

**ECONOMIES OF SCOPE AND SCALE EFFICIENCY GAINS DUE TO
DIVERSIFICATION**

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*Selected Paper prepared for presentation at the Western Agricultural Economics
Association Annual Meeting, Denver, Colorado, July 13-16, 2003*

Abstract

Using a nonparametric linear programming approach, our contribution is to examine if efficiency gains in Western crop production are realized due to diversification and to demonstrate that the diversification efficiency gains realized are a product of economies of scope efficiency gains and scale efficiency gains. The analysis employed cropping sector data for six major crops for the period, 1975-1996. Results indicate efficiency gains are realized due to diversification for all the two-crop combinations.

ECONOMIES OF SCOPE AND SCALE EFFICIENCY GAINS DUE TO DIVERSIFICATION

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 changes¹ 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 in particular 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 lead to a decreasing trend of diversification in non-farm and farming sectors.

¹ 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.

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.

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 approach² of measuring efficiency in public and private sectors has received renewed attention. Data Envelopment Analysis (DEA) has certain advantages,

² The non-parametric programming approach to the study of efficiency has had a relatively short history in agriculture sector, know familiarly know 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.

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 vast 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

$C(\sum_{k=1}^K Y^k, w) \leq \sum_{k=1}^K C(Y^k, w)$ 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.

Objective

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 cropping data of six major crops for the period, 1975-1996. The analysis used national data. Thus, the results hold for the West and the remainder of the U.S. The results for the six crops reported in this analysis are widely grown in the West.

The diversification analysis employed here is applicable where there is widespread diversification in cropping activities on individual producing units. In western U.S. agriculture there are more crops grown than the six of this analysis.

However, some excluded crops are grown under specialized production, particularly under irrigation. Hence, crops such as peanuts, rice, and cotton although produced in selected areas of the West, are excluded from consideration. Also, it should be recognized that all six analysis crops are rarely produced in significant proportions in all areas of the West. However, there is sufficient diversification of all or part of the six crops on farms in the West to allow the estimation of scope and scale economies under diversification.

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_t . Input requirement set transforming I -dimensional vector of inputs $x_{i,t}^k \in \mathfrak{R}_+$ into a vector of output $y_t^k \in \mathfrak{R}_+$ is represented by input set for firm k :

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

$$t = 1, \dots, T \quad i = 1, \dots, I$$

where z is a nonnegative and $z \succ 0$ 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:

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

$$t = 1, \dots, T \quad i = 1, \dots, I \quad k = 1, \dots, K$$

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 $z \succ 0$ 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) with the exception of input vector is represented by an input set as:

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

$$t = 1, \dots, T \quad i = 1, \dots, I \quad k = 1, \dots, K$$

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

The diversification efficiency gains is computed by comparing the frontiers of k individual specialized firms $\sum_{k=1}^K L(Y^k)$ and diversified firm (combined k firms) $L\left(\sum_{k=1}^K Y^k\right)$

under constant returns to scale assumption as:

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

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:

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

or

$$\min_{\lambda, z} \lambda \quad s.t. \quad y_t \leq zY \quad ,$$

$$\sum_{i=1}^I \lambda x_{i,t} \geq z X_i \quad i = 1, \dots, I$$

$$z \geq 0 \quad \text{or} \quad (z = 1)$$

sum of k individual specialized firms as:

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

or

$$\min_{\lambda, z} \lambda \quad s.t. \quad \sum_{k=1}^K y_t^k \leq z Y^k \quad k = 1, \dots, K$$

$$\sum_{k=1}^K \sum_{i=1}^I \lambda x_{i,t}^k \geq z X_i \quad i = 1, \dots, I$$

$$z \geq 0 \quad \text{or} \quad (z = 1)$$

and diversified firm as:

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

or

$$\min_{\lambda, z} \lambda \quad s.t. \quad \sum_{k=1}^K y_t^k \leq z Y^k \quad k = 1, \dots, K$$

$$\sum_{i=1}^I \lambda x_{i,t} \geq z X_i \quad i = 1, \dots, I$$

$$z \geq 0 \quad \text{or} \quad (z = 1)$$

where $D_i^S()$ and $D_i^D()$ is the input distance function for k specialized firms and diversified firm respectively. The intensity variable $z \geq 0$ describes the constant returns to scale (CRS) technology and $z \leq 1$ 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:

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

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:

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

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:

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

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

$$(11) \quad \text{Scale Efficiency gains} = \frac{S_i^S(y, x)}{S_i^D(y, x)} = \frac{\frac{OX/OX^F_s}{OX/OX_S}}{\frac{OX/OX^F_d}{OX/OX_D}} = \frac{OX_S/OX^F_s}{OX_D/OX^F_d}$$

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

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

Cost of Production Data on US Major Crops

To compute economies of scope, efficiency gains, scale efficiency gains and diversification efficiency gains due to crop diversification, cost of production data and output production for the six major crops are employed. The input data for each of the crop is available on a 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 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. A single output and three inputs are used to compute economies of scope and scale efficiency gains due to diversification.

Results

To examine 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) is estimated. Output and input data of the six 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 time period for each of the six 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 actually 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 examined employing a t-test at 5% level of significance. However emphasis is given only to those crop combinations that exhibit diversification.

In Table 3 acreage changes in each of the six study crops are presented for the 1975-96 time period. These acreages can be viewed in concert with the estimated scope and scale relationships.

Overall Technical and Scale Efficiency

Overall technical efficiency $D_i(y, x|CRS)$ defined as a product of pure technical efficiency $D_i(y, x|VRS)$ and scale efficiency $S_i(y, x)$ is presented in Table 1 for each crop. Overall efficiency is highest for corn with moderate efficiencies observed for wheat and oats. For corn this is caused by large scale efficiencies while wheat and oats have moderate technical efficiency. Barley, sorghum, and soybeans have low overall efficiency. For barley and sorghum this is caused by low scale efficiencies (negative for sorghum). Soybeans had a low technical efficiency level for the period.

Observing changes in crop acreages over the time period, the efficiency causes may be better understood by the rate of change in efficiencies. High gains in overall efficiency were observed for corn, soybeans, and grain sorghum and lower gains for barley, oats, and wheat. These differences follow methods of production, row crops vs. small grain production respectively. With the exception of sorghum these changes in efficiency mirror changes in acreage. For sorghum, negative scale efficiency was observed which may explain part of the decline. The remainder, however, is explained by the two-crop diversification relationships in the following section. Scale efficiency gains technical efficiency gains for corn and soybeans while the opposite occurs for barley, sorghum, and wheat. For oats the two efficiency gains are roughly equal.

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 two-crop analysis, scope efficiencies are achieved from more efficient use of labor and machinery. Where there are crop rotations practiced, increased efficiency is also possible due to enhanced crop yields and reduced use of inputs. Scale relationships for two-crop relationships relate to efficiencies derived from expanding both crops simultaneously. Research into scale relationships in agriculture has been concentrated on single products. This is largely because data is not readily available on resource use and

product output for multiple product firms. The methodology used here, however, enables multiproduct scale relationships to be estimated.

Results from Table 2 indicate both technical efficiency gains and the scope efficiency gains have been realized for all the two crop-diversification. Only one crop combination (barley and sorghum) experienced declining average scale efficiency gains suggesting that firm cannot realize efficiency gains by just increasing factors of production.

Average overall diversification gains (a crop in combination with the other five crops) are highest for corn and soybeans with the lowest observed for barley, oats, and wheat. Sorghum was in an intermediate position.

Between crops high gains were observed for corn (with sorghum and soybeans) and soybeans (with barley, corn, and wheat). At the other extreme low overall gains were observed for wheat (with all crops except soybeans) and oats (with barley and corn). These relationships are again consistent with the acreage changes over the time period where large increases were observed for corn and soybeans with declines for the remaining crops. It can be observed that corn-soybean diversification is very high and considerably higher than for corn-sorghum or sorghum-soybeans. Thus, sorghum's diversification potential with other row crops is not as high as the other two row crops.

In general, crop combinations having high scope diversification efficiency had high scale diversification efficiency. However, some exceptions involving sorghum occurred (barley-sorghum, corn-sorghum, and sorghum-soybeans).

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 (oats in combination with barley, corn, and sorghum; barley in combination with sorghum; wheat in combination with barley and corn) 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 crops is contributed by pure technical and scale efficiency. 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.

References

- Boles, J.N. 1966. Efficiency Squared - Efficient Computation of Efficiency Indexes. *Prov. W. Farm Econ. Assn.* 137-142.
- Bressler, R.G. 1966. The Measurement of Productive Efficiency. *Proc. W. Farm Econ. Assn.* 129-136.
- Charnes, A., W.W. Cooper, and E. Rhodes. 1978. Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research.* 2(6), 429-444.
- Christensen, Laurits R. and William H. Greene. 1976. Economies of Scale in U.S. Electric Power Generation. *Journal of Political Economy.* 84: 655-676.
- Cohn, Elchanan, Sherrie L.W. Rhine, and Maria C. Santos. 1989. Institutions of Higher Education as Multi-Product Firms: Economies of Scale and Scope. *Review of Economics and Statistics.* 71: 284-290.
- Eaton, B. Curtis and S.Q. Lemche. 1991. The Geometry of Supply, Demand and Competitive Market Structure with Economies of Scope. *American Economic Review.* 81: 901-911.
- Fare, Rolf. 1986. Addition and Efficiency. *Quarterly Journal of Economics.* 101, 861-866.

- Fare, Rolf. 1988. "Efficiency Gains from Addition of Technologies: A Nonparametric Approach." In Wolfgang Eichhorn and W. Erwin (eds.), *Measurement in Economics: Theory and Applications of Economic Indices*. Heidelberg: Physica-Verlag; New York: Springer-Verlag.
- Fare, Rolf and Daniel Primont. 1988. "Efficiency Measures for Multiplant Firms with Limited Data." In Wolfgang Eichhorn and W. Erwin (eds.), *Measurement in Economics: Theory and Applications of Economic Indices*. Heidelberg: Physica-Verlag; New York: Springer-Verlag.
- Fare, Rolf, S. Grosskopf, and C.A.K. Lovell. 1994. *Production Frontiers*. Cambridge [England]; New York, NY, USA: Cambridge University Press.
- Farrell, M.J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society, Series A, General* 120, 253-281.
- Farrell, M.J. and Fieldhouse. 1962. Estimating Efficient Production Functions Under Increasing Returns to Scale. *Journal of the Royal Statistical Society, Series A, General* 125, Part 2, 252-267.
- Gardner, B.D and R.D Pope. 1978. How is Scale and Structure Determined in Agriculture. *American Journal of Agricultural Economics*. 60: 295-302.
- Huffman, Wallace E. and R.E. Evenson. 1997. "Long Run Structural and Productivity Change in U.S. Agriculture: Effects of Prices and Policies." Staff paper.
- Hallam, Arne. 1993. "Empirical Studies of Size, Structure, and Efficiency in Agriculture," in A. Hallam, ed., *Size, Structure, and the Changing Face of American Agriculture*. Boulder, CO: Westview Press, pp. 204-231.
- Kislev, Y. and W. Peterson. 1982. Prices, Technology, and Farm Size. *Journal of Political Economics*. 90: 578-595.
- Kislev, Y. and W. Peterson. 1996. "Economies of Scale in Agriculture: A Reexamination of the Evidence." In *The Economics of Agriculture: Papers in Honor of D. Gale Johnson*, Vol. 2, J.M. Antle and D.A. Sumner, eds., The University of Chicago Press, pp. 156-170.
- Lawrence, Collin. 1989. Banking Costs, Generalized Functional Forms, and Estimation of Economies of Scale and Scope. *Journal of Money, Credit, and Banking*, 21: 368-379.

- Lovell, C.A.K. 1993. Production Frontiers and Productive Efficiency in: H. Fried, C.A.K. Lovell, and P. Schmidt, eds., *The Measurement of Productive Efficiency: Techniques and Applications*. Oxford University Press 3-67.
- Panzar, John C. and Robert D. Willig. 1977. Economies of Scale in Multi-Output Production. *Quarterly Journal of Economics*. 91: 481-493.
- Panzar, John C. and Robert D. Willig. 1981. Economies of Scope. *American Economic Review*. 71: 286-272.
- Penrose, E.T. 1959. *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.
- Pulley, Lawrence B. and Yale M. Braunstein. 1992. A Composite Cost Function for Multiproduct Firms with an Application to Economies of Scope in Banking. *Review of Economics and Statistics*. 74: 221-230.
- Seitz, W.D. 1966. Efficiency Measures for Steam-Electric Generating Plants. *Proc. W. Farm Econ. Assn.* 143-151.
- Sitorus, B.L. 1966. Productive Efficiency and Redundant Factors of Production in Traditional Agricultural of Underdeveloped Countries: A Note on Measurement. *Proc. W. Farm Econ. Assn.* 153-161.

Figure 1. Scope and Scale Efficiency Gains Due to Diversification

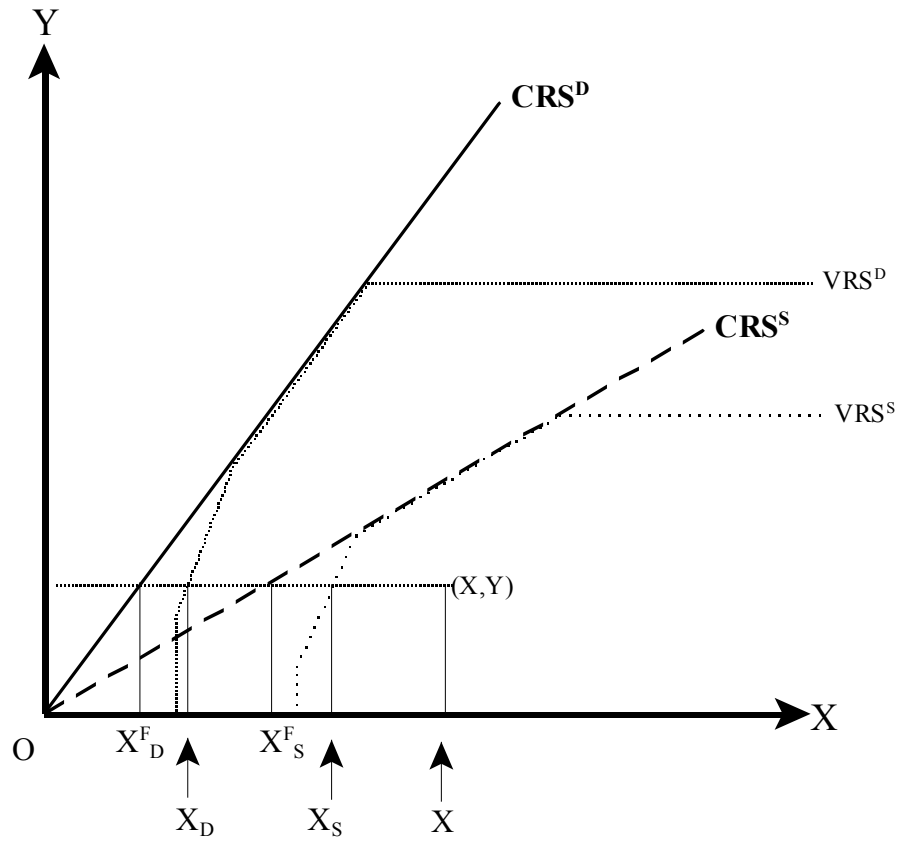


Table 1. Average Output and Input per acre, and Technical, Pure Technical and Scale Efficiency of Major Crops for the period, 1975-1996.

Variables	Barley	Corn	Oats	Sorghum	Soybean	Wheat
Production per acre	51.69	108.38	54.07	59.72	31.95	35.25
Variable (1990-92 Mil \$ /acre)	103.93	219.96	90.66	119.62	122.85	92.71
Capital (1990-92 Mil \$ / acre)	40.48	52.23	34.20	43.88	40.63	33.13
Land (Mil acres)	8.59	68.48	7.62	12.08	60.76	64.49
Overall Efficiency						
$D_i(y, x CRS)$	0.847	0.920	0.873	0.838	0.810	0.895
$D_i(y, x VRS)$	0.920	0.914	0.897	0.879	0.931	0.946
$S_i(y, x)$	0.924	0.865	0.973	0.955	0.868	0.947
Rate of Change (ROC)						
$D_i(y, x CRS)$	1.074	1.770	0.871	1.628	1.647	0.779
$D_i(y, x VRS)$	0.876	0.543	0.439	1.659	0.156	0.684
$S_i(y, x)$	0.196	1.220	0.430	-0.031	1.490	0.095

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.

Scope Efficiency Gains					
	Corn	Oats	Sorghum	Soybean	Wheat
Barley	1.017*	1.013*	1.031*	1.017*	1.007*
Corn		1.011*	1.012*	1.018*	1.014*
Oats			1.018*	1.009*	1.006*
Sorghum				1.005*	1.010*
Soybean					1.024*
Scale Efficiency Gains					
	Corn	Oats	Sorghum	Soybean	Wheat
Barley	1.020*	1.003	0.995	1.016*	1.009
Corn		1.009	1.021*	1.038*	1.005
Oats			1.009	1.017*	1.009*
Sorghum				1.021*	1.009*
Soybean					1.018*
Overall Diversification Efficiency Gains					
	Corn	Oats	Sorghum	Soybean	Wheat
Barley	1.037*	1.016*	1.024*	1.032*	1.017*
Corn		1.019*	1.033*	1.056*	1.019*
Oats			1.027*	1.027*	1.015*
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.

Table 3. Acreages (000) of Corn, Soybeans, Wheat, Sorghum, Barley, and Oats in the West (Northern Plains, Southern Plains, Mountain, and West) 1975-96.

Northern Plains	Corn	Soybeans	Wheat	Sorghum	Barley	Oats
1975	12212	8078	56308	14167	7191	5592
1976	13087	7209	56088	13135	6998	4838
1977	13661	8320	53488	12360	8099	6257
1978	14034	9088	47918	12027	7661	4875
1979	14471	10376	51444	11624	6225	4196
1980	13593	9470	56456	11075	5953	3491
1981	13705	9845	60766	11945	7470	4124
1982	13968	10845	58995	12398	7568	4696
1983	10528	9555	46305	8340	8375	4391
1984	14419	10770	50910	12245	9709	3775
1985	15204	9710	52306	12745	9946	3651
1986	14369	9680	49648	11415	10450	3027
1987	13101	10005	45973	9135	8618	3053
1988	13251	10475	40843	8055	6368	2347
1989	14248	10820	46954	10015	7045	2967
1990	15006	10495	53160	7965	6340	2602
1991	16166	10755	45973	8720	7089	2282
1992	16615	11020	51001	10585	6171	2051
1993	15633	10705	50887	7850	5673	1671
1994	18395	11870	50446	7865	5648	1806
1995	15977	12165	49854	7400	5295	1282
1996	18573	12580	50376	10770	5878	1298