PRODUCTIVITY AND FARM SIZE

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Abstract

The objective of this paper was to examine productivity differences among individual farms. The Malmquist index approach was used to estimate productivity for each farm and to decompose productivity change into technical change and efficiency change. The relationship between productivity and farm size was explored. In addition, the relationships between each productivity component and outputs, and each productivity component and inputs were explored. For the sample of Kansas farms used in this study, average annual productivity change over the 20-year period for the sample of farms was 2.16%. Technical change averaged 1.54% per year and efficiency change averaged 0.61% per year. Productivity was significant and positively related to farm size and feed grain production, and significant and negatively related to labor use. The largest farms, those with real gross farm income greater than $500,000, had the largest annual average productivity change at 3.20%.

Keywords: productivity, competitive advantage, farm performance

Introduction

Productivity measures the quantity of outputs of a production process relative to the level of inputs. The more output resulting from a given level of input, the more productive the process. Productivity growth has been a relatively constant feature of U.S. agriculture. Output increases relative to input use have allowed fewer farmers to produce increasing amounts of commodities on a relatively constant or declining land base. Annual output growth for U.S. agriculture was 1.76% from 1948 to 2002 (United States Department of Agriculture 2005). Rather than growth in inputs, almost all of this output growth was due to an increase in productivity. Productivity growth enabled farms to increase outputs in relation to inputs or improve the output/input ratio.

By the end of the twenty-year period 1982 to 2002, 5% fewer U.S. farms were farming 5% more hectares. Kansas farm numbers over the same period show a similar trend, falling by 12% from 73,315 farms to 64,414 farms while hectares in farms remained relatively constant at around 19.1 million hectares (Kansas Department of Agriculture, *2004 Kansas Farm Facts*). Clearly, U.S. and Kansas farms became more productive in general over this time period. Fewer people managing more total hectares is a continuation of a historical trend in U.S. agriculture. People fed per farm worker has increased from 15.3 people fed per farm worker in 1950 to 103 people fed per farm worker in 1998 (Hallberg 2001).

Previous research has focused on the measurement of productivity at the state or country level (e.g., Ball et al. 1997; Arnade 1998; Ball et al. 2004). Research that examines productivity differences among farms is sparse. This research would be useful in understanding the structure of agriculture. Specifically, this research could be used to determine the competitive position of individual farms or groups of farms.

This paper examines productivity differences among individual farms in Kansas. The Malmquist productivity index is computed for each farm. The Malmquist productivity index is then decomposed to measure technical change and efficiency change for each farm. Differences in productivity, technical change, and efficiency change indices among farm size groups are presented and discussed.

Productivity Indices

Productivity indices, technical change indices, and efficiency change indices are computed in this paper using the input based Malmquist index approach. As discussed by Färe et al. (1994) and Färe and Grosskopf (1996), with this approach distance functions and linear programming are used to estimate Malmquist indices for each pair of years. The advantage of using this approach to estimate productivity is that it does not impose a functional form on the underlying technologies.

The Malmquist productivity index for each pair of years was decomposed into a technical change component and an efficiency change component. Technical change (TECHC) represents a shift in the production frontier and enables farms to produce more output with the same level of inputs or the same output with a lower level of inputs. Efficiency change (EFFC) involves a movement towards or away from the production frontier. If a farm exhibits positive efficiency change, they are said to be catching up. Positive efficiency change would enable a farm to have an output/input ratio that is similar to the most efficient farms or those on the production frontier.

Improvements in productivity over time yield Malmquist indexes greater than one. Deterioration in productivity results in a Malmquist index that is less than one. Similarly, improvements in the TECHC and EFFC components of the Malmquist index are also associated with a value of one and deterioration less than one. While the product of the TECHC and EFFC must equal the Malmquist index, these components can be moving in different directions (Färe et al. 1994; Färe and Grosskopf 1996).

Productivity indices were summarized by farm size group. The farms were categorized into groups using the following farm size categories: those with an average annual real gross farm income (rgfi) less than \$100,000; those between \$100,000 and \$250,000; those between \$250,000 and \$500,000; and those farms with an average annual real gross farm income greater than \$500,000.

To further examine the relationship between productivity and farm size, the following regression was used:

$$\ln \text{prodi} = \alpha + \beta(\ln \text{rgfi}) \qquad (1)$$

where ln is the natural logarithm, prodi is the Malmquist productivity index, and rgfi is real gross farm income. The β coefficient in this regression represents an elasticity which can be used to examine the sensitivity of productivity to changes in farm size.

Regression analysis was also used to examine the relationship between each productivity component and outputs, and each productivity component and inputs. To ease interpretation of these regressions, outputs and inputs were normalized using real gross farm income.

Data

Data collected and maintained by the Kansas Farm Management Association (KFMA) from 195 Kansas farms that had continuous data from 1984 to 2003 were utilized in this study. The KFMA database for 2003, from which the 20-year continuous member subset comes, contains 2,370 variables per farm for approximately 2,000 farms (Langemeier 2003). For this study, six outputs, small grain income (wheat), feed grain income (afg), oilseed income (oil), hay and forage income (ahay), beef income (beefi), and other income (otheri) were used. Other income includes crop insurance proceeds, machine hire, farm program payments, and other miscellaneous income such as patronage dividends.

Output quantities were derived by dividing production values by the appropriate price. Prices were collected from the Kansas Department of Agriculture (*Agricultural Prices*, various issues). Wheat prices were used for small grains, corn prices for feed grains, soybean prices for oilseeds, the price of all beef for beef, and the all hay price for hay and forage.

For inputs, purchased inputs (pinputs), capital inputs (capital), and total labor (tlabor) were used. Purchased inputs include feed, seed, insurance, fertilizer, and chemicals. Capital includes interest, depreciation, repairs, fuel, and land. Total labor (i.e., workers per farm) includes hired labor and unpaid operator and family labor. Aggregate input prices were used to create implicit input quantity indices for capital and purchased inputs (United States Department of Agriculture, *Agricultural Prices*, various issues).

Information pertaining to real gross farm income (rgfi) and total hectares (tacres) was collected. Rgfi includes all farm income deflated by the implicit price deflator for personal consumption expenditures (United States Department of Commerce). Total hectares include all hectares, cropland and pasture, owned and rented by the farm.

Summary statistics for the 195 farms are displayed in Table 1. For the 195 farms, real gross farm income averaged $232,236 over the 20-year period 1984-2003 with a maximum of $850,337 and a minimum of $33,877. Total hectares averaged 668 hectares with a 20-year average minimum of 86 hectares and a maximum of 2,287 hectares.

Output variables had 20-year averages for all farms of 319 metric tones (M/T) for wheat, 474 M/T for feed grains, 137 M/T for oilseeds, 69 M/T for all hay, and 25 M/T for all beef. Other income, which includes crop insurance proceeds, machine hire, farm, program payments, and other miscellaneous income, averaged $39,745. Purchased inputs, capital, and labor averaged 69,241, 100,892, and 1.46, respectively.

Table 1: Summary Statistics for Sample of 195 Kansas Farms.[a]

Variable	Unit	Average	Max	Min	Std. Dev.
Real Gross Farm Income	$	232,236	850,337	33,877	150,743
Total Hectares	Hectares	668	2,287	86	365
Wheat	M/T	319	1,624	5	270
Feed Grains	M/T	474	2,575	1	507
Oilseeds	M/T	137	1,123	-0-	185
Hay and Forage	M/T	69	1,566	-0-	152
Beef	M/T	25	279	-0-	37
Other Income	$	39,745	247,343	4,608	30,459
Purchased Inputs	Index	69,241	435,609	8,224	57,494
Capital Inputs	Index	100,892	35,8214	18,593	62,998
Total Labor	Workers	1.46	6.56	0.40	0.07

[a] 20-year averages.

Table 2 summarizes farm characteristics for farms grouped by real gross farm income. Approximately 77% of the farms had a real gross farm income between $100,000 and $500,000. The average real gross farm income for the largest farm size group was $663,813 and ranged from $533,843 to $850,337.

Table 2: Characteristics of Farms by Farm Size Category

	Farms < $100k	Farms $100k to $250k	Farms $250k to $500k	Farms > $500k
# of farms	34	96	55	10
Rgfi	$76,370	$172,625	$354,169	$663,813
Max Rgfi	$99,682	$245,231	$499,217	$850,337
Min Rgfi	$33,877	$101,362	$251,327	$533,843
Hectares	282	626	898	1,121

Results

Average productivity change for the 195 farms for the 20-year period was 2.16%. The largest farms, those with real gross farm income greater than $500,000, had an average annual productivity change of 3.20% (Table 3). The smallest farm group, those with real gross farm income less than $100,000, had an average annual productivity change of 2.13%. The two middle groups of farms, those with real gross farm income between $100,000 and $250,000 and those with real gross farm income between $250,000 and $500,000, had average annual productivity changes of 1.61% and 2.96%, respectively.

Table 3: Productivity Measures Farm Size Category

	Farms < $100k	Farms $100k to $250k	Farms $250k to $500k	Farms > $500k
Number	34	96	55	10
Rgfi	$76,370	$172,625	$354,169	$663,813
Hectares	282	626	898	1,121
TECHC	1.0130	1.0115	1.0211	1.0305
EFFC	1.0082	1.0045	1.0083	1.0015
PRODI	1.0213	1.0161	1.0296	1.0320

TECHC – technical change
EFFC – efficiency change
PRODI – Malmquist productivity change index

The fact that the group with average real gross farm income between $100,000 and $250,000 had the lowest productivity change index is interesting. A farm at the upper end of the real gross farm income range for this group would generate, on average, enough income to support one farm family. However, if the farm operator of a farm in this group has lower productivity than farms in the largest two farm size groups, he or she has a competitive disadvantage and thus will need to make a decision on whether he or she should decrease farm size and become a part-time farmer, or increase farm size to augment productivity. If the productivity remains relatively low for this group, it will become increasingly difficult for these farms to cover family living expenditures.

The Malmquist index was decomposed into technical change (TECHC) and efficiency change (EFFC). Technical change averaged 1.54% per year and efficiency change averaged 0.61% per year for the sample of farms. For the largest farms, TECHC averaged 3.05% and EFFC averaged 0.15%. The middle groups of farms had TECHC of 1.15% and 2.11%, and EFFC of 0.45% and 0.83%, respectively. The smallest farms averaged 1.30% for TECHC and 0.82% for EFFC. These decompositions suggest that technical change was, on average, a larger contributor to productivity change for the sample of farms. This was particularly true for larger farms for which almost all of the productivity change was due to technical change.

The regression examining the relationship between productivity and farm size for the entire sample of farms yielded an estimated β of 0.0072. This parameter estimate was statistically significant at the 5% level. This would suggest that for all 195 farms in the sample, over the 20-year period, a 1% increase in real gross farm income resulted in a 0.0072% increase in productivity. A doubling of farm size (increasing average farm size from $232,236 to $464,472) would result in a 0.72% increase in productivity.

As illustrated in Table 4, regressions examining the relationship between productivity and farm size were run for each farm size category. The estimated coefficients remained relatively small in magnitude in all four cases. None of these parameter estimates were statistically significant at the 5% level.

Table 4: Regressions Examining the Relationship Prodivtivity and Farm Size

	Farms < $100k	Farms $100k to $250k	Farms $250k to $500k	Farms > $500k
β‡	0.0219	0.0070	0.0046	-0.0041
t-stat	1.4191	0.6037	0.2979	-0.0733
Adj-R^2	0.0298	-0.0067	-0.0172	-0.1242

‡ Regression coefficient on the natural logarithm of real gross farm income
* Significant at the 5% level
** Significant at the 1% level

Further analysis was done to assess the impact of outputs and inputs on the PRODI measure, and on TECHC and EFFC. These results are summarized in Table 5, Table 6, and Table 7. Table 5 presents the results for productivity. Table 6 and Table 7 present the results for technical change and efficiency change, respectively.

Productivity was significantly related to feed grain production and labor use (Table 5). Farms that increased the proportion of feed grain income to gross farm income were relatively more productive. Farms that used relatively less labor in proportion to gross farm income were relatively more productive. This result reveals the importance of labor efficiency improvements to productivity growth.

Table 5: Regressions Examining Relationship between Productivity, Outputs, and Inputs

	β‡	t-stat	Adj-R^2
Prodi-outputs†			0.122466
Wheat	0.003426	1.587169	
Afg	0.006457	3.132454**	
Oil	0.001277	1.099791	
Ahay	-0.001110	-0.691965	
Beef	-0.001580	-1.178818	
Prodi-inputs†			0.041138
Tlabor	-0.014010	-2.785491**	
Pinputs	0.012644	1.611806	
Capital	0.016505	1.759575	

† Outputs and inputs normalized by real gross farm income
‡ Prodi regressed on normalized outputs and inputs
* Significant at the 5% level
** Significant at the 1% level

Table 6 presents the results of the regression analysis examining the relationship between technical change, and output and input mixes. Farms with higher levels of feed grain and oilseed production in relation to all other outputs exhibited higher levels of technical change. These results suggest that technology (e.g., adoption of no-till practices) was biased towards feed grains and oilseeds. All three inputs were significantly related to technical change. The input results in Table 6 suggest, in general, that technology was biased towards capital and purchased input use.

Table 6: Regressions Examining Relationship between Techinical Change, Outputs, and Inputs

	β‡	t-stat	Adj-R^2
TECHC-outputs†			0.211211
Wheat	-0.000310	-0.156184	
Afg	0.001411	2.177326*	
Oil	0.004573	2.877649**	
Ahay	-1.59E-03	-0.916828	
Beef	-0.000210	-0.128979	
TECHC–inputs†			0.144869
Tlabor	-0.013910	-4.132480**	
Pinputs	0.018695	2.638690**	
Capital	0.016103	2.620173**	

† Outputs and inputs normalized by real gross farm income
‡ TECHC regressed on normalized outputs and inputs
* Significant at the 5% level
** Significant at the 1% level

The results of the regression analysis examining the relationship between efficiency change, and output and input mixes are presented in Table 7. Efficiency change was positively related to wheat production, thus farms with higher levels of wheat production moved towards the production frontier. There was not a significant relationship between efficiency change and any of the inputs. This result means that farms that were moving towards the frontier did not use relatively more or less of any input. This result also suggests that the results with respect to productivity and labor discussed above were due to technical change rather than efficiency change.

Table 7: Regressions Examining Relationship between Efficiency Change, Outputs, and Inputs

	β‡	t-stat	Adj-R^2
			0.044100
EFFC-outputs†			
Wheat	0.003734	2.733881**	
Afg	0.001884	1.358308	
Oil	-0.000130	-0.127460	
Ahay	0.000483	0.513618	
Beef	-0.001360	-1.959407	
EFFC –inputs†			-0.013780
Tlabor	-0.000100	-0.024562	
Pinputs	-0.003460	-0.624718	
Capital	-0.002190	-0.358905	

† Outputs and inputs normalized by real gross farm income
‡ EFFC regressed on normalized outputs and inputs
* Significant at the 5% level
** Significant at the 1% level

Summary and Implications

Productivity measures the quantity of outputs of a production process relative to the level of inputs. The more output resulting from a given level of input, the more productive the process. Productivity growth has been a relatively constant feature of U.S. agriculture. Output increases, relative to input use, have allowed fewer farmers to produce increasing amounts of commodities on a relatively constant or declining land base. Productivity measures for a sample of KFMA farms that had continuous data for the period 1984-2003 were computed in this study.

Annual average productivity change over the 20-year period for this sample of farms was 2.16%. Productivity increased by 0.0072% for every 1% increase in real gross farm income. The largest farms, those with real gross farm income greater than $500,000, had the largest annual average productivity change at 3.20%. When regressed against outputs, feed grain production had a statistically significant and positive impact on productivity, while labor use was negatively related to productivity. These results suggest that productivity increased as farms added more feed grains and reduced labor relative to gross farm income.

Productivity was decomposed into a technical change component and an efficiency change component. Technical change averaged 1.54% per year and efficiency change averaged 0.61% per year for the sample of farms implying that most of the gains in productivity came through technological improvements rather than through gains in efficiency. In contrast to the small farms for which 38% of productivity was attributed to efficiency change, only 5% of productivity change for the largest farm size group was attributed to efficiency change. Thus, technical change played a much larger role in overall productivity change for the large farms.

This study has implications for the structure of agriculture. The productivity growth for the large farms was substantially higher than the productivity growth for the small farms. Also, technical change, a major component of productivity growth, was substantially higher for large farms. These results suggest that large farms have a competitive advantage and that consolidation will continue to be a major force impacting Kansas agriculture.

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