EFFICIENCY GAINS DUE TO ECONOMIES OF SCOPE AND SCALE

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Abstract
Using a non-parametric linear programming approach, our contribution is (1) to examine if efficiency gains are realized due to diversification and (2) to demonstrate the diversification efficiency gains realized is a product of economies of scope efficiency gains and scale efficiency gains employing U.S. cropping sector made up of nine major crops for the period, 1975-1996. Results indicate efficiency gains are realized due to diversification for all the two-crop combinations. Further the average diversification efficiency gains are explained by scope efficiency gains and scale efficiency gains, with the t-test at the 5% level of significance indicates the mean diversification efficiency gains, scope efficiency gains and scale efficiency gains (with exceptions) are significantly different from one.

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Diversification of production units have been advocated by sustainable agricultural due to its advantages over and above specialized farming, but the technological advances leading to structural changes (See Hallam (1993) , Gardner and Pope (1978), Kislev and Peterson (1982 and 1996), Huffman and Evenson (1997) for research on structural changes with respect to farm size, farm specialization, off-farm wages, input price changes, technical, efficiency and productivity.) in agriculture inclined more towards specialization. Specially the technological advances in farming sector inclined more towards on-farm specialization and the trend in reduced crop diversification has continued but at much reduced rate. Further the proportions of farms without livestock has significantly increased. The reasons for these changes are not clear in that the economic studies have shown little advantage of large specialized units over moderate sized units. Currently beginning farmers tend to concentrate on crop production alone and encounter difficulties in assembling financial control over adequate sized units.

In general, there may well be a lack of understanding of the existing advantages of integrated operations and agriculture sector i.e., diversification and what enterprises can be integrated for purposes of higher economic return and reduced risk. Similarly, in the non-farm sector, the concept of diversification has been fading more so in the recent times due to specialization of technological advances and manufacturing process. The increased efficiency in producing specialized goods has led to a decreasing trend of diversification in non-farm and farming sectors.

Examination of the structural changes due to technological determinants at the firm or industry producing a single output (more than one output) can be identified with economies of scale (scope). Considerable literature [Panzar and Willig (1981); Eaton and Lemche (1991); and Lawrence and Braunstein (1992)] has been directed towards examining economies of scope due to production of multiple outputs or products. Economies of scope exist if $C(y_1, y_2) < C(y_1, 0) + C(0, y_2)$ where $C(y_1, y_2)$ is the firm's cost of producing multiple outputs, i.e., output 1 and 2 given input prices. Christensen and Greene (1976), and Panzar and Willig (1977) have addressed the economies of scale due to output expansion. The overall scale economies (or ray economies of scale) exist if $C(y_1, y_2) / \sum_i y_i C_i(y_1, y_2)$ is greater than one, where $C_i(y_1, y_2)$ is the marginal cost of producing i^{th} output. Some others [Lawrence (1989), and Cohn et al (1989)] have examined the economies of scale and scope in the dual framework.

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An alternative to the econometric estimation of economies of scope and scale is the use of non-parametric linear programming approach. In recent times, the programming approach of measuring efficiency in public and private sectors has received renewed attention. The non-parametric programming approach to the study of efficiency has had a relatively short history in agriculture sector, know familiarly known as Data Envelopment Analysis (DEA). M.J. Farrell (1957) discussed the empirical estimation of efficiency for multiple outputs and multiple inputs.

The application made was to U.S. agriculture. Farrell and Fieldhouse (1962) published another analysis using farm survey data. In 1966 at the Western Farm Management Association four papers were presented (Bressler, Boles, Seitz, and Sitorus) related to issues of different components of efficiency and their measurement. In 1978 DEA was introduced by Charnes et al and popularized in a more informative and easily applied way by Fare et al (1994). Lovell (1993) presented a selective overview of the existing techniques and models to estimate productive efficiency.

Data Envelopment Analysis (DEA) has certain advantages, in that it does not impose a priori functional form, can handle multi-outputs and multi-inputs, and compute efficiency without the need of output and input prices. A clear majority of DEA models use only quantity (quantity and price) data and calculate direct primal (indirect dual) measures. Fare (1986), and Fare and Primont (1988) have proposed the estimation of diversification efficiency gains identified with economies of scope invoking the duality equivalency between the subadditivity $C(\sum_{k=1}^{K} Y^k, w) \le \sum_{k=1}^{K} C(Y^k, w)$ of the cost function for input prices (w) and the superadditivity $L(\sum_{k=1}^{K} Y^k) \supseteq \sum_{k=1}^{K} L(Y^k)$ of the input requirement set. Extending the work of Fare and Primont, utilizing the duality equivalency between the cost function and the input requirement set, and the decomposition of the technical efficiency into pure technical efficiency and scale efficiency, we (1) examine if efficiency gains are realized due to diversification and (2) demonstrate the diversification efficiency gains realized is due to economies of scope efficiency gains and economies of scale efficiency gains employing U.S. cropping data of nine major crops for the period, 1975-1996.

Nonparametric Programming Model for Scope and Scale Gains

Let an industry with ***k*** specialized firms engage in production of ***k*** unique products over time ***t*** with vector of inputs x_i. Input requirement set transforming I -dimensional vector of inputs $x_{i,t}^k \in \Re_+$ into a vector of output $y_t^k \in \Re_+$ is represented by input set for firm ***k***:

$$(1) \qquad L(Y^k) = \{ x : \ zY^k \ge y_t^k \ , \ \sum_{i=1}^{I} zX^k \le x_{i,t}^k \ , \ z \ge 0 \}$$

$$t = 1,\ldots..,\mathrm{T} \quad i = 1,\ldots..\mathrm{I}$$

where z is a nonnegative and $z \ge 0$ indicates constant return to scale assumption, I and T is the input vector and the length of the time series respectively.

The input set for sum of ***k*** individual specialized firms can be represented as

$$(2) \qquad \sum_{k=1}^{K} L(Y^k) = \{ \ x : \ \sum_{k=1}^{K} zY^k \ge y_t^k \ , \ \sum_{k=1}^{K}\sum_{i=1}^{I} zX^k \le x_{i,t}^k \ , \ z \ge 0 \ \}$$

$$t = 1,\ldots..,\mathrm{T} \quad i = 1,\ldots..\mathrm{I} \quad k = 1,\ldots..\mathrm{K}$$

where I, T and K is the identical input vector in each of the ***k*** firms, length of the time series, number of specialized firms engaged in production of ***k*** unique products respectively, and $z \geq 0$ indicates constant return to scale assumption.

Instead of have identical input vector for each of the ***k*** firms, the diversified firm produces ***k*** unique products with set of I non-allocable input vector. The production technology of combined ***k*** firms (diversified firm) utilizing the same variables in equation (2) except for input vector is represented by an input set as:

$$(3) \qquad L(\sum_{k=1}^{K} Y^k) = \{\ x :\ \sum_{k=1}^{K} zY^k \geq y_t^k\ ,\ \sum_{i=1}^{I} zX \leq x_{i,t}\ ,\ z \geq 0\ \}$$

$$t = 1,.....,\mathrm{T} \quad i = 1,.....\mathrm{I} \quad k = 1,.....\mathrm{K}$$

where the definitions are like the those defined for equation (2) above.

The diversification efficiency gains are computed by comparing the frontiers of ***k*** individual specialized firms $\sum_{k=1}^{K} L(Y^k)$ and diversified firm (combined ***k*** firms) $L(\sum_{k=1}^{K} Y^k)$ under constant returns to scale assumption as:

$$(4) \quad \text{Diversification Efficiency gains } = \sum_{k=1}^{K} L(Y^k) \Big/ L(\sum_{k=1}^{K} Y^k)$$

where the ratio great (equal to) than one indicates efficiency (no efficiency) gains due to diversification.

The concept of input set can be represented by the input distance function for firm ***k*** as

$$(5) \qquad D_i(y_t\,,\ x_{i,t})^{-1} = \min_{\lambda,z} \lambda\ \{\lambda\!: (y_t\,, \lambda\, x_{i,t}) \in L(Y)\}$$

or

$$\begin{aligned} \min_{\lambda,z} \lambda \quad s.t. \qquad & y_t \leq zY \qquad\qquad , \\ & \sum_{i=1}^{I} \lambda\, x_{i,t} \geq\ z\, X_i \qquad i = 1,.....,I \\ & z\ \geq 0\ \ or\ \ (z = 1) \end{aligned}$$

sum of ***k*** individual specialized firms as:

$$(6) \qquad D_i^S(y_t^k\,,\ x_{i,t}^k)^{-1} = \min_{\lambda,z} \lambda\ \{\lambda\!: (y_t^k\,, \lambda\, x_{i,t}^k) \in \sum_{k=1}^{K} L(Y^k)\}$$

or

$$\begin{aligned} \min_{\lambda,z} \lambda \quad s.t. \qquad & \sum_{k=1}^{K} y_t^k\ \leq zY^k \qquad k = 1,.....,K \\ & \sum_{k=1}^{K} \sum_{i=1}^{I} \lambda\, x_{i,t}^k\ \geq\ z\, X_i^k \qquad i = 1,.....,I \\ & z\ \geq 0\ \ or\ \ (z = 1) \end{aligned}$$

and diversified firm as:

$$(7) \qquad D_i^D(y_t^k,\, x_{i,t})^{-1} = \min_{\lambda,z} \lambda \ \{\lambda : (y_t^k, \lambda\, x_{i,t}) \in L(\sum_{k=1}^{K} Y^k)\}$$

or

$$\begin{aligned} \min_{\lambda,z} \lambda \quad s.t. \quad & \sum_{k=1}^{K} y_t^k \le zY^k && k = 1,\ldots\ldots,K \\ & \sum_{i=1}^{I} \lambda\, x_{i,t} \ge \ z\, X_i && i = 1,\ldots\ldots,I \\ & z \ \ge 0 \ \ or \ \ (z = 1) \end{aligned}$$

where $D_i^S()\, and \ D_i^D()$ is the input distance function for ***k*** specialized firms and diversified firm respectively. The intensity variable $z \ge 0$ describes the constant returns to scale (CRS) technology and $z = 0$ describes the variable return to scale (VRS) technology. The scale efficiency can be computed for ***k*** specialized firms and diversified firm as the ratio of input distance functions under the assumption of constant returns to scale and variable returns to scale technology as:

$$(8) \qquad \begin{aligned} S_i^S(y,x) &= \frac{D_i^S(y,x|_{CRS})}{D_i^S(y,x|_{VRS})} \\ S_i^D(y,x) &= \frac{D_i^D(y,x|_{CRS})}{D_i^D(y,x|_{VRS})} \end{aligned}$$

where $S_i^S()\, and \ S_i^D()$ is the scale efficiency for ***k*** specialized firms and diversified firm respectively.

Utilizing the decomposition of technical efficiency into pure technical efficiency and scale efficiency by Farrell, the diversification efficiency gains can be defined as a product of economies of scope efficiency gains (due to pure technical efficiency) and economies of scale efficiency gains (due to scale efficiency). The diversification efficiency gains defined as a product of scope and scale can be represented by input distance functions as:

$$(9) \qquad \frac{\sum_{k=1}^{K} L(Y^k)}{L(\sum_{k=1}^{K} Y^k)} \equiv \frac{D_i^S(y,x|_{CRS})}{D_i^D(y,x|_{CRS})} = \frac{D_i^S(y,x|_{VRS})}{D_i^D(y,x|_{VRS})} * \frac{S_i^S(y,x)}{S_i^D(y,x)}$$

Diversification Efficiency gains = Scope gains $*$ Scale gains

where D_i is the input distance function, CRS is the constant returns to scale, VRS is variable returns to scale, S_i is the scale efficiency, and superscript ***S*** is sum of ***k*** specialized firms, ***D*** is diversified firm. The first part on the right-hand side represents efficiency gains due to scope (as in Fare 1986, 1988) with the second part ascribed to efficiency gains due to scale. Hence, the diversification efficiency gains can be attributed to scope and scale efficiency gains.

The measure of the diversification efficiency gains, the scope efficiency gains and scale efficiency gains is graphically represented in Figure (1). In Figure 1, the firm's CRS and VRS technology for specialized and diversified technology is represented as $CRS^S \ and \ VRS^S$ and

CRS^D *and* VRS^D respectively. Based on Figure 1, the input based scope efficiency gains (first part of equation 9) due to diversification can be represented:

$$(10) \qquad \text{Scope Efficiency gains} = \frac{D_i^S(y, x|_{VRS})}{D_i^D(y, x|_{VRS})} = \frac{OX/OX_S}{OX/OX_D} = \frac{OX_D}{OX_S}$$

The input based scale efficiency gains (second part of equation 9) due to diversification can be represented as:

$$(11) \qquad \text{Scale Efficiency gains} = \frac{S_i^S(y, x)}{S_i^D(y, x)} = \frac{\dfrac{OX/OX^{F_S}}{OX/OX_S}}{\dfrac{OX/OX^{F_D}}{OX/OX_D}} = \frac{OX_S/OX^{F_S}}{OX_D/OX^{F_D}}$$

and the input based diversification efficiency gains can be represented as:

$$(12) \qquad \frac{D_i^S(y, x|_{CRS})}{D_i^D(y, x|_{CRS})} = \frac{OX_D}{OX_S} * \frac{OX_S/OX^{F_S}}{OX_D/OX^{F_D}} \equiv \frac{OX^{F_D}}{OX^{F_S}}$$

Cost of Production Data on US Major Crops (WILL BE UPDATED FOR THE PRESENTATION)

To compute the economies of scope, efficiency gains, scale efficiency gains and diversification efficiency gains due to crop diversification, the cost of production data and output production for major crops are employed. The major crops used in the analysis are barley, corn, cotton, oats, peanuts, sorghum, soybeans, rice and wheat.

The input data for each of the crop is available on per acre basis from the cost of production data published by Economic Resource Service (ERS) of United States Department of Agriculture (USDA). The yield per acre and harvested acres for each crop is available from National Agricultural Statistical Service (NASS). In our current analysis, the output production (equal to the yield per acre times the harvested acres) in million bushels or pound depending upon the crop used as output. The units of output in case of barley, corn, oats, sorghum, soybean and wheat are in bushels per acre (yield) and million bushels (production). The units for yield are pounds per acre for all the three crops, while the units for production are in million bales, million pounds and million hundred weight for cotton, peanuts and rice respectively.

The per acre cost of production data aggregated to variable cost, capital cost and the land in acres are used as inputs. The variable cost is the sum of the variable cash expenses, general farm overhead, taxes and insurance and unpaid labor in dollars per acre. The capital cost includes capital replacement, operating capital and other nonland capital in dollars per acre. The variable and capital costs are multiplied by the harvested acres to compute the total variable cost and the total capital cost. These two inputs are further converted into real terms using the gross domestic product implicit price deflator. Single output and three inputs from 1975 to 1996 are used to compute the economies of scope and scale efficiency gains due to diversification.

Empirical Application and Results

To examine the economies of scope efficiency gains (equation 10), scale efficiency gains (equation 11) and diversification efficiency gains (equation 12) due to crop diversification, the input distance function defined in equations (6 and 7) are estimated. The U.S. level, output and input data of the nine crops for the period 1975-1996 are used to examine the efficiency gains due to diversification. Table 1 presents the average of the output and input variables employed in the analysis, the average efficiency scores over time, and rate of change in efficiency scores over the same period for each of the nine major crops estimated utilizing the input distance function defined in equation (5). The individual technical efficiency, pure technical efficiency and scale efficiency scores of each crop provide the basis for decomposition of the diversification efficiency gains into scope efficiency gains and scale efficiency gains due to crop diversification. Table 2 presents the average diversification, scope and scale efficiency gains due to two-crop diversification although it is very difficult to observe all the two-way crop combinations in practice. Also, the results of the null hypothesis that diversification efficiency gains, scope efficiency gains and scale efficiency gains for each of the two-crop combination is equal to one are examine employing a t-test at 5% level of significance. However, emphasis is given only to those crop combinations that exhibit diversification.

The average technical efficiency $D_i(y,x|CRS)$ defined as a product of pure technical efficiency $D_i(y,x|VRS)$ and scale efficiency $S_i(y,x)$ for each crop presented in Table 1 indicate the mean of the average technical efficiency (0.871) across all the crops is explained by the scale efficiency (0.924) and pure efficiency (0.913) equally. At the individual crop level, the average technical efficiency was more explained by pure technical efficiency (scale efficiency) in the case of barley, corn, peanuts, soybeans and wheat (cotton, oats, rice and sorghum).

The rate of change in the pure technical efficiency and scale efficiency between 1975-1996 indicates all the crops had a positive rate of change except for peanuts (-0.272) and sorghum (-0.031) having a negative rate of change in scale efficiency. This negative rate of change in scale efficiency corroborates with the negative rate of change in peanuts (-0.378) and sorghum (-1.200) acreage. However, the negative rate of change in acreage (-1.133, -0.023 and -0.458) is identified with lower rate of change in scale efficiency (0.196, 0.410 and 0.095) and higher rate of change in pure technical efficiency (0.876, 0.875 and 0.684) for barley, rice and wheat respectively. On the contrary, a positive rate of change in acreage (0.326, 1.752, and 0.761) is driven by higher rate of change in scale efficiency (1.220, 1.388, and 1.490) and lower rate of change in pure technical efficiency (0.543, 0.366, and 0.156) in corn, cotton and soybean respectively. Results from Table 1 extend support to the influence of pure technical efficiency and the scale efficiency on the technical efficiency. This importance of pure technical efficiency (scope efficiency gains) and scale efficiency (scale efficiency gains) in the computation of the technical efficiency (diversification efficiency gains) is examined for the two-crop diversification.

Scope and Scale Efficiency Gains Due to Two-Crop Diversification

The additional insights of the potential influence on the structural changes due to diversification can be carefully conceptualized based on the decomposition of average technical efficiency gains into scope efficiency gains and scale efficiency gains. The average efficiency gains, a product of efficiency gains due to scope and efficiency gains due to scale for all two crop-diversification are presented in Table 2 for the period, 1975-1996. Results from Table 2 indicate both technical efficiency gains and the scope efficiency gains have been realized for all the two crop-diversification. Only three crop combinations experienced declining average scale efficiency gains suggesting that firm cannot realize efficiency gains by just increasing factors of production. The three combinations are barley-rice, barley-sorghum, and peanuts-sorghum. However, the three crop combinations exhibited technical efficiency gains, indicating the technical efficiency gains can be attributed only to economies of scope.

The technical efficiency gains due to diversification of wheat with corn, peanuts and rice is explained more than 70 percent by scope efficiency gains. The diversification of wheat with barley, cotton, oats, sorghum and soybean is explained equally by efficiency gains due to scope and scale. However, the technical efficiency gains due to diversification of soybean with corn, cotton, oats, rice and sorghum (barley and peanuts) is explained more than 50 percent by the efficiency gains due to scale (efficiency gains due to scope). The outstanding feature of sorghum diversification with barley, peanuts and rice is the decreasing scale efficiency gains. A similar decreasing scale efficiency gains was observed by the barley-rice and the cotton-peanuts diversification. In the case of rice diversification with cotton, oats and peanuts, the technical efficiency gains are explained more than 50 percent by increasing efficiency gains due to scope rather than scale. A similar trend of increasing efficiency gains due to scope was indicated by oats diversification with barley, corn and cotton. The diversification of cotton with barley (corn) indicated more than 60 percent of technical efficiency gains is explained by efficiency gains due to scope (scale). Finally, the diversification of corn with barley is explained equally by efficiency gains due to scope and scale.

The corn-soybean crop combination is frequently observed in several areas of the U.S., however the average technical efficiency gains realized to diversification was close to 1.056 (5.61%), of which 1.018 (1.77%) and 1.038 (3.78%) was explained by average efficiency gains due to scope and scale respectively. It can be recalled from the results in Table 1 that corn and soybean crops individually had estimated average scale efficiency that were very high (1.220 and 1.490) compared to average scope efficiency (0.543 and 0.156).

The results of the $t-$test examining the null hypothesis that the realized diversification efficiency gains, scope efficiency gains and scale efficiency gains for each of the two-crop combination is equal to one are presented in Table 2. Based on the test statistic and $p-$value for the $t-$test at the 5% level of significance, this test indicates the mean diversification efficiency gains and scope efficiency gains are significantly different from one. However, with the exceptions (barley in combination with cotton, oats, peanuts, rice and sorghum; corn in combination with oats and wheat; cotton in combination with oats, peanut, rice and wheat; oats in combination with peanuts, rice and sorghum; peanuts in combination with sorghum and wheat; and rice in combination with sorghum and wheat) the mean scale efficiency gains are also significantly different from one.

Overall, results of the average efficiency gain measures and the $t-$test indicate all the two crop-combinations experienced diversification efficiency gains, a product of the efficiency gains due to economies of scope and scale. This demonstrates the importance of economies of scope and scale gains due to diversification of crops to be able to realize higher economic returns and reduced risk.

Conclusions

Utilizing the non-parametric linear programming approach, theoretically and empirically we demonstrate -the diversification efficiency gains realized is due to economies of scope efficiency gains and the economies of scale efficiency gains. The individual crop estimates of the efficiency measures over time indicate the average technical efficiency across all the crops of 0.845 is contributed equally by the pure technical (0.913) and scale efficiency (0.924). This supports the importance of pure technical efficiency (scope efficiency gains) and the scale efficiency (scale efficiency gains) in explaining the technical efficiency (diversification efficiency gains). In case of two-crop combinations, the diversification efficiency gains realized is explained by the efficiency gains due to scope and scale efficiency gains.

This indicates there is potential for higher efficiency gains of integrated operations i.e., diversification and what enterprises can be integrated for purposes of higher economic return and reduced risk. This study can be useful for further research to address the issue of spatial efficiency gains that can be realized by regional analyses of diversification, efficiency gains due to crop-livestock diversification and finally efficiency gains due to vertical diversification.

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Figure 1. Scope and Scale Efficiency Gains Due to Diversification

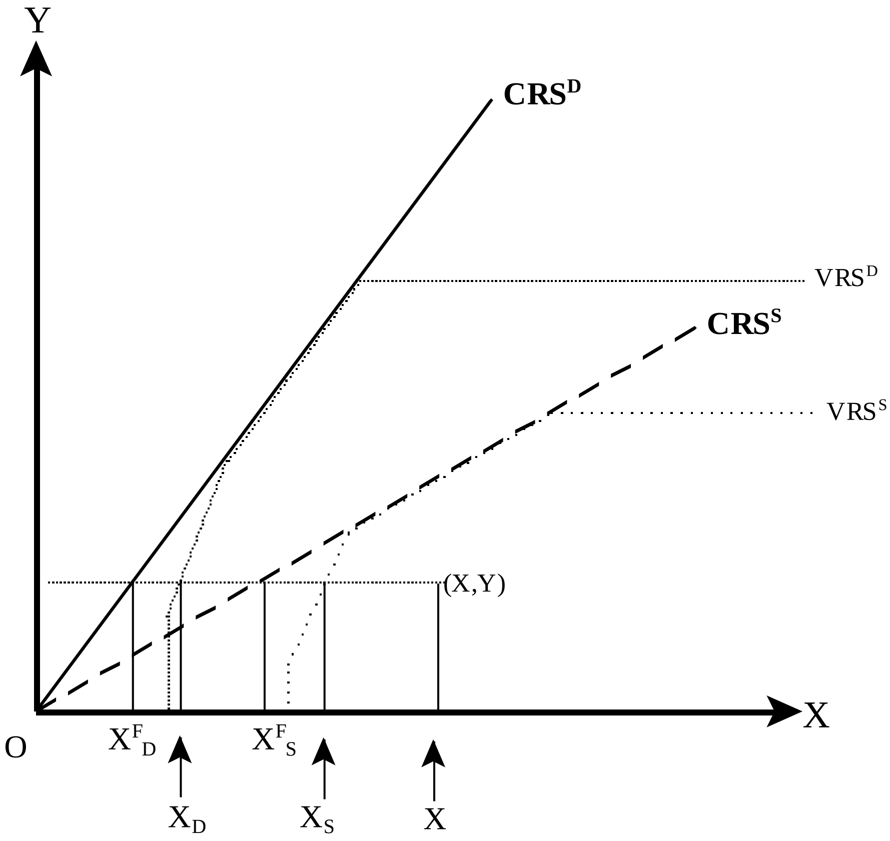

Table 1. Average Output and Input Variables per acre, and Technical, Pure Technical and Scale Efficiency of Major U.S. Crops for the period, 1975-1996.

Variables	**Barley**	**Corn**	**Cotton**	**Oats**	**Peanuts**	**Rice**	**Sorghum**	**Soybean**	**Wheat**	**Mean**
Production per acre	51.69	108.38	528.99	54.07	2448.58	5196.48	59.72	31.95	35.25	
Variable (1990-92 Mil $ /acre)	103.93	219.96	364.29	90.66	536.91	431.63	119.62	122.85	92.71	231.40
Capital (1990-92 Mil $ / acre)	40.48	52.23	85.66	34.20	84.64	84.36	43.88	40.63	33.13	55.47
Land (Mil acres)	8.59	68.48	11.53	7.62	1.55	2.83	12.08	60.76	64.49	26.44
Average Efficiency										
$D_i(y,x\|CRS)$	0.847	0.920	0.924	0.873	0.870	0.867	0.838	0.810	0.895	0.871
$D_i(y,x\|VRS)$	0.920	0.914	0.875	0.897	0.929	0.923	0.879	0.931	0.946	0.913
$S_i(y,x)$	0.924	0.865	0.906	0.973	0.936	0.939	0.955	0.868	0.947	0.924
Rate of Change (ROC)										
$D_i(y,x\|CRS)$	1.074	1.770	1.760	0.871	-0.272	1.348	1.628	1.647	0.779	1.178
$D_i(y,x\|VRS)$	0.876	0.543	0.366	0.439	0.000	0.875	1.659	0.156	0.684	0.622
$S_i(y,x)$	0.196	1.220	1.389	0.430	-0.272	0.470	-0.031	1.490	0.095	0.554
Acreage	-1.133	0.326	1.752	-6.978	-0.378	-0.023	-1.200	0.761	-0.458	-0.815

where $D_i(y,x|CRS)$ is the overall technical efficiency computed under the assumption of constant returns to scale, $D_i(y,x|VRS)$ is the pure technical efficiency computed under the assumption of variable returns to scale, $S_i(y,x)$ is the scale efficiency computed under as the ratio $D_i(y,x|CRS)$ over $D_i(y,x|VRS)$, and ROC is the rate of change over the time period, 1975-1996 computed as $\sqrt[T]{X_{t=T}/X_{t=1}}*100$

Table 2. Scope Efficiency Gains, Scale Efficiency Gains and Diversification Efficiency Gains due to Two-Crop Diversification, 1975-1996.

Average Scope Efficiency Gains

	Corn	Cotton	Oats	Peanuts	Rice	Sorghum	Soybean	Wheat
Barley	1.017*	1.027*	1.013*	1.036*	1.028*	1.031*	1.017*	1.007*
Corn		1.018*	1.011*	1.063*	1.032*	1.012*	1.018*	1.014*
Cotton			1.025*	1.075*	1.054*	1.029*	1.022*	1.012*
Oats				1.047*	1.023*	1.018*	1.009*	1.006*
Peanuts					1.042*	1.099*	1.055*	1.047*
Rice						1.040*	1.026*	1.025*
Sorghum							1.005*	1.010*
Soybean								1.024*

Average Scale Efficiency Gains

	Corn	Cotton	Oats	Peanuts	Rice	Sorghum	Soybean	Wheat
Barley	1.020*	1.011	1.003	1.008	0.992	0.995	1.016*	1.009
Corn		1.032*	1.009	1.019*	1.034*	1.021*	1.038*	1.005
Cotton			1.007	0.995	1.004	1.004	1.061*	1.011*
Oats				1.008	1.006	1.009	1.017*	1.009*
Peanuts					1.010*	0.995	1.032*	1.012
Rice						0.998	1.053*	1.009
Sorghum							1.021*	1.009*
Soybean								1.018*

Average Diversification Efficiency Gains

	Corn	Cotton	Oats	Peanuts	Rice	Sorghum	Soybean	Wheat
Barley	1.037*	1.039*	1.016*	1.045*	1.018*	1.024*	1.032*	1.017*
Corn		1.052*	1.019*	1.084*	1.067*	1.033*	1.056*	1.019*
Cotton			1.032*	1.067*	1.058*	1.033*	1.084*	1.023*
Oats				1.055*	1.029*	1.027*	1.027*	1.015*
Peanuts					1.052*	1.092*	1.089*	1.059*
Rice						1.036*	1.082*	1.033*
Sorghum							1.026*	1.020*
Soybean								1.043*

*Indicates an outcome beyond 5% level of significance for the t-test examining the null hypothesis that the diversification efficiency gains, scope efficiency gains and scale efficiency gains for each of the two-crop combinations is equal to one.