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What Determines Productivity Growth of Agricultural Cooperatives?

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This paper examines productivity of a sample of grain marketing and farm supply cooperatives from 1990 to 1998. The cooperative industry's productivity or growth was mainly due to improvement in technology rather than improvement in pure efficiency or scale. The cooperative industry's productivity was primarily associated with the grain, fertilizer, and agrochemical product lines. Policies that raise fertilizer prices would encourage a cooperative to be technically more productive. In general, policies that raise prices of grain, fertilizer, and agrochemicals would encourage a cooperative to be more productive overall.

Key Words: agribusiness, cooperatives, input bias, output bias, productivity

JEL Classifications: D24, Q13

Productivity growth is the main driving force of the future competitive balance of an industry. Productivity statistics play an important role in a short-run analysis of trends in prices and in the competitiveness of a nation's exports (Dean, Harper, and Otto). Multi-factor productivity measures reflect a change in output that cannot be accounted for by a change in the combined inputs. Multi-factor productivity measures the joint effects of new technologies, economies of scale, and managerial skill.

Grain marketing and farm supply cooperatives are a prominent institutional form in U.S. agriculture, and the question of their productivity growth has not received considerable attention. Increased competition and consolidation have intensified the interest in the analysis of the structure and the factors affecting the productivity growth of the grain marketing and farm supply cooperative industry. Ariyaratne et al. found that many agribusiness cooperatives operated on the decreasing region of their average cost curves during the past decade. Thus, incentives encouraged agricultural cooperatives to get larger by diversifying or specializing their operations. Farmer Cooperative Statistics (Kraenzle et al.) reported that nominal net cooperative business volume increased from $72.1 billion in 1989 to $104.7 billion in 1998, but the total number of marketing and farm supply cooperatives declined from 4,799 in 1989 to 3,651 in 1998, a net decline of 1,148. The long-term decline in the number of cooperatives reflects, in part, the decreasing number of farmers in the United States.

Bruno used a factor price frontier framework to estimate productivity growth and to find sources of productivity growth for the manufacturing sectors of the United States, the U.K., Germany, and Japan. He found much of

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the slowdown in manufacturing productivity during the 1970s to be due to the rise in relative input prices. Adelaja examined productivity in food manufacturing using New Jersey's food manufacturing sector as a case study. He found that greater factor productivity is encouraged by rising raw material prices, wage rates, and regulation and by declining food prices. Ball et al. (1997) and Ball et al. (1999) estimated productivity growth and identified patterns of state productivity growth in the U.S. agriculture sector. Most of the studies used econometric methods to estimate productivity. Relative to other agricultural and nonagricultural sectors, very little economic research has been conducted to explain the agricultural cooperative sector's productivity growth.

This paper complements the work of other researchers who have examined the theoretical aspects of productivity and approaches to measure productivity. It also complements the work of other applied economists' research on agricultural cooperatives. A traditional parametric analysis of productivity may give results that are sensitive to the particular parametric specification utilized. In this context, analysis of productivity that is less dependent on the parametric specification of the model could be more insightful. Specifically, the first objective of this study is to determine the productivity of grain marketing and farm supply cooperatives using nonparametric methods, which place no functional form restriction on the technology. The second objective is to estimate input and output biases. The third objective is to determine the factors affecting productivity growth of grain marketing and farm supply cooperatives in Colorado, Illinois, Iowa, Kansas, Missouri, Nebraska, Oklahoma, South Dakota, and Texas.

Productivity

Productivity is the change in outputs in relation to the change in inputs and occurs when the efficiency of converting inputs to outputs changes and/or technical change (TC) occurs. Changes in efficiency relate to the distance that an observation is from the production frontier, whereas TC involves the shifting of the production frontier (Färe et al.). In this paper, we closely follow Färe et al. (1994) and Färe and Grosskopf (1996) in defining input-based Malmquist productivity indices (MPIs) and their decomposition into efficiency change and TC. To estimate the Malmquist input-based productivity index, we need to define input distance functions with respect to two different periods. Distance functions are representations of multiple-output and multiple-input technology, which require data on input and output quantities. The MPI is a primal index of productivity change and does not require cost or revenue shares to aggregate inputs and outputs (Färe and Grosskopf 1994).

We assume that there are n inputs $x = (x_1, x_2, \ldots, x_n) \in R^+$, m outputs $y = (y_1, y_2, \ldots, y_m) \in R^+$, k cooperatives ($k = 1, 2, \ldots, K$), t time periods ($t = 1, 2, \ldots, T$), and the production technology S^t. Throughout this paper k^i represents an individual cooperative. We assume that the set S^t is nonempty, closed, and convex and that both inputs are freely disposable. The input distance functions for within period (time t) and adjacent period (time t and $t + 1$) are:

$$(1) \qquad D_i^t(y^t, x^t) = \sup[\lambda_a : (y^t, x^t/\lambda_a) \varepsilon S^t] \quad \text{and}$$

$$(2) \qquad D_i^t(y^{t+1}, x^{t+1}) = \sup[\lambda_b : (y^{t+1}, x^{t+1}/\lambda_b) \varepsilon S^t].$$

By using period t as the reference technology, we can calculate the MPI by solving the following within-period and adjacent-period LP models:

$$(3) \qquad \min_{\{\lambda^{k'}, z\}} \lambda_a^{k'} = [D_i^t(y^{k',t}, x^{k',t}) \,|\, CRS]^{-1}$$

s.t.

$$\sum_{k=1}^{K} z^{k,t} y_m^{k,t} \geq y_m^{k',t}$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq \lambda_a^{k'} x_n^{k',t} \qquad z^{k,t} \geq 0 \quad \text{and}$$

$$(4) \qquad \min_{\{\lambda^{k'}, z\}} \lambda_b^{k'} = [D_i^t(y^{k',t+1}, x^{k',t+1}) \,|\, CRS]^{-1}$$

s.t.

$$\sum_{k=1}^{K} z^{k,t} y_m^{k,t} \geq y_m^{k',t+1}$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq \lambda_b^{k'} x_n^{k',t+1} \qquad z^{k,t} \geq 0,$$

where *CRS* stands for constant returns to scale technology. Through use of Equations (3) and (4), the MPI with reference to the *t*th period is represented as follows (Caves, Christensen, and Diewert):

$$(5) \qquad M_i^t(\cdot) = \frac{[D_i^t(y^t, x^t) \mid CRS]}{D_i^t(y^{t+1}, x^{t+1}) \mid CRS]} = \frac{\lambda_a^{k'}}{\lambda_b^{k'}}.$$

$M_i^t(\cdot)$ compares (y^t, x^t) to (y^{t+1}, x^{t+1}) by scaling y^{t+1} to the $D_i^t(y^{t+1}, x^{t+1})$ distance function and using period *t* technology as a reference. Although $D_i^t(y^t, x^t) \leq 1$, it is possible that $D_i^t(y^{t+1}, x^{t+1}) > 1$, because period $t + 1$ data may not be feasible with period *t* technology. The input distance functions for within period (time $t + 1$) and adjacent period (time $t + 1$ and *t*) are:

$$(6) \qquad D_i^{t+1}(y^{t+1}, x^{t+1}) = \sup[\lambda_c^k : (y^{t+1}, x^{t+1}/\lambda_c^k) \varepsilon S^{t+1} \quad \text{and}$$

$$(7) \qquad D_i^{t+1}(y^t, x^t) = \sup[\lambda_d^k : (y^t, x^t/\lambda_d^k) \varepsilon S^{t+1}].$$

We can calculate the MPI with $t + 1$ as the reference technology by solving the following within-period and adjacent-period LP models:

$$(8) \qquad \min_{\{\lambda_c^{k'}, z\}} \lambda_c^{k'} = [D_i^{t+1}(y^{k',t+1}, x^{k',t+1}) \mid CRS]^{-1}$$

s.t.

$$\sum_{k=1}^{K} z^{k,t+1} y_m^{k,t+1} \geq y_m^{k',t+1}$$

$$\sum_{k=1}^{K} z^{k,t+1} x_n^{k,t+1} \leq \lambda_c^{k'} x_n^{k',t+1} \qquad z^{k,t+1} \geq 0 \quad \text{and}$$

$$(9) \qquad \min_{\{\lambda_d^{k'}, z\}} \lambda_d^{k'} = [D_i^{t+1}(y^{k',t}, x^{k',t}) \mid CRS]^{-1}$$

s.t.

$$\sum_{k=1}^{K} z^{k,t+1} y_m^{k,t+1} \geq y_m^{k',t}$$

$$\sum_{k=1}^{K} z^{k,t+1} x_n^{k,t+1} \leq \lambda_d^{k'} x_n^{k',t} \qquad z^{k,t+1} \geq 0.$$

The MPI with reference to the $t + 1$ period is computed using Equations (8) and (9):

$$(10) \qquad M_i^{t+1} = \frac{[D_i^{t+1}(y^t, x^t) \mid CRS]}{[D_i^{t+1}(y^{t+1}, x^{t+1}) \mid CRS]} = \frac{\lambda_d^{k'}}{\lambda_c^{k'}}.$$

Färe et al. decomposed the MPI into TC, pure efficiency change (PEC), and scale change (SC) components by using the geometric mean of Equations (5) and (10):

$$(11) \qquad M_i(y^{t+1}, x^{t+1}, y^t, x^t) = \left\{ \left[\frac{D_i^t(y^t, x^t)}{D_i^t(y^{t+1}, x^{t+1})} \right] \times \left[\frac{D_i^{t+1}(y^t, x^t)}{D_i^{t+1}(y^{t+1}, x^{t+1})} \right] \right\}^{1/2}.$$

Following Färe et al., we can rewrite Equation (11) as:

$$(12) \qquad M_i(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{D_i^t(y^t, x^t)}{D_i^{t+1}(y^{t+1}, x^{t+1})} \right] \times \left\{ \left[\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^{t+1}, x^{t+1})} \right] \times \left[\frac{D_i^{t+1}(y^t, x^t)}{D_i^t(y^t, x^t)} \right] \right\}^{1/2} = \frac{A}{C} \times \left(\frac{C}{B} \times \frac{D}{A} \right)^{1/2}.$$

The ratio outside the brackets (A/C) in Equation (12) represents the efficiency change component, and the geometric mean of the ratios inside the brackets (C/B times D/A) represents the TC component. This decomposition allows for the evaluation of the source of changes in productivity. The TC component represents productivity growth due to innovation or the shifting of the production frontier. A change in efficiency indicates that the firm is moving towards or away from the industry's production frontier.

The efficiency change component is calculated relative to CRS technology. It can be decomposed into a PEC component, which is calculated relative to the variable returns to scale (VRS) technology, and a residual scale component, which captures changes in the deviation between variable returns and constant returns to scale technology. The PEC and SC can be estimated as follows:

(13) *Pure efficiency change*

$$= \frac{[D_i^t(y^t, x^t \mid VRS)]}{[D_i^{t+1}(y^{t+1}, x^{t+1} \mid VRS)]} \quad \text{and}$$

(14) $$\textit{Scale change} = \frac{[D_i^t(y^t, x^t \mid CRS)]}{[D_i^t(y^t, x^t \mid VRS)]} \div \frac{D_i^{t+1}(y^{t+1}, x^{t+1} \mid CRS)]}{[D_i^{t+1}(y^{t+1}, x^{t+1} \mid VRS)]}.$$

The distance functions under VRS can be found by constraining the z's defined in Equations (3) and (8) to sum to 1. With reference to the above information, if the MPI is greater than 1, productivity has improved; if the MPI is less than 1, productivity has deteriorated. A value of 1 reflects no change in productivity.

Färe and Grosskopf (1996) further demonstrated how the TC component in Equation (12) could be decomposed to examine bias. Specifically, they proposed the following decomposition:

(15) *Technical change*

$$= \left[\frac{D_i^{t+1}(y^t, x^t)}{D_i^t(y^t, x^t)}\right] \times \left\{\left[\frac{D_i^t(y^t, x^t)}{D_i^{t+1}(y^t, x^t)}\right] \times \left[\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^{t+1}, x^{t+1})}\right]\right\}^{1/2} = \frac{D}{A} \times \left(\frac{A}{D} \times \frac{C}{B}\right)^{1/2}.$$

The ratio of D/A measures the magnitude of TC along a ray through period t data. The geometric mean of the identity inside the bracket (A/D times C/B) measures the bias of TC between periods t and $t + 1$. It is the geometric mean of the ratio of the magnitude of TC along a ray through $t + 1$ data to the magnitude of TC along a ray through period t data. It is possible to further decompose the bias index into an input bias index and an output bias index:

(16) *Bias index*

$$= \left[\frac{D_i^t(y^t, x^t)D_i^{t+1}(y^t, x^{t+1})}{D_i^{t+1}(y^t, x^t)D_i^t(y^t, x^{t+1})}\right]^{1/2} \times \left[\frac{D_i^t(y^t, x^{t+1})D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^{t+1}(y^t, x^{t+1})D_i^t(y^{t+1}, x^{t+1})}\right]^{1/2}$$

$$= \left(\frac{A}{D} \times \frac{F}{E}\right)^{1/2} \times \left(\frac{C}{B} \times \frac{E}{F}\right)^{1/2}$$

$= \textit{input bias index} \times \textit{output bias index}.$

The period t input bias index holds the output vector constant at y^t and compares the magnitude of TC along a ray through x^{t+1} with the magnitude of TC along a ray through x^t. The period t output bias index involves the input vector from period $t + 1$ and output vector from both periods. By holding the input vector constant at x^{t+1}, the magnitude of TC along a ray through y^t is compared. Thus, an opportunity is provided to isolate the magnitude of the TC and efficiency change by making adjustments for input and output biases. The distance functions labeled E and F can be estimated with mixed period LP models (Färe and Grosskopf 1996). In summary, the MPI can be written as a product of the efficiency change (A/C), magnitude of TC, input bias, and output bias indices.

(17) $$M_i(\cdot) = \left[\frac{D_i^t(y^t, x^t)}{D_i^{t+1}(y^{t+1}, x^{t+1})}\right] \times \left[\frac{D_i^{t+1}(y^t, x^t)}{D_i^t(y^t, x^t)}\right] \times \left[\frac{D_i^t(y^t, x^t)D_i^{t+1}(y^t, x^{t+1})}{D_i^{t+1}(y^t, x^t)D_i^t(y^t, x^{t+1})}\right]^{1/2} \times \left[\frac{D_i^{t+1}(y^{t+1}, x^{t+1})D_i^t(y^t, x^{t+1})}{D_i^t(y^{t+1}, x^{t+1})D_i^{t+1}(y^t, x^{t+1})}\right]^{1/2} = \frac{A}{C} \times \frac{D}{A} \times \left(\frac{A}{D} \times \frac{F}{E}\right)^{1/2} \times \left(\frac{C}{B} \times \frac{E}{F}\right)^{1/2}$$

Factors Explaining Productivity

Induced innovation theory suggests that technical progress is determined by relative factor and product prices. It is expected that increases in relative factor prices induce research to save the more scarce factors of production, and increases in relative product prices direct research toward the more valuable commodities (Binswanger). Bruno explains why input price increases cause sectoral productivity growth. That is, input price increases encourage input substitution in the short run and induce input-saving TC in the long run. Factors other than input prices that affect productivity include product prices, input intensity and quality, public regulation, and general economic conditions (Adelaja). Based upon these theoretical relations, the following ordinary least square (OLS) models were formulated to explain the productivity and its components,

(18) (1) $PEC_{t+1} = f(Pk_t, Pl_t, Prm_t, Pgr_t, Pfer_t, Pchm_t, Ppet_t, Pfd_t, Po_t, MPI_t)$

(2) $SC_{t+1} = f(Pk_t, Pl_t, Prm_t, Pgr_t, Pfer_t, Pchm_t, Ppet_t, Pfd_t, Po_t, MPI_t)$

(3) $TC_{t+1} = f(Pk_t Pl_t, Prm_t, Pgr_t, Pfer_t, Pchm_t, Ppet_t, Pfd_t, Po_t, MPI_t)$

(4) $MPI_{t+1} = f(Pk_t Pl_t, Prm_t, Pgr_t, Pfer_t, Pchm_t, Ppet_t, Pfd_t, Po_t, MPI_t)$

where *PEC, SC, TC,* and *MPI* are pure efficiency change, scale change, technical change, and Malmquist productivity index, respectively. Prices of capital, labor, raw materials, grain, fertilizer, chemical, petroleum products, feed, and other products are symbolized by *Pk, Pl, Prm, Pgr, Pfer, Pchm, Ppet, Pfd,* and *Po,* respectively. Because the previous year's productivity gain or loss affects the current year's productivity, lagged MPIs were used (Adelaja).

To explain input and output bias indices and the magnitude of TC, the input-biased index, the output-biased index, and the magnitude component of the TC index were regressed on shares of inputs, outputs, and both inputs and outputs, respectively.

Data

Annual time series financial records from 1990 to 1992 and 1996 to 1998 were obtained from the Cooperative Finance Association (CFA), a subsidiary of Farmland Industries. The CFA data contains complete balance sheet and income statement data taken from audited financial statements. The CFA database did not contain disaggregated expenditure and revenue data from 1993 to 1995; hence, the years 1993, 1994, and 1995 were excluded from the analysis. To investigate productivity, input and output quantity data or indices and firms' output and input prices or indices are required. Because only financial records were available, transformations of several data series were necessary. In addition, dollar values of the expenses and the annual sales are adjusted for inflation by converting to 1998 constant dollars. Fiscal year differences in a cooperative's annual financial data records were accounted for when the annual expenses and the annual sales values were converted to real dollar quantities. Six outputs were defined for the cooperatives: grain, fertilizer, agrochemicals, petroleum products, feed, and other goods (antifreeze, tires, batteries, automotive parts, and miscellaneous goods) and services. Input expenses for the cooperatives included capital, labor, and all the other expenses except capital and labor. Capital expenses were defined as the sum of annual depreciation, total assets times the interest rate for the Federal Reserve Bank of New York, and rents and leases. Labor expenses included management expenses.

A total of 107 cooperatives had data for each year from 1990 to 1992 and from 1996 to 1998. The cooperatives were spread across nine states: Colorado (13), Illinois (3), Iowa (10), Kansas (41), Missouri (7), Nebraska (15), Oklahoma (14), South Dakota (3), and Texas (1). One cooperative was not involved in providing other goods and services during at least some of the study period. Twelve of the cooperatives were not involved in grain marketing during at least some of the study period. Seventy of the cooperatives did not sell feed at least 1 year during the study period. Sixty-seven, 74, and 91 of the cooperatives did not sell fertilizers, agricultural chemicals, and petroleum products, respectively, during at least part of the study period.

Summary statistics for the agribusiness are presented in Table 1. All dollar values are expressed in 1998 constant dollars. The mean dollar value of the capital expenses in 1998 was \$0.71 million. Capital expenses varied from \$0.01 to \$3.89 million. The mean dollar values of labor expenses and other expenses in 1998 were \$1.15 million and \$0.94 million. The mean dollar value of the grain sales in

Table 1. Summary Statistics of Cooperatives' Real Expenditures and Revenues

		Capital Expenses ($ million)	Labor Expenses ($ million)	Other Expenses ($ million)	Grain Sales ($ million)	Fertilizer Sales ($ million)	Agrochemical Sales ($ million)	Petroleum Product Sales ($ million)	Feed Sales ($ million)	Other Goods & Services Sales ($ million)
1990	Mean	0.73	0.79	0.61	9.65	1.01	0.48	1.25	0.70	0.70
	Std. Deviation	0.67	0.74	0.56	11.57	1.44	0.84	2.25	1.56	0.71
	Minimum	0.02	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.02
	Maximum	4.82	3.88	3.13	91.08	6.88	5.23	11.81	14.20	5.16
1991	Mean	0.63	0.86	0.66	9.30	1.06	0.55	1.35	0.70	0.74
	Std. Deviation	0.61	0.81	0.60	10.96	1.50	0.94	2.18	1.60	0.81
	Minimum	0.02	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.02
	Maximum	4.40	4.59	3.12	90.96	6.57	5.66	9.97	14.64	5.67
1992	Mean	0.51	0.89	0.66	9.98	1.06	0.58	1.24	0.75	0.69
	Std. Deviation	0.49	0.81	0.59	11.70	1.60	0.96	2.01	1.69	0.70
	Minimum	0.01	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.01
	Maximum	3.32	4.51	3.40	93.45	8.46	5.17	9.34	15.58	4.92
1996	Mean	0.77	1.06	0.78	13.90	1.67	0.91	0.94	0.94	0.75
	Std. Deviation	0.76	0.98	0.70	18.79	2.17	1.31	2.52	1.90	0.79
	Minimum	0.01	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
	Maximum	5.19	5.40	3.67	157.24	10.14	6.78	15.91	14.27	4.43
1997	Mean	0.71	1.08	0.88	14.38	1.71	0.93	1.64	0.87	0.91
	Std. Deviation	0.60	0.96	0.85	14.79	2.39	1.41	2.45	2.23	0.91
	Minimum	0.01	0.04	0.03	0.02	0.00	0.00	0.00	0.00	0.01
	Maximum	3.30	5.29	5.59	99.38	12.15	7.70	13.90	20.52	6.16
1998	Mean	0.71	1.15	0.94	13.38	1.62	0.97	1.43	0.86	0.99
	Std. Deviation	0.64	1.13	1.02	15.50	2.26	1.41	2.14	2.04	1.00
	Minimum	0.01	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.01
	Maximum	3.89	6.79	6.78	126.60	13.19	8.46	12.05	17.70	5.77

1998 was $13.38 million with a standard deviation of $15.5 million. The means of fertilizer sales, agrochemical sales, petroleum product sales, feed sales, and other sales in millions of 1998 dollars were $1.62, $0.97, $1.43, $0.86, and $0.99, respectively.

Summary statistics for the price indices are presented in Table 2. Input prices for capital were based on interest rates for the Federal Reserve Bank of New York (U.S. Department of Labor). Input prices for labor were the state average hourly earnings of production workers on manufacturing payrolls from the Department of Labor's Employment and Earnings. The producer price index for crude materials for further processing (U.S. Department of Labor) was used as the other input price. The shares of corn, sorghum, soybean, and wheat production (U.S. Department of Agriculture, various issues) for the state in which the cooperative was located were multiplied by their respective price indices (U.S. Department of Agriculture 1999) to construct a producer price index for grain. The U.S. producer price index for mixed fertilizers, the U.S. producer price index for agrochemicals, the U.S. producer price index for petroleum products (refined), and the U.S. producer price index for prepared animal feed were used (U.S. Department of Labor). A chained-type gross domestic product deflator (U.S. Department of Labor) was used as the other products and services price.

The intermediation approach from the banking literature is adopted to define outputs. Two approaches have typically been used in the banking literature: the production approach and the intermediation approach. The intermediation approach views depository institutions as providing services related to their role as a financial intermediary, whereas the production approach assumes that they are producers of services (Clark). Marketing and supply cooperatives, in many respects, act more like an intermediary than a producer. To be consistent with the intermediation approach (value added), outputs are defined as follows. First, the output sales are divided by the output price index found in Table 2 to determine the quantity transacted. Next the gross margin on each of the outputs is determined and divided by the quantity determined above to obtain a price index. This price represents the mark up (value added) that the cooperatives use capital, labor, and other inputs to produce. Thus, the cost of goods sold is accounted for in the value-added approach.

Productivity Results

This section discusses the MPI and TC (input bias TC, output bias TC, and magnitude of TC), PEC, and SC components from 1990 to 1992 and 1996 to 1998. The MPI and its components for the two periods were estimated by taking geometric averages of individual cooperative productivity indices across the 3-year periods. Recall that values of the MPI or any of its components that are greater than 1 denote improvements in performance, whereas values less than 1 denote deterioration in performance. These measures capture performance relative to the best practice in the sample, where best practice represents an industry frontier. Cochran's *t*-test procedure was used to test whether the indices were significantly different from unity (Griffiths et al.).

Tests showed that all of the indices were statistically different, except the SC component of the MPI. The geometric mean of the input-based MPI for the periods from 1990 to 1992 and 1996 to 1998 were 1.061 and 1.121, respectively (Table 3). Average MPIs of 1.061 and 1.121 imply that the average cooperative experienced increased productivity of 3% per annum from 1990 to 1992 and 6% per annum from 1996 to 1998. Of the 107 cooperative operations, 74 increased their productivity and 33 experienced deterioration of their productivity from 1990 to 1992. From 1996 to 1998, 88 cooperatives increased their productivity and 19 experienced deterioration of their productivity. The geometric mean of the TC component of the MPIs from 1990 to 1992 and 1996 to 1998 were 1.112 and 1.063, respectively. Of the 107 cooperatives, 95 experienced technological progression and 12 faced regressive technology or a downward shift in the production function from 1990 to 1992. From 1996 to 1998, only 83 cooperatives were

Table 2. Summary Statistics of Price Indices

		Price Indices								
		Capital	Labor	Other Expenses	Grain	Fertilizer	Chemical	Petroleum Products	Feed	Other Products
1990	Average	1.040	9.943	1.114	1.677	1.150	1.045	1.850	1.255	0.903
	Std. Deviation	0.010	0.571	0.023	0.092	0.008	0.016	0.053	0.005	0.007
	Minimum	1.028	7.959	1.057	1.552	1.138	1.025	1.709	1.247	0.894
	Maximum	1.058	10.866	1.131	2.040	1.161	1.072	1.885	1.264	0.914
1991	Average	1.079	10.276	1.031	1.830	1.154	1.091	1.610	1.274	0.921
	Std. Deviation	0.009	0.582	0.008	0.128	0.008	0.009	0.026	0.007	0.004
	Minimum	1.066	8.323	1.023	1.595	1.137	1.079	1.585	1.262	0.915
	Maximum	1.096	11.043	1.046	2.190	1.164	1.107	1.668	1.285	0.928
1992	Average	1.079	10.385	1.050	1.549	1.085	1.094	1.563	1.246	0.936
	Std. Deviation	0.010	0.618	0.012	0.179	0.036	0.011	0.034	0.016	0.009
	Minimum	1.066	8.049	1.038	1.381	1.062	1.077	1.513	1.239	0.930
	Maximum	1.097	11.076	1.059	1.706	1.101	1.118	1.590	1.266	0.942
1996	Average	1.070	10.333	1.180	1.794	1.079	1.075	1.507	1.366	0.993
	Std. Deviation	0.005	0.658	0.013	0.127	0.004	0.004	0.023	0.010	0.002
	Minimum	1.064	7.962	1.160	1.603	1.074	1.072	1.465	1.345	0.990
	Maximum	1.079	11.025	1.196	2.058	1.084	1.083	1.537	1.377	0.994
1997	Average	1.038	10.279	1.094	1.443	1.037	1.047	1.253	1.204	0.995
	Std. Deviation	0.003	0.644	0.039	0.055	0.005	0.004	0.097	0.075	0.002
	Minimum	1.034	7.888	1.016	1.377	1.029	1.039	1.078	1.065	0.994
	Maximum	1.043	10.933	1.149	1.907	1.044	1.052	1.382	1.285	0.998
1998	Average	1.004	10.019	0.979	1.097	0.995	0.987	1.004	0.952	1.006
	Std. Deviation	0.004	0.571	0.015	0.064	0.004	0.009	0.057	0.030	0.004
	Minimum	1.000	7.938	0.960	1.049	0.988	0.974	0.954	0.913	1.000
	Maximum	1.011	10.567	1.003	1.427	1.000	1.000	1.135	1.000	1.013

Table 3. Summary Statistics of Productivity and Its Components

	Summary Statistics	Productivity Change	Technical Change	Technical Change: Input Bias	Technical Change: Output Bias	Technical Change: Magnitude	Pure Efficiency Change	Scale Change
1990–92	Geo. Mean	1.0605	1.1123	1.0515	1.0448	1.0124	0.9623	0.9908
	Std. Deviation	0.1496	0.0890	0.0426	0.0643	0.1132	0.1147	0.0431
	Minimum	0.6644	0.9220	0.9512	0.9622	0.7139	0.6362	0.7812
	Maximum	1.5058	1.3702	1.2100	1.3743	1.2944	1.4053	1.0926
	$M_i > 1$	74	95	96	86	61	33	41
	$M_i = 1$	0	0	0	0	0	27	17
	$M_i < 1$	33	12	11	21	46	47	49
1996–98	Geo. Mean	1.1212	1.0630	1.0193	1.0369	1.0057	1.0456	1.0088
	Std. Deviation	0.1647	0.0884	0.0325	0.1113	0.1195	0.1032	0.0544
	Minimum	0.7694	0.8819	0.9147	0.8741	0.4923	0.7662	0.8611
	Maximum	1.9244	1.3400	1.1105	1.8325	1.2770	1.4004	1.4361
	$M_i > 1$	88	83	83	77	60	62	58
	$M_i = 1$	0	0	0	0	0	26	16
	$M_i < 1$	19	24	24	30	47	19	33

technically progressive. The geometric average of the PEC components from 1990 to 1992 and 1996 to 1998 were 0.962 and 1.046, respectively. The geometric mean of the SC components from 1990 to 1992 and 1996 to 1998 were 0.991 and 1.009, respectively.

On average, the productivity, technology, pure efficiency, and scale improvements from 1990 to 1992 were 6.1%, 11.2%, −3.8%, and −0.9%, respectively. During this period, the cooperative industry's productivity or growth was mainly due to improvement in technology rather than pure efficiency and scale. On average, the productivity, technology, pure efficiency, and scale improvements from 1996 to 1998 were 12.1%, 6.3%, 4.6%, and 0.9%, respectively. During this period, the cooperative industry's productivity or growth was mainly due to improvement in technology and pure efficiency.

Decomposition of the TC component of the MPI into input bias TC, output bias TC, and magnitude of TC was performed to determine contribution of these indices to TC. Input bias involves a rotation of the isoquants, and output bias represents a rotation of the production possibilities curve. On average all three indices were greater than one for the 1990 to 1992 and 1996 to 1998 periods (Table 3). Although all three indices were positive, their magnitudes were different. From 1990 to 1992, the contribution of the input bias index to TC was prominent. The contribution of the output bias to TC was much higher from 1996 to 1998. After making adjustments for input and output biases, the magnitude changes for the 1990 to 1992 and 1996 to 1998 periods were 1.24% and 0.57%, respectively.

Regression Results

The relationships between productivity indices and the input and output prices are examined in this section. Price and lagged TC index values were checked for collinearity using principle component analysis. Results suggested that high degrees of collinearity existed among the fertilizer price index and the petroleum product price index and the other products index and the chemical price index. This led to exclusion of the petroleum product price index and the other products index from the analysis. The error terms of each of the individual OLS models were tested to determine whether they were normally distributed using the chi-square goodness-of-fit test for normality. The chi-square goodness-of-fit test statistics were 23.18, 21.83, and 23.36, for pure efficiency change (PEC), technical efficiency change (TE), and MPI models, respectively. The χ^2

critical value with nine degrees of freedom and the 0.5% level of significance was 23.59. The null hypothesis of normally distributed error residuals for OLS estimates could not be rejected at the 0.5% level of confidence with the chi-square goodness-of-fit test for estimation of models PEC, TC, and MPI. However, for the scale efficiency change (SC) model, the chi-square goodness-of-fit test statistic of 85.34 was greater than the χ^2 critical value of 23.59 with 9 degrees of freedom and the 0.5% level of significance. The null hypothesis for the SC model could thus be rejected. OLS parameter estimates for the period from 1990 to 1992 and OLS parameter estimates for the period from 1996 to 1998 were tested for changes using the Chow F-test. Chow F statistics of 1.97, 1.78, 1.43, and 1.53 for the models PEC, SC, TC, and MPI, respectively, were less than the critical value of 2.41 with 9 and 196 degrees of freedoms and the 1% level of significance. Thus, the productivity indices were pooled over time, resulting in 214 observations for a particular productivity measure (107 cooperatives times 2 periods). Table 4 presents OLS regression results.

The feed price index was negatively correlated to the PEC and statistically significant at the 10% level. A negative relation among product price indices and the dependent variable can be explained by using Bruno's finding, which suggests that higher output prices reduce the incentive to substitute inputs and implement input saving measures by adjusting resource allocations. The grain price was positively correlated to the PEC and statistically significant at the 5% level. Increased grain prices encouraged cooperatives to gain productivity from resource allocation. Falling output prices encourage cooperatives to find new technical relations to reallocate their inputs more efficiently to attain the industry's production frontier, but it does not necessarily mean cooperatives substitute factors of production for each other. The capital, labor, and other input price indices were positively related to the PEC. Both capital and labor input price indices were not statistically significant. The other input price index was positively correlated to the PEC and statistically significant at the 5% level. These results suggest that during the study period, labor and capital input prices did not encourage cooperatives to move towards the industry's production frontier. A positive coefficient for the other input price indicates that an increase in other input prices encourages pure efficiency gain through input substitution and input saving technologies. Lagged MPI change was negatively correlated to the PEC and statistically significant at the 5% level, suggesting that previous periods' productivity progress negatively affected a cooperative's movement towards the industry's production frontier.

The price index for fertilizer was positively correlated to TC and statistically significant at the 5% level (Table 4). Increases in the fertilizer price encouraged cooperatives to shift the industry's production frontier by finding new technologies. The capital and other input price indices were positively related to the TC and statistically significant at the 5% level.

In the final regression model (Table 4), the grain, fertilizer, and agrochemical prices were positively correlated to the MPI and statistically significant at the 5%, 10% and 10% levels, respectively, while feed price index was negatively related to the MPI and statistically significant at the 10% level. The other input price index was positively correlated to the MPI and statistically significant at the 5% level, whereas previous periods' productivity progress was negatively related and statistically significant at the 5% level.

The input-biased index, output-biased index, and magnitude component of the TC index were regressed on shares of inputs, outputs, and both inputs and outputs to explain input and output biases. Because these regression models did not give statistically significant evidence to explain input and output biases, they are not reported.

Overall, the cooperative industry's productivity was mainly related to the grain prices, fertilizer prices, and other input prices. Because labor price was not statistically significant with any of the productivity measures, labor price did not affect the grain marketing and farm supply cooperative industry's productivity. This is surprising because some

Table 4. Factors Related to Productivity

			Prices							
	Constant	Grain	Fertilizer	Chemical	Feed	Capital	Labor	Other Expenses	Lagged Malmquist Index	R^2
Pure efficiency change										
Est.	−4.348	0.420**	−0.810	2.364	−2.745*	3.448	0.012	2.713**	−0.231**	0.21
T-ratio	−0.929	3.205	−0.403	0.776	−1.615	0.854	0.512	1.998	−4.237	
Scale change										
Est.	9 3.487**	0.100**	−1.333*	2.845**	−0.643	−3.349**	0.007	0.094	0.012	0.07
T-ratio	1.786	1.824	−1.591	2.238	−0.906	−1.988	0.651	0.166	0.527	
Technical change										
Est.	−11.118**	−0.077	6.112**	−2.387	−0.111	5.273**	0.006	2.348**	−0.041	0.34
T-ratio	−2.844	−0.701	3.641	−0.938	−0.078	1.653	0.293	2.069	−0.894	
Malmquist productivity index										
Est.	15.208**	0.429**	4.148*	5.389*	−3.414*	3.028	0.028	5.729**	−0.268**	0.16
T-ratio	2.427	2.440	1.542	1.321	−1.500	0.560	0.866	3.149	−3.659	

(** = significant at 5% and * = significant at 10%).

studies (Bruno, Adelaja) indicated the importance of labor prices in an industry's productivity growth. It is interesting that an increase in capital rental rate drives cooperatives productivity. It is important to note that this study did not use any random sampling procedures; therefore, generalization of the results is limited. Cooperatives in the CFA database may possess some special characteristics that nonparticipating cooperatives do not possess. Participating cooperatives may be financially well managed, technologically progressive, or the opposite. These types of cooperatives' financial characteristics can affect productivity estimates. Because the CFA database did not report cooperative specific inputs and outputs and prices, the study used several aggregate indexes to convert the annual expenses and the annual sales values to the real dollar quantities. Those data conversion procedures may not be completely representative of an actual individual cooperative's inputs and outputs.

Summary and Implications

This study used nonparametric approaches to measure productivity using a sample of grain marketing and farm supply cooperatives in the Great Plains for the period from 1990 to 1998. The MPI for the period from 1990 to 1992 and 1996 to 1998 were 1.061 and 1.121, respectively. An average productivity index of 1.061 implies that the average cooperative from 1990 to 1992 in the sample experienced 6.1% increased productivity in its cooperative operation during the period. Of the 107 cooperative operations, 74 cooperatives increased their productivity, while 33 experienced deterioration of their productivity during 1990 to 1992. From 1996 to 1998, 88 cooperatives increased their productivity, while 19 experienced deterioration of their productivity. During the study period, the cooperative industry's productivity or growth was mainly due to improvement in the technology rather than pure efficiency or SC.

To identify the factors related to productivity, OLS regressions were used to examine the relationship between productivity indices and prices of inputs and outputs. Productivity changes in the cooperative industry have been related to increases in grain, agrochemical, fertilizer, and other input prices and to decreases in feed prices. The effects of increasing output prices on an industry's future productivity are similar to those of decreasing input prices. Under declining output prices, cooperatives may look for alternatives for increased market share or nontraditional products. This analysis helps to explain consolidation in the industry. To be a leader in the industry, a cooperative needs to become more productive whether by adjusting input use or by adjusting output mix.

Some important implications of this study are as follows. Cooperatives could further increase their productivity through efficient utilization of inputs and operating at the optimum capacity, as indicated by the pure efficiency and SC indices. In addition, changing technology has rotated the production possibilities curve on the output side (output bias) and has rotated the isoquant (input bias). Cooperatives can gain productivity by including such products as fertilizer, grain, and agrochemicals in their product portfolio. Because fertilizer, grain, and agrochemical products prices are related to productivity growth in the industry, cooperatives with those product lines need to be aware of the future trends related to these commodities.

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