Determinants of Farm Size and Structure

Proceedings of the program sponsored by the NC-181 Committee on Determinants of Farm Size and Structure in North Central Areas of the United States, held January 6, 8, and 9, 1990, in Albuquerque, New Mexico.

Boehlje/Alternative Models of Structural Change in Agriculture and Related Industries

Hornbaker and Denault/Recent Changes in Size and Structure of North Central Agriculture: A Study of Selected States in the North Central Region

Ahearn, Whittaker and Glaze/Cost Distribution and Efficiency of Corn Production

Atwood and Hallam/Farm Structure and Stewardship of the Environment

Casler/Firm Level Agricultural Data Collected and Managed at the State Level

Carlin and Saupe/Structural Change in Agriculture and Its Relationship to Rural Communities and Rural Life

Tweeten/Government Commodity Program Impacts on Farm Numbers

Helmers, Watts, Smith and Atwood/The Impact of Income Taxes on Resource Allocation and Structure of Agriculture

Cooke and Sundquist/Scale Economies, Technical Change, and Competitive Advantage in U.S. Soybean Production

Janssen, Stover and Clark/The Structure of Families and Changes in Farm Organization and Structure

Stanton and Olson/The Impacts of Structural Change and the Future of American Agriculture

Iowa State University
Ames, Iowa 50011
December 1990

SCALE ECONOMIES, TECHNICAL CHANGE, AND COMPETITIVE ADVANTAGE IN U.S. SOYBEAN PRODUCTION

Stephen C. Cooke and W. Burt Sundquist*

The Problem

A straightforward index procedure has emerged in the literature for measuring the difference in cost efficiency[1] and productivity[2] between enterprises producing the same commodity (Diewert; Denny and Fuss; Cooke and Sundquist, 1989). This index procedure has been used to analyze technical change, competitive advantage and scale economies of U.S. corn and cotton enterprises (Cooke and Sundquist, 1989 and 1991; Hazilla and Kopp).

The analysis reported here derives a set of cost efficiency and productivity indexes for representative soybean enterprises in selected regions of the U.S. between 1974-83. These indexes were computed for enterprises in each of four homogeneous soil and rain fall regions in Illinois, Iowa, Mississippi and Ohio. To determine scale economies within each of these four production regions, cost efficiency and productivity indexes were computed for very large and large soybean enterprises relative to medium size ones. Our analysis of U.S. soybeans necessarily includes measures of cost efficiency and productivity across time (technical change) and between regions (competitive advantage). We have included an abbreviated discussion of technical change and competitive advantage at the end. However, the primary emphasis in this report is on analyzing the extent and sources of scale economies in U.S. soybean production by size categories.

The Data

The primary data on U.S. soybean enterprises used in this study are from the original cost-of-production surveys conducted by USDA through its Firm Enterprise Data System (FEDS) program. FEDS surveys were conducted in winters of 1975, 1979, 1984, for the 1974, 1978, and 1983 production years, respectively. The FEDS cost data were augmented with yield and production data, as referenced in this report, from other USDA and Census of Agriculture sources.

The enterprise survey data for each year and region were sorted in ascending order by total planted acres and then partitioned into very large (91st to 100th percentiles), large

---

*Stephen C. Cooke is an assistant professor, Department of Agricultural Economics and Rural Sociology, University of Idaho, and W. Burt Sundquist is a professor, Department of Agricultural and Applied Economics, University of Minnesota.

(71st to 90th percentiles), and medium (41st to 70th percentiles) size enterprises. The smallest 40 percentiles of soybean enterprises, many of them part-time, included so much variation in size and production technology so as to defy the identification of representative enterprises for which production costs per acre could be validly approximated.

Once sorted and partitioned, the FEDS data were used to construct a total of 36 representative enterprise budgets used in our analysis (3 time periods x 4 production regions x 3 size categories). The capital components of these 36 enterprise budgets were constructed by the authors using the USDA Economic Research Service budget generator from which total fixed costs of capital were expressed as a flow of annual costs. These budgets then provided the basis for determining input prices, quantities and expenditures for capital, labor, energy, fertilizer, materials and land or KLEFMA input categories. These data were also separated into an expanded KLEFMA input category scheme in which the capital input category was disaggregates into tillage, applications, plantings, harvesting, and hauling subcategories. Methodologically, total and partial productivity and cost efficiency indexes were constructed using both input classification schemes and the results were compared.

Table 1 shows the location of the four homogeneous FEDS substate production regions as well as the total number of very large, large and medium size soybean enterprises in these regions in each of the three time periods. Table 2 shows the average planted acres for the very large, large, and medium soybean enterprises in the four soybean regions in each time period. Also shown is the weighted average enterprise size in planted acres across the production regions and enterprise sizes. The weighted averages are based on soybean production by enterprise size published in the 1974, 1978 and 1982 editions of the U.S. Census of Agriculture. As shown in Table 2, average enterprise size was higher for enterprises in the 1983 sample as compared to 1978 and 1974 with the exception of the very large Mississippi enterprise. Significantly, by 1983, average sample enterprise size in all study regions was 684 acres or more for the very large category. Since the sampling objective of the three surveys was to provide an equal probability of inclusion for any specific acre of soybean in the sample region, no claim is made that equal probability is provided for inclusion of soybean enterprises on individual farms.

The Models

The objective of our analysis of scale economies is to determine both the cost efficiency and the productivity indexes based on transcendental-logarithmic (translog) models of the cost and production functions, respectively. For a cost function, unit cost is a function of input prices and discrete variables for time, region, and size of enterprise. For a production function, output per acre is a function of the quantity of inputs per acre adjusted for time, regions, and size. These functions in translog form are shown in equations 1 and 2.

Unit Cost Function:

(1) $\ln C_{tru} = f(\ln P_{itru}, T, R, U)$.

Where C_{tru} is total cost per bushel of soybean in time t, region r and enterprise size u; T is time; R is region and U is enterprise size; P_{itru} is price per unit of input i in time t, region r and size u; and i is capital (k), labor (l), energy (e), fertilizer (f), materials (m), and land (a) for the KLEFMA input scheme; the expanded KLEFMA scheme expands the capital category only to include tillage (kt), application (ka), planting (kp), harvesting (kh), and hauling (kl); and, finally, all categories of factors are variable while factors within a category move in fixed proportion.

Production Function:

(2) $\ln Q_{tru} = g(\ln X_{itru}, T, R, U)$.

Where Q_{tru} is bushels of soybeans per acre in time t, region r and enterprise size u; X_{itru} is the input quantity i per acre in time t, region r and size u; all other notation and assumptions are the same.

Equations 1 and 2 are the dual cost and production functions, respectively. The presence of one output precludes the problem of separability.

These translog functions are evaluated relative to the geometric mean of the chosen point (a) and reference point (b), as the average of the factor shares Sa and Sb, (using Diewert quadratic lemma), to determine the Fisher input price and Tornquist input quantity indexes (Diewert, p. 120-21). The cost efficiency index is possible to determine because it has been shown that the change in unit costs equals the change in input prices weighted by the geometric means of the substitution effect[3] ceterus paribus (Diewert, p. 121). There is a analogous relationship between output per acre and its share-weighted input quantities per acre (Diewert, p. 120). The cost efficiency and productivity indexes are exact in that they reflect a second order approximation of a linearly homogeneous functions (Diewert, p. 120). The results are two models that provide "superlative" second-order discrete approximations of technical change, competitive advantage and scale economies in terms of cost efficiency and productivity indexes that can be determine arithmetically using observable data and are shown in equations 3 and 4.

Fisher cost efficiency indexes:

(3) $\frac{1}{2}(\alpha_{ta} + \alpha_{tb})(T_b - T_a) + \frac{1}{2}(\alpha_{ra} + \alpha_{rb})(R_b - R_a) + \frac{1}{2}(\alpha_{ua} + \alpha_{ub})(U_b - U_a) = \ln(C_{trub} / C_{trua}) - \frac{1}{2}\Sigma_i(S_{itrua} + S_{itrub}) \ln(P_{itrub} / P_{itrua})$.

Tornquist productivity indexes:

(4) $\frac{1}{2}(\beta_{ta} + \beta_{tb})(T_b - T_a) + \frac{1}{2}(\beta_{ra} + \beta_{rb})(R_b - R_a) + \frac{1}{2}(\beta_{ua} + \beta_{ub})(U_b - U_a) = \ln(Q_{trub} / Q_{trua}) - \frac{1}{2}\Sigma_i(S_{itrua} + S_{itrub}) \ln(X_{itrub} / X_{itrua})$.

The log of cost efficiency measure of scale economies between enterprise size categories can be expressed as the difference between the log of unit-cost ratio and the share-weighted average of the log of input prices ratio where time and region are held constant and equal to zero. Similarly, the difference between the log of production per acre ratio and the share-weighted average of the log of the input quantity per acre ratio between enterprise size categories equals the productivity measure of scale economies, assuming time and region differences are zero. The key assumption is that both the cost and production functions are linearly homogeneous within size categories. The cost efficiency and productivity indexes are conceptually equal and empirically approximately equal to the inverse of the other. In particular, when the factor shares are approximately constant, as in a Cobb-Douglas function, then the cost efficiency or the productivity index is very nearly equal to the inverse of the other (Diewert, p. 124).

In summary of method, data on total cost, yield, factor shares and input prices and quantities, disaggregated on the bases of time, region and enterprise size, are used to approximate cost efficiency and productivity indexes for a set of 36 representative soybean enterprises. Tables 3, 4, 5, and 6 present the yield,[4] total cost, unit cost and factor share data used in this study. The key analytical concepts are Diewert's approximation to the Fisher input price and Tornquist input quantity indexes in the context of translog cost and production functions. These algorithms are explained in additional detail in Cooke and Sundquist (1989 and 1991).

Finally, it have been pointed out that the "augends and addends" of the total indexes can be used as partial productivity indexes to determine the sources of the technical change (Cooke and Sundquist, 1991). By analogy, we can use the partial productivity indexes of the cost and production functions to determine the sources of pecuniary and technical economies of scale.

An Example

An illustration of the procedure used to determine the Tornquist input quantity index and associated productivity index of scale economies between the very large and medium Iowa soybean enterprises in 1983 is shown in Table 7. Very large soybean enterprises in Iowa, FEDS area 201, in 1983 have a 6% technical economies of scale advantage relative to the medium size enterprises. This 6% productivity difference is traceable to the combination of a 1% higher yield and 5% lower input use per acre by very large soybean enterprises in Iowa. We can also see that all of the input reduction for very large enterprises appears in the materials category. This category includes such inputs as pesticides, seed, repairs, and custom work. We know from examining the disaggregated data that the difference in this particular case is due to the additional expense for custom tillage, planting, cultivating, harvesting and hauling (without a comparable reduction in capital inputs) paid on average by the medium size enterprises.

Table 8 shows the procedure for determining the Fisher input price index and associated cost efficiency index of scale economies using the same Iowa enterprise data as in table 7. The inverse of the cost efficiency index of 6% is the same as the productivity index, which suggest that factor shares between enterprise are sufficiently constant to imply the same Cobb-Douglas function across both enterprises in this region. The Fisher price index shows that input prices were 5% higher for very large enterprises and yet their unit costs were 1% lower resulting in a 6% inverse cost efficiency index. Very large Iowa soybean enterprises paid more per unit of input for capital (3%) and materials (2%) than medium size enterprises. This analysis suggests that the 6% technical economies of scale of very large Iowa soybean enterprises in 1983 slightly more than offset the 5% pecuniary diseconomies of scale relative to the medium size enterprises.

The Results Using the KLEFMA Input Categories

We repeat the above two procedures for the very large and large enterprise sizes relative to the medium in each of the four regions for each of the three time periods for a total of 24 indexes for each procedure. In addition, we estimate an additional six indexes as the weighted average across regions by size category. In this section of the study, we report on results based on the KLEFMA input categories. Subsequently, we will re-estimated each of these indexes using the extended KLEFMA input categories.

Table 9 shows the 24 Tornquist productivity indexes of scale economies for the soybean enterprises (2 size groups x 4 regions x 3 time periods) and the 6 weighted averages. On average, between 1974-83, across the selected soybean regions, very large enterprises were 3-6% and large enterprises were 0-3% more productive than medium size enterprises. The implication is that for a proportional increase in inputs on both medium and very large soybean enterprises, output would increase 3-6% more than inputs on the very large enterprises i.e., increasing returns to scale. This represents an arc output elasticity of 1.03-1.06 between medium and very large enterprises. This contrasts with the .98 "pseudo increasing returns" to U.S. soybean production from 1939-78 reported by Thirtle (p. 40). The size of percentage change in productivity did vary between production regions and across time within individual regions. In 1983, very large and large enterprises in Mississippi had a 9-13% productivity advantage compared to medium size enterprises, while Iowa and Illinois very large enterprises had a 6-7% productivity advantage. Over all, the largest diseconomies (-2%) in scale between very large and medium enterprises was realized in Ohio in 1974 and the largest economies (28%) in Mississippi 1978.

Table 10 shows the partial productivity indexes for very large and large relative to medium size enterprises in 1974, 1978 and 1983 as a weighted average across the four regions. We can use these partial productivity indexes to determine the source of technical economies of scale differences. The increasing economies of scale are technical in that input use becomes increasingly specialized with an increase in enterprise size (Jensen, p. 11-12). Yield difference represent 0-3% of the 0-6% scale economies. Input differences account for the remaining 3-6% of the difference in technical scale economies. Within the input contribution to scale economies, capital (1-3%) and materials (-1-2%) are the sources of productivity gains. The breakdown of total scale economies (0-6%) into the yield, materials, and capital categories corresponds approximately to a biological (0-3%), chemical (-1-2%) and mechanical (1-3%) technology designations.

Table 11 shows the disaggregation of the Fisher cost efficiency indexes for the same categories as table 10. The inverse of cost efficiency index (0-6%) equals the productivity index. This result suggests that factor share are sufficiently constant across size categories (see table 6) such that a Cobb-Douglas functional form can be used in the future to determine scale economies across soybean enterprise size categories in a given region at a point in time (Diewert p. 124).

Unit cost measures ranges from (-2 to 0%) less for the very large and large soybean enterprises relative the medium size. Prices are -2 to 5% more for the very large and large enterprises. As with Iowa in 1982, capital (0 to 3%) and materials (-4 to 3%) categories are, on average, more expensive per unit for the very large and large enterprises except in 1974. The higher capital and material prices for very large enterprises represent pecuniary diseconomies of scale. In general, we can say that the technical scale economies (0 to 6%) for very large and large soybeans enterprises are slightly more than enough to make up for the pecuniary diseconomies of scale (-2 to 5%) associated with capital and materials inputs.

The Results Using the Extended KLEFMA Input Categories

The above indexes were determined using the KLEFMA input categories. We can get even more insight into the sources of scale economies in soybeans in the U.S. by using the extended KLEFMA input categories. Tables 12 and 13 represent a recalculation of table 10 and 11 in term of the extended KLEFMA categories. This restructuring of the data underlying the indexes resulted in an 2 percentage point increase in the range of the index of scale economies for very large and large enterprises from 0-6% to -1-7%.

Restructuring the categories alters array of inputs that are substitutes and complements. If we assume inputs are perfect complements when they are substitutes, we depress the expression of productivity. Alternatively, the intermingling of a large number of complementary inputs into a single category can give the specialization of one important input the additional factor share weight of the entire category when productivity is measured. S. C. Ray concluded in his study of U.S. agriculture productivity using a translog function that "... this study should have used farm level behavioral data. Use of aggregate data here ... introduces a measure of aggregation bias." Yet our results suggests that separating inputs into Leontief and non-Leontief categories introduces an aggregation bias even when enterprise level data is used. Therefore, a prudent rule of thumb to avoid aggregation bias when determining Fisher and Tornquist indexes is to keep the input categories as disaggregated as possible.

Tables 12 and 13 also show that the technical scale economies appear in the tillage and harvesting capital and materials categories. It is also these categories that exhibit pecuniary diseconomies of scale.

Technical Change

Tables 14 and 15 shows weighted average total and partial productivity and cost efficiency indexes of technical change for the very large, large, and medium size soybean enterprises in 1983 and 1878 compared to 1974. Total productivity and cost efficiencies were, on average, about 12-18 percent higher in 1983 than in 1974 over all three size groups or about 1.1-1.7% per year. The size of the percentage change in productivity and cost efficiency did vary between production areas and between sizes within individual areas. The smallest average productivity gain (10-13%) was realized on medium size enterprises and largest (14-18%) on the very large and large enterprises.

Thirtle reported a 1.1% biological productivity increase and a 2.5% mechanical productivity increase for a total of 3.6% productivity increase per year for U.S. soybeans between 1939-78 (p. 38). Thirtle's overall annual productivity gains are about triple the gains we have found between 1974-83. However, if we assume that the mechanical gains i.e., the substitution of capital for labor, are largely behind us since labors' current share of cost is down to about 5% of total cost, then Thirtle's biological productivity gains (1.1%) match the overall gains found in this study (1.1-1.7%) quite closely.

The source of productivity gains were from a reduction in the use of capital and labor, which was partially offset by increases in fertilizer and material use. Yield increases were the principle contributor to productivity gains in soybeans. The price level for soybean inputs doubled and tripled in 1978 and 1983 relative to 1974. Land price increases was the major cause of the input price inflation.

Competitive Advantage

Table 16 shows the total and partial productivity indexes of competitive advantage for 1983, 1978, and 1974 with the indexes for the Illinois enterprises set equal to 100. These indexes show a relative loss in competitive advantage by Iowa enterprises and a relative gain for Ohio enterprises. The Mississippi soybean enterprises were much less efficient in 1974, relative to Illinois, and this situation changed very little in 1978 and 1983. The quantity of input use per acre was about the same in Ohio, Iowa and Illinois and 10-14% higher in Mississippi. Thus, yield variations largely account for the difference in competitive advantage.

The Conclusions

The discussion presented here provides an analytical procedure by which total and partial Tornquist productivity and Fisher cost efficiency indexes of soybean production among enterprise sizes, over time, and between regions can estimate the extent and sources of scale economies, technical change and competitive advantage.

Our analysis suggest that, on average, there were only small positive technical scale economies (3 to 7%) for very large and (-1 to 3%) for large enterprises relative to the medium size category between 1974-83.[5] Lower input use accounted for 2-5% of the scale economies for very large and 0-3% of the gain for large soybean enterprises over this period. The lower input use categories include tillage and harvest capital and materials in which it is assumed that increases specialization has taken place.

Pecuniary economies of scale (1-7%) for very large enterprises were found relative to the medium size. Pecuniary diseconomies were associated with the tillage capital, harvesting capital and materials input categories. These pecuniary diseconomies approximately offset the technical economies of scale for very large soybean enterprises. The fact that the input categories for the source of technical scale economies match those for the source of pecuniary diseconomies suggests that the resource owners rather than the producers are the principle beneficiaries of productivity increases associated with scale economies. This result is consistent with the Ricardian theory of economic rent for inputs available in less than perfectly elastic supply, in which producers' quasi-rents are passed on as rent to resource owners.

We learned two items regarding the methodology for determining scale economies, one specific and one general. Specifically, we found that the total productivity and cost efficiency indexes for scale economies for soybeans are approximately equal to the inverse of the other across four regions. This suggests that the simpler Cobb-Douglas functional form could be use to determine scale economies in soybeans for other regions of the United States. In general, the expanded KLEFMA analysis shows that aggregation bias is possible even at the enterprise level. Consequently, we would suggest using as disaggregated a set of input categories as possible when determining index numbers of the type in this analysis. Finally, our analysis suggest (1) that there were substantial increases in productivity due to technical change (1.1 to 1.7% per year) between 1974 and 1983, and (2) that Illinois has a 9 to 45% competitive advantage in soybeans production relative to Iowa (9%), Ohio (11%), and Mississippi (45%) in 1983.

Table 1. The Number of Soybean Enterprises and Production in Selected Regions of the U.S.

Soybeans	State	Illinois	Iowa	Mississippi	Ohio	Total[1]	Percent
	FEDS Area	300	201	200	101		of
	Location	(E. Cent)	(No.Cent.)	(Delta)	(W. Cent.)		Total
1983 Very Large[2]	#	1883	376	517	499	3275	9
Large	#	4429	2519	477	2156	9581	27
Medium	#	4430	11176	477	6575	22658	64
Total	#	10742	14071	1471	9230	35514	100
1978 Very Large	#	850	3228	315	410	4803	9
Large	#	4827	8142	315	2207	15491	30
Medium	#	14719	8142	1144	7981	31986	61
Total	#	20396	19513	1774	10598	52281	100
1974 Very Large	#	2603	2031	595	928	6157	11
Large	#	2603	7874	595	928	12000	21
Medium	#	21417	7874	1317	8541	39149	68
Total	#	26622	17779	2506	10396	57303	100
1983 U.S. production[2]	%	7.80	5.25	1.90	3.40	18.35	

[1] Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

[2] Source: USDA/SRS data tapes on county level planted acres and production for 1972-1976; 1976-1980 and 1979-1985. Also, 1974, 1978, and 1982 Census of Agriculture Table 41 "Specified Crops by Harvested Acres" data were use to detemine the number of very large, large and medium size enterprises in the state. This number was then multiplied by the ratio of FEDS region multiple-year average production from USDA/SRS data to COA 1982 production data to obtain the number of enterprises by size for the region.

[3] Source: USDA/SRS data tapes on county level production 1979-1985 and USDA/ERS Ag. Info. Bull. No. 476 "Soybeans: Background for 1985 Farm Legislation," Appendix Table 7 on U.S. aggregate production 1979-1983.

Table 2. Average Soybeans Enterprise Size by Production Region (Planted Acres).

State	Illinois	Iowa	Mississippi	Ohio	Weighted	Size
FEDS Area	300	201	200	101	Average[1]	Index
Location	(E. Cent)	(No.Cent.)	(Delta)	(W. Cent.)		(M=100)
1983 Very Large	684	707	1262	897	794	259
Large	418	341	894	493	464	151
Medium	270	210	795	244	307	100
Average[2]	441	291	1095	436	472	154
1978 Very Large	579	572	6504	650	1243	460
Large	330	261	1232	298	404	150
Medium	215	203	782	194	270	100
Average[2]	299	260	2649	284	544	201
1974 Very Large	384	302	2000	485	557	311
Large	262	188	697	264	289	161
Medium	171	126	427	131	179	100
Average[2]	222	189	1083	217	307	172

Source: Mean of USDA/ERS FEDS survey planted acres for very large, large and medium size enterprises.

1 Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

2 Weights for average enterprise size within a region and across size categories are based on 1982, 1978, and 1974 Census of Agriculture Table 41, "Specified Crops by Harvested Acres" as a ratio of production of this size category to the sum of production across size categories.

Table 3. Soybean Yields for Selected Regions (Bushels / Planted Acre).

State	Illinois	Iowa	Mississippi	Ohio	Weighted	Yield
FEDS Area	300	201	200	101	Average[1]	Index
Location	(E. Cent)	(No.Cent.)	(Delta)	(W. Cent.)		(M=100)
1983 Very Large	40.50	37.40	24.90	37.00	37.30	103
Large	39.60	37.20	23.50	36.10	36.50	100
Medium	39.60	36.90	23.50	35.70	36.40	100
Wt Ave[2]	39.90	37.00	24.30	36.00	36.70	
1978 Very Large	37.80	37.10	23.20	36.90	35.80	101
Large	38.80	36.60	23.20	35.90	35.90	101
Medium	38.60	36.50	20.80	35.80	35.50	100
Wt Ave[2]	38.60	36.60	22.30	36.00	35.70	
1974 Very Large	34.70	33.90	21.40	31.50	32.40	100
Large	34.70	33.90	21.40	30.40	32.20	100
Medium	34.90	33.90	21.60	30.30	32.30	100
Wt Ave[2]	34.80	33.90	21.50	30.50	32.30	

Source: USDA/SRS data tapes on county level planted acres and production for 1972-1976; 1976-1980 and 1979-1985. Also, 1974, 1978, and 1982 Census of Agriculture Table 41 "Specified Crops by Harvested Acres" data were use to detemine the ratio of very large, large and medium size yields to state-wide average. This ratio was then multiplied by the FEDS region multiple-year average yield from USDA/SRS data to obtain yield by size for the region.

[1] Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

[2] Weights for average enterprise size within a region and across size categories are based on 1982, 1978, and 1974 Census of Agriculture Table 41, "Specified Crops by Harvested Acres" as a ratio of production of this size category to the sum of production across size categories.

Table 4. Total Costs of Production in Selected Regions for Soybeans (Dollars / Acre).

State	Illinois	Iowa	Mississippi	Ohio	Weighted	Cost
FEDS Area	300	201	200	101	Average[1]	Index
Location	(E. Cent)	(No.Cent.)	(Delta)	(W. Cent.)		(M=100)
1983 Very Large	381	361	280	359	360	102
Large	368	355	297	333	350	99
Medium	375	359	285	335	353	100
Wt Ave[2]	374	358	285	338	353	
1978 Very Large	236	218	148	216	217	101
Large	231	216	163	217	217	101
Medium	233	209	159	213	214	100
Wt Ave[2]	233	213	157	214	215	
1974 Very Large	114	115	85	114	111	98
Large	116	112	88	110	111	98
Medium	118	116	93	109	113	100
Wt Ave[2]	117	114	88	110	112	

Source. Total costs are based on FEDS survey data

[1] Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

[2] Weights for average enterprise size within a region and across size categories are based on 1982, 1978, and 1974 Census of Agriculture Table 41, "Specified Crops by Harvested Acres" as a ratio of production of this size category to the sum of production across size categories.

Table 5. Unit Costs of Production in Selected Regions for Soybeans (Dollars / Bushel).

State	Illinois	Iowa	Mississippi	Ohio	Weighted	Cost
FEDS Area	300	201	200	101	Average[1]	Index
Location	(E. Cent)	(No.Cent.)	(Delta)	(W. Cent.)		(M=100)
1983 Very Large	9.41	9.64	11.26	9.70	9.73	99
Large	9.28	9.54	12.65	9.22	9.71	99
Medium	9.47	9.73	12.13	9.39	9.82	100
Wt Ave[2]	9.39	9.67	11.71	9.38	9.72	
1978 Very Large	6.23	5.87	6.38	5.84	6.07	100
Large	5.96	5.91	7.05	6.04	6.06	100
Medium	6.05	5.73	7.63	5.94	6.11	100
Wt Ave[2]	6.04	5.83	7.08	5.96	6.08	
1974 Very Large	3.29	3.40	3.96	3.62	3.45	98
Large	3.35	3.31	4.09	3.61	3.47	98
Medium	3.29	3.42	4.29	3.59	3.53	100
Wt Ave[2]	3.37	3.37	4.10	3.60	3.49	

[1] Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

[2] Weights for average enterprise size within a region and across size categories are based on 1982, 1978, and 1974 Census of Agriculture Table 41, "Specified Crops by Harvested Acres" as a ratio of production of this size category to the sum of production across size categories.

Table 6. Interenterprise Factor Shares for Soybeans in 1983, 1978 & 1974 for the Extended KLEFMA Model (Percent).

Soybeans	1983			1978			1974		
(Size)	V Large	Large	Medium	V Large	Large	Medium	V Large	Large	Medium
Tillage	5	4	5	5	5	5	6	7	7
Planting	2	1	1	2	2	2	1	1	1
Applying	1	1	1	1	0	0	0	0	1
Harvest	6	6	6	6	6	6	7	8	7
Hauling	2	2	2	2	2	2	3	3	2
Capital	16	15	15	15	15	15	18	19	18
Labor	3	3	3	4	4	4	6	7	7
Energy	3	3	4	2	2	2	4	4	4
Fertilizer	3	1	2	1	1	1	3	1	1
Materials	13	14	14	16	16	14	17	16	17
Land	62	64	63	62	63	63	53	53	52
Total Share	100	100	101	100	101	99	101	100	99

Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

Table 7. Scale Economies of Very-Large Iowa Soybean Enterprises in 1983: The Tornquist Productivity Index

	Capital	Labor	Energy	Fert.	Materials	Land	Total
Costs							
IO VL 1983 ($/acre)	57.06	10.21	11.71	4.29	41.45	235.87	360.59
IO M 1983 ($/acre)	47.61	10.43	10.94	4.12	50.18	235.87	359.15
Cost Shares							
IO VL 1983 (%)	.16	.03	.03	.01	.12	.65	1.00
IO M 1983 (%)	.13	.03	.03	.01	.14	.66	1.00
$1/2\ (S_{VL}+S_M)$ (%)	.14	.03	.03	.01	.13	.66	1.00
Inputs & Input Indexes							
IO VL 1983 (Units/Acre)	1.91	2.59	10.48	22.52	3.74	1.00	
IO M 1983 (Units/Acre)	1.97	2.65	9.64	22.46	5.35	1.00	
$Ln(I_{VL}/I_M)$ (Input Ratio)	-0.03	-0.02	0.08	0.00	-0.36	0.00	
$1/2(S_{VL}+S_M)Ln(I_{VL}/I_M)$	-0.00	-0.00	0.00	0.00	-0.05	0.00	-0.05
Yields & Results							
IO VL 1979-85 (Ave Bushels/Acre)							37.40
IO M 1979-85 (Ave Bushels/Acre)							36.90
$Ln(Q_{VL}/Q_M)$ (Yield Ratio)							0.01
$\Sigma 1/2(S_{VL}+S_M)Ln(I_{VL}/I_M)$ (Tornquist's Input Ratio)							-0.05
$1/2(\beta_{VL}+\beta_M)(U_{VL}-U_M)$ (Scale Economies Measure)							0.06
$100\ e^{1/2(\beta VL+\beta M)(UVL-UM)}$ (Scale Economies Index, Medium = 100)							106

Table 8. Scale Economies of Very-Large Iowa Soybean Enterprises in 1983: The Fisher Cost Index.

	Capital	Labor	Energy	Fert.	Materials	Land	Total
Costs							
IO VL 1983 ($/acre)	57.06	10.21	11.71	4.29	41.45	235.87	360.59
IO M 1983 ($/acre)	47.61	10.43	10.94	4.12	50.18	235.87	359.15
Cost Shares							
IO VL 1983 (%)	.16	.03	.03	.01	.12	.65	1.00
IO M 1983 (%)	.13	.03	.03	.01	.14	.66	1.00
1/2 $(S_{VL}+S_M)$ (%)	.14	.03	.03	.01	.13	.66	1.00
Prices & Price Indexes							
IO VL 1983 ($/Unit)	29.90	3.94	1.12	.19	11.07	234.93	
IO M 1983 ($/Unit)	24.15	3.94	1.13	.18	9.38	234.93	
$Ln(P_{VL}/P_M)$ (Price Ratio)	0.21	0.00	-0.02	0.04	0.17	0.00	
$1/2(S_{VL}+S_M)Ln(P_{VL}/P_M)$	0.03	0.00	-0.00	0.00	0.02	0.00	0.05
Yields, Costs & Results							
IO VL 1979-85 (Ave Bushels/Acre)							37.40
IO M 1979-85 (Ave Bushels/Acre)							36.90
$Ln(Q_{VL}/Q_M)$ (Yield Ratio)							0.01
$Ln(TC_{VL}/TC_M)$ (Total Cost Ratio)							0.00
$Ln(C_{VL}/C_M)$ (Unit Cost Ratio)							-0.01
$\Sigma 1/2(S_{VL}+S_M)Ln(P_{VL}/P_M)$ (Fisher's Price Ratio)							0.05
$-1/2(\alpha_{VL}+\alpha_M)(U_{VL}-U_M)$ (Scale Econonies Measure)							0.06
$100\ e^{-1/2(\alpha VL+\alpha M)(UVL-UM)}$ (Scale Economies Index, Medium = 100)							106

Table 9. Interenterprise Productivity Indexes for Soybeans in 1983, 1978 & 1974 (Medium = 100).

Soybeans (Size)		Illinois Area 600	Iowa Area 500	Mississippi Area 200	Ohio Area 200	Average
1983	Very Large	102	106	113	107	105
	Large	103	99	109	105	103
	Medium	100	100	100	100	100
1978	Very Large	101	102	128	110	106
	Large	102	103	109	103	103
	Medium	100	100	100	100	100
1974	Very Large	106	101	104	98	103
	Large	103	94	100	102	100
	Medium	100	100	100	100	100

Interpretation: Since the index is computed relative to the medium = 100 base, numbers greater than 100 indicate the extent to which very large and large enterprises are more productive than the medium size category, and conversely for numbers less than 100.

Table 10. A Decompostion of Interenterprise Productivity Indexes for Soybeans in 1983, 1978 & 1974 (Medium = 100).

Soybeans	1983			1978			1974		
(Size)	V Large	Large	Medium	V Large	Large	Medium	V Large	Large	Medium
Capital	99	99	100	97	99	100	97	99	100
Labor	100	100	100	99	100	100	99	100	100
Energy	100	100	100	100	100	100	100	100	100
Fertilizer	101	100	100	100	100	100	102	100	100
Materials	98	99	100	100	99	100	101	101	100
Land	100	100	100	100	100	100	100	100	100
Input Index	97	97	100	96	98	100	97	100	100
Yield	103	100	100	101	101	100	100	100	100
Productivity	105	103	100	106	103	100	103	100	100

Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

Table 11. A Decompostion of Interenterprise Cost Efficiency Indexes for Soybeans in 1983, 1978 & 1974 (Medium = 100).

Soybeans	1983			1978			1974		
(Size)	V Large	Large	Medium	V Large	Large	Medium	V Large	Large	Medium
Capital	103	101	100	103	100	100	103	102	100
Labor	100	100	100	100	100	100	100	100	100
Energy	100	100	100	100	100	100	100	100	100
Fertilizer	100	100	100	100	100	100	100	100	100
Materials	102	101	100	102	103	100	98	96	100
Land	100	100	100	100	100	100	100	100	100
Price Index	105	102	100	105	103	100	101	98	100
Unit Costs	99	99	100	100	100	100	98	98	100
Total Costs	102	99	100	101	101	100	98	98	100
Yield	103	100	100	101	101	100	100	100	100
Input Index	97	97	100	96	98	100	97	100	100
$Efficiency^{-1}$	105	103	100	106	103	100	103	100	100

Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

Table 12. A Decomposition of Interenterprise Productivity Indexes for Soybeans in 1983, 1978 & 1974 for the Extended KLEFMA Model (Medium = 100).

Soybeans	1983			1978			1974		
(Size)	V Large	Large	Medium	V Large	Large	Medium	V Large	Large	Medium
Tillage	99	99	100	98	99	100	98	99	100
Planting	99	99	100	100	100	100	100	100	100
Applying	100	100	100	100	100	100	100	100	100
Harvest	99	100	100	99	100	100	100	100	100
Hauling	100	100	100	100	100	100	100	100	100
Capital	98	99	100	96	99	100	97	99	100
Labor	100	100	100	99	100	100	99	100	100
Energy	100	100	100	100	100	100	100	100	100
Fertilizer	101	100	100	100	100	100	102	100	100
Materials	98	99	100	100	99	100	101	101	100
Land	100	100	100	100	100	100	100	100	100
Input Index	96	97	100	95	98	100	98	100	100
Yield	103	100	100	101	101	100	100	100	100
Productivity	106	103	100	107	103	100	103	99	100

Weights for average enterprise size across regions and within size categories are based on 1979-85, 1975-80, and 1972-76 average county-level USDA/SRS data as a ratio of a region's production to the sum of production across regions.

Table 13. A Decomposition of Interenterprise Cost Efficiency Indexes for Soybeans in 1983, 1978 & 1974 for the Extended KLEFMA Model (Medium = 100).

Soybeans	1983			1978			1974		
(Size)	V Large	Large	Medium	V Large	Large	Medium	V Large	Large	Medium
Tillage	101	100	100	102	100	100	102	101	100
Planting	101	101	100	100	100	100	100	100	100
Applying	100	100	100	100	100	100	100	100	100
Harvest	102	100	100	101	100	100	100	100	100
Hauling	100	100	100	100	100	100	100	100	100
Capital	104	101	100	104	100	100	103	101	100
Labor	100	100	100	100	100	100	100	100	100
Energy	100	100	100	100	100	100	100	100	100
Fertilizer	100	100	100	10C	100	100	100	100	100
Materials	102	101	100	102	103	100	98	96	100
Land	100	100	100	100	100	100	100	100	100
Price Index	106	102	100	107	103	100	101	98	100
Unit Costs	99	99	100	100	100	100	98	98	100
Total Costs	102	99	100	100	101	100	98	98	100
Yield	103	100	100	101	101	100	100	100	100
Input Index	96	97	100	95	98	100	97	100	100
$Efficiency^{-1}$	106	103	100	107	103	100	103	99	100

Table 14. Intertemporal Partial and Total Productivity Indexes for Soybeans in the U.S. by Enterprise Size in 1983 & 1978 (1974 = 100).

Soybeans	1983			1978		
(Time)	V Large	Large	Medium	V Large	Large	Medium
Capital	97	95	95	97	97	97
Labor	99	99	99	99	99	99
Energy	100	99	100	100	100	100
Fertilizer	103	101	101	99	101	101
Materials	101	103	106	102	101	103
Land	100	100	100	99	99	99
Tornquist Quantity Index	99	97	100	97	97	98
Yield Index	115	113	113	111	112	110
Total Productivity	116	118	113	115	116	112

Interpretation: Since the total productivity indexes are computed relative to the 1974 = 100 base, numbers greater than 100 indicate the extent to which enterprises were productive in 1978 and 1983 than previously. For the partial productivity indexes, number greater than 100 indicates the extent to which input use and yield were more in 1978 and 1983 than previously, and conversely for number less than 100.

Table 15. Intertemporal Partial and Total Efficiency Indexes for Soybeans in the U.S. by Enterprise Size in 1983 & 1978 (1974 = 100).

Soybeans	1983			1978		
(Time)	V Large	Large	Medium	V Large	Large	Medium
Capital	124	122	123	113	111	112
Labor	103	103	103	102	102	102
Energy	104	104	104	101	101	101
Fertilizer	101	100	101	100	100	100
Materials	112	112	108	107	110	103
Land	217	220	217	162	162	162
Fisher Price Index	326	327	312	200	203	192
Yield Index	115	113	113	111	112	110
Cost Index	323	316	314	194	196	193
Total Efficiency^{-1}	116	117	112	114	115	110

Interpretation: Since the total efficiency indexes are computed relative to the 1974 = 100 base, numbers greater than 100 indicate the extent to which enterprises were productive in 1978 and 1983 than previously. For the partial cost efficiency indexes, number greater than 100 indicates the extent to which input prices, costs and yields were more in 1978 and 1983 than previously.

Table 16. Interregional Partial and Total Productivity Indexes for Soybeans in 1983, 1978 & 1974 (Illinois = 100).

Soybeans (Region)		Illinois Area 600	Iowa Area 500	Mississippi Area 200	Ohio Area 200
1983	Capital	100	98	102	100
	Labor	100	100	100	100
	Energy	100	100	100	100
	Fertilizer	100	101	101	104
	Materials	100	104	105	98
	Land	100	100	102	100
	Total Inputs	100	102	110	102
	Yield	100	93	61	91
Total Productivity		100	91	55	89
1978	Capital	100	98	104	100
	Labor	100	100	101	100
	Energy	100	100	101	100
	Fertilizer	100	99	99	101
	Materials	100	99	106	99
	Land	100	100	101	100
	Total Inputs	100	97	112	100
	Yield	100	95	58	93
Total Productivity		100	98	52	93
1974	Capital	100	99	102	99
	Labor	100	100	101	100
	Energy	100	100	100	100
	Fertilizer	100	100	103	104
	Materials	100	97	105	100
	Land	100	100	101	101
	Total Inputs	100	96	114	102
	Yield	100	97	62	88
Total Productivity		100	101	54	86

Interpretation: Since the total productivity indexes are computed relative to the Illinois = 100 base, numbers less than 100 indicate the extent to which enterprises were less productive than those in Illinois, conversely for numbers greater than 100. For the partial productivity indexes, number greater than 100 indicates the extent to which input use and yields were greater than in Illinois , and conversely for number less than 100.

Endnotes

1. The difference in cost efficiency between two enterprises is defined as the ratio of unit costs of output divided by the ratio of input prices for the chosen and reference points i.e., the ratio of the quantity of inputs to the ratio of the quantity of output.

2. The difference in productivity between two enterprises is defined as the ratio of the quantity of output to the ratio of the quantity of inputs for the chosen and reference points i.e., the inverse of cost efficiency.

3. The substitution effect is equal to changes in an input's shares of total cost (S_{ia} - S_{ib}).

4. In order to minimize the effects of year-to-year variability in soybean yields on cost efficiency per bushel, we used a 7-5 year moving average of soybean yields in our calculations of cost efficiency and productivity indexes.

5. Our analysis did not include the smallest 40 percentiles of enterprises and we would expect that these smaller scale enterprises were less productive than those studied.

References

Cooke, Stephen C. and W. Burt Sundquist. "Cost Efficiency in the U.S. Corn Production". American Journal of Agricultural Economics, 71(4):1003-10 November 1989.

Cooke, Stephen C. and W. Burt Sundquist. "Measuring and Explaining the Decline in U.S. Cotton Productivity Growth." forthcoming, Southern Journal of Agricultural Economics, July 1991.

Denny, M. and M. Fuss. "A General Approach to Intertemporal and Interspatial Productivity Comparisons." Journal of Econometrics 23(3):315-30 1983.

Diewert, W. E. "Exact and Superlative Index Numbers." Journal of Econometrics 4:115-45 1976.

Hazilla M. and R. Kopp. "Intertemporal and Interspatial Estimates of Agricultural Productivity." Agricultural Productivity: Measurement and Explanation, ed. S. Capalbo and J. Antle. Washington, D.C.: Resources for the Future, 1988.

Jensen, H. "Another Look at Economies of Size Studies in Farming." Economic Report ER82-7, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, MN, August 1982.

Ray, S. C. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77." American Journal of Agricultural Economics, 64(3):490-498, August 1982.

Thirtle, C. G. "Technological Change and Productivity Slowdown in Field Crops: United States, 1939-78." Southern Journal of Agricultural Economics 17(2):33-42 December 1985.

U.S. Department of Agriculture. Costs of Producing Selected Crops in the United States - 1974. 94th Congress Committee Print. Washington, DC: Government Printing Office, January 1976.

______. Economic Research Service. Soybeans: Background for the 1985 Farm Legislation. Agriculture Information Bulletin No. 471. Washington, DC: Government Printing Office, September 1984.

______. Economic Research Service. Firm Enterprise Data System, National Survey of Producers of Agricultural Commodities. Conducted by R. Krenz and G. Garst, ERS, 1975, 1979 and 1984. Stillwater, Oklahoma, unpublished.

______. Statistical Reporting Service/National Agricultural Statistical Service. County Planted Acres, Yield and Production Data by Commodity, 1972 to 1985. Edited by J. Brueggan. Washington, D.C., available on tape.

U.S. Department of Commerce. Census of Agriculture. Washington, DC: Government Printing Office, 1974, 1978, and 1982.