

# Productivity and Farm Size

## 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 acreage base. Annual output growth for U.S. agriculture was 1.88% from 1948 to 1994 (Ball et al. 1997). 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 US farms were farming 5% more acres. Kansas farm numbers over the same period show a similar trend, falling by 12% from 73,315 farms to 64,414 farms while acres in farms remained relatively constant at around 47.1 million acres. Clearly, U.S. and Kansas farms became more productive in general over this time period. Fewer people are managing more total acres. This is a continuation of a historical trend in US 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).

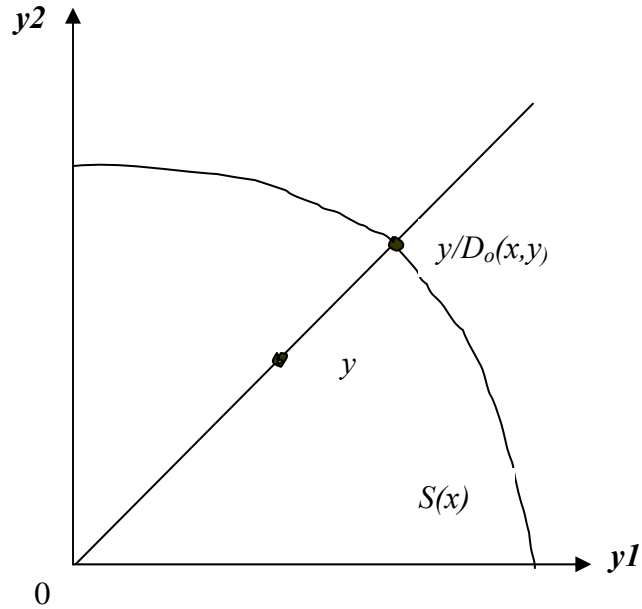
The paper is organized as follows: the next section gives a brief overview of how productivity change is measured using distance functions to calculate a Malmquist productivity index; the third section provides a description of the data followed by a

discussion of the results; the paper concludes with a summary and implications

### Distance Functions and Productivity Indexes

Productivity change can be measured using distance functions. A graphical representation of an output based distance function is illustrated by *Figure 1*.

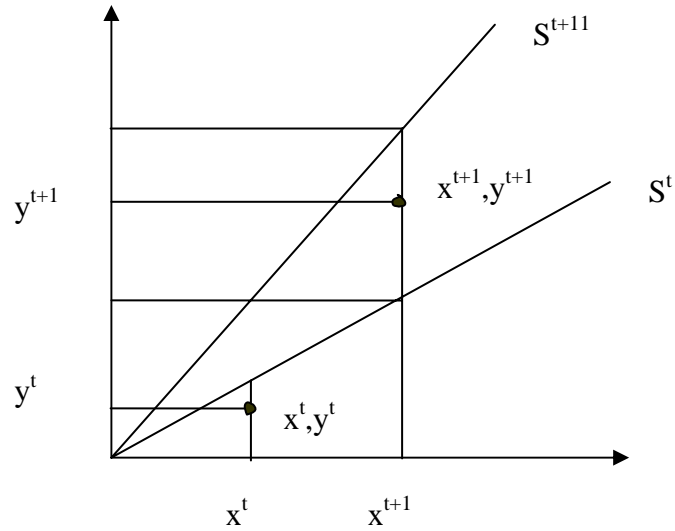
*Figure 1.*



In the figure above, the output vector  $y$  belongs to the output set  $S(x)$ , the output vector  $0y$  represents the combinations of outputs  $y_1$  and  $y_2$  that can be produced given the current technology. The output distance function  $D_0(x,y)$  is the ‘maximal’ feasible radial expansion of  $y$ . The value of  $D_0(x,y)$  is one if and only if the output vector is on the production possibilities frontier. Efficiency therefore is measured relative to the production possibilities frontier (Fare and Grosskopf 1996).

Figure 2 illustrates a shift in the production frontier, or technical change, from  $S^t$  to  $S^{t+1}$ , output at  $y^t$  is feasible with inputs  $x^t$  but not inputs  $x^{t+1}$  and  $y^{t+1}$  is feasible with inputs  $x^{t+1}$ .

Figure 2.



The Malmquist productivity index includes efficiency change and technical change. Technical change (TECHC) represents a shift in the production frontier and enables firms 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 firm exhibits positive efficiency change, they are said to be catching up. Positive efficiency change would enable a firm to have an output/input ratio that is similar to the most efficient firms 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 less than one. Similarly, improvements in the EFFC and TECHC components of the Malmquist index are also associated with a value of one and deterioration less than one. While the product of the EFFC and TECHC must equal the Malmquist index, these components can be moving in different directions (Fare *et al.* 1994).

## 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 analyzed 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 Agricultural Statistics Service (KASS). 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 used for hay and forage income. 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, workers per farm, includes hired labor and unpaid operator and family labor. Input prices come from the U.S Department of Agriculture, "Agricultural Prices". Input quantities thus determined for capital and purchased inputs are interpreted to be indexes. Additionally, real gross farm income (*rgfi*) and total acres (*tacres*) were collected. *Rgfi* includes all farm income deflated by the "Implicit Price Deflator for Personal Consumption Expenditures". Total acres include all acres, cropland and pasture, owned and rented by the farm.

Summary statistics for the set of 195 farms are displayed in Table 1. For the 195 farms, *rgfi* averaged \$232,236 over the 20-year period 1984-2003 with a maximum of \$850,337 and a minimum of \$33,877. Total acres averaged 1,651 acres with a 20-year maximum of 5,650 and a minimum of 212 acres.

Output variables had 20-year averages for all farms of 11,737 bushels for wheat, 18,657 bushels for all feed grains, 5,380 bushels for oilseeds, 76 tons for all hay and 540 cwt 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.

## **Results**

Table 2 summarizes farm characteristics for farms grouped by *rgfi*. In addition to ‘all farms’, the farms were categorized into groups by *rgfi*: those with an average annual *rgfi* greater than \$500,000; those between \$250,000 and \$500,000; those between \$100,000 and \$250,000; and those farms with an average annual *rgfi* less than \$100,000.

Average productivity change for the 195 farms for the 20-year period was 2.16% (Table3). The largest farms, those with *rgfi* greater than \$500,000, had an average productivity change of 3.20%. The smallest farm category, those with *rgfi* of less than \$100,000, had an average productivity change of 2.13%. The two middle groups of farms, those with *rgfi* between \$100,000 and \$250,000 and those with *rgfi* between \$250,000 and \$500,000, had average productivity changes of 1.61% and 2.96%, respectively.

The Malmquist index can be decomposed into technical change (TECHC) and efficiency change (EFFC). 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 a larger contributor to productivity change for the largest farms.

To estimate the effect of farm size on productivity, the following regression was used:

$$\ln prodi = \alpha + \beta(\ln rgfi) \quad (1)$$

where  $\ln prodi$  is the natural logarithm of the Malmquist productivity index, and  $rgfi$  is real gross farm income. Table 4 displays the regression results. The estimated  $\beta$  can be interpreted as an elasticity. The estimated  $\beta$  for ‘all farms’ is 0.0072 and positive. 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  $rgfi$  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.

In addition to ‘all farms’, a similar procedure was applied to each size grouping. The estimated coefficients remained relatively small in magnitude in all four cases, positive in sign for the three smaller groups as would be expected, but negative for the greater than \$500 thousand group. None of these parameter estimates were statistically significant at the 5% level.

Further analysis was done to assess the impact of outputs and inputs on the PRODI measure and on TECHC. These results are summarized in Tables 5 & 6.

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 the other inputs were relatively more productive. This result reveals the importance of labor efficiency improvements to productivity growth.

Table 6 presents the relationship between technical change, and output and input mixes. Farms with higher levels of feed grain and oil seed production in relation to all other outputs exhibited higher levels of technical change. 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.

### **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 acreage 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 *rgfi*. The largest farms, those with *rgfi* over \$500,000, had the largest annual average productivity change at 3.20%. When regressed against outputs, feed grain production (*afg*) 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 other inputs.

The Malmquist productivity index calculated can be decomposed into a technical change component (TECHC) and an efficiency change (EFFC) component. TECHC averaged 1.54% and EFFC averaged 0.61% for this sample of farms implying that most of the gains in productivity came through technological improvements rather than through gains in efficiency.

The implications of this study are that for this set of Kansas farms productivity has indeed increased over the study period with the largest farms having the largest gains. Technological improvement played a greater role in overall productivity change for the largest farms than did improvements in efficiency. Feed grain production and labor use were the principal drivers of productivity change.

## References

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**Table 1.** Summary Statistics for a Sample of 195 Kansas Farms<sup>a</sup>

Variable	Unit	Mean	Max	Min	Std. Dev.
Real Gross Farm Income (rgfi)	\$	232,236	850,337	33,877	150,743
Total acres	Acres	1,651	5,650	212	902
Wheat	Bu	11,737	59,680	166	9,917
Feed grain	Bu	18,657	101,361	56	19,959
Oilseed	Bu	5,380	44,217	-0-	7,298
All hay	Tons	76	1,727	-0-	167
Beef	Cwt	540	6,145	-0-	812
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

<sup>a</sup> 20 year averages**Table 2.** Characteristics of Farms by *rgfi* Grouping

	Farms < \$100k	Farms < \$250k, > \$100k	Farms < \$500k, > \$250k	Farms > \$500k	All Farms
# of farms	34	96	55	10	195
<i>Avrgfi</i>	\$ 76,370	\$ 172,625	\$ 354,169	\$ 663,813	\$ 232,236
<i>Maxrgfi</i>	\$ 99,682	\$ 245,231	\$ 499,217	\$ 850,337	\$ 850,337
<i>Minrgfi</i>	\$ 33,877	\$ 101,362	\$ 251,327	\$ 533,843	\$ 33,877
Avacres	697	1,547	2,220	2,770	1,651
Maxacres	1,555	5,660	4,230	4,250	5,660
Minacres	212	257	586	1,734	212

**Table 3.** Productivity measures - Farms by *rgfi* Grouping

	Farms < \$100k	Farms < \$250k, > \$100k	Farms < \$500k, > \$250k	Farms > \$500k	All Farms
Number	34	96	55	10	195
<i>Avrgfi</i>	\$ 76,370	\$ 172,625	\$ 354,169	\$ 663,813	\$ 232,236
Avacres	697	1,547	2,220	2,770	1,651
TEHC	1.013011	1.011505	1.021122	1.030496	1.015440
EFFC	1.008192	1.004509	1.008275	1.001487	1.006056
PRODI	1.021310	1.016066	1.029572	1.032028	1.021590

TEHC – technical change

EFFC – efficiency change

PRODI – Malmquist productivity change index

**Table 4.** Prodi – *rgfi* by Farm Grouping

	Farms < \$100k	Farms < \$250k, > \$100k	Farms < \$500k, > \$250k	Farms > \$500k	All Farms
$\beta^{\ddagger}$	0.021902	0.007016	0.004589	-0.004077	0.007217
t-stat	1.419093	0.603736	0.297938	-0.073260	2.490358*
Adj-R <sup>2</sup>	0.029806	-0.006735	-0.017164	-0.124246	0.026114
Reg-F	2.013825	0.364497	0.088767	0.005366	6.201884

<sup>‡</sup> Prodi regressed on *rgfi*

**Table 5.** Prodi-outputs and inputs

	$\beta^{\ddagger}$	t-stat	Adj-R <sup>2</sup>
<b>Prodi-outputs</b>			0.122466
<b>Wheat</b>	0.003426	1.587169	
<b>Afg</b>	0.006457	3.132454**	
<b>Oil</b>	0.001277	1.099791	
<b>Ahay</b>	-0.001110	-0.691965	
<b>Beef</b>	-0.001580	-1.178818	
<b>Prodi-inputs</b>			0.041138
<b>tlabor</b>	-0.014010	-2.785491*	
<b>pinputs</b>	0.012644	1.611806	
<b>capital</b>	0.016505	1.759575	

† Outputs and inputs normalized by *rgfi*

‡ Prodi regressed on normalized outputs and inputs

\* Significant at the 5% level

\*\* Significant at the 2% level

**Table 6.** TECHC-outputs and inputs

	$\beta^{\ddagger}$	t-stat	Adj-R <sup>2</sup>
<b>TECHC-outputs</b>			0.211211
<b>Wheat</b>	-0.000310	-0.156184	
<b>Afg</b>	0.001411	2.177326*	
<b>Oil</b>	0.004573	2.877649*	
<b>Ahay</b>	-1.59E-03	-0.916828	
<b>Beef</b>	-0.000210	-0.128979	
<b>TECHC -inputs</b>			0.144869
<b>tlabor</b>	-0.013910	-4.132480**	
<b>pinputs</b>	0.018695	2.638690*	
<b>capital</b>	0.016103	2.620173*	

† Outputs and inputs normalized by *rgfi*

‡ TECHC regressed on normalized outputs and inputs

\*\* Significant at the 2% level

\* Significant at the 5% level