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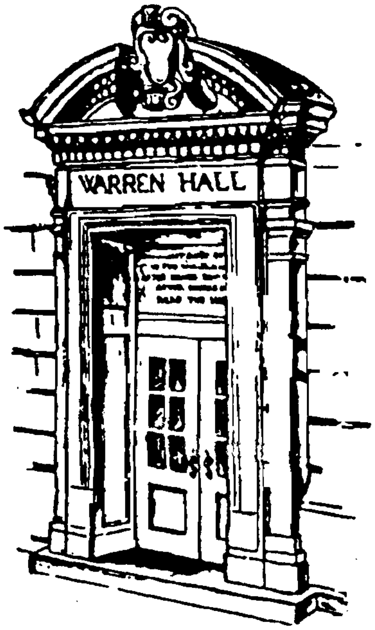

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Productivity of Dairy Production In Individual States

by

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Abstract

In a competitive market dairy production will shift to that region which is the most productive. Thus, this paper reports the measurement of productivity of dairy production in the various states of the U.S using recent Census data and non-parametric Malmquist index techniques. These are total factor productivity measures that do not require the assumption of cost or profit maximization behavior for aggregation.

The Malmquist approach utilizes distance functions and can be used to measure technical and efficiency differences over time and between regions at a point in time. Using two output and six input variables, the distance functions were calculated via linear programming methods. The scalar values from those distance functions were used to calculate indexes for efficiency, technical, and productivity changes across the time periods.

Individual state estimates of changes in efficiency, technology, and productivity from 1987 to 1992 were computed, divided by 1987 values. Over these states the average increase in productivity was 3.6 percent, or about 0.7 percent per year. Almost all of the productivity increase occurred from technological change, since the average increase in efficiency was only 0.1 percent. Technological change averaged 3.5 percent over the five year period, or about 0.7 percent each year.

If there is a significant decrease in the number of farms in a state, it might be expected that the remaining farms are more efficient, under the assumption that the least efficient farms are those that exit the industry. This was tested by regressing the percent change in efficiency on the percent change in farm numbers. The results were statistically insignificant. Likewise, if the output of the average farm increased it might be expected that efficiency might fall. This was tested by regressing the percent change in efficiency on the percent change in output per farm. Again the results were statistically insignificant. It was further expected that states that increased output per farm might have done so by using new technology. This was tested by regressing percent technological change on the percent change in output per farm. These results were also statistically insignificant.

Productivity of Dairy Production in Individual States

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Introduction

The U.S. dairy industry has experienced restructuring as production has shifted regionally, and many small dairy farms have gone out of business. A watershed event that marked this paradigm shift was when California replaced Wisconsin as the number one producing dairy state in 1994. Although California has a few small dairy farms, and Wisconsin has some large dairy farms, milk production in California is dominated by large dry-lot producers, and Wisconsin consists mostly of smaller dairy farms.

This transition has been occurring for a number of years, and various studies have explored this shift (Chavas and Magand, Gilbert and Akor). Studies have concluded that the cost of production is lower in the dry-lot dairies of the West and Southwest, compared to the traditional dairy areas of the Lake States and the Northeast (Fallert, Blayney and Miller). Yet, although the cost of production may be lowest in the Pacific region, that cost advantage should only last until equilibrium is reached (Weersink and Tauer). After all, land resources in much of the Lake States are ideally suitable for dairy, and it is not imaginable that a large amount of milk would not continue to be produced in that region.

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Underlying any economics of the situation is the productivity of the resources used in dairy production. In a free market situation, production will occur in that region that is the most productive. Thus, this paper reports the measurement of productivity of dairy production in the various states of the U.S. Other studies have measured state dairy productivity (Shoemaker and Somwaru). This study uses recent Census data and non-parametric Malmquist indices techniques to measure productivity. These non-parametric measures are total factor productivity measures which do not require the assumption of cost or profit maximization behavior for aggregation. No underlying function form is presumed.

Approach

Productivity difference between regions can be measured by the difference in the ratio of outputs to inputs used in the production process. Since multiple inputs and outputs are involved in a production process, various procedures have been developed to aggregate inputs and outputs and to measure differences. The Malmquist index, originally formulated by Malmquist, 1953, has been recently developed within the nonparametric or Data Envelopment Analysis (DEA) framework by Färe *et al.*, 1990. The technique has been used to measure the productivity of countries (Färe, Grosskopf, Yaisawarng, Li and Wang, 1994), electric utilities (Hjalmarsson and Veiderpass), the natural gas industry (Price and Weyman-Jones), and agriculture (Fulginiti and Perrin). Most of these articles present graphics to illustrate the Malmquist index. A book length treatment is Färe, Grosskopf and Lovell (1994).

The approach utilizes distance functions and can be used to measure technical and efficiency differences over time and between regions at a point in time. An output distance function can be defined as (Cornes, 1992):

$$(1)\qquad D_o^k\left(x^k, y^k\right) = \left(\max\left\{\theta:\left(x^k, \theta y^k\right) \in s^k\right\}\right)^{-1}.$$

This essentially shows how much output(s) y can be increased given a quantity of input(s) x, such that x and θy remain in the production set. An input distance function can similarly be defined and under constant returns it's value is the reciprocal to the output distance function. The reference technology set s^k consists of observations of individual production units.

To construct the Malmquist index, it is necessary to define distance functions with respect to two periods k and k+1 as:

$$(2)\qquad D_o^k(x^{k+1}, y^{k+1}) = \left(\max\left\{\theta:\ \left(x^{k+1}, \theta y^{k+1}\right) \in s^k\right\}\right)^{-1}$$

and

$$(3)\qquad D_o^{k+1}(x^k, y^k) = \left(\max\left\{\theta:\ \left(x^k, \theta y^k\right) \in s^{k+1}\right\}\right)^{-1}.$$

The distance function specified by equation (2) measures the maximal proportional change in output required to make (x^{k+1}, y^{k+1}) feasible in relation to the technology used in period k. Similarly, the distance function specified by equation (3) measures the maximal proportional change in output required to make (x^k, y^k) feasible in relation to the technology used in period k+1.

Efficiency difference between periods k and k+1 is measured as:

$$E_o^{k+1}\left(y^{k+1}, x^{k+1}, y^k, x^k\right) = \frac{D_o^{k+1}(x^{k+1}, y^{k+1})}{D_o^k(x^k, y^k)}$$, where the numerator is the distance function, equation (1), measured for period k+1.

Technical difference between period k and k+1 is measured as:

$$T_o^{k+1}\left(y^{k+1}, x^{k+1}, y^k, x^k\right) = \left[\left(\frac{D_o^k(x^{k+1}, y^{k+1})}{D_o^{k+1}(x^k, y^k)}\right) x \left(\frac{D_o^k(x^k, y^k)}{D_o^{k+1}(x^{k+1}, y^{k+1})}\right)\right]^{\frac{1}{2}}.$$

The Malmquist productivity index is the product of the efficiency index and the technical index, $M_o^{k+1}(.) = E_o^{k+1}(.) \bullet T_o^{k+1}(.)$.

These defined distance functions are reciprocals to the output-based Farrell measure of technical efficiency and can be calculated for each region using nonparametric programming techniques (Färe *et al.*, 1994). The linear programming model to calculate the output distance function (1) for each of the k regions is:

(5) $\left(D_o^k(x^{k'}, y^{k'})\right)^{-1} = \max \theta^{k'}$

subject to

(5.a) $\sum_{k=1}^{K} z^k y_m^k \geq \theta^{k'} y_m^{k'}$ $\quad$ m = 1,...,M

$\sum_{k=1}^{K} z^k x_n^k \leq x_n^{k'}$ $\quad$ n = 1,...,N

(5.b) $z^k \geq 0$ $\quad$ k = 1,...,K

where z is the intensity vector, y is output, x is input, θ is the inverse of the efficiency score, M is the number of outputs, N is the number of inputs, and K is the number of regions. The technology specified here is nonparametric but assumes constant returns to scale and strong disposability of inputs and outputs. The nonparametric computation of $D_o^{k+1}\left(x^{k+1}, y^{k+1}\right)$ is exactly like (5), where k+1 is substituted for k.

The two distance functions specified in equations (2) and (3) require data from two different periods. The first is computed for period k as:

$$(6) \qquad \left(D_o^{k}(x^{k'+1}, y^{k'+1})\right)^{-1} = \max \theta^{k'}$$

subject to

$$\sum_{k=1}^{K} z^k y_m^{\ k} \geq \theta^{k'} y_m^{\ k'+1} \qquad m = 1,\ldots,M$$

$$n = 1,\ldots,N$$

$$\sum_{k=1}^{K} z^k x_n^{\ k} \leq x_n^{\ k'+1} \qquad k = 1,\ldots,K$$

$$z^k \geq 0$$

The second is specified as in (6), but the k and k+1 superscripts are transposed.

Using two output and six input variables described below, the distance functions were calculated via linear programming methods. The scalar values from those distance functions were used to calculate indexes for efficiency, technical, and productivity changes across the time periods.

Data

Data were from the Census of Agriculture summarized by the Standard Industrial Classification of 024 (Dairy farms). These Census data are summarized by state and available for the two Census years 1987 and 1992. The Census format for 1982 and earlier years is not comparable with the years of 1987 and 1992. The data for states

Alaska, Hawaii, Nevada, New Hampshire, Oregon and Wyoming were not included in the analysis due to unavailability of some data, primarily because of non-disclosure restrictions.

The two output variables were: 1) the market value of dairy products sold, 2) the market value of agricultural products other than dairy products sold, plus other farm-related income, and direct government payments. Other farm-related income includes such items as customwork income and income from the sale of forest products.

Expenses were grouped by six categories and were used as input variables. These were: 1) livestock expenses, 2) feed expenses, 3) crop and production expenses, 4) service flow from land, machinery and buildings, 5) labor expenses, and 6) operator labor. All variables were calculated as farm averages for each state.

Livestock expenses were simply livestock and poultry purchases. The feed expenses included feed for livestock and poultry. Fertilizer, chemicals, and seed, bulb, plant and tree purchases, all energy and petroleum expenses, repair and maintenance expenses were grouped together in the category crop and production expenses.

Value of land and building, and value of machinery and equipment are reported in the Census as average values per farm. To calculate a service flow from these assets the reported values were multiplied by percentage rates. The average value of land and building was multiplied by 10 percent, reflecting an average rent value in agriculture; the average value of machinery and equipment was multiplied by 20 percent to reflect a depreciation rate of 15 percent and interest rate of 5 percent. Hired farm labor, contract labor and custom work hired were grouped together as a labor input.

Information on unpaid family labor is not collected by the Census. The data on operator labor are the number of days of work off the farm, grouped by number of respondents into four categories: none, 1 to 99 days, 100 to 199 days, and 200 days or more. An average composite of hours worked on the farm was computed by subtracting from an assumed 365 days available, a weighting of the number of respondents in each of the four groups by their respective means - 0 days, 50 days, 150 days, and 250 days - and then dividing by the total number of respondents.

Results

Individual state estimates of changes in efficiency, technology, and productivity from 1987 to 1992, divided by 1987 values are reported in Table 1. Note that these changes are for the five year period and are not annualized. Because of non-disclosure rules, results for only 43 of the 50 states were computed. These 43 states, however, include the leading dairy producing states, and represent most of the dairy production in the United States. Over these states the average increase in productivity was 3.6 percent, or about 0.7 percent per year. Almost all of the productivity increase occurred from technology change since the average increase in efficiency was only 0.1 percent. The correlation between efficiency and technology change across the 43 states was only 0.06.

There was variation across states. Sixteen of the states saw a decrease in their efficiency with Kentucky displaying the greatest decrease at 5.7 percent. Ten states increased their efficiency with Massachusetts leading at 10.7 percent. Seventeen of the 43 states did not experience any change in computed efficiency over the 5 year period.

Table 1. Dairy Production Efficiency, Technical, and Productivity Changes in Individual States from 1987 to 1992

	Efficiency	Technical	Productivity
Alabama	1.060	1.074	1.138
Arizona	1.000	0.836	0.836
Arkansas	1.000	1.062	1.062
California	1.000	0.985	0.985
Colorado	0.997	1.016	1.013
Connecticut	1.014	1.051	1.065
Delaware	1.000	0.861	0.861
Florida	0.997	1.026	1.023
Georgia	0.987	1.049	1.036
Idaho	1.030	1.102	1.135
Illinois	0.997	1.025	1.022
Indiana	0.984	1.032	1.016
Iowa	0.981	1.043	1.024
Kansas	1.000	0.967	0.967
Kentucky	0.943	1.111	1.048
Louisiana	1.000	1.024	1.024
Maine	0.988	0.896	0.886
Maryland	1.014	0.999	1.013
Massachusetts	1.107	1.089	1.206
Michigan	1.000	1.053	1.053
Minnesota	1.000	1.038	1.038
Mississippi	1.000	1.069	1.069
Missouri	1.000	1.063	1.063
Montana	0.974	0.991	0.965
Nebraska	1.000	1.000	1.000
New Jersey	1.000	0.999	0.999
New Mexico	0.988	0.909	0.899
New York	1.009	1.027	1.037
North Carolina	0.945	1.039	0.981
North Dakota	1.000	1.247	1.247
Ohio	0.974	1.035	1.008
Oklahoma	0.987	1.111	1.096
Pennsylvania	0.996	0.985	0.981
South Carolina	1.006	1.055	1.061
South Dakota	1.000	1.114	1.114
Tennessee	0.956	1.085	1.037
Texas	1.000	1.050	1.050
Utah	1.032	1.045	1.078
Vermont	0.979	1.056	1.034
Virginia	1.003	1.063	1.066
Washington	1.000	1.101	1.101
West Virginia	1.082	1.015	1.098
Wisconsin	1.000	1.096	1.096
Average	1.001	1.035	1.036

Technological change averaged 3.5 percent over the five year period, or about 0.7 percent each year. North Dakota technology increased the most at 24.7 percent, or almost 5 percent a year, while Arizona experienced regressive technological change of 16.4 percent. Ten of the 43 states experienced regressive technological change. Two of these, California and Pennsylvania, are significant milk producing states, although the decrease in both of these states was only 1.5 percent.

Productivity is the product of technological and efficiency changes. Thirty three of the 43 states experienced an increase in their productivity, with the average productivity change being 3.6 percent. Since efficiency changed little for most of the states, changes in productivity was mostly due to changes in technology. The correlation between technology and productivity for the 43 states was .92, while the correlation between efficiency and productivity was only .44.

Table 2 shows the number of dairy farms in each state in 1992, the percent change in the number of dairy farms from 1987 to 1992, and the percent change in the output per farm over the same period. The number of dairy farms decreased in all states except Alabama, New Mexico, and Texas. New Mexico experienced an increased of 25 percent. Output per farm increased in each state but Alabama and South Carolina, both of which experienced only a 2 percent decrease. Idaho experienced the largest percent increase at 65.

It was hypothesized that a relationship may exist between the change in farm numbers and farm output, and changes in efficiency and technology change within a state. For instance, if there is a significant decrease in the number of farms in a state, it might be expected that the remaining farms are more efficient, under the assumption that the

Table 2: Change in Farm Numbers and Output per Farm from 1987 to 1992

	Number of Dairy Farms in 1992	Percent Change in Number of Farms	Percent Change in Output/Farm
Alabama	511	14	- 2
Arizona	111	-22	52
Arkansas	879	- 8	15
California	2373	- 6	35
Colorado	391	-17	47
Connecticut	360	-22	21
Delaware	83	-21	28
Florida	372	- 4	27
Georgia	675	- 8	40
Idaho	1169	-24	65
Illinois	2027	-25	55
Indiana	2247	-18	31
Iowa	3531	-16	37
Kansas	1109	-20	29
Kentucky	2874	-28	35
Louisiana	789	- 8	17
Maine	654	-24	36
Maryland	1074	-20	27
Massachusetts	434	-22	23
Michigan	4271	-18	32
Minnesota	11289	-21	32
Mississippi	751	- 8	14
Missouri	3469	-17	24
Montana	187	-27	30
Nebraska	901	-27	38
New Jersey	299	-28	18
New Mexico	162	25	59
New York	9698	-20	33
North Carolina	900	-20	27
North Dakota	1022	-25	32
Ohio	5110	-21	28
Oklahoma	1113	0	19
Pennsylvania	10799	-14	31
South Carolina	252	-13	- 2
South Dakota	1443	-26	40
Tennessee	1988	-24	30
Texas	2726	13	14
Utah	685	-11	39
Vermont	2194	-15	30
Virginia	1469	-19	29
Washington	1215	-16	47
West Virginia	359	-12	18
Wisconsin	28264	-19	28
Average	2610	-15	30

least efficient farms are those that exited the industry. This was tested by regressing the percent change in efficiency from Table 1 on the percent change in farm numbers from Table 2. The results were statistically insignificant, with an adjusted R squared value of .02. Numerical results are not presented. Likewise, if the output of the average farm increased it might be expected that efficiency might fall. This was tested by regressing the percent change in efficiency on the percent change in output per farm. Again the results were statistically insignificant and are not presented. It was further expected that states that increased output per farm might have done so by using new technology. This was tested by regressing percent technological change on the percent change in output per farm. These results were also statistically insignificant. Apparently, average changes in efficiency and technology at the state level are not impacted by the changes in farm numbers or output per farm.

Troublesome are some of the individual state estimates of efficiency or technological change. The non-parametric method used here is sensitive to outliers from data limitations (Färe, Grosskopf, and Lovell). Probably the most severe data limitation is the use of the market values of real estate and machinery to compute economic depreciation flow. Disturbing is the result for New Mexico, where the rate of technological change was regressive at .909. New Mexico was one of the few states that experienced an increase in the number of dairy farms. It is plausible that the average efficiency of New Mexico dairy operations did fall the computed 1.2 percent as these new comers learned dairy farming, but it is skeptical that the average technological change would fall 9.1 percent since they would be expected to use the newest technology when they built new facilities in New Mexico.. The neighboring state of Arizona likewise suffered a technological decrease of 16.4 percent. These results may be due to the fact that the economic depreciation flow from the market value of new investment is a much lower percent of market value than the flow from the market value of older investments (Yotopoulos). Since vintage of capital by state is not available from Census data, a constant percentage flow from market value was used across all states.

The result that North Dakota experienced the largest rate of technological change at 24.7 percent may also be due to data errors. Yet, it is interesting that it's neighbor to the south, South Dakota, experienced the second largest rate of technological change at 11.4 percent. Data limitations may be affecting the results for both states, but it may also be possible that these states experienced significant rates of technological change.

Since the capital input used may be biased it was dropped as an input and efficiency, technological, and productivity changes were computed as before with the two outputs and the five remaining inputs. Individual state results are not reported here, but the computed measures for Arizona, New Mexico, North Dakota, and South Dakota did not noticeable change, and the correlation between the new and old productivity changes for all sates was 0.99.

Summary

This paper reports the measurement of productivity of dairy production in the various states of the U.S. Non-parametric techniques are used, which measure total factor productivity without requiring the assumptions of either cost or profit maximization behavior, nor any underlying functional form. The technique also allows productivity to be measured as separate efficiency and technology components. Agriculture Census data for 1987 and 1992 are used for each state.

Technological change averaged 3.5 percent over the 5 year period for the 43 states in which complete data were available. Ten of the states experienced regressive technological change. Efficiency change only averaged 0.1 percent, with 28 of the 43 states increasing their efficiency. Productivity, which is the product of efficiency change and technical change averaged 3.6 percent. The correlation between efficiency and technology change across the 43 states was only 0.06.

It was expected that states that experienced significant reductions in farm numbers would have experienced increases in their average farm efficiency. However, regressions of efficiency estimates and then technology change estimates on the percent change in farm numbers and output per farm by state produced statistically insignificant results. Some state results may also be due to data limitations since Census data do not provide information to accurately measure capital flows.

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