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AN ANALYSIS OF CHANGES IN MILK PRODUCTION PER COW BY STATE, 1950-87

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Abstract

Changes in state milk production per cow are analyzed as a time series to determine the form and size of increase. Future milk yields are projected using parameter estimates. States are also grouped according to the correlation matrix of residuals to determine which states react similarly to exogenous shocks.

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Introduction

Milk production per cow has consistently been shown to be a major determinant of dairying success. Increased production per cow increases feed utilization efficiency since a greater proportion of the ration is used for milk production rather than for maintenance (Bath). Other inputs are also more intensely utilized lowering average cost. Increased milk yield can thus increase total income over costs under the proper combination of milk and feed prices (Schmidt and Pritchard).[1] The rate of return on investment in dairy operations has also been shown to be positively influenced by milk production per cow (Buxton et. al.). Given the importance of milk yield to the financial performance of dairy farming, an erosion of efficiency relative to competing states may have severe implications for the viability of the dairying industry within an individual state.[2]

The purpose of this paper is to examine the changes in state milk production per cow from 1950 through 1987. The changes in milk yield are analyzed as a time series with no other explanatory variables.[3] The next section describes the approach and the seemingly unrelated regression (SUR) estimation procedure utilized. Results presented include a breakdown and ranking of the states into those which have experienced an absolute versus

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[1]Besides high feed costs relative to milk prices, factors which may tend to decrease the profitability of increased production per cow include decreased digestibility of feed with increased feed intake (Tyrell and Moe), increased health costs (Hansen et. al.), reduced reproductive efficiency (Olds et. al.), and greater investment in terms of both labor and capital.

[2]Low production per cow does not necessarily mean that the dairying is not viable and profitable in that region. New Zealand's dairy industry is healthy due to its low production costs despite low milk yields .

[3]Factors which have been found to influence milk production include the milk price received by farmers, input costs of running a dairy farm, profits available in alternative farm enterprises, and general economic conditions. Recent studies which have incorporated these explanatory variables include Buxton; Lafrance and deGoerter; and Kaiser, Liu, and Streeter.

geometric increase of milk production per cow over time. States are also grouped according to the correlation of the error terms of the regression equations. The parameter estimates are then used to project future state milk yields. The implications of the continuation in trend patterns are discussed in the final section.

Methodology

The model estimated is

$$Y_{t+1,m} = b_{1,m} + b_{2,m} Y_{t,m} + e_{t,m} \quad (1)$$

where $Y_{t,m}$ is milk production per cow in year t for state m, $b_{1,m}$ and $b_{2,m}$ are regression coefficients for the intercept and lagged milk yield respectively, and $e_{t,m}$ is the value of the disturbance in year t for state m. If for a particular state m, $b_2 = 1$ and $b_1 \neq 0$, then $Y_{t+1} - Y_t = b_1$ and milk production per cow increases by the same absolute amount, b_1, each year. On the other hand, if $b_2 \neq 1$ and $b_1 = 0$, then $Y_{t+1} = b2\, Y_t$ and milk yield increases by the rate of b_2 each year.[4]

The error term is assumed normally distributed with mean zero. However, there is a strong probability that error terms are correlated across states. Any impact causing production per cow to be off the regression surface in any year would likely occur in other states as well. The existence of cross equation correlation means that ordinary least squares (OLS) is no longer the most efficient means of estimating the regression coefficients

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[4]The case of $b_2 = 1$ and $b_1 \neq 0$ is identical to estimating the model $Y_t = c_1 + c_2 t$ where c_2 is the absolute increase each year ($b_1 = c_2$). The case of $b_2 \neq 1$ and $b1 = 0$ is identical to estimating the model $\ln(Y_t) = \ln(a) + rt$ or $Y_t = ae^{rt}$ where r is the continuous rate of growth that would equal the discrete rate of growth (b_2 - 1).

(Kmenta). Therefore, seemingly unrelated regression (SUR) is used to simultaneously estimate the system of state equations.

The first step in SUR is to estimate each of the state equations separately using OLS. The OLS residuals are then used to estimate the covariance matrix of the regression disturbances and this matrix is used in the simultaneous estimation of all state equations (Kmenta). Because of computation difficulties, only the top 36 milk producing states in 1987 were used in the analysis.[5] These states collectively account for 97 percent of aggregate milk production. The 1987 yield and production figures for these 36 states are presented in descending order in Table 1. The values on milk production per cow and milk supply are obtained from Milk: Production, Disposition, and Income.

Results

The parameter estimates for each state milk yield equation obtained from using seemingly unrelated regression are presented in Table 2 along with statistical measures of fit. The adjusted R squared values indicate that much of the variation in milk production per cow is explained by the time trend incorporated in equation 1.

The null hypotheses to be tested with the estimated parameters is whether an individual state exhibits an absolute rate of increase in milk yield

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[5]In the estimation procedure, the covariance matrix was deemed to be singular when all 50 states were estimated simultaneously using SUR. SAS consultants felt the obtained singularity was due to the inefficiency of the algorithm used to invert the 50 x 50 matrix rather than the matrix being indeterminate due to linear relationships between disturbances. The states excluded are Alabama, Alaska, Connecticut, Delaware, Hawaii, Massachusetts, Montana, Nevada, New Hampshire, New Jersey, Rhode Island, South Carolina, West Virginia, and Wyoming.

Table 1- State Rankings of Milk Yield and Milk Production in 1987

State	Milk Yield (lbs. per cow)	State	Milk Production (million lbs.)
Washington	18091	Wisconsin	24800
California	17970	California	17934
New Mexico	16879	New York	11362
Oregon	15989	Minnesota	10436
Arizona	15911	Pennsylvania	10183
Colorado	15893	Michigan	5248
Utah	15149	Ohio	4810
Idaho	14937	Texas	4300
Michigan	14537	Washington	3763
North Carolina	14136	Iowa	3550
Pennsylvania	14123	Missouri	2900
Virginia	13903	Illinois	2775
Vermont	13851	Indiana	2415
Wisconsin	13816	Vermont	2410
Maine	13694	Idaho	2375
New York	13243	Kentucky	2338
Maryland	13228	Florida	2209
Nebraska	13137	Tennessee	2207
Missouri	13122	Virginia	2016
Illinois	13090	South Dakota	1759
Texas	13070	North Carolina	1555
Ohio	13000	Maryland	1508
Minnesota	12680	Oregon	1471
Florida	12480	Arizona	1432
Indiana	12448	Nebraska	1340
South Dakota	11885	Kansas	1241
North Dakota	11860	Colorado	1192
Kansas	11819	Oklahoma	1170
Iowa	11755	Georgia	1155
Arkansas	11688	Utah	1121
Georgia	11667	North Dakota	1103
Mississippi	10917	New Mexico	979
Tennessee	10872	Louisiana	877
Oklahoma	10734	Mississippi	786
Kentucky	10725	Arkansas	748
Louisiana	9966	Maine	671
U.S.	13786	U.S.	142461

Table 2- SUR Parameter Estimates for State Milk Yield Equations

State	Intercept		Lagged Yield		Root MSE	R-Square
	Estimate	Approx. Std Error	Estimate	Approx. Std Error		
Arizona	374.56	110.99	0.991	0.009	324.77	0.988
Arkansas	125.82	105.87	1.016	0.014	346.85	0.984
California	116.48	140.41	1.024	0.011	286.80	0.990
Colorado	50.55	119.02	1.025	0.011	325.23	0.989
Florida	214.68	116.80	1.000	0.013	250.18	0.989
Georgia	232.84	70.36	0.998	0.008	226.09	0.994
Idaho	47.02	98.15	1.019	0.009	225.67	0.992
Illinois	244.98	107.78	0.995	0.011	199.61	0.991
Indiana	396.52	89.94	0.978	0.009	168.56	0.993
Iowa	430.79	155.21	0.970	0.017	361.27	0.970
Kansas	274.54	92.96	0.990	0.010	270.01	0.989
Kentucky	144.45	97.12	1.005	0.013	274.93	0.983
Louisiana	175.46	46.36	1.004	0.006	176.50	0.996
Maine	195.00	111.73	1.002	0.011	298.99	0.985
Maryland	298.82	124.47	0.990	0.012	287.54	0.988
Michigan	285.62	126.16	0.994	0.012	286.97	0.987
Minnesota	274.53	137.79	0.990	0.014	274.71	0.981
Mississippi	-22.71	44.29	1.043	0.007	143.79	0.997
Missouri	140.29	65.03	1.012	0.007	195.62	0.995
North Carolina	128.44	85.37	1.016	0.009	255.07	0.994
North Dakota	60.74	94.03	1.018	0.011	270.60	0.984
New Mexico	177.82	97.36	1.018	0.008	372.23	0.992
New York	238.39	98.09	0.993	0.009	202.83	0.990
Nebraska	130.25	91.66	1.011	0.010	254.38	0.990
Ohio	402.96	88.52	0.978	0.009	203.16	0.991
Oklahoma	415.70	69.84	0.970	0.008	221.80	0.992
Oregon	-149.76	94.76	1.045	0.009	236.09	0.994
Pennsylvania	68.18	72.56	1.015	0.007	166.95	0.995
South Dakota	286.77	111.00	0.990	0.012	346.18	0.980
Tennessee	221.93	76.33	0.996	0.009	261.92	0.991
Texas	270.14	63.46	0.999	0.007	220.06	0.995
Utah	121.93	127.24	1.011	0.012	303.46	0.986
Vermont	159.70	95.40	1.006	0.010	204.99	0.993
Virginia	131.48	72.81	1.015	0.007	255.86	0.993
Washington	77.83	84.40	1.016	0.011	242.44	0.990
Wisconsin	48.96	98.89	1.023	0.008	259.82	0.995

per cow ($b_2 = 1$ and $b_1 \neq 0$), or whether the rate of increase in yield is geometric ($b_2 \neq 1$ and $b_1 = 0$). One of these two cases was accepted for all states at the 5 percent level of significance with the exception of three; Indiana, Ohio, and Oklahoma. For these states, the intercept or absolute rate of increase was significantly different from zero and the coefficient attached to lagged yield or the geometric rate of increase was significantly different from one.

The parameter restrictions resulting from the hypothesis testing were imposed on the state equations and the model was re-estimated using SUR. The estimated rates of increase in state milk production per cow are presented in Table 3. The annual increases in milk yield range from approximately 300 pounds per cow in Texas to about 150 pounds per cow in Kentucky. In contrast, those states estimated to possess a geometric rise in milk production per cow display a rate of increase within a small range between 2 and 3 percent. The three states which have both forms of increase exhibit the largest absolute rate of increase but also a geometric rate of increase less than one. Continuation of such a trend would eventually result in milk production per cow falling.

In comparing the grouping of states based upon the form of increase to the milk yield figures given in Table 1, one notes that states can be distinguished by their position relative to national milk production per cow. Those states which have displayed a geometric rate of increase are generally above the national average while those with an absolute rate of increase are below. A continuation of those trends could result in a large discrepancy among the productivities of the milk producing states. This in turn could have significant effects on the distribution of milk production across the country given the impacts of milk yield on economic viability noted earlier.

Table 3- Form and Rate of Increase in State Milk Production Per Cow

State	Absolute Rate Of Increase Estimate	Absolute Rate Of Increase Std Error	State	Geometric Rate Of Increase Estimate	Geometric Rate Of Increase Std Error
Kentucky	148.39	32.35	Ohio*	0.976	0.004
Iowa	154.46	52.81	Indiana*	0.982	0.005
Tennessee	168.30	34.73	Oklahoma*	0.987	0.004
Minnesota	168.46	36.72	Pennsylvania	1.020	0.002
New York	168.46	28.99	Idaho	1.022	0.003
Kansas	170.16	34.25	North Dakota	1.025	0.005
South Dakota	171.78	40.23	California	1.026	0.003
Illinois	178.12	27.73	Colorado	1.026	0.004
Maryland	185.98	31.92	Virginia	1.026	0.002
Nebraska	188.16	34.28	Wisconsin	1.027	0.003
Maine	190.51	38.22	North Carolina	1.028	0.003
Michigan	190.54	39.01	Washington	1.029	0.004
Louisiana	191.26	20.25	Oregon	1.029	0.003
Florida	191.81	34.98	New Mexico	1.037	0.003
Arkansas	201.21	47.76	Mississippi	1.038	0.003
Georgia	203.70	26.11			
Utah	204.98	41.85			
Vermont	208.01	28.79			
Missouri	228.58	28.25			
Arizona	247.27	47.63			
Texas	256.74	28.92			
Ohio*	291.80	37.30			
Indiana*	334.50	49.38			
Oklahoma*	369.59	32.41			

*- Ohio, Indiana, and Oklahoma have both an intercept term (absolute increase) and a term associated with lag yield (geometric increase).

The exceptions to this categorization are Arizona and Utah which are estimated to exhibit absolute rates of increase. However, the size of the annual change in milk yield for these two states is relatively large. The other exceptions are Mississippi and North Dakota which are estimated to display geometric rates of increase in milk production per cow despite yield figures below the national average. The low milk yields in the early years of the study explain these results. The other point to note from Table 3 is that the states with a geometric rate of increase are generally located in the western portion of the country or are major milk producing states such as Pennsylvania or Wisconsin.

To examine the effect of a continuation in past trends, the parameter estimates are used to simulate state milk yields for a 5 and 10 year future period. The projected state milk production figures for 1992 and 1997 are presented in descending order in Table 4. Table 4 also contains the 1950 milk yield values and 1950 relative rankings for the states. Yields for 1987 appear in Table 1. Continuation of trends would produce further realignment in terms of state productivity rankings. The western states are projected to generally have the highest production per cow. In contrast, the traditional milk producing states of the Northeast and Midwest will fall behind due to slower rates of increase in milk yield. The southeastern states are forecast to continue having the lowest milk yields on average. In addition, the variation between these lowest yields and the highest production levels may increase over time as indicated by the larger coefficient of variation (C.V.) for the projected years compared to the last year of the sample.

The groupings presented in Table 3 are based on the form of increase in milk production per cow over time. The seemingly unrelated regression procedure also permits grouping states according to the covariance matrix of the estimated residuals. States whose production react similarly to exogenous

Table 4.- Past and Predicted State Rankings of Milk Yield Per Cow

State	Actual 1950 Milk Yield (lbs. per cow)	State	Predicted 1992 Milk Yield (lbs. per cow)	State	Predicted 1997 Milk Yield (lbs. per cow)
California	7710	Washington	20871	New Mexico	24274
Wisconsin	6850	California	20431	Washington	24078
New York	6810	New Mexico	20241	California	23229
Washington	6640	Oregon	18446	Oregon	21280
Utah	6550	Colorado	18069	Colorado	20544
Pennsylvania	6320	Arizona	17147	North Carolina	18632
Idaho	6300	Idaho	16654	Idaho	18568
Michigan	6280	North Carolina	16229	Arizona	18384
Minnesota	5980	Utah	16174	Wisconsin	18034
Oregon	5940	Virginia	15807	Virginia	17971
Arizona	5900	Wisconsin	15785	Pennsylvania	17216
Vermont	5900	Pennsylvania	15593	Utah	17199
Maine	5700	Michigan	15490	Michigan	16442
Illinois	5630	Vermont	14891	Vermont	15931
Maryland	5600	Maine	14647	Mississippi	15852
Ohio	5580	Texas	14354	Texas	15637
Iowa	5490	Missouri	14265	Maine	15599
Indiana	5350	Maryland	14158	Missouri	15408
Colorado	5300	New York	14085	North Dakota	15182
Nebraska	4870	Nebraska	14078	Maryland	15088
Kansas	4550	Illinois	13981	Nebraska	15019
North Dakota	4530	Minnesota	13522	New York	14928
Virginia	4490	Florida	13439	Illinois	14871
North Carolina	4460	North Dakota	13419	Florida	14398
Florida	4400	Mississippi	13155	Minnesota	14365
Missouri	4400	Indiana	12981	Georgia	13704
South Dakota	4210	Ohio	12904	Arkansas	13700
New Mexico	4060	South Dakota	12744	South Dakota	13603
Kentucky	4040	Arkansas	12694	Kansas	13521
Tennessee	3720	Georgia	12686	Indiana	13467
Oklahoma	3680	Kansas	12670	Iowa	13300
Georgia	3580	Iowa	12527	Oklahoma	12904
Texas	3390	Oklahoma	11855	Ohio	12818
Arkansas	3230	Tennessee	11714	Tennessee	12555
Mississippi	2790	Kentucky	11467	Kentucky	12209
Louisiana	2550	Louisiana	10922	Louisiana	11879
Average	5077	Average	14725	Average	16161
Std. Deviation	1261	Std. Deviation	2523	Std. Deviation	3268
C. V.	0.25	C. V.	0.17	C.V.	0.20

shocks can be inferred from the correlation between the regression disturbances.

Table 5 contains a grouping of states based upon both the correlation between the estimated residuals and geography.[6] North Dakota and South Dakota represent examples of how the categorization of states was performed. As was true for most neighboring states, the correlation between the residuals for these two states was rather high at approximately 0.65. However, the correlation with other regional states differed significantly. The estimated residual correlation for North Dakota with the states in the West region is approximately 0.4 versus 0.27 for South Dakota. In contrast, the correlation between North Dakota and the other Northern Plain states of Nebraska and Kansas averaged 0.2 while for South Dakota it was 0.56. The

Table 5- State Groupings Based on Residual Correlation

Region	States
Northeast	Maine, New York, Pennsylvania, Vermont
Southeast	Georgia, Florida, Kentucky, Maryland, North Carolina, Virginia
Delta	Arkansas, Louisiana, Mississippi, Missouri, Tennessee,
Mid-West	Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin
Northern Plains	Kansas, Nebraska, South Dakota
Southern Plains	New Mexico, Oklahoma, Texas
West	Arizona, California, Colorado, Idaho, North Dakota, Oregon, Washington

[6]Given the size of the matrix, 36 x 36, the correlation matrix of the residuals is not presented.

same procedure was performed on all states to obtain the groupings given in Table 5.

A probable explanation for the difference between North and South Dakota is the form of increase in milk yield noted in Table 2. North Dakota is placed together with the western states which generally displayed a geometric rate of increase while South Dakota exhibited an absolute increase similar to that of the northern plain states with which it is grouped. The hypothesis is given further support by the relatively high average degree of correlation (0.31) shown between the western states and Pennsylvania whose milk production per cow has grown geometrically over time. However, Pennsylvania is not categorized with these states for there is a similar degree of correlation with other states within the Northeast region. Thus, geographical considerations influenced the final categorization of Pennsylvania. Similar effects dictated the placement of Wisconsin.

The seven groupings given in Table 5 are comparable to the ten farm production regions defined by the USDA. Fewer regions are obtained by dividing the Appalachian region between the Delta and Southeast regions, by combining the Lake states and Corn Belt to form a Mid-West region, and by amalgamating the Mountain and Pacific states into a West region.

Exceptions between the regional groupings besides the placement of North Dakota into the West region, include moving New Mexico from the West region to the Southern Plains with Oklahoma and Texas. In addition, Maryland is combined with the neighboring Appalachian states and placed in the Southeast region with Georgia and Florida. The remaining Appalachian state of Tennessee is placed in the Delta region as is Missouri which is defined to be in the Corn Belt under the USDA classification.

Conclusions

This paper determined the form and size of the increase in state milk yield for the top 36 milk producing states. States are categorized based upon whether the increase in milk production per cow has been absolute or geometric. The obtained parameter estimates are then utilized to project future milk yields. The relative rankings are predicted to continue shifting in favour of the western states who have generally shown a geometric rate of increase and away from the traditional milk producing states. The projected range between the top and bottom states will increase in relative terms over time.

Parameter estimates are obtained by estimating all states simultaneously using seemingly unrelated regression (SUR). The SUR estimation procedure also permits grouping states according to the reaction of milk yield to exogenous shocks, inferred from the correlation of the estimated residuals between state equations. The state groupings are similar to the USDA farm production regions with differences due in part to the form of increase in state milk production per cow.

The present analysis used time series data on milk yield to determine changes in this variable. The research should be extended to determine factors influencing both the size and form of increases in milk yield by state.

REFERENCES

Bath, D.L. "Nutritional Requirements and Economics of Lowering Feed Costs." Journal of Dairy Science. 68(1985):1579-1584.

Buxton, B.M. "Factors Affecting U.S. Milk Production." Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No.527. March 1985.

Buxton, B.M., T.McGuckin, R.Selley, and G.Willett. "Milk Production: A Four-State Earnings Comparison." Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No.528. February 1985.

Hansen, L.B., C.W. Young, K.P. Miller, and R.W. Touchberry. "Health Care Requirements of Dairy Cattle. I. Response to Milk Yield Selection." Journal of Dairy Science. 62(1979):1922-1931.

Judge, G.G., W.E. Griffiths, R.C. Hill, H. Lutkepohl, T.C. Lee. The Theory and Practice of Econometrics, 2nd edition NewYork:John Wiley & Sons, 1985.

Kaiser, H.M., D.H. Streeter, & D.J. Liu. "A Dynamic Analysis of the Food Security Act and the Harkin-Gephardt Bill: The Dairy Sector." American Journal of Agricultural Economics. 70(1988):848-858.

Kmenta, J. Elements of Econometrics, New York:Macmillan Publishing Co., 1971

Lafrance, J. and H.G. deGoerter. "Regulation in a Dynamic Market: The U.S. Dairy Industry." American Journal of Agricultural Economics. 67(1985):821-831.

Olds, D., T. Cooper, and F.A.Thrift. "Relationships Between Milk Yield and Fertility in Dairy Cattle." Journal of Dairy Science, 62(1979):1140-1144.

Schmidt, G.H., and D.E. Pritchard. "Effects of Increased Production per Cow on Economic Returns." Journal of Dairy Science. 70(1987):2695-2704.

Tyrell, H.F., and P.W. Moe. "Effect of Intake on Digestive Energy." Journal of Dairy Science. 58(1975):1151-1163.

United States Department of Agriculture. Milk: Production, Disposition, and Income, Statistical Reporting Service, Washington, D.C., various issues.

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