA. Although actual Commodity Credit Corporation purchases and sales are included in EXTRA, the results of simulation 2 cannot be expected to yield actual results because random events in the real world are again ignored. Comparing the results of simulations 1 and 2, however, will permit us to assess the extent to which actual Commodity Credit Corporation purchases and sales helped to minimize price variations in the absence of any other type of price-support legislation.

Simulations 3 and 4 enable us to examine the dairy industry as it is expected to operate in the absence of either marketing orders or price supports. The values assigned to DIFF are assumed to be the values that represent actual cost differences between the production of Grade A and Grade B milk in their respective years. It is assumed here and in subsequent simulations that in the absence of marketing orders, the difference in the cost of marketing the two grades of milk would be negligible. The values assigned to EXTRA are assumed to be the values that would have been realized under two different scenarios of free-market conditions. The level of EXTRA under free-market conditions is, of course, unknown. It is assumed that under such conditions EXTRA will be a stable function of OUTPUT. To examine the impact of the level of EXTRA on instability, we arbitrarily set EXTRA equal to 2 and 4 percent of OUTPUT.

Simulation 5 allows us to study the dairy industry's response to a significant external shock. Here it was assumed that 1979 was a drought year resulting in a 10-percent reduction in output per cow. Simulation 6 permits us to examine the dairy industry as it might operate without marketing orders but with price-support legislation intended to mitigate against wide year-to-year price swings.

All simulations were carried out to year 1999 in the hope that the dynamic character of the dairy industry under each situation simulated would be evident. The following annual percentage increases in exogenous variables were assumed:

Variable	Percent
PCAN	2.5
PVEAL	2.5
PFEED	2.5
CPI	6.0
INCOME	6.0
POP	2.0

The age structure of the population was assumed (however unrealistically) to remain constant from 1978 through 1999. Trends in technology and consumer tastes observed over the sample period, as reflected by inclusion of the TIME variable in the estimated relations of the model, were assumed to continue. In simulation 2, EXTRA was set equal to its 1978 level throughout the 1979-99 period. In simulation 1, the initial value of EXTRA tested in each year of the simulation period was the 1978 value.

The results of these simulations must be interpreted in light of the model used to generate them. This model is, of course, suspect in the sense that it is used to simulate a situation (that is, no or limited Government intervention) that did not exist during the period over which the model was estimated. This raises several questions: Are the estimated response coefficients, or indeed the form of the equations assumed, those that would likely exist under no Government programs? More specifically, if removal of Government programs would cause significant increases in price instability, would dairy farmers respond differently than indicated by the behavioral equations of the model? What, if any, role would manufacturing firms play in moderating price variations through their storage policies in the absence of Commodity Credit Corporation activity? Unfortunately, we cannot answer such questions with certainty. Based on the information available, however, there is little reason to project any major differences in the parameter estimates or in the form of the structural equations estimated.[7] Furthermore, sensitivity analyses conducted with the model led to the conclusion that minor differences in the parameter estimates or equation forms would have little impact on the major conclusions reached here.

Any exercise in which one attempts to simulate industry behavior beyond the sample period (or beyond the range of past experience and level of exogenous variables) is likely to be frustrating because the exogenous variables are difficult to predict. The present case was no exception. Preliminary results produced explosive cull-to-cow and heifer-to-lagged-cow ratios. We resolved the problem here by assigning values to the exogenous variables PCAN and PVEAL so that the above ratios did not exceed 0.36 in any one year—the maximum value of these ratios observed during the sample period. Thus, in some years, PCAN and PVEAL were not permitted to increase by 2.5 percent.

Simulation Results

Selected results of the simulations of primary interest are shown in table 4 and in figures 1-6. The indexes of variation (table 4) help one considerably in distinguishing among the different simulations. The method of calculating the index of variation is explained in the appendix. Basically, it measures the degree of variation about a linear trend line drawn through the points of the relevant time series. If the index is zero, all points lie on the trend line, and, according to the definition of instability adopted here, the series is stable. The larger the index, the greater the instability of the series.

[7] Statistical analyses revealed no significant producer response to price variability of the magnitudes observed during the 1955-78 period.

Indexes of variation computed from 1955-78 data for selected agricultural products including milk are as follows:

Product	Index of variation
Choice steers, Omaha	14.41
Barrows and gilts, 7 markets	28.53
Broilers	23.99
Eggs	16.46
Potatoes	26.43
Wheat	33.36
Corn	29.48
All milk wholesale	19.72

The results of the simulations point to several interesting conclusions—some surprising and some fairly consistent with common beliefs. There is little question that price variation (and perhaps quantity variation) would be greater in the U.S. dairy industry without Government regulations of the type provided by marketing orders and price supports. It also seems clear that the industry is characterized by relationships which cause it to produce natural long-term price instabilities in response to exogenous shocks.

The results of simulation 1 suggest that the constructed model, when constrained to reflect the intention of existing Government programs, reproduces the actual character of the U.S. dairy industry over the sample period fairly well (table 4 and figs. 1 and 2). Thus, the model can be used with reasonable confidence for the purposes intended here.

Table 4—Indexes of variation of selected endogenous variables

Item	PFLUID	PMFG	PMILK	OUTPUT
		Sample period, 1955-78		
Actual data	17.39	25.97	19.72	2.41
Simulation				
1	16.27	24.11	19.32	2.25
2	26.65	37.78	31.28	2.86
3	34.08	34.68	34.31	2.78
4	26.94	27.15	26.96	2.37
5	34.08	34.68	34.31	2.78
6	23.70	23.64	23.57	1.98
		Projection period, 1979-99		
1	5.45	5.89	5.71	1.83
2	6.17	6.68	6.49	1.47
3	9.20	9.46	9.36	2.11
4	7.07	7.26	7.18	1.78
5	9.57	9.86	9.73	1.46
6	4.75	4.87	4.83	2.25

Figure 1

Wholesale Price of All Milk

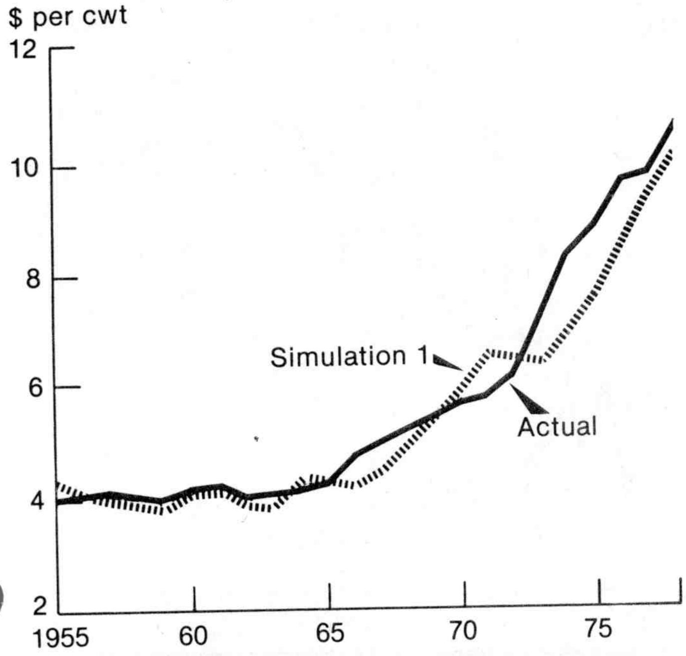


Figure 2

Total Milk Production

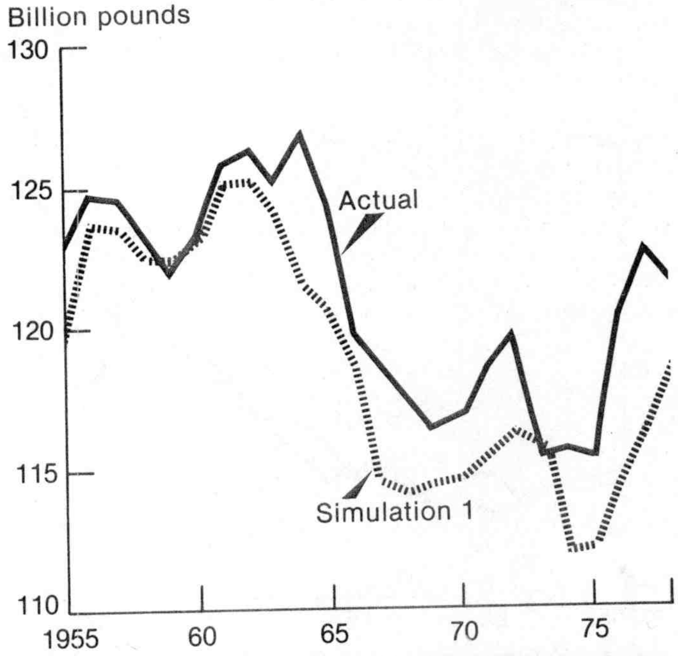


Figure 3

Wholesale Price of All Milk

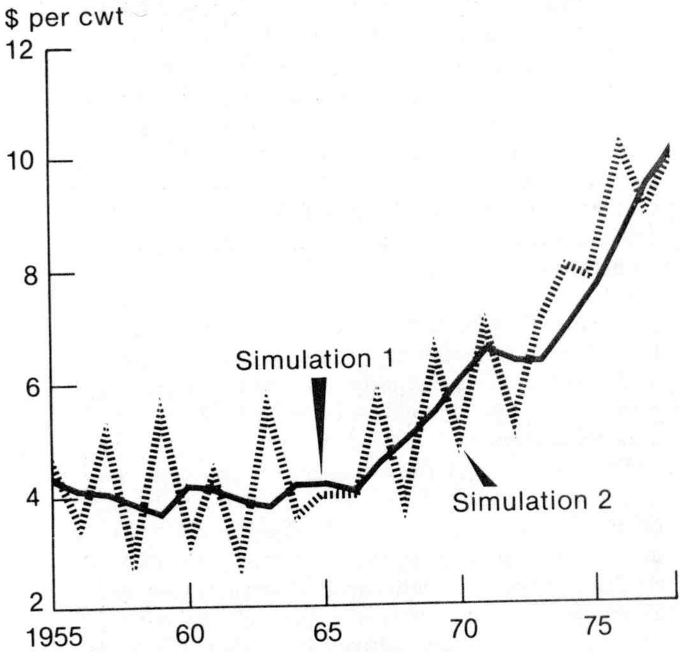


Figure 4

Wholesale Price of All Milk

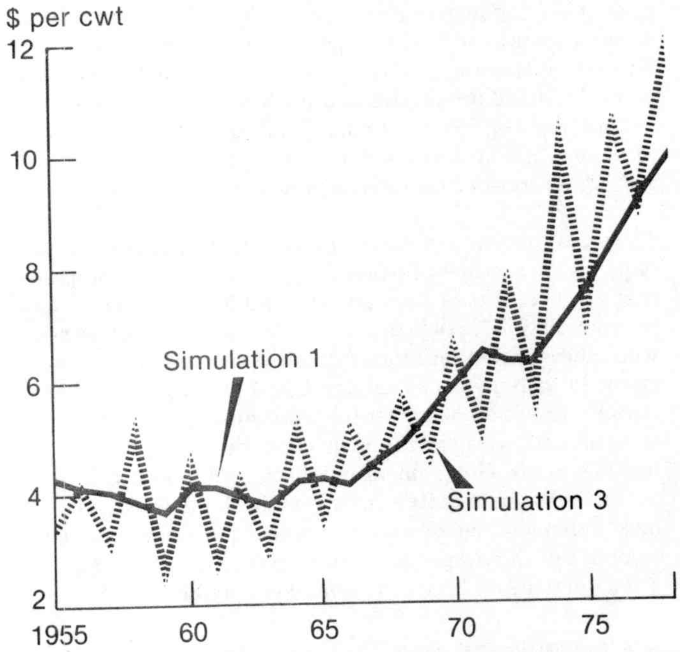


Figure 5

Wholesale Price of All Milk

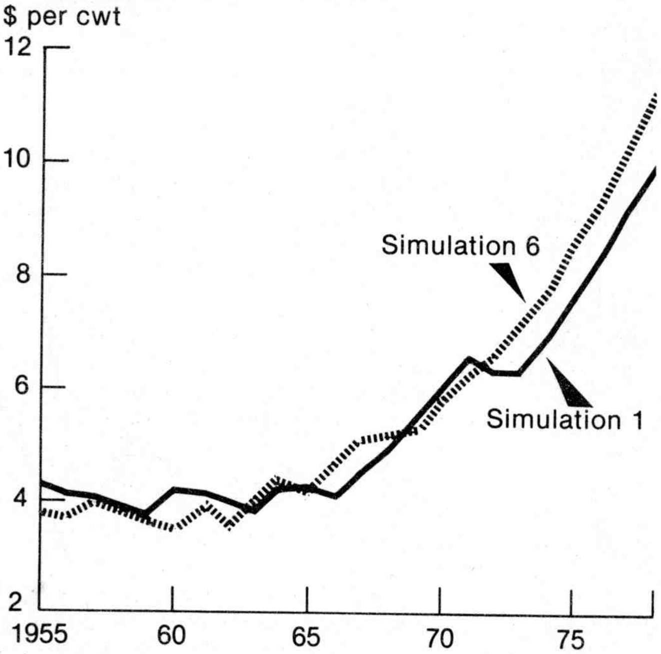
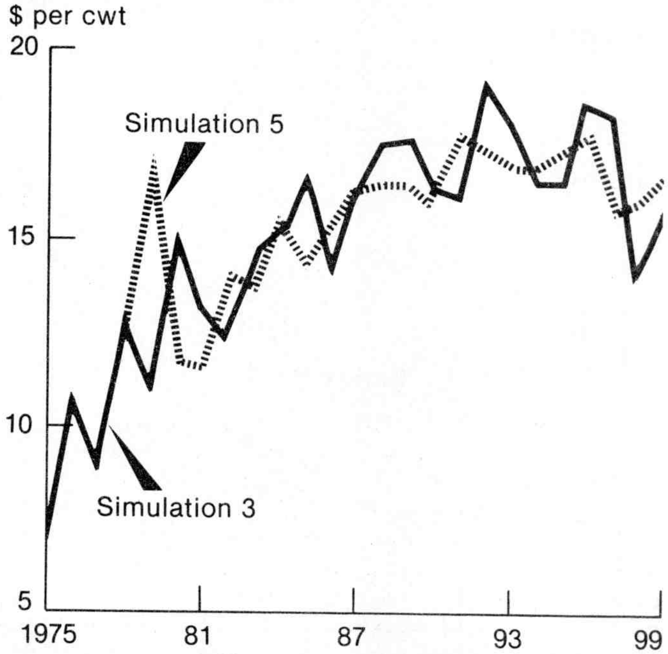


Figure 6

Wholesale Price of All Milk



A question of considerable importance is the extent to which Government programs have distorted milk prices in the long run. Many people argue that Government purchases of dairy products (required in large part to implement the dairy price-support program) were excessive during the first half of the sample period (table 5). If so, this would imply that milk prices were too high during these years, and perhaps in subsequent years as well. Although precise and objective answers to such questions cannot be given, figure 3, which compares simulated prices with (simulation 1) and without (simulation 2) price supports, suggests that the regulatory machinery has at least correctly anticipated the trend in prices over most of the sample period.

The major question at issue, however, is that of price instability in the absence of Government programs. A comparison of the results of simulations 2 and 3 with those of the base simulation leave little doubt that 1955-78 milk prices would have varied far more without the Government programs actually in place (see figs. 3 and 4). Simulation 3 contains no provision whatever for Government purchases and sales to limit price variations. In simulation 2, EXTRA includes actual Government purchases and sales. However, as prices fluctuate quite widely even in simulation 2, one must conclude that actual Government purchases and sales were not of the proper magnitude or timing to minimize price fluctuations under "free-market" conditions.

It is interesting that when DIFF was set at its competitive level in simulation 3, milk prices fluctuated fairly regularly for a time. Once the system became disturbed by external shocks (slower population growth rate, changing age distribution of the population, and higher beef prices in the late fifties), forces affecting the industry reduced the level of price fluctuations in the midsixties and then intensified price fluctuations significantly through the seventies (fig. 4). However, when DIFF exceeded its competitive level as in simulation 2, milk prices were quite unstable during the fifties and sixties, but not so unstable during the volatile seventies as in simulation 3 (fig. 3). These results can most likely be explained by the fact that in simulation 2 the values assigned to EXTRA (actual values) helped to moderate price swings in the seventies whereas in simulation 3, EXTRA was forced to be relatively constant over the entire period and, thus, could play no price-moderating role (table 5).

Simulation 6 confirms two notions about the dairy industry. If the price differential between fluid and manufacturing grade milk had been permitted to seek its competitive level, over most of the sample period the price of fluid grade milk would have been lower than that actually observed, and the price of manufacturing grade milk would have been *higher* than that actually observed. This is hardly a surprising conclusion given the differences in the elasticities of demand for fluid and for manufacturing grade milk. These results are consistent with those of previous research (*6*). Simulation 6 also indicates that relatively stable milk prices are possible under competitive conditions if EXTRA is permitted to take on appropriate values.

Table 5—Actual and simulated values of EXTRA for sample period, selected simulation runs

Year	Actual	Simulation runs		
		1	3 and 5	6
		Million pounds[1]		
1955	5,798	5,198	2,400	4,104
1956	6,292	7,648	2,361	3,076
1957	6,477	6,478	2,439	2,284
1958	3,951	4,357	2,299	2,385
1959	3,376	3,376	2,432	2,643
1960	5,131	5,131	2,321	2,404
1961	7,962	7,961	2,423	2,388
1962	6,729	7,790	2,338	2,778
1963	5,602	5,602	2,429	1,762
1964	5,693	4,093	2,286	2,344
1965	3,707	3,707	2,361	2,329
1966	1,170	1,170	2,262	1,681
1967	3,318	-2,382	2,295	1,540
1968	1,424	-2,276	2,218	2,239
1969	1,020	-480	2,289	2,240
1970	1,934	1,134	2,198	1,826
1971	2,928	2,928	2,292	2,228
1972	2,948	2,948	2,188	2,231
1973	-1,182	406	2,314	2,242
1974	491	-5,209	2,145	-1,315
1975	-1,278	-6,578	2,291	-2,725
1976	2,367	-5,633	2,231	-1,280
1977	2,980	-4,820	2,339	477
1978	71	-4,629	2,323	1,224

[1] Fluid milk equivalent.

Simulation 5 (fig. 6) reveals some interesting notions about the ability of the U.S. dairy industry to cope with an exogenous shock without Governmental assistance. First, as might be expected, the industry overadjusts to the shock in a cobweb fashion so that a saw-tooth effect is produced in the timepath of prices.[8] Second, the ripples produced from the shock can be enormous for the first few years, tend to dampen down fairly rapidly, but clearly extend over several years. No strong evidence exists however, for a dairy cycle as long as the beef cycle.

Clearly the results of simulation 5 are conditional upon the exogenous conditions assumed through 1999. Additional experimentation, for example, showed that if the industry had been subjected to somewhat greater demand pressure than assumed here (that is, if aggregate demand had been assumed to grow at a slightly faster rate), milk prices would have been much more volatile through 1999. However, if demand pressure is great enough to cause large and sustained increases in cow numbers, milk prices tend to stabilize around a steeply increasing trend.

As suggested earlier, the sample data were generated during a period when Government regulations were in effect. These regulations may well have discouraged dairy farmers from responding so that a cycle would be evident. Hence, the possibility of a cycle in the absence of Government regulations cannot be ruled out.

Conclusions

Simulations based on an econometric model incorporating behavioral and biological lags suggest clearly that milk prices would be more variable without marketing orders and price supports. Whether or not the degree of instability generated by the model would be acceptable must ultimately be determined in the political arena and in conjunction with other costs and benefits of deregulation. It is instructive to compare the degree of instability projected here under no Government programs with that for prices received by farmers for a few other agricultural products during the 1955-78 period. Indexes of variation suggest that over this period, even under the worst scenario simulated here, milk prices at the farm level would have been no more, or only slightly more, volatile than those for corn, wheat, or hogs. In some instances, however, the simulated year-to-year variation in prices was much greater than that observed for any other commodity. Such levels of instability would most likely be unacceptable.

Under the assumptions of the model used in this study, removal of marketing orders would be accompanied by a reduction in the price of fluid milk, an increase in Grade B milk production, and some adjustments among marginal milk producers and perhaps among milk processors. One might also project more emphasis on innovative marketing techniques and on developing new products. These same results could be obtained, of course, by keeping marketing orders in place, but by ensuring that price formulae are more in line with competitive results.

Additional research on the issue is warranted. The model estimated here does not differentiate between the response of Grade A and Grade B milk producers. It also assumes the industry itself imposes no constraints on year-to-year price variations through storage policy decisions or other mechanisms. Finally, some of its relationships permit rather drastic changes from year to year, depending on exogenous conditions (for example, the output per cow relation). Although model revisions to accommodate these limitations

[8] The price of fluid and manufacturing grade milk follows the same general pattern of variation as does the price of all milk wholesale.

are not expected to lead to differences in the major conclusions, such fine-tuning would contribute much to greater realism.

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Appendix

A statistic frequently used to indicate the degree of instability of prices (or quantities) is the coefficient of variation, V. For many time series, however, this statistic is an inappropriate measure of instability. Consider a time series having a strong trend due to inflation. The coefficient of variation for such a series will have a large numerical value suggestive of much instability whereas, in fact, there may be little or no true instability, merely a strong inflationary trend.

The statistic used here is somewhat more difficult to compute, but is superior to V in that it minimizes overestimates of instability due to trend. I call this statistic the index of variability. It is computed as follows:

$$I_v = 100 \sqrt{\left\{ \sum_{i=1}^{n} [(Y_i - \hat{Y}_i) \div \hat{Y}_i]^2 \right\} \div (n-1)}$$

where *n* is the number of observations in the time series on Y, and $\hat{Y}_i$ is the estimated value of Y_i based on a regression of Y on some function of time, CPI, or other variable. This index of variability is a function of the sum of squares of percentage deviations from the regression line. If all observed values lie on the regression line, $I_v = 0$. If there is no trend in the series so that $\hat{Y}_i = \overline{Y}$ for all i, $I_v = V$. In table 3 of the text, I computed the indexes of variation based on the linear regression, $\hat{Y}_i = a + bt$.