RESOURCE PRODUCTIVITY STUDIES IN TWENTY-TWO KANSAS COUNTRY ELEVATORS OF MODERN CONSTRUCTION

by

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INTRODUCTION

Efficiency in the National Economy

The interest in any type of research is ultimately in its contribution to social welfare,[1] one of the most important indices of which is full employment. In the current world situation, however, the United States as well as the rest of the democratic nations need and should not concentrate upon regulating production in the interest of full employment, but upon maximum production at minimum cost. The new role of the United States as the leader of democratic nations calls for high expenditures for military preparedness and will keep the whole economy stimulated to a high degree of employment and production for the years ahead.

"The problem will continue to be how to deal with inflation, not depression," writes Shepherd in his preface to 1952 edition of "Agricultural Price and Income Policy."[2]

In the race for military preparedness economic efficiency is a must. If military goods are to be produced without too great a sacrifice in production of civilian goods, the conditions of economic efficiency have to be met.

The necessary conditions for economic efficiency involve, first, maximum quantity of output from given set of resources and, second, minimum use of resources for given quantity of output. These conditions are not

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[1]Earl O. Heady, Economics of Agricultural Production and Resource Use, p. 10.

[2]Geoffrey S. Shepherd, Agricultural Price and Income Policy, p. VI.

sufficient to define the ratios in which variable and fixed resources should be combined. The sufficient condition can be formulated only when price relationships are used to denote maximum profits for the firm.

To the extent that the pricing system accurately reflects the value system and choices of the consumer, the marginal value productivities of resources can serve as indices of production efficiency from the standpoint of the society.[1]

Unless the necessary and sufficient conditions are all attained at the same time, resources are not used efficiently; they can always be rearranged to allow a greater total output of the products desired by the consuming society. This statement is valid for any given pattern of income distribution.[2]

The Purpose

The three objectives of this study were (1) to estimate and compare the marginal value productivities of resource services in Kansas country elevators of modern construction in terms of departure from the optimum efficiency conditions defined by the economic principle, with special reference to the different marketing services performed, (2) to predict within the limitations of the data and the method the effect of varying combinations and quantities of resources on the value of the product produced, and (3) to measure the returns to scale for the different functions.

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[1]Heady, op. cit., pp. 706-707.

[2]Heady, op. cit., p. 712.

Kansas is the leading wheat-producing state in the nation. "A topography which permits the use of power machinery, together with a climate and soil that favor wheat production, helps to give wheat a comparative advantage over other crops" such as corn, grain sorghums, oats, barley, and alfalfa.[1]

Marketing Kansas wheat is a job of major importance to the state's agriculture. It begins at the hundreds of local elevators where farmers deliver their wheat for storage and for sale.

In addition to offering the farmer a cash market for grain, providing storage service, and assembling small lots for carlot shipment, local elevators often perform a shipping and selling function for the farmer with the title remaining in his name. Some engage in cleaning and mixing grain. Many engage in making sales of certain farm commodities such as fuel, cement, coal, salt, feed, and insecticides. These sidelines often enable an elevator to obtain more nearly capacity use of some of its facilities.

In view of the alternative methods by which grain can be handled, such as merchandising or storage, the directors and management of each elevator company ought to give consideration to the question: can we increase our earnings or do a better job of marketing the grain of our community by performing other or fewer functions than those we now perform?

Efficient operation of country grain elevators is of interest not

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[1]Leo M. Hoover and John H. McCoy, Economic Factors that Affect Wheat in Kansas, Kansas Agricultural Experiment Station's Bulletin 369, January 1955, p. 5.

only to the owners, stockholders, and managers of these companies, but to all grain producers; the more efficiently the elevator businesses are operated, the better the market they can furnish for grain.

Again, because many farmers own a part interest in many grain elevators, they, as producers, have the alternative of using certain resources either in elevators, in their farm businesses, or other investments. A greater knowledge and understanding of the most productive uses of labor and capital would help these farmers (1) direct the resources available to them into the activities where highest profits are possible, and (2) distribute the resources between the alternative enterprises available to them, so that maximum efficiency might be attained.

Since economic efficiency may be affected by governmental policies, customs, institutions, and any other developments which change production possibilities, cost structures, and resource management, policy-formulating agencies should have a clear picture of the economic possibilities and limitations of resources in a marketing activity such as that performed by grain elevators. The 22 country elevators in this study represent modern concrete elevators, constructed in the past ten years. While the homogeneous sample thus achieved is primarily important for statistical reasons, it also represents a trend in elevator construction for the years ahead and should therefore be of particular interest for future policy reasons.

According to the principles of most effective resource allocation from the standpoint of the society the following conditions have to be met.[1]

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[1]Heady, op. cit., p. 708.

1. Resources must be allocated within each firm so that the marginal value productivities of the resource services are equal.

2. Resources must be distributed between firms so that marginal value productivities are equal.

3. Resources must be distributed between agricultural, industrial, and marketing activities to allow attainment of equal value productivity.

4. The various factors must be allocated between industries to bring about attainment of these identical conditions.

5. Resources must be allocated over time so that their discounted value products are equal.

Empirical studies have been reported on the productivity of resources in manufacturing by Douglas and associates since 1928 and more recently by Heady, Tintner, and others. The recent surveys have dealt with primary production in agriculture and have provided valuable information for policy-makers. Both time-series and cross-section surveys have been made. A current study deals with resource productivity in agricultural marketing firms of the Great Plains.[1]

In the study on hand estimates will be derived for total plant operation in country elevators as well as for the productivity of resources used in storage, sidelines, and grain merchandising. In this connection, the first of efficiency conditions stated by Heady is particularly relevant. Translated into the terms of this study it runs as follows: resources must be allocated between the different marketing services performed by the elevators so that the values of marginal products of all resource services are equal. The elevators should not use a unit of labor or capital for

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[1]Paul L. Kelley, Henry Tucker and Milton L. Manuel, Resource Returns and Productivity Coefficients in the Kansas Cooperative Grain Elevator Industry, No. 225, Department of Agricultural Economics, and No. 22, Statistical Laboratory. Contribution to the Kansas Agricultural Experiment Station.

storage if it can produce a greater value product in grain merchandising. Resources must be so arranged that it would be impossible to increase earnings by transferring them from one use to another use in the plant.

This kind of analysis involves isolation of the various factors of production employed in grain elevators, so that the productivity, efficiency, and combination of the factors of production can be determined with the central goal of profit maximization in mind.

The Methods

Profit maximization is assumed to be the main goal of the firm in this study. Furthermore, the firm is assumed to operate in a perfectly competitive market. More than one elevator is accessible to almost every farmer. The farmers are seldom so tied to one elevator that they will continue to patronize it regardless of high operating costs, poor service, or higher than average prices on services or sidelines merchandise.

In the long run, a purely competitive equilibrium is characterized by the absence of profits. Profits that do arise will be a result of either departure from pure competition or a process of dynamic change in which long-run equilibrium cannot be attained persistently. It may be argued that in the long run the downswings exactly counterbalance the gains of upswings, so that on the average no genuine profit share is created. This may be true if there is neither progressive deflation nor progressive inflation.

It is obvious that the assumption of a market not perfectly competitive and frictionless would make the problem more complex but also somewhat more realistic. However, such an approach has not been used in previous studies of this kind because of difficulties in analysis.

The conditions of equilibrium in hiring of resources for a firm operating in a perfectly competitive market with profit maximization as its main goal have been worked out by Heady[1] and others.

Profits for a firm can be maximized if the least-cost combination for each level of output is attained by

1. a) Equating the price ratio of productive services with their substitution ratio. This condition is given in the following equation for productive services X_1 and X_2 where P refers to the price of the productive service indicated by the attached subscript and MP refers to the marginal physical product of each factor:

$$\frac{P_{x_1}}{P_{x_2}} = \frac{\Delta X_2}{\Delta X_1} = \frac{MP_{x_1}}{MP_{x_2}}$$

b) Equating the price ratio of products with their substitution ratio. This condition is given in the following equation for products Y_1 and Y_2 where P refers to the price of the product indicated by the attached subscript:

$$\frac{P_{y_1}}{P_{y_2}} = \frac{\Delta Y_2}{\Delta Y_1}$$

c) Equating the factor-product price ratios with their marginal transformation ratio. This condition is given in the following equation for productive service X and product Y where P_x

[1]Heady, op. cit. p. 196.

refers to the price of X and P_y refers to the price of Y and MP_x is the marginal physical product of X:

$$\frac{P_x}{P_y} = \frac{\Delta Y}{\Delta X} = MP_x \text{ and}$$

2. Extending output as long as the marginal cost of the resources is less than the marginal value product. "When this condition has been attained, resources cannot be rearranged to add more to net profit and the marginal value productivities of all resource services are equal."[1]

The value of the marginal product of a factor is found by multiplying its marginal physical product by the price of output.* - An elevator operator who wants to maximize the profits of the firm would, under pure competition, add factor units to the point where they just pay for themselves. This point is seldom reached, however, because of lack of knowledge, uncertainty, capital rationing, or monopolistic tendencies in the market.

The production function for any productive process has the symbolic form $Y = f(X_1, X_2, \ldots X_i, \ldots X_n)$, where Y refers to a single product expressed as a function of specific factors of production $(X_1, X_2, \ldots X_i, \ldots X_n)$.

Historically, there are four factor categories in production — land, labor, capital, and entrepreneurship. Theoretically any number of factor classes can be defined as long as they are not perfect complements or perfect substitutes for one another.

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[1]*Loc. cit.*

*It follows that the absolute optimum would be reached if all the "net values" of marginal products are zero, the net value being defined as the difference between the marginal value product of a factor and the cost of this factor.

It follows that a knowledge of the substitutability or complementarity of factors is essential for their classification into different factor categories for the purpose of economic analysis. Numerous variations in factor-factor relationships are relevant in resource co-ordination, ranging from fixed proportions to perfect substitutes. The concept of fixed proportions is important in returns-to-scale analysis. Heady has to say the following on the concept:

> When two factors are complementary to the extent that they must be used in fixed proportions, they represent, for all practical purposes, a single amalgam factor, and there is little gain in dividing them into separate categories. Water is made up of both hydrogen and oxygen. For purposes of production, however, water alone needs to be considered. There is no basis or reason for considering either of the particular elements in isolation.[1]

Of the historical four factor categories this study will include only labor and capital. Land, a fixed resource and therefore passive, is not an essential factor in a study which is conducted to measure the deviations from the optimum conditions in a particular time period; the total cost of its services is constant over the whole range of output. Entrepreneurship, a very important factor but extremely hard to measure, has been omitted as in previous productivity studies.

When the input-output relationship is to be estimated for a single variable resource, for instance labor, the short-run production function takes the following form: $Y = f(X_1 | X_2, \ldots X_i, \ldots X_n)$, where X_1 is variable and all other resources are fixed in quantity. Over the long run, all resources become variable, and the nature of the long-run production function becomes a problem of returns to scale in elevator operation.

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[1]Heady, op. cit. p. 308.

Returns-to-scale relationships are accurately reflected only if all factors, including management, are increased in equal proportions. The classical production function includes a range of increasing returns to scale, a range of decreasing returns to scale, and a point of constant returns to scale.

If, when all factors are increased by the same proportion, the product increases by the same proportion, constant returns to scale prevail; an increase by a greater proportion indicates increasing returns to scale; an increase by a smaller proportion — decreasing returns to scale.

According to the Euler theorem, the total product will under specified conditions be exactly exhausted if the claims of each factor are met. Sums of the quantities of resources multiplied by their marginal productivities then equal the total quantity produced. This is the case of constant returns to scale. There would be a deficit in case of increasing returns, and a residual in case of decreasing returns.

Specialization and division of labor by tasks provide one basis for and hypothesis of ranges of increasing returns to scale. Firms have not reached optimum scale when increasing returns prevail. Heady writes:

> If scale or size economies are very great, other ends may be extended only at a very great sacrifice. If scale economies are small or nonexistent, small firms might be used with little sacrifice in attaining a more nearly equal distribution of wealth.[1]

Numerous algebraic functions can be used in estimating input-output relationships. The Spillman production function ($Y = m - ar^x$) is based on the notion that elasticity of production changes but that the ratio of

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[1]Heady, _op. cit._ p. 349.

marginal products is constant over all ranges of input.* The Cobb-Douglas production function ($Y = aX^b$), on the contrary, is based on the idea of constant elasticity of production but does not allow constant marginal product ratios. A "simple" polynomial such as $Y = a + bX + cX^2$ would be more satisfactory than either one of the former functions because it allows neither constant elasticity nor constant marginal product ratios, but does allow diminishing total productivity.

With limited funds, however, the Cobb-Douglas production function is better than the quadratic or any other equation.**

Tintner brings out the following advantages of the Cobb-Douglas type production function:[1]

1. It yields elasticities immediately.

2. It permits the phenomenon of decreasing returns to come into evidence with the use of the least complicated function. This would not be the case if we, for instance, should choose a function which is linear in the original data.

The Cobb-Douglas function which is used in this study has been applied since 1927-28 to the statistical verification of the marginal productivity theory of distribution. In the normal form the production function appears as follows:

$$Y = aX_1^{b_1}, X_2^{b_2}, \ldots X_i^{b_i} \ldots X_n^{b_n},$$

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[1]Gerhard Tintner, Econometrics, p. 54.

*Y = total production, X = the quantity of the variable factor, m = the maximum output which can be attained from the fixed technical unit, r = the ratio by which increments are added to total production, and a = the maximum output which can be added by the particular variable factor.

**For six factors in a Cobb-Douglas function, only six elasticities have to be computed, while in a quadratic equation containing the same number of factors the number of elasticities to be computed would be twenty-seven.

where the exponents b_i are the elasticities of production of the factors X_i, and a is a constant. Converted into logarithms, the function becomes linear and takes the following form:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_i \log X_i + \dots + b_n \log X_n.$$

The statistical method of deriving estimates of the elasticities is the method of least squares, commonly called multiple regression analysis.

Review of Literature

That the amount of product would increase by diminishing increments if successive combined doses of labor and capital were applied to a given piece of land, was pointed out simultaneously by Malthus and Sir Edward West in 1815. The principle was adopted by Ricardo in his "Principles of Political Economy" two years later as the basis for his theory of distribution. The joint return to labor and capital was declared by Ricardo to be governed by and to be equal to the amount of product added by the last combined dose of labor and capital, which were bound together in fixed and unvarying proportions. There was no way of isolating the specific contributions of these two factors as a means of determining the rates of wages and interest. These rates were instead presumed to be regulated by cost-of-supply factors which would keep wages down to a fixed minimum close to basic subsistence and interest close to the low minimum needed to compensate savers and investors. Such was the classical Malthusian theory of distribution.[1]

Because of his statement that the rate of wages and of interest are equal to the amounts of the product added by the last increments of each,

[1]Paul H. Douglas, "Are There Laws of Production?" American Economic Review, March 1948, 38 (Part I):1.

von Thunen is considered to be the discoverer of the marginal productivity theory which is today the most widely held theory among economists in respect to earnings received by wage earners and capitalists. During the 1840's, von Thunen pointed out that, when each of the factors (labor and capital) was separately increased and the others held constant, the product increased by diminishing increments. He also reasoned that the product added by each equal increment of a factor was a constant fraction of the preceding increment of product and that it would be necessary to increase a factor in a given geometric ratio in order to increase the product by equal arithmetic amounts.[1]

This theory was perpetuated in Mitscherlich's Law of the Soil and Spillman's production function.

Von Thunen's theory was rediscovered and popularized in America by John Bates Clark in 1888 in his book "The Distribution of Wealth," and a series of articles. Clark was the father of the marginal productivity theory of distribution as the world knows it today, and as it is found incorporated in so many modern textbooks on economics. The theory, as conceived by Clark, rests upon the premises of the free play of competition and the supremacy of the self-interest principle among men, and the superiority of the regime of private property over any other economic order.[2]

It was Philip Wicksteed who subsequently maintained in his "The Co-ordination of the Laws of Distribution" that the payment according to the marginal productivities of each unit of the respective factors of

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[1] Ibid., pp. 1-2.

[2] John M. Ferguson, Landmarks of Economic Thought, p. 245.

production completely absorbed the product, without either surplus or deficit, if production were characterized by a homogeneous linear function of the first degree. He proved it by use of the classical theory of rent rather than by means of the Euler Theorem.

Later Knut Wicksell pointed out that, while the homogeneous production function could not be expected to apply over the whole range of output within a plant, under perfect competition each firm would tend to carry its scale of output to the point where neither increasing nor decreasing returns prevailed, i.e. where the rate of return was constant.

Two essential conditions for marginal analysis, substitutability and minute divisibility of all factors, were emphasized by Pareto (Pareto: Cours d'Economie Politique, Lausanne, 1896) and subsequently by Durand.[1] The latter pointed out that capital may not be truly substituted for labor. The number of possible combinations would be too limited, so the result would be a discontinuous production function.

Production functions, especially the Cobb-Douglas function, have been widely explored and discussed by economists as well as econometricians and statisticians since the publishing of Douglas' article, "A Theory of Production," in the American Economic Review (1928).[2] Together with co-author Charles W. Cobb,[2] the great pioneer of econometrics in this article set forth his production function. Douglas limited his study to manufacturing. Assuming that the product of manufacturing is a function of capital and

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[1]David Durand, "Some Thoughts on Marginal Productivity with Special Reference to Professor Douglas' Analysis," Journal of Political Economy, December 1937, 45:741.

[2]Charles W. Cobb and Paul H. Douglas, "A Theory of Production," American Economic Review, March 1928, 18 (Part I, Supplement):139-164.

labor alone, he compiled indices of production, labor, and capital for the United States over the years 1899 to 1922, measured the changes in the amount of labor and capital, and determined the relationships existing between the three variates. The original function was of the form $P' = bL^{k}C^{1-k}$, meaning that production is a first degree homogeneous function of labor and capital, where P' approximates P (production) over the period. P represented the total value product of industry deflated for price changes, L — total labor employed in production, and C — total fixed capital available for production. The constants b and k were obtained by the method of least squares.

By multiple regression analysis the values of b and k arrived at were: $P' = 1.01\ L^{.75}C^{.25}$. The average percentage deviation of P' from P without regard to sign was 4.2 per cent. Any departure of P from P' may be represented by a change in the value of the coefficient b which was independent of L and C. The coefficient b was thus made a catch-all for the effects of any force for which no quantitative data were available.[1]

The sum of the exponents for labor and capital, k and 1 - k, was made equal to unity, meaning that 1 per cent increase in the quantities of each of these factors would be expected to call forth a corresponding increase in the quantity of the product. This would constitute true constant returns. The marginal productivity of each factor, when multiplied by the corresponding quantities of each, would when totaled be equal to the total quantity produced. It also followed that the share of the total product received by the factors under conditions of perfect competition would be equal to k for labor and 1 - k for capital.

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[1] *Ibid.*, p. 155.

Durand cast doubt on the assumptions of homogeneity and linearity of the production function based on the premise of constant returns.

> First, a homogeneous function is entirely inappropriate for competing firms operating at minimum cost. Such a function demands that firms operate in a state of constant returns under all conditions. There is, then, no such thing as a state of minimum cost, and competition will have no effect on the size of any firm. Second, a homogeneous linear function is inappropriate for the whole of industry. Constant returns to an individual firm in a society in which vestiges of competition still remain are possible but constant returns to industry must first be demonstrated with inductive, not deductive methods.[1]

He suggested a production function of more general form: $P = bL^kC^j$, where k and j are constants whose sum is not necessarily one, i.e. increasing and decreasing returns are possible.

Horst Mendershausen expressed doubts as to the reliability of the methods of Douglas and his results because of the alleged instability of the parameters of the function fitted.[2] He also questioned the advisability of minimization in the product direction by alleging that it was equally important to minimize in labor and capital directions as well, and that if this were done the results would be so different that no real credence should be given to these obtained from minimizing in the product direction.

The essays of Durand and Mendershausen contained the most far-reaching criticisms to the Cobb-Douglas function to date.

Douglas decided that Durand's suggestion of a new production function of a more general form should be adopted, and subsequently launched a new field of investigation — cross-section analyses.

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[1]Durand, op. cit., p. 749.

[2]Horst Mendershausen, "On the Significance of Professor Douglas' Production Function," Econometrica, April 1938, 6:143-153.

In an article in the Journal of Political Economy Douglas and co-author Bronfenbrenner (1) devised ways and means of eliminating cases leading to extreme statistical instability and (2) adduced statistical or economic reasons why minimization in the product direction leads to particularly valid results.[1]

They suggested that results derived from data in which any of the following three "stability conditions" are not fulfilled should be disregarded:

1. There should not be more than one zero-order correlation between any pair of variables which exceed a certain maximum, say .95.

2. No two independent variables should be correlated more highly with each other than is any independent variable with the dependent one.

3. All regression coefficients must be statistically significant.[2]

They admitted that judged by the three tests of stability, the majority of planes fitted to the data appeared unstable. However, they asserted:

> The most unstable fits...are precisely those yielding nonsense parameters in the Cobb-Douglas function. Every case of abnormally high k (above .85) and of abnormally low j (below .15) is a case of unstable fit... High standard errors of parameters, even where the fits appear statistically stable, make impossible conclusive statements as to the economic meaning of the results.[3]

Bronfenbrenner and Douglas also found that fits using total-capital statistics gave better results than those using the fixed-capital series. "This was to be expected theoretically due to the large random errors in

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[1] M. Bronfenbrenner and Paul H. Douglas, "Cross-Section Studies in the Cobb-Douglas Function," Journal of Political Economy, December 1939, 47:761-785.

[2] Ibid., p. 769.

[3] Ibid., pp. 773-776.

allocation of total capital between the categories of fixed and working capital."[1]

Although the assumption of a linear homogeneous function was not made in later studies, the sum of the elasticities tended to equal one, indicating constant returns. There was a "surprisingly close agreement among the values found for k in the various economies."[2] This would indicate that in all the countries investigated in the great variety of periods analyzed, there were no discernible economies or diseconomies of large-scale production (i.e. small and large enterprises were approximately equally profitable within the range of data used.)

Regarding the elasticity coefficient for labor, k, Douglas and Gunn asserted that, "in a formula where the sum of the exponents is greater than unity, the share which might be imputed to labor might be expected more closely to approximate the ratio of k to k + j rather than purely k itself."[3]

If $k = .74$, $j = .32$, $k + j = 1.06$, then $\frac{k}{k+j} = \frac{.74}{1.06} = .70$, a value which comes closest to the actual share received by labor which is usually lagging behind, and always expected to be less in years of rising prices.

In a cross-section study of 556 manufacturing industries in the United States in 1919 Douglas and Gunn found that k was .76 and that j was .25.

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[1] Ibid., p. 774.

[2] Grace T. Gunn and Paul H. Douglas, "The Production Function for American Manufacturing in 1919," American Economic Review, March 1941, 31:69.

[3] Ibid., p. 71.

This meant that if conditions of perfect competition had prevailed throughout, labor would have received 76% of the value of the product. The actual wages paid totaled only 60% of the product. This discrepancy may have been an important factor in the large number of strikes during that year.[1]

To determine whether or not the same three variables which were previously used -- namely P, L, and C -- should be included in the function, Douglas and Gunn constructed bunch maps (detailed discussion of bunch maps in Statistical Confluence Analysis by Means of Complete Regression Systems by Ragnar Frisch, Oslo, 1934) to see how the addition of a third variable alters the relationships between the first two.[2] The relationship between P and L was but little altered when the third variable, C, was included. The addition of L made a greater change in the P/C relationship and the consideration of P altered even more that of L/C.

From the formula $P = 2.39\ L^{.76}C^{.25}$ the product was computed using the actual values of L and C for each industry. This "theoretical" product was called P' and its logarithm X_1'. For each industry, the theoretical and observed values of the logarithm of product were plotted on a graph; X_1', the theoretical, along the horizontal and X_1, the observed, along the vertical. The locus of points for which $X_1' = X_1$ became a heavy line. Broken lines were drawn at a distance of one and two standard errors (S) of estimate parallel to either side of the central locus line.*

For 435 industries, or 82 per cent of the cases, the observed value of X_1 lay within the range $X_1 \pm S$. In 97 per cent, X_1 lay within

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[1] *Ibid.*, p. 73.

[2] *Ibid.*, p. 73-74.

*The standard error of estimate = the standard deviation of the residuals, $X_1 - X_1'$.

$X_1 \pm 2S$. This indicates that the actual values in general were surprisingly close to what they should be according to the formula ... The closeness of the two series (actual products and those expected theoretically) furnishes added proof of the general reliability of the (Cobb-Douglas) formula ...[1]

Gunn and Douglas also used the equation $P = bL^kC^j$ for computing the flexibility of wages (= the flexibility of the marginal product curve), and the elasticity of demand for labor (= the elasticity of the marginal product curve).

For an individual employer, provided his output does not alter the demand curve for his product, the demand curve for labor is the marginal net productivity curve of labor. The elasticity of demand for labor is then the reciprocal of $_L$, the flexibility of the marginal productivity of wages.[2]

(1) $$\phi_L = \frac{\partial(MP_L)}{\partial L} \cdot \frac{L}{MP_L} \qquad \text{(flexibility)}$$

(2) $$MP_L = \frac{\partial P}{\partial L} = kbL^{k-1}C^j = k\frac{P}{L} \qquad \text{(marginal productivity)}$$

(3) $$\frac{\partial(MP_L)}{\partial L} = k(k-1)\,bL^{k-2}C^j$$

(4) $$\phi_L = k - 1$$

(5) $$\eta = \frac{1}{k-1} \qquad \text{(elasticity of demand)}$$

Since the value of k was found to be approximately 3/4, the elasticity of demand for labor for the firm was - 4, which would mean that an increase of 1 per cent in wages, cet. par., would bring a 4 per cent decrease in the number employed by a typical firm. This was based on two assumptions: (1) that the employer knows the marginal productivity of labor and hires laborers to the exact point at which marginal productivity is equal to wage;

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[1] Ibid., p. 79.

[2] Loc. cit.

(2) that changes in the output of his firm do not change the demand curve for the product.

Also, if the marginal productivity of labor were kP/L and the wage equaled marginal productivity, the wage bill would amount to 3/4 of the product.

In a comment in the American Economic Review in 1941 Mendershausen[1] questioned the reliability of the selection of one minimization direction (X_1 = Product) and the neglect of the two possible alternatives. Gunn and Douglas answered:

> ...if there is any common-sense concept in economics it is that product (P) is a function of labor (L) and capital (C). To refuse to find the parameters of the regression equation merely because the quantities of labor and capital are also interrelated is to throw the baby out with the bath.[2]

Mendershausen replied:

> As far as I am aware, these production functions have not been computed for the purpose of estimating the value of production on the basis of known capital and labor inputs. They are established for quite a different purpose, namely, the estimation of the structural relationship among the three variables (marginal productivities, elasticities, etc.)... What is correct procedure in setting up an estimating equation for X_1 is not necessarily correct in evaluating the structural relationships between X_1, X_2, and X_3. The two purposes can be served by one and the same method only if all "disturbances" are concentrated in X_1, while X_2 and X_3 enter into the computations with their "true" values.* Otherwise the computation of structural coefficients requires some different approach... in order to arrive at a justification for the use of elementary regression coefficients (production = dependent variable) in determining structural coefficients the authors (Gunn and

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[1] Horst Mendershausen vs. Grace T. Gunn and Paul H. Douglas, "On the Significance of Another Production Function," A Comment, American Economic Review, September 1941, 31:563-564.

[2] Grace T. Gunn and Paul H. Douglas vs. Horst Mendershausen, "On the Significance of Another Production Function," A Reply to Dr. Mendershausen's Criticism, American Economic Review, September 1941, 31:566.

Douglas) would have to go several steps farther and assume <u>absence of disturbances in the figures for capital and labor</u>.[1]

**"True" values are generally defined as the strictly related parts of the observed variables, "disturbances" as the remainder.

That two problems of validity have to be taken into account before launching into a cost-output relationship study with Cobb-Douglas function was pointed out by Ruggles: "First, are the data reliable enough to yield a correct function, and second, is the linear function both the best possible and the only regression which will fit the data?"[2]

He listed the following objections to total cost data in empirical studies employing the Cobb-Douglas function:

1. The statistical data are always dynamic, and the static conditions of economic theory can never be fulfilled.

2. The data are fairly rough due to the lack of refined short-period accounting.

3. The failure of the cost incurred within a given period to correspond to the output of that period is another serious problem since time-lag procedure is always in some degree incorrect even under the most favorable circumstances.[3]

Ruggles also pointed out that

> ...there still remains the problem as to whether a linear regression is the only line of best fit. (But) in the majority of these studies no statistical test is employed and in a few the investigator is content to show that the scatter of means of regression line may be accounted for...by the probable error around the regression line... This test is not entirely satisfactory since it might be quite possible to have an infinite number of curves within a given probable error estimate... Considerable variations may occur in the marginal cost curve without causing the total cost function to depart widely from apparent linearity.[3]

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[1]Horst Mendershausen, op. cit., A Rejoinder, 31:568.

[2]Richard Ruggles, "The Concept of Linear Total Cost Output Regressions," American Economic Review, June 1941, 31:332-335.

[3]Ibid., p. 333.

Marschak and Andrews raised doubt as to whether the Cobb-Douglas function can be identified with the production function as understood by the economists.[1] They claimed that the economist cannot perform experiments by choosing one variable as "dependent" and, while keeping the other "independent" ones under control, watch the values taken by the dependent uncontrolled variable.

> The economist has no independent variables at his disposal because he has to take the values as they come, produced by a mechanism outside his control. This mechanism is expressed by a system of simultaneous equations, as many of them as there are variables.*

They emphasize that the production function will change from firm to firm and from year to year, depending on the technical knowledge, the will, effort and luck of a given entrepreneur. They summarize these factors as "technical efficiency," which may be represented by one or more random parameters.

> If a single parameter, say ϵ_f, suffices to characterize the "technical" efficiency of a firm f, while the production function is in all other aspects similar for all firms, we may write for this firm: $X_0 = \phi(X_1, X_2, \epsilon_f)$, meaning that the production functions of various firms belong to a one-parameter family, the changing parameter being ϵ_f, the "technical efficiency."[2]

They assert that the "marginal-productivity equations"

$$\frac{\partial X_0}{\partial X_1} = \frac{P_1}{P_0} \qquad \frac{\partial X_0}{\partial X_2} = \frac{P_2}{P_0}$$

are also random equations because (1) they involve the derivatives of the

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[1]Jacob Marschak and William H. Andrews, Jr., "Random Simultaneous Equations and the Theory of Production," Econometrica, July-October 1944, 12:143-205.

[2]Ibid., p. 145.

*The importance of simultaneous random equations for economic research has also been emphasized by Haavelmo.

function ϕ, (2) there are differences in the prices paid or received by various firms ("if we drop, as realistically we must, the assumption of perfect competition") and (3) there are "differences in economic efficiency of various firms, i.e. the ability or willingness to choose or have luck in choosing the most profitable combination of resources."[1]

Bronfenbrenner summarized what had been said to date on the Cobb-Douglas function as follows:

1. The interfirm* production function fitted by the Cobb-Douglas analysis is a legitimate theoretical tool which can be utilized for the empirical verification of the theory of distribution.

2. While logically valid alternative explanations of results achieved by the use of interfirm production function are possible, the frequency of variable results tends to cast doubt on the practical significance of such of these alternative explanations as depend largely upon chance factors.

3. The interfirm production function does not enable the statistician to make valid quantitative estimates of the elasticity of demand for production factors, since results obtained from it have a systematic upward bias.[2]

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*Compare to the production functions of conventional economic theory, the so-called "theoretical" or Reder's intrafirm functions.

Gerhard Tintner of Iowa State College was one of the pioneers in using the Cobb-Douglas function empirically to analyze farm data.[3] He made a cross-section study of 609 Iowa farms for the year of 1942, where the dependent variable was the total gross profit of the farms, and the independent variables were (1) land, measured in total acres, (2) labor, measured in man

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[1] Loc. cit.

[2] M. Bronfenbrenner, "Production Functions: Cobb-Douglas, Interfirm, Intrafirm," Econometrica, January 1944, 12:44.

[3] Gerhard Tintner, "A Note on the Derivation of Production Functions from Farm Records," Econometrica, January 1944, 12:26-34.

months, (3) value of farm improvements, (4) liquid assets, including livestock, feed, seed, and supplies, (5) working assets, including breeding cattle, horses, tractors, crop machinery, livestock equipment, special machinery, trucks, farm share of the automobile, and (6) cash operating expense, including livestock expense, feed purchased, repairs, fuel, and oil for all equipment on the farm.

With the exception of the coefficient for working assets, all regression coefficients were significant at the 5 per cent level of probability. The difference between the observed sum of elasticities (0.866) and 1.0 was not significant, indicating that constant returns to scale might have prevailed.

Tintner's work was followed by studies conducted by himself or Earl O. Heady and associates. In a study of a random sample of 738 Iowa farms for the year 1939 Heady developed separate functions for either of (1) crop, hog, dual-purpose and dairy, general, and special farms, and (2) small farms and large farms.[1] Some of his findings which were particularly valuable for policy reasons indicated that (1) contrary to expectations, no increasing returns to scale prevailed on the "smaller" farms, (2) livestock was the most profitable enterprise, and should therefore be expanded, (3) the marginal productivities were highest on the most productive land which was undercapitalized (i.e. the marginal productivity of the land was found to be higher than the rent received for it), (4) labor showed a rather low marginal productivity, (5) the returns to machinery and equipment were highest in the poorer areas of the state which were largely undermechanized at the time.

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[1]Earl O. Heady, "Production Functions from a Random Sample of Farms," Journal of Farm Economics, November 1946, 28:986-1004.

Heady emphasized the difficulty of the classification of independent variables into categories which are really independent. If factors are used jointly in the production process, they are complementary to each other, and when this relationship exists, the resource efficiency measurement of a particular resource taken separately has little statistical significance because of high correlation. Such variables should be combined into one independent variable when a high degree of correlation exists as predetermined by statistical analysis of the variables.

A study of 194 dry-land wheat farms conducted by Hu Harries for the year 1939/40 in Saskatchewan, Canada, was one of the few studies that seemed to indicate increasing returns to scale.* Harries emphasized that the results obtained in his own and similar studies should be carefully analyzed before any statement of causal relationships is made, because a high degree of relationship between the input and output variables is not necessarily a causal relationship.[1]

A subsequent study conducted by Fienup on resource productivities in Montana dry-land wheat farms indicated increasing returns to scale for the crop function and decreasing returns to scale for the livestock function.[2] Total cash crop expenses were found to have the highest statistically significant marginal productivity.

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[1]Hu Harries, "Development and Use of Production Functions for Firms in Agriculture," Scientific Agriculture, Agricultural Institute of Canada, October 1947, 27:487-493.

[2]Darrell F. Fienup, Resource Productivity on Montana Dry-Land Crop Farms, Montana State College, Agricultural Experiment Station's mimeographed Circular 66, June 1952.

*These returns to scale were not tested statistically.

One of the latest and most noteworthy studies employing the statistical production function, a so-called area study, was conducted by Earl O. Heady and Russell Shaw.[1] The study was based on random samples drawn in 1951 for the Piedmont area of Alabama, north central Iowa, southern Iowa, and a dry-land wheat area of Montana. Two production functions, one for livestock and the other for crops, were computed for each region. For crops, three categories of resource inputs were used: land services, capital (crop and machine) services, and labor services. The two categories used in the livestock equations were capital services and labor services. All regression coefficients were significant at the 1-8 per cent probability level, except for crop labor in Montana. Only the equation for south Iowa indicated increasing returns to scale for livestock. Crop functions, however, indicated profitability of expansion for all four areas.

The various steps employed in the marginal analysis of this study included computation of marginal products, comparison of differences in marginal products of resources in different areas, comparison of departure of marginal products from resource prices, interstrata productivity comparisons, and prediction of marginal products of labor with different quantities of land and capital services.

Another recent area study of considerable interest to political economists has been made by Earl O. Heady and Schalk du Toit[2] on agricultural

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[1] Earl O. Heady and Russell Shaw, "Resource Returns and Productivity Coefficients in Selected Farming Areas," Journal of Farm Economics, May 1954, 34:243-257.

[2] Earl O. Heady and Schalk du Toit, "Marginal Resource Productivity for Agriculture in Selected Areas of South Africa and the United States," Journal of Political Economy, December 1954, 52:494-505.

resource productivities in selected areas of South Africa and the United States (the areas in the United States are the sample areas used the previous study.)

This study provided the first comparisons of resource productivities for agriculture at different world locations. The independent variables used in the study were land, labor, and capital. Disequilibriums between marginal productivities and factor prices were found to be very great in South Africa. Labor productivity was nearly double the wage rate in Africa as contrasted to the situation in the United States where it was below the price of labor. Significant differences existed in capital productivity for Africa as compared to the figures for livestock in all American areas. It was concluded that the world product could be augmented by transfers of capital from the United States areas to the African areas.

First studies of resource productivities in the agricultural marketing firms of the Great Plains were undertaken by Paul L. Kelley.[1] Cross-section as well as time-series studies were made. Cross-section studies were based on a population of 215 cooperative grain elevators in the 1949 wheat crop year, and a population of 168 cooperative creameries in 1952-53. The time-series study was based on three Kansas cooperative dairy manufacturing plants.

The 215 elevators were stratified on both area and diversification (or percentage of sideline sales) bases. The independent variables used in the analysis were labor services, operating services, and capital services in dollars; the dependent variable was the value added in manufacture.

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[1]Kelley, Tucker and Manuel, op. cit.

EMPIRICAL INVESTIGATION

The Sample

Economic Organization of Production Area. Economic organization in grain elevators is influenced by the nature of primary production because elevators as agricultural marketing firms and secondary producers depend on farmers, primary producers, for their inputs.

The importance of wheat to Kansas agricultural economy as compared to that of other grains and livestock is apparent from Plate I, Fig. 1. Wheat is by far the most important crop in Kansas, and is grown in every county of the state. Cash-crop farms are the dominant type in most of the western Kansas areas. From 1943 to 1952 Kansas produced nearly one-fifth of all the wheat produced in the United States (Plate I, Fig. 2).[1]

Wheat has been the dominant crop in Kansas since World War I. Before this time the acreage of corn was well above that of wheat. The wheat-producing capacity in the United States as well as Kansas has undergone great expansion during and following World War II. The largest crop, 308 million bushels, was harvested in 1952.

Corn is practically limited to the eastern one-fourth of the state and a narrow belt across the northern boundary. Grain sorghums, oats, barley and alfalfa are of minor significance.

Although yields are highest and vary least in eastern Kansas, a comparatively small part of the wheat crop is grown in this area. On the other hand, a great deal of wheat is grown in western Kansas where average

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[1]Leo M. Hoover and John H. McCoy, op. cit. pp. 4-5.

EXPLANATION OF PLATE I

Fig. 1. Sources of cash farm income from marketings in Kansas, 1943-1952.
(Computed from data provided by the Federal-State Crop Reporting Service)

Fig. 2. The principal wheat-producing states of the United States. Average annual production for the ten-year period, 1943-1952.
(Source: U.S. Department of Agriculture, Agricultural Statistics, 1943 through 1952.

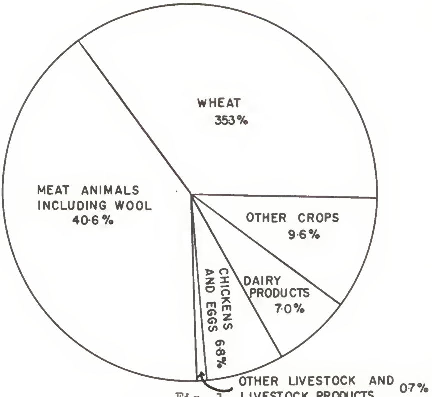
WHEAT
35.3%
MEAT ANIMALS
INCLUDING WOOL
40.6%
OTHER CROPS
9.6%
DAIRY
PRODUCTS
7.0%
CHICKENS
AND EGGS 6.8%
OTHER LIVESTOCK AND
LIVESTOCK PRODUCTS 0.7%

Fig. 1

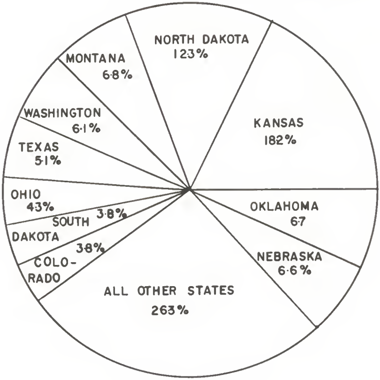
NORTH DAKOTA
12.3%
MONTANA
6.8%
WASHINGTON
6.1%
TEXAS
5.1%
OHIO
4.3%
SOUTH
DAKOTA
3.8%
COLO-
RADO
3.8%
KANSAS
18.2%
OKLAHOMA
6.7
NEBRASKA
6.6%
ALL OTHER STATES
26.3%

Fig. 2

yields are relatively low and annual yield varies widely. The topography and climate in the western and central parts of the state, which is well adapted to large-scale wheat farming, appears to be one reason for this seeming paradox. A second reason for the dominance of wheat in these areas is probably the fact that many other crops that grow successfully in the east are not well adapted to central Kansas and are not adapted to most of western Kansas. While in the east a great number of crop and livestock combinations are available, the number of alternative farm enterprises decreases rapidly from east to west.[1]

The acreage of wheat harvested in Kansas has never equaled the acreage seeded. The highest per cent of abandonment was in 1917 when less than 40 per cent of the acreage seeded was harvested.[2]

Sample Design. The sample of 22 elevators used for the study was previously drawn for a cost survey in 1951. Additional data needed for fitting production functions to the sample were collected on a resurvey of these elevators in the spring of 1954.

The population consisted of elevators with a licensed storage capacity from 95,000 to 850,000 bushels and was located in the western two-thirds of Kansas.

Of a total of 1070 country elevators under consideration in this area 884 were less than 95,000 bushels in capacity. These were, in general, either old wooden structures or were too small to have any importance in a long-range storage program. Of the remaining 186 elevators that qualified

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[1]Leo M. Hoover and John H. McCoy, *op. cit.*

[2]*Ibid*, p. 9.

as to capacity and type of construction, 98 kept similar records, had been constructed during the 1942-51 period, and were willing to cooperate. This subpopulation of 98 was stratified into four size groups: 96,000 to 150,000; 200,000 to 265,000; 280,000 to 480,000; and 500,000 to 850,000 bushels of licensed storage capacity. From the subpopulation of 98 elevators a stratified random sample of 22 elevators was selected, with the number selected in each stratum proportional to the total number of elevators in the stratum.

The final sample of 22 was approximately 25 per cent of the elevators qualifying from the standpoint of type of construction, capacity, time of construction, and availability of records, and 11.8 per cent of the elevators qualifying as to capacity and type of construction.

Table 1 shows the sample distribution by size group and type of ownership. Plate II gives the geographical distribution of the sample which corresponds, roughly, to the heaviest producing hard red winter wheat area in Kansas.

Table 1. Distribution of the 22 sample elevators by size and type of ownership, Kansas, 1951.

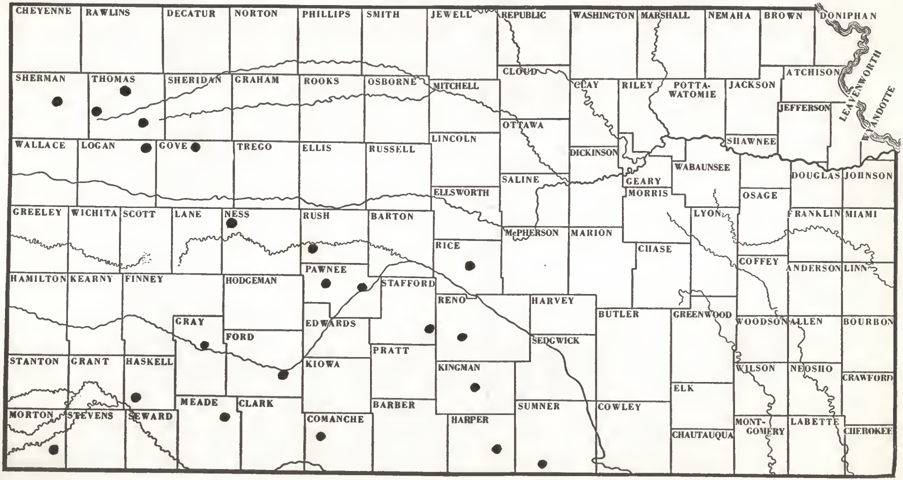
Size group, bushels	Number	Type of ownership		
		Cooperative	Private-single	Private-line
96 - 150,000	5	4	-	1
200 - 265,000	6	3	2	1
280 - 480,000	6	3	3	-
500 - 850,000	5	4	1	-
Total	22	14	6	2

Technological Considerations. Modern elevator storage construction in central and western Kansas, where the elevators of this study were located,

EXPLANATION OF PLATE II

Fig. 3. Geographical distribution of the 22 Kansas country elevators.

PLATE II


CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLOUD
CLAY
RILEY
POTTA-
WATOMIE
JACKSON
ATCHISON
LEAVENWORTH
JEFFERSON
WYANDOTTE
OTTAWA
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
LINCOLN
SHAWNEE
DICKINSON
WABAUNSEE
SALINE
GEARY
DOUGLAS
JOHNSON
MORRIS
ELLSWORTH
OSAGE
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
LYON
FRANKLIN
MIAMI
McPHERSON
MARION
RICE
CHASE
COFFEY
PAWNEE
ANDERSON
LINN
HAMILTON
KEARNY
FINNEY
HODGEMAN
STAFFORD
RENO
HARVEY
BUTLER
GRAY
EDWARDS
GREENWOOD
WOODSON
ALLEN
BOURBON
FORD
SEDGWICK
PRATT
STANTON
GRANT
HASKELL
KIOWA
KINGMAN
WILSON
NEOSHO
CRAWFORD
ELK
MEADE
CLARK
BARBER
SUMNER
COWLEY
MORTON
STEVENS
SEWARD
COMANCHE
HARPER
MONT-
GOMERY
LABETTE
CHEROKEE
CHAUTAUQUA

is predominantly of reinforced concrete, with a few units of upright steel construction of 80,000 to 100,000 bushels capacity. Although there still remain a number of wooden crib structures, they are fast losing in popularity. Few new structures of wooden construction are being built today. In a long-run wheat storage program overwhelming reliance would be on reinforced concrete structure.

Plant layout, equipment, and working methods were in general uniform in the 22 elevators. Over a period of years, any increase in efficiency and speed of grain handling can usually be attributed to changes in equipment rather than changes in building construction.

> Once the building is constructed the structure does not yield to major modifications over time. Minor changes and additions can be provided in the blueprints but, generally speaking, the building does not lend itself to modifications so as to permit changes in methods of grain handling. On the other hand, the installation of more modern elevator equipment is more common (because) equipment changes are not nearly as cost prohibitive as building changes.[1]

Collection and Processing of the Data. The data were collected by personal interview and inspection of office records. The primary source of the cost data was the annual audit.

Records were obtained from each elevator for the fiscal year which included the harvesting of the 1951 wheat crop. Calendar dates for which the data were obtained were not exactly the same for all elevators. However, since the price level of important cost items was comparatively stable during the period, significant differences in storage costs due to differences in time periods seemed improbable.

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[1]Kansas Agricultural Experiment Station, Country Elevator Study, Unpublished Report, 1953.

Costs were allocated between storage, grain merchandising, and sidelines functions performed by the 22 elevators.

Primary information for allocation was obtained by personal interview and examination of records. Elevator managers were asked to identify those items which were logically allocable to sidelines. Where sidelines costs were incurred jointly with costs allocable to other functions, elevator managers were asked to estimate the proportion of total for each item attributable to sidelines.

After allocation had been made to sidelines, the remainder of the costs, mostly of joint nature, was distributed between storage and grain merchandising. Proportional use made of equipment, building, and labor in performing each of the functions was the primary basis of allocation. Data for determination of proportional use were obtained from records of grain merchandised and stored, utilization of buildings and equipment, records of labor utilization, and managers' estimates.

Costs such as taxes and insurance on buildings and equipment were excluded from the functions. It was assumed that homogeneity in type of construction, period of construction, and plant layout and organization brought uniformity in investment in building and equipment on a volume basis.

Amounts paid for wages and salaries were obtained from payroll records. Labor utilization in various functions was estimated. Wages and salaries as well as electricity, maintenance, and repairs were allocated on the basis of proportional use.

Table 2 shows total observed cost and allocation by function for the 22 elevators.

Table 2. Total observed cost and allocation by function, 22 Kansas country elevators, 1951.

No. of elev.	Total cost	Sidelines	Storage	Grain merch.
1	$ 18,651.04	$ 10,673.87	$ 4,068.66	$ 3,908.51
2	8,667.82	2,628.78	3,558.62	2,480.42
3	8,739.67	2,694.07	3,347.81	2,697.79
4	21,845.92	9,847.61	5,938.25	6,060.06
5	45,512.38	29,978.91	9,208.72	6,324.75
6	19,851.77	—	8,662.17	11,189.60
7	14,730.92	—	7,565.51	7,165.41
8	15,407.13	2,864.24	6,011.27	6,531.62
9	21,507.18	7,599.35	7,558.37	6,349.46
10	22,750.96	4,417.14	9,882.61	8,451.21
11	17,311.89	3,840.79	8,963.73	4,507.37
12	18,846.36	—	15,292.09	3,554.27
13	47,497.95	27,264.63	14,209.28	6,024.04
14	27,248.57	11,284.75	11,011.68	4,952.14
15	21,774.47	1,594.25	12,152.47	8,027.75
16	123,758.10	99,835.42	16,005.27	7,917.41
17	41,904.48	11,621.51	14,480.48	15,802.49
18	45,119.35	6,978.73	27,079.02	11,061.60
19	70,975.19	50,627.59	12,899.17	7,448.43
20	84,546.39	50,231.53	23.289.57	11,025.29
21	36,911.33	10,966.19	20,870.67	5,074.47
22	51,115.92	15,731.08	23,395.12	11,989.72
Total	784,674.79	360,680.44	265,450.54	158,543.81

Classification of Input-Output Variables. Four functions were computed: one for each marketing service performed, and one aggregate plant function. The functions were (1) storage function, (2) grain merchandising function, (3) sidelines function, and (4) plant function.

Of the form $Y = aX_1^{b1}, X_2^{b2}, X_3^{b3}$, the functions included the following variables:

Dependent variable: Y = gross income in dollars

Independent variables: X_1 = labor services in dollars
X_2 = operating expenses in dollars
X_3 = capital services in dollars

The classification of these variables follows.

Total Function. Gross income (Y) consists of (1) the total value of goods and services sold and ending inventory less the total value of goods and services purchased and beginning inventory, and (2) other operating income; excluding income from items not normal to elevator operation such as patronage refunds, stock dividends, purchase discounts, and prorations. Detailed list of exclusions is given in Appendix A, Table 1.

Income was not in a strict sense a homogeneous variable, but was derived from different sources. Although practically all of the grain handled was wheat, small amounts of other grains were handled. For instance, grain sorghums became increasingly important in the Southwest. The different kinds of sideline merchandise handled included fuels, greases, feeds, seed, salt, machinery and parts etc. The special services provided by the elevators in the handling of wheat and sidelines included weighing, grinding, drying, cleaning and treating, t ruck hauling, rental of equipment, and seed testing. Petroleum facilities ranged from a small tank to a complete service station.

Labor services (X_1) include the salary of the manager and assistant manager, the wages paid to other employees, and directors' fees. The value used was arrived at by totaling the costs of labor services listed under sidelines, storage, and grain merchandising functions.

Managers of firms handling between 100,000 and 200,000 bushels of grain usually perform the multiple functions of manager, laborer, and office worker. Of course, the larger the volume of grain handled by a firm, the greater is the proportion of the manager's time spent on management functions and the less is he engaged in labor. Since management, office help, and elevator working force may thus substitute at constant rates for many of the labor requirements throughout the plant, labor services can be regarded as a reasonably homogeneous function.

Operating expenses (X_2) are the total cost of operating expenses listed under sidelines, storage, and grain merchandising functions. They include all the current operating expenses, except capital service charges and expenses such as taxes, insurance, bonds, interest paid, licenses, audit and tax service, legal expenses, corporation fees, documentary stamps, bad debts and other losses, and bank charges. The main items included under current operating expenses are office supplies common to elevator operation; and plant supplies such as fumigants, rodent controls, insecticides etc. Advertising, donations which are generally considered a form of local advertising in the grain elevator operation, and travel expense were also included.

Capital services (X_3) are the total value of capital services listed under the sidelines, storage, and grain merchandising functions; including depreciation reserve for buildings and equipment, electricity, scales test, rent, railroad lease, machine expense, truck expense, and maintenance and repairs.

No variable for current operating capital was included in the plant function. It was assumed that in a static function cash will not be required as the production processes begin and end in the period of the function.

Equal degrees of capital durability and intensity of capital use were assumed for all firms, and all units were assumed to have developed over time at similar rates, thus introducing similar levels of depreciation charge in the various elevators considered.

Sidelines Function. Y was computed from the audits and includes income from sidelines sales and sidelines services plus miscellaneous income from other sources than storage and grain merchandising, excluding items listed in Appendix A, Table 2.

Storage Function. Y was computed by taking the number of bushel months stored as a measure of capital use intensity, each bushel month providing an income of 1 cent from storage.

Grain Merchandising Function. Y was computed by subtracting storage income and sidelines income from total gross income.

Labor services, operating expenses, and capital services for each function equaled the dollar amounts previously allocated to them.

A detailed classification of cost items for each function is given in Appendix B.

Economic Organization of the Elevators

Statistics characterizing the economic organization of the 22 sample elevators are presented in Tables 3 through 8.

Arithmetic Sums are given in Table 3. The value of the total sidelines, storage, and grain merchandising product was $1,542,600. The greatest proportion of the total value product came from grain merchandising (22 observations), the next greatest from sidelines (19 observations), and the smallest from storage (22 observations). Inputs were greatest for sidelines and storage, in that order. The total value input was $784,700.

Minimum and Maximum Values. Output as well as inputs varied considerably depending on the size of business, proportion of grain to sidelines, types of commodities handled, and types of services performed.

Differences in the size of total product for all firms ranged from $8,600 to $277,200 (Table 4). The maximum product for sidelines was as much as

587 times larger than the minimum product. Sidelines function had both the widest product range and the widest inputs range. Storage had the smallest product range with maximum product 70 times larger than the minimum product. Grain merchandising had the smallest range of inputs.

Table 3. Sums of input-output variables, 22 Kansas country elevators, 1951.

Function	Number of elev.	Gross inc. ($)	Labor ($)	Op.exp. ($)	Capital ($)	Sum of inp.($)
Sidelines	19	544,400	249,600	33,300	77,800	360,700
Storage	22	363,900	114,900	22,400	128,200	265,500
Grain merch.	22	634,300	82,000	15,600	61,000	158,600
Total	22	1,542,600	446,500	71,300	266,900	784,700

Table 4. Minimum and maximum values of range of variables, 22 Kansas country elevators, 1951.

Function	Number of elev.	Min.or max. values	Gross inc. ($)	Labor ($)	Op.exp. ($)	Capital ($)
Sidelines	19	Min.	200	700	100	100
		Max.	117,500	70,900	9,700	19,200
Storage	22	Min.	1,800	700	200	1,800
		Max.	42,900	11,300	3,200	16,300
Grain merch.	22	Min.	600	700	100	500
		Max.	144,500	7,400	1,500	9,600
Total	22	Min.	8,600	3,800	300	4,000
		Max.	277,200	83,500	14,400	25,800

Arithmetic Means. The average value products in sidelines and grain merchandising, shown in Table 5, were $28,653 and $28,832 respectively, i.e. of approximately the same size. The average sum of inputs in sidelines, however, was more than twice the sum of inputs in grain merchandising.

Table 5. Arithmetic means of input-output variables, 22 Kansas country elevators, 1951.

Function	Number of elevators	Gross inc. ($)	Labor ($)	Op.exp. ($)	Capital ($)	Sum of inp.($)
Sidelines	19	28,653	13,137	1,753	4,095	18,985
Storage	22	16,541	5,223	1,018	5,827	12,068
Grain merch.	22	28,832	3,727	709	2,773	7,209
Total	22	70,118	20,295	3,241	12,132	35,668

To make an interfunction comparison, inputs of both labor services and operating expenses were highest in sidelines and smallest in grain merchandising, whereas storage function required the greatest capital input, and grain merchandising the smallest capital input.

On an intrafunction basis, labor was the major input in sidelines, capital next in importance, and operating expenses only approximately 13 per cent of labor inputs.

In the storage function capital service inputs exceeded labor inputs, while operating expenses were less than 10 per cent of capital service expenses.

In grain merchandising labor was the greatest value input, with capital services next in order. Operating expenses were approximately 20 per cent of labor expenses.

Labor cost was the largest single expense item accounting for almost two-thirds of all expenses combined.

Although the wide range in labor expenses observed seemed to be principally due to differences in volume of business, it could also be explained in part by differences in the utilization of labor and in part by the proportion of sideline sales to total sales.

Labor cost to handle a carload of grain is much less than that required to handle small unit sideline sales of comparable value. Likewise, labor cost for such sideline services as grinding and mixing is relatively high compared to grain and merchandise handling.

Residua of Value Added in Manufacture Over Resource Costs. The residuum of the arithmetic mean of value added in manufacture (gross income) over the arithmetic mean of all productive resource services in the total plant function was $34,450. As can be seen in Table 6, the greatest value surplus was realized from grain merchandising, the second greatest from sideline sales, and the smallest from storage.

Table 6. Residuum of arithmetic mean of value added in manufacture over arithmetic mean of all productive resource services, 22 Kansas country elevators, 1951.

Function	Number of elevators	Residuum ($)
Sidelines	19	9,668
Storage	22	4,473
Grain merchandising	22	21,623
Total	22	34,450

Differences between value of output and value of resource inputs were considerable in all three lines. The residuum was almost 300 per cent of the value of resource services used in grain merchandising, almost 60 per cent of the value of resources used in sidelines and more than 37 per cent of the value of resources used in storage.

These residua can be looked upon as gross profits for each function above the cost of productive resource services.

Proportion of Total Productive Inputs by Category of Input. Relative inputs of different categories of resource services are shown in Table 7.

Table 7. Proportion of total productive inputs by category of input, 22 Kansas country elevators, 1951.[a]

Function	Number of elevators	Percentage of total value input		
		Labor	Op. exp.	Capital
Sidelines	19	69.2	9.2	21.6
Storage	22	43.3	8.4	48.3
Grain merch.	22	51.7	9.8	38.5
Total	22	56.9	9.1	34.0

[a]Based on arithmetic means.

Operating expenses represented less than 10 per cent of the total inputs in each of the four functions, labor inputs varied from 43.3 per cent for storage to 69.2 per cent for sidelines. Capital services varied from 21.6 per cent for sidelines to 48.3 per cent for storage.

This does not necessarily mean that the productivity of a resource is always proportional to its input value or that the productivity is constant irrespective of the amount of resources used.

Capital-Labor Service Ratios. Differences in labor-capital ratios, given in Table 8, again pointed to the different resource combinations required in each function.

Storage was the only function where the capital-labor ratio was greater than one; an average capital input of $1.12 accompanied a labor input of $1.

In sideline sales, $1 of labor was accompanied by a capital input of only 31 cents.

Table 8. Capital-labor service ratios, 22 Kansas country elevators, 1951.

Function	Number of elevators	Arithmetic ratio*
Sidelines	19	.31
Storage	22	1.12
Grain merch.	22	.74
Total	22	.60

*Based on arithmetic means of variables.

Analytical Procedures

Regression Equations. Simple scatter diagrams were drawn to ascertain whether the relationships between the Y and the X's were essentially linear in the logarithms. Cobb-Douglas production functions which are linear in the logarithms of observations were then fitted to the data.

These functions have the form $Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}$. The dependent variable Y refers to the value of output and the independent variables (the X's) refer to the value of resource inputs used.

The b's or the regression coefficients represent the elasticities of production for the respective resource categories, indicating the percentage increase in product for each 1 per cent increase in the input of the resource in question when other inputs are constant; the a is a constant in the function.

The following equations were estimated by least-squares multiple regression analysis.*

Sidelines: $Y = .4690 \; X_1^{1.1469} X_2^{.0725} X_3^{.1185}$

Storage: $Y = 1.3253 \; X_1^{.3699} X_2^{.3414} X_3^{.6166}$

Grain merchandising: $Y = 30.2560 \; X_1^{.4409} X_2^{.0924} X_3^{.0157}$

Total: $Y = 3.0518 \; X_1^{.8791} X_2^{-.1397} X_3^{.2463}$

These four equations provided the basis for marginal-productivity, rate-of-substitution, and returns-to-scale estimates.

Elasticity coefficients for the data along with associated statistics of analytical interest are presented in Table 9. The elasticities have the following interpretation. In the case of sidelines labor, an increase of 1 per cent would, under the assumption of no changes in the other relationships, increase the total product on the average 1.1469 per cent. Other inputs could be at any level within the range of the data.

The standard errors of the elasticities are shown in Table 9. The calculated t-values were significant at the 5 per cent level in three cases: (1) sidelines — labor, (2) storage — capital services, (3) total — labor. Of these three t-values, sidelines labor was significant at the 1 per cent level and labor services and operating expenses in storage were significant at the 20 per cent level. No other t-values were significant at an acceptable level.

The regression coefficient for operating expenses of the total function and consequently also the marginal productivity were negative. Since the

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*Y = value of output, X_1 = labor services, X_2 = operating expenses, X_3 = capital services.

Table 9. Regression coefficients and associated statistics. Levels of significance for regression coefficients and multiple correlation coefficient R, 22 Kansas country elevators, 1951.[a]

Type of statistic	Sidelines	Storage	Gr. merch.	Total
Value of a, log form	- .3288	.1223	1.4808	.4845
Value of a, arithmetic form	.4690	1.3253	30.2560	3.0516
Values of b (elasticities)				
Labor services	1.1469	.3699	.4409	.8791
Operating expenses	.0725	.3414	.0924	- .1397
Capital services	.1185	.6166	.0157	.2463
Standard errors of elasticities				
Labor services	.3399	.2710	.6660	.3194
Operating expenses	.2907	.2165	.4992	.3035
Capital services	.3376	.2429	.4884	.3629
Sums of elasticities	1.3379	1.3279	.5490	.9857
Calculated t-values				
Labor services	3.375**	1.365'	.662	2.752*
Operating expenses	.244	1.577'	.185	- .460
Capital services	.351	2.538*	.032	.672
R, Multiple correlation coefficient	.890**	.869**	.231	.829**

[a]The data were coded in hundreds of dollars.

**Significant at the 1% level, *significant at the 5% level, 'significant at the 20% level.

negative value of the regression coefficient was, however, nonsignificant according to the t-test, there is no evidence to suggest that the actual productivity differed from zero.

A negative marginal product does not require the application of economic choice criteria; it indicates that production is in an irrational stage, and that the total product can be increased by not using the resources which have negative marginal productivity. Resources are used inefficiently because a greater value product would be forthcoming with the same or smaller outlay.

However, a negative marginal product in a short-run function does not necessarily indicate negative productivity in the long run. It may well be possible that in the particular year the study was made the sample elevators made larger than average purchases of, for instance, plant supplies. In such a case, total operating expenses may give a positive marginal productivity estimate next year when few purchases will be made, and the negative marginal product will then be balanced by a positive marginal product.

R, the Multiple Correlation Coefficient. The multiple correlation coefficients presented in Table 9 were significant at the 1 per cent level for the sidelines, storage, and total functions, indicating that the relationships between the mean product and the mean inputs were larger than due to chance variation.

The multiple correlation coefficient for the grain merchandising function was not significant, indicating that the gross product was not related to the combined action of the inputs as measured.

Returns to Scale. The sums of the elasticities for labor services, operating expenses, and capital services, shown in Table 9, yielded the nature of returns to scale by indicating the percentage increase in the total value of product when all factors were increased by 1 per cent.

Consequently, $b_1 + b_2 + b_3 = 1$ signifies constant returns to scale, $b_1 + b_2 + b_3$ 1 increasing returns to scale, and $b_1 + b_2 + b_3$ 1 diminishing returns to scale.

While the sums of the exponents for the sidelines and storage functions (1.3379 and 1.3279) indicated increasing returns to scale and the sum of the exponents for grain merchandizing decreasing returns to scale (.5490), the sum of exponents for the total function turned out to be .9857, indicating by its proximity to unity constant or almost constant returns to scale.

Tintner's test for the hypothesis of constant returns to scale was used to find out whether the sums of the exponents differed significantly from unity, i.e. whether the production function was or was not a linear homogeneous function of the first degree.

A new regression function was fitted under the assumption that the sums of the elasticities or the regression coefficients were equal to 1.

The error sums of squares of the residua for both fits were then compared and the null hypothesis tested at the 1 per cent significance level. The results have been tabulated in Table 10.

The F-values for the sideline and storage functions were significant at the 1 per cent level; hence the hypothesis of constant returns to scale was rejected in both cases.

The F-value for grain merchandising function was not significant at an acceptable level; hence the hypothesis of constant returns to scale was not rejected.

The F-value for the total function was rounded off to zero, indicating constant returns to scale.

Table 10. F-values for testing returns to scale, 22 Kansas country elevators, 1951.

Function	Number of elevators	F-values
Sidelines	19	3.54**
Storage	22	48.18**
Grain merchandising	22	.57
Total	22	0

**Significant at the 1% level.

Analysis of Variance. The following analysis of variance was computed for the three fixed variates of the sidelines, storage, and total functions.

Table 11. Analysis of variance, 22 Kansas country elevators, 1951.

Function and source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
SIDELINES				
Regression	3	8.4547	2.8182	19.0763**
Due to X_1 only	1	8.4072	8.4072	56.9076**
Due to X_2 and X_3, adj.for X_1	2	0.0475	0.0237	NS
Error	15	2.2160	0.1477	
STORAGE				
Regression	3	2.4132	0.8044	18.4647**
Due to X_1 only	1	2.0169	2.0169	46.2987**
Due to X_2 and X_3, adj.for X_1	2	0.3962	0.1981	4.5476
Error	18	0.7841	0.0436	
TOTAL				
Regression	3	2.0379	0.6791	13.2348**
Due to X_1 only	1	2.0113	2.0113	39.1965**
Due to X_2 and X_3, adj.for X_1	2	0.0261	0.0130	NS
Error	18	0.9236	0.0513	

*Significant at the 5% level; **significant at the 1% level.

Since the F-ratios derived for testing the significance of the regression equation did not reveal how much was contributed by each of the fixed variates, the general regression was broken down into two of its components to see whether the net contribution of any of the X's was significant.

The following conclusions were derived from the analysis of variance:

1. The over-all reduction due to the use of the regression equation was significant at the 1 per cent level in the sidelines, storage, and total functions.

2. The reduction due to X_1 only (labor services) was highly significant in all three functions.

3. The added reduction due to X_2 and X_3 adjusted for X_1 (operating expenses and capital services adjusted for labor services) was nonsignificant as far as the sidelines and total functions were concerned, but was significant at the 5 per cent level for the storage function.

The above conclusions coincided with the estimations based on the significance of t-values for regression coefficients.

Geometric Means. Geometric means, computed when solving for regression coefficients, were used in calculating the marginal productivity estimates. Since means enter into marginal productivity estimates together with regression coefficients and their standard errors, and since the two latter values had been computed from logarithmic equations, it was feasible to use logarithmically computed geometric rather than simple arithmetic means. The geometric means are presented in Table 12.

Marginal Products and Tests of Significance. To estimate the marginal productivities of resources, geometric means of product and resource values and predicted elasticities (regression coefficients) were used.

Table 12. Geometric means of input-output variables, 22 Kansas country elevators, 1951.

Function	Number of elevators	Total inc. ($)	Labor ($)	Op.exp. ($)	Capital ($)
Sidelines	19	9,678	6,605	847	2,243
Storage	22	11,892	4,344	812	4,799
Grain merch.	22	17,570	3,300	621	2,228
Total	22	49,761	14,808	2,330	10,252

Given resources X_1, X_2, and X_3, the marginal productivity of X_1, for instance, was estimated as a derivative in the following manner:

$$MP_{X_1} = \frac{\partial Y}{\partial X_1} = b_1 \frac{Y}{X_1}$$

The marginal productivities thus derived are shown in Table 13. They represent the added return that might be expected from the addition of another dollar of investment in the resource being considered. The marginal products may be interpreted as follows. If conditions in the population of country elevators are, on the average, the same as in the 22 elevators sampled in 1951, then, _cet. par._, the addition of one dollar's worth of a specific factor will increase the product by the following amounts in dollars (see Table 13 on next page).

All these results should be interpreted in the light of the statistical variability of the elasticities as described by their approximate standard errors and evident in their t-values.

Since the calculated t-values were significant at the 5 per cent level for labor in the sidelines function, capital in the storage function, and labor in the total function, and at the 20 per cent level for labor and

Table 13. Marginal products for resource variables, 22 Kansas country elevators, 1951.

Function	Number of elevators	Labor ($)	Oper. exp. ($)	Capital ($)
Sidelines	19	1.68**	.83	.51
Storage	22	1.01'	5.00'	1.53*
Grain merch.	22	2.35	2.61	.12
Total	22	2.95*	- 2.98	1.20

**Significant at the 1% level, *significant at the 5% level, 'significant at the 20% level.

operating expenses in the storage function, the elasticities of production and hence the marginal productivities for these functions can be determined with some accuracy.

For mean resource combinations, labor had the greatest predicted productivity in both sidelines and total functions when compared with other resources. The value of the marginal product for labor in the total function was as high as $2.95.

As for storage, the added input of one dollar's worth of labor increased the value of the product by approximately $1.01. Capital services had a marginal productivity of $1.53 and operating expenses yielded a marginal return as high as $5. However, the elasticity coefficient for storage operating expenses was significant only at the 20 per cent level.

Labor and capital productivities for the four functions were, by and large, as expected upon examination of the capital-labor ratios in Table 8 and resource quantities employed in Table 3.

A re-examination of Table 8 helps to clarify some of the reasons for differences in marginal productivities. Storage had a high capital-labor ratio in comparison with other functions which all had relatively low ratios. It also had a relatively high capital productivity. The lowest capital-labor ratio (or the highest labor-capital ratio) was computed for sidelines, which function also had a high labor productivity.

The marginal productivities estimated should not be strictly interpreted to indicate the returns which might be earned in any individual elevators of the type outlined above, were they to use more of the resources with estimated high marginal returns. The predictions are based on average statistics; consequently, they suggest only "average" resource productivities.

Tests of Interfunction Differences in Marginal Productivities. To find out whether the marginal productivities were significantly different from function to function, elasticity coefficients necessary to give marginal productivity in one line equal to that in another line were computed, and differences between the actual productivities and the new values compared in terms of the standard errors of the elasticity coefficients.

The new coefficients were calculated according to Heady and Shaw.[1]

The marginal product, based on mean product and mean input of the resource in question, say labor, had previously been estimated by the equation: $MP_{X_i} = \frac{\partial Y}{\partial X_i} = b_i \frac{Y}{X_i}$. To compare the elasticity b_1 of labor X_1, estimated for function a, with b'_1, the elasticity necessary to give the marginal product of function c when X_1 and Y are those of function a, the following equations were used:

$$(1) \quad \frac{Y_a}{X_{1_a}} = \frac{Y_c}{X_{1_c}} = \frac{b'_{1_a} Y_a}{X_{1_a}} = \frac{b_{1_c} Y_c}{X_{1_c}}$$

[1]Heady and Shaw, op. cit. p. 251.

$$(2) \quad b'_{1_a} = b_{1_c} \frac{Y_c X_{1_a}}{X_{1_c} Y_a}$$

The b'_i-s or "the elasticity coefficients necessary to give a marginal product in the group of comparison equal to the value (considered as a constant) computed as the marginal product in the group of contrast" are presented in Table 14.

Table 14. Comparison of differences in marginal productivities of resources by functions performed. Elasticity coefficients necessary to give marginal productivity in one function equal to marginal productivity in another function, 22 Kansas country elevators, 1951.

Resource and function against which test is made	Function for which test is made		
	Sidelines	Storage	Grain merch.
Labor services			
Sidelines	——	.6139	.3156
Storage	.6911	——	.1902
Grain merch.	1.6920	.8575	——
Operating expenses			
Sidelines	——	.0565	.0293
Storage	.4375	——	.1767
Grain merch.	.2288	.1785	——
Capital services			
Sidelines	——	.2064	.0648
Storage	.3541	——	.1938
Grain merch.	.0287	.0499	——

The t-values were then computed as follows:

$$t = \frac{b_{1_a} - b'_{1_a}}{\sqrt{s^2 b_{1_a} + \left(\frac{Y_c X_{1_a}}{X_{1_c} Y_a}\right)^2 s^2 b_{1_c}}}$$

None of the t-values presented in Table 15 were significant at an acceptable level.*

*The assumption is made that labor services used in the various elevator activities are independent.

Table 15. Values of t for comparison of differences in resource productivities by functions performed, 22 Kansas country elevators, 1951.

Resource and function against which test is made	Function for which test is made: Sidelines	Storage	Grain merch.
Labor services			
Sidelines	----	-.7474	+.1862
Storage	+.7474	----	+.3684
Grain merch.	-.1862	-.3684	----
Operating expenses			
Sidelines	----	+.9083	+.1232
Storage	-.9083	----	-.1647
Grain merch.	-.1232	+.1647	----
Capital services			
Sidelines	----	+.6450	-.0942
Storage	-.6450	----	-.3603
Grain merch.	+.0942	+.3603	----

To follow an example, an elasticity of .6139 for storage labor would have been necessary to give a marginal product of \$1.68, the sidelines labor average, in storage (as compared to the actual mean labor productivity in storage, \$1.01). In comparing the .6139 elasticity against the actual elasticity of .3699 a t-value of .7474 was obtained, which was not significant at an acceptable probability level.

These nonsignificant results were more or less anticipated in the light of the relatively large standard errors of the elasticity coefficients, which could have been due to the smallness of the sample. It is conceivable that a larger sample than the one used for this study would have resulted in significant interfunction differences in marginal productivities.

<u>Efficiency of Factor Pricing</u>. The next step in marginal analysis was to determine the extent to which the marginal productivities of capital and operating expenses approached factor prices, i.e. the extent of general

equilibrium or disequilibrium. This was done to investigate the need for eventual adjustments in the direction of the flow of these resources. For instance, if capital productivity were less or in excess of the cost of capital by a significant difference, a reason would have been provided for adjustments in the capital market.

To make the comparison, a hypothesis of $b_1 \frac{Y}{X_1} = K$ was set up, where $b_1 \frac{Y}{X_1}$ was the marginal productivity of capital (or operating expenses) and K was a constant or the value necessary to equal a one-dollar service input of capital services or operating expenses plus the interest cost of that one dollar.

The t-test used to test the difference between K and $b_1 \frac{Y}{X_1}$ was

$$t = \frac{b_1 \frac{Y}{X_1} - K}{\sqrt{s^2_{b_1} \left(\frac{Y}{X_1}\right)^2}}$$

The interest rate included in the value of K was computed from the interest rates charged by the Wichita Bank for Cooperatives for operating capital loans (3%) and facility loans (4%). These rates were considered as typical of interest charges to elevator businesses for the period.

The proportion of capital services made up of depreciation and repairs was assumed to come from the service flow of fixed assets with the interest rate of 4 per cent. The balance was assumed to be due to items for which an interest rate of 3 per cent was thought to be more appropriate. The weighted average interest rate for capital services was 3.08 per cent, which was rounded off to 3 per cent for the purposes of this study.

The t-tests of significance for differences between marginal products and factor prices provided no evidence to reject the hypothesis that the productivities of capital services or operating expenses equaled the cost of capital. The t-values, all of them nonsignificant, are presented in Table 16.

Table 16. Values of t and levels of significance for tests of difference between capital service productivity and capital cost, 22 Kansas country elevators, 1951.

Function	Number of elevators	t-values
Sidelines	19	-.3570 NS
Storage	22	.8306 NS
Grain merch.	22	.2363 NS
Total	22	.0965 NS

As in the analysis of interfunction differences it is possible that a larger sample would have yielded significant differences between marginal productivities and factor prices.

<u>Effects of Variations in Operating Expenses and Capital Services on Labor Productivity</u>. Since labor services accounted for almost two-thirds of all the service inputs in the elevators, possible intrafirm adjustments which increase the efficiency of labor in elevators would be beneficial to elevator businesses as well as to labor and society.

As a first step in determining the marginal productivity of labor with various quantities of capital and operating expenses held fixed at specified levels, maximum and minimum values of the range of variables as percentages of their mean values were computed. These values are presented in Table 17.

On the examination of Table 17 and the list of original observations it became apparent that the wide ranges evident in the table were due to a few extreme observations.

Table 17. Maximum and minimum values of range of variables as percentages of their mean values, 22 Kansas country elevators, 1951.

Function	Number of elevators	Min.or max.	Per cent of mean			
			Total	Labor	Op.exp.	Capit.
Sidelines	19	Min.	2.1	10.6	11.8	4.5
		Max.	1,214.1	1,073.4	1,145.2	856.0
Storage	22	Min.	15.1	16.1	24.6	37.5
		Max.	360.7	260.1	394.1	339.7
Grain merch.	22	Min.	3.4	21.2	16.1	22.4
		Max.	822.4	224.2	241.5	430.9
Total	22	Min.	17.3	25.7	12.9	39.0
		Max.	557.1	563.9	618.0	251.7

For this reason, values of the three resource categories were computed at the specified levels of 50, 100, 150, and 200 per cent of their means, which levels were assumed to be more typical and to provide more vital estimates than the near-extreme levels.

The values of the three input categories at specified levels are tabulated in Table 18.

Predicted marginal productivities of labor for specified levels were obtained from the logarithmic regression equations by substituting the values at different levels of input for geometric mean values; then solving for the Y's (or predicted gross income) from which the marginal products of labor were finally computed.

The estimates obtained are presented in Table 19. They provide some notion of the way in which different resource ratios affect labor productivity in the four functions. All proportions in the table fall within the range of observations actually found in the sample.

In sidelines, labor productivity was found to increase as more labor service was added; in the storage, grain merchandising, and total functions, labor productivity decreased as more labor service was added.

Table 18. Values of resource inputs for specified levels, 22 Kansas country elevators, 1951.

Resource and function	Number of elevators	Per cent of mean			
		50	100	150	200
Labor services					
Sidelines	19	$3,302	$6,605	$9,908	$13,210
Storage	22	2,172	4,344	6,516	8,688
Grain merch.	22	1,650	3,300	4,950	6,600
Total	22	7,404	14,808	2,212	29,616
Operating expenses					
Sidelines	19	424	847	1,271	1,694
Storage	22	406	812	1,218	1,624
Grain merch.	22	310	621	931	1,242
Total	22	1,165	2,330	3,495	4,660
Capital services					
Sidelines	19	1,121	2,243	3,364	4,486
Storage	22	2,399	4,799	7,198	9,598
Grain merch.	22	1,114	2,228	3,342	4,456
Total	22	5,126	10,252	15,378	20,504

The addition of capital services and operating expenses caused the greatest absolute increase in labor productivity in storage, and the least absolute increase in labor productivity in grain merchandising.

The addition of another dollar of labor to sidelines with labor, operating-expense, and capital inputs at 200 per cent of their means is expected to add $2.124 to the total product; the same amount of labor added to storage with labor, operating-expense, and capital-service inputs at 200 per cent of the mean is expected to add $1.271 to the total product.

Predicted marginal products for specified levels are useful not only for "between"-function estimates but also for labor productivity estimates in a single function.

Given an elevator which is operating with sideline-labor inputs at the mean ($6,605) and capital and operating-expense inputs at 50 per cent of the mean (or $1,545 from Table 18), the doubling of capital-service and operating-expense inputs (i.e. increasing them by $1,545) is expected to increase labor productivity by $.208 and increasing them by yet another 50 per cent, by $.136.

Table 19. Predicted marginal productivities of labor services with operating expenses and capital services at specified levels, 22 Kansas country elevators, 1951.

Function and labor inputs in dollars	Dollar values of marginal productivity of labor with operating expenses and capital services at			
	50% of mean	100% of mean	150% of mean	200% of mean
Sidelines				
3,302	1.329	1.518	1.640	1.733
6,605	1.472	1.680	1.816	1.918
9,908	1.563	1.784	1.927	2.036
13,210	1.630	1.860	2.010	2.124
Storage				
2,172	.807	1.568	2.312	3.045
4,344	.521	1.013	1.494	1.968
6,516	.404	.785	1.157	1.524
8,688	.337	.654	.965	1.271
Grain merch.				
1,650	3.208	3.458	3.613	3.727
3,300	2,178	2.347	2.452	2.530
4,950	1.736	1.871	1.955	2.017
6,600	1.478	1.593	1.664	1.717
Total				
7,404	2.984	3.213	3.555	3.459
14,808	2.744	2.954	3.085	3.181
22,212	2.621	2.813	2.937	2.029
29,616	2,500	2.717	2,837	2.925

Starting with a sideline-labor input of $3,302 (50 per cent of the mean) and a combined operating-expense and capital-service input of 50 per cent of the mean, an increase in capital services and operating expenses from 50 to 200 per cent of the mean is expected to increase the marginal product of labor by \$.404.

An increase of 50 to 200 per cent in the operating expenses and capital services of the total function would increase labor productivity by \$.475 when labor is at 50 per cent of the mean, and an increase of 50 to 200 per cent in the capital services and operating expenses of the storage function is expected to increase labor productivity by \$2.238, when labor is at 50 per cent of the mean.

On the other hand, if labor inputs in each function were to be increased by 50 to 200 per cent of the mean, with capital services and operating expenses held at their mean values, labor productivity would advance by \$.342 in sidelines and decline by \$.914 in storage, by \$1.865 in grain merchandising, and by \$.496 in the total function.

The estimates discussed here are subject to the same limitations as the estimates discussed before in regard to the significance of the elasticity coefficients.

Labor-Capital Substitution Ratios. These ratios were derived from the production functions fitted to each set of data. Values of a and b were constants for each function. X_2 and Y were held constant at their respective means.

The following working formula was derived from the Cobb-Douglas function:

$$\log X_3 = \frac{\log Y - \log a - b_2 \log X_2 - b_1 \log X_1}{b_3}$$

Values of X_3 were then computed as functions of four arbitrarily selected X_1-values around the mean.

Although the various levels of resource inputs assumed represented only a very rough and limited range of possible inputs, sufficient evidence was obtained that, on the average, more efficient combinations of labor and capital than those actually used in the three functions analyzed would have been possible (Table 20).

Table 20. Selected levels of labor- and capital-service inputs, 22 Kansas country elevators, 1951.

Function	Inputs of services in dollars				Total inputs of labor and capital in dollars
	Labor		Capital		
Sidelines	5,000		33,188		38,188
	6,000		5,686		11,686
	6,605	mean	2,243	input	8,848
	7,000	least-cost	1,280	"	8,280
	8,000		351		8,351
Storage	2,000		7,640		9,640
	3,000	least-cost	5,991	input	8,991
	4,000		5,041		9,041
	4,344	mean	4,799	"	9,143
	5,000		4,409		9,409
Total	10,000		41,624		51,624
	14,808	mean	10,252	input	25,060
	20,000	least-cost	3,507	"	23,507
	30,000		825		30,825
	40,000		295		40,295

By increasing labor inputs and decreasing capital inputs the same level of output could be attained with less cost in both sidelines and total functions. By increasing capital inputs and decreasing labor inputs, the least-cost combination could be attained in the storage function.

DISCUSSION

In the following discussion, production and resource efficiencies will be analyzed under the assumption that the distribution of income and the basic organization of industry and primary production is given. The estimates arrived at in the equilibrium analysis have to be regarded as only rough indicators of how to improve production efficiency. A perfect equilibrium is a condition practically unattainable in the agricultural marketing industry.

Although the pricing system is supposed to take care of resource allocation and rationing in an efficient manner, the movement of productive factors into fields of greatest comparative advantage does not always take place because of the immobility of resources, the cost of transferring them, imperfect knowledge, risk and uncertainty, inflexible human abilities, and social restrictions.

Fluctuating climatic conditions make the primary production process variable and introduce technical risk and uncertainty. Acquisition and loss of foreign as well as domestic markets for wheat coupled with high-level wheat production complicate the adjustment. Finally, changing governmental policies concerning price support and acreage reduction programs bring added complications.

Surplus of wheat, one of the main dilemmas of American agriculture, probably indicates a far from frictionless pricing mechanism and misallocation of primary resources. Since farm productivity studies conducted by Tintner, Heady, and others have indicated low marginal returns for labor in the Great Plains area, it seems logical that a transfer of this resource from primary production to secondary production may help to solve the dilemma, provided that labor has a higher marginal productivity in the industry function. But would this transfer be profitable in the long run?

The after-World War II boom in the elevator business seems to be a result of the accumulating wheat surplus mainly caused by declining markets for wheat, encouraged by favorable federal income tax regulations and the Commodity Credit Corporation's guaranteed occupancy plan. Since the agricultural policy recently has tended to discourage wheat production by reductions in wheat acreage, this boom may reverse itself. In view of the impending crisis, the question of excessive investment in resources has caused much concern among farmer-owners, processors, and bankers, the more because alternative uses of fixed elevator facilities for other than grain storage purposes are practically nonexistent.

Customers of the country elevator, the grain-growing farmers, are primarily interested in the kind, quality, and cost of service it renders. Their interest as probable stockholders — the investor's viewpoint — is secondary to the patron's viewpoint. If it were not so, how could one explain the growth of cooperative elevators in the first place? The very incentive behind the development of the cooperative movement in Kansas was the desire on the part of the farmers to get full market price for their grain and to purchase supplies of acceptable quality at reasonable cost. The ability of the cooperative elevator to perform these functions at the lowest possible unit cost provides one criterion of its efficiency.

Since both cooperative and private country elevators are in daily competition, neither can get far out of line in quality of service rendered or in the cost of giving that service without losing patronage. It is apparent, therefore, that those able to show a net income at the end of their business year demonstrate their ability to meet competition, to cover operating expenses, and to safeguard the investment of their stockholders, regardless of the form of organization.

The same criteria are valid in a comparison of single- and multiple-unit elevators. That the type of business seems to have little effect on the cost of doing business, was pointed out by Larson and Whitney in a study conducted by the Oklahoma Agricultural Experiment Station in 1954.[1]

In an Illinois Agricultural Experiment Station study in 1941 Norton[2] noticed a tendency on the part of privately owned elevators to engage in grain merchandising and hedging more extensively than was the case with cooperative elevators*. A similar trend seems to be true of the elevators in this study. Management decisions as to emphasis placed on grain merchandising may also be related to the government grain storage program and the ability to acquire capital.

That labor accounted for more than half of the inputs in grain merchandising in this study is logical because labor includes manager's salary. Ultimately, it is the entrepreneurial capability of the manager that

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[1] A.L. Larson and H.S. Whitney, Relative Efficiencies of Single-Unit and Multiple-Unit Cooperative Elevator Organizations. Oklahoma Agricultural Experiment Station's Bulletin 426, June 1954.

[2] L.J. Norton, Business Policies of Country Grain Elevators. Illinois Agricultural Experiment Station's Bulletin 477, 1941, p. 283.

*He brought out three probable reasons to explain this trend:

1. Farmers' elevators have emphasized lower margins and higher volume on grain trade and many have built up an adequate volume of business for successful operations merely buying and shipping.

2. Private grain dealers are as a rule more familiar with hedging techniques than many managers of farmers' elevators are.

3. Boards of directors and managers of many farmers' elevators are prejudiced against trade practices involving future trading.

determines the successfulness of grain merchandising activities.

The scale of the firm or the size of the investment had apparently nothing to do with the profitability of merchandising activities. The rather high marginal productivities estimated for labor and operating expenses were statistically nonsignificant and cannot therefore be taken as conclusive to higher relative inputs. There is some indication that relatively too much of capital services was used in this function.

The predicted marginal returns to labor had a tendency to decline as more labor services were added. Although labor productivity seemed to advance with the addition of capital services and operating expenses, the increases tended to be smaller than productivity increases in storage and sidelines, and were statistically nonsignificant.

The storage function indicated the profitability of expansion. This is to be expected. As the plant expands its storage facilities, bushel costs decline and earnings increase together with grain volume. The overhead costs of an elevator are influenced by the extent to which its facilities are being utilized. Depreciation, repairs, taxes, and insurance on the buildings and equipment keep accumulating from day to day through the year regardless of whether a single bushel of wheat is handled. If these costs are distributed over a large business volume, the unit cost is low, if not, these costs are high.

Although there is some reason to believe that marginal returns to operating expenses and capital in storage are high (estimated as $5.00 and $1.53 in this study), additional expansion might be unwise in face of the recent government reductions in acreage and uncertainty as far as the continuing wheat surplus is concerned. The day might come when there is no need for the government to store the surplus wheat. Excessive idle capital in buildings, equipment, and inventory is costly and might then prove financially disastrous.

Besides government storage, a complicating factor, grain volume is limited by 1) size of territory, 2) importance of grain production and sales in the territory,* 3) proportion of total grain produced that it can attract, and 5) width of margin on grain. These are the factors that ultimately set the limit for expansion of storage facilities. Thus, an elevator located in an area where soils are poor and grain volume low must keep its costs down and try to build up business in some other way.

Competition for grain may be based on loyalty to a particular company, on service, or on price. Loyalty is no doubt a factor in maintaining business. A cooperative elevator which regularly returns surplus earnings or a private dealer who is able to make and keep friends can count on the farmers' goodwill. However, prices charged and services rendered are probably more valid bases for comparison, particularly at times when new methods or new firms come into the picture.

Sales of neither storage services nor merchandise can be expanded too much, and since competitive price leadership does not seem to be popular even with large companies, the best policy seems to be to take as wide margins as possible without losing revenue.

In view of the above, the foremost goal of the average elevator would appear to be a more efficient use of its present storage resources rather than headlong expansion, and this can be brought about through equating the

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*Ultimately determined by the climate, soil, and topography of the area.

marginal productivities of resources.

The average proportions of total productive inputs for storage in the 22 elevators were: labor — 43.3 per cent, operating expenses — 8.4 per cent, and capital services — 48.3 per cent. The respective marginal productivities were $1.01, $5.00, and $1.53. In order to be at absolute optimum, the "net values" of marginal productivities would have to be zero, so that every dollar invested yielded a dollar in return. This would be so under the ideal conditions of competitive equilibrium, with output measured by gross receipts and inputs as a flow of resources and not the stock of resources from which the flow is derived. It would then be impossible to increase net elevator income in the short-run sense.

The estimated net marginal product of labor, 1¢, thus indicates an economically efficient use of the resource in performing various handling-storing operations. The mechanical advantage and layout of the elevator for receiving and loading out grain is probably an important factor in bringing about efficient use of storage labor in these modern elevators, also the relative homogeneity in grain varieties.

The high marginal returns to operating expenses and capital services would seem to indicate the profitability of an increase in operating expenses and capital services if the prices of all inputs and the output remain the same or increase or decrease in the same proportion.

A greater input of operating expenses would mean a greater investment in supplies (plant, store, and office supplies), postage, rodent control, advertising and donations, hauling, telephone and telegraph etc.

The input of operating expenses was measured at the actual cost of these expenses. Many separate items are included in this category, which makes economic interpretation difficult. It is impossible to say which factor or in what proportion they should be increased, for the effect each factor has on total output is not known. There is only the indication that a more efficient use of these resources could be brought about.

In previous elevator studies no definite correlation has been established between volume of sales and advertising expenses. It is conceivable that certain particular methods of advertising, or donations, might prove profitable.

Efficient communication and transportation media are without doubt a service to the community, particularly at peak seasons, and would probably attract additional grain volume.

Since the $4.00 net return to operating expenses was significantly different from a zero return at a probability level as low as 20 per cent, moderation should be employed when expending.

The net marginal return to capital was $.53 at the more reliable 5 per cent level, indicating the profitability of further investment in buildings or equipment. A least-cost ratio of labor and capital could be attained by increasing capital and decreasing labor inputs relative to mean inputs of these resources. However, in face of the market outlook, expansion cannot be recommended.

The addition of capital services and operating expenses caused a greater increase of labor productivity in storage than in either sidelines or grain merchandising. A doubling of the inputs of these resources almost doubled labor productivity. Again, these estimates have to be regarded with reservation in view of recent acreage reductions.

Moreover, although capital and operating expense inputs in sidelines as well as capital inputs in grain merchandising indicated negative net marginal returns, there is no reason to believe that a transfer of resources between different functions would bring about a more efficient allocation than the present one. This statement is, of course, subject to the limitations of the sample pointed out previously. A larger sample might produce different results.

The sidelines function provides evidence of increasing returns to scale. A doubling of mean labor input in sidelines increases the marginal return by \$.18 and, when at the same time both capital and operating expenses are doubled, by \$.44. A ready-made conclusion therefore would be that an expansion in sidelines operations is profitable and to be recommended.

Although it is quite conceivable that some elevators may handle sidelines without a profit either to accommodate customers or to attract trade to more profitable items, most firms handle them for the following three reasons:

1. To use facilities and labor more efficiently throughout the year. Grain marketing alone does not permit year-round use of labor facilities.

2. To overcome the disadvantage of a small volume of business. When grain volume is lacking, sidelines may become a substantial source of business volume.

3. To diversify and stabilize the business. Sideline sales volume varies less than grain volume, changes in the value of sideline sales being caused mainly by changing price levels. Consequently for elevators located in areas of high variability of yields, the introduction or a more extensive specialization in sidelines sales might reduce the variability of total income. This is one of the reasons why large cooperative marketing agencies are interested in encouraging an expansion of sidelines in country elevators.

Sidelines labor showed a marginal return of \$1.68 (at the 1 per cent level of probability) regardless of the fact that the inputs of this factor were already more than two-thirds of total sideline inputs. Given mean operating expenses, the least-cost combination of labor and capital in an average elevator could be attained by increasing labor and decreasing capital inputs within technical limits.

Operating expenses and capital services, when increased separately, did not yield a return significantly different from zero. This would indicate a probable optimum use at the current level of inputs.

Capital may influence the scope of the services and functions performed by a country elevator. To expand into the handling of merchandise, added capital is required. Young grain companies which are short of capital and older unsuccessful companies that have depleted their capital are probably handicapped in this respect. Private firms may also have more difficulties in acquiring necessary capital than cooperative associations. Although the tests for efficiency of factor pricing gave no reason to believe that adjustments in the flow of "fixed" or operating capital would be needed — capital productivity was not significantly less or more than capital cost or interest charge — the fact that the three companies in the sample which did not operate sidelines were private firms may point to the contrary.

It costs more to handle a dollar's worth of sidelines than a dollar's worth of grain. Salaries and wages, light and power, advertising, bad debts, taxes and licenses, and trucking expense are probably the expense items that increase most markedly. Hence, there is a definite need to realize a wider gross margin on sidelines than on grain if each is to bear its fair share of expense.

It might be advantageous to start out with merchandise which returns greatest profits with the least capital investment. Just what merchandise and how many kinds of merchandise an elevator should handle is difficult to determine.

The elasticity coefficient for labor in the total function was significant at the 5 per cent level and the marginal product estimated for this factor was as high as $2.95, whereas marginal products for operating expenses and capital services were not significantly different from zero. Consequently greater inputs of labor services would reduce the marginal productivity to this factor and thus bring about a more efficient allocation of resources in the short run when the scale of plant is fixed. The least-cost combination of labor and capital can be attained in this function by increasing labor and decreasing capital inputs.

In view of high marginal returns to labor in each of the four functions it is conceivable that salaries of management and/or wages of labor might be too low. It might be profitable to raise the salaries and, in this manner, attract more capable people into the elevator industry. This point is especially valid in regard to large diversified firms and those firms desiring to expand. Management must be competent to handle efficiently the technical problems involved in the various elevator operations. More knowledge is required to store and merchandise grain successfully or to run a business involving a variety of lines of merchandise than is needed merely to buy and ship grain.

A word of caution is in order at this point, however. A decline in sales volume often is not accompanied by comparable decreases in salaries and wages paid. If sales volume cannot be maintained it is imperative that the total salaries and wages be adjusted downward if net margins are to be maintained.

Tests indicated that there are probably no economies or diseconomies of large-scale production with the proportions of resource inputs now employed in the total plant function. However, it seems likely that the entrepreneurial factor, which was excluded from this analysis, ultimately determines the most efficient size of the firm. It is the manager's reaction to risk and uncertainty that ultimately determines the kind and cost of services given by the company, the advisability of adding and extending sidelines, grain merchandising and storage activities and, last but not least, the amount of net profit.

The gross profits that were realized by the 22 elevators in this study were noteworthy. The residual value between output and total input was 300 per cent of the value of resource inputs in grain merchandising, 60 per cent in sidelines, and 37 per cent in storage.

It is possible that the sample was somewhat biased because of higher than average level of management in these modern elevators with well-kept records.

It is also conceivable that these high profits were due to certain restrictions of entry to new companies. This is quite compatible with even a "perfectly" competitive market given a "perfectly elastic" demand curve for the output of the industry.[1]

Robinson[2] has demonstrated that the association of high normal profits with imperfect competition is a purely empirical one. She alleges that trades which require either unusual personal ability or special qualifications, such

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[1]Edward Hastings Chamberlin, The Theory of Monopolistic Competition, p. 200.

[2]Joan Robinson, "What Is Perfect Competition?" Quarterly Journal of Economics, November 1934, 49:104-111.

as the power to command a large amount of capital for the initial investment, will tend to have a high level of normal profits, whileas trades which are easy to enter will have a lower level.

The idea of normal profits in its most naive form is the idea of a single general level of profits. Robinson makes it clear that there is not one level of normal profits but two.

> The level of profits which will attract new enterprise into an industry is usually higher than the level which is just sufficient to retain existing enterprise. Entry into a trade is likely to involve considerable initial expense, and often involves, as Marshall was fond of pointing out, a lean period of low profits before the name of the firm becomes known...there is no necessary connection between (imperfect competition and this gap). The existence of the gap depends upon costs of movement from one industry to another, and these may very well occur when competition is perfect...A gap between the upper level of reward necessary to tempt new resources into industry and the lower level, necessary to drive old resources out, will exist wherever there is cost of movement between one trade and another, and the double level of normal profits is merely one example of a phenomenon which may affect every factor of production equally.[1]

From 1951 to 1954 available storage capacity for grain in Kansas increased from 199,192,000 bushels to 279,512,000 bushels,[2] but there is reason to believe that most of this increase was in terminal elevator capacity. Large amount of capital investment needed and uncertainty because of varying climatic conditions and other factors outlined above probably provided some restriction to entry.

In spite of the high rate of average profits in the elevators studied, quite a few companies suffered losses and an additional number had relatively

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[1] *Ibid.*, p. 108.

[2] U.S. Department of Agriculture, Kansas State Board of Agriculture, Office of the Agricultural Statistician, news releases of June 25, 1951, and Nov. 1, 1954.

low profits. On the other hand was a group of companies which were enjoying relatively very high profits. This would seem to agree with Robinson's concept of two normal levels of profit.

LIMITATIONS

Any conclusions drawn from this study are only broad attempts to estimate current trends. They are subject to the following limitations:

The production function assumed belongs to a given state of technology. The analysis is, by and large, static, whereas the problems under discussion relate to a dynamic world where flexibility, uncertainty, and imperfect knowledge cannot be eliminated.

The analysis applies only to the short run and will hold from year to year only if factor and product prices increase or decrease proportionally or remain the same and physical relationships are also maintained.

It is only in an entrepreneurless economy that the linear production function will hold and Euler's theorem is applicable. The exclusion of any measurement of the entrepreneurial factor eliminates the probability of differences between firms depending upon the ability, effort, and luck of a given entrepreneur.

Permanent or temporary immobility of resources due to either frictions in the market or technical limitations may hamper introduction and withdrawal of resources.

The accuracy and adequacy of the analysis depends on the accuracy of the original data. Thus, labor charge might be erratic in the sense that some personnel is probably kept on the payroll during winter months so as to be certain of their services in the peak periods. Also, accounting records may not provide correct measurements of capital cost because of tax considerations on the part of the management.

The statistical tests computed in the study are valid only under the assumption of normality and independence of observations.

The analysis is restricted to the year 1951. Further studies would be needed to determine if the same situation exists in periods of lower or higher yields and under different price and weather conditions.

Although every effort was made to pick homogeneous elevators, different resource combinations exist because of probable differences in managerial abilities. Neither could the resource categories used be made perfectly homogeneous.

Since the analysis applies to the "average" elevator, it is not necessarily applicable to any one country elevator. The study should be more revealing, however, for those who are responsible for public policy formation and thus concerned with the general, average situation.

SUMMARY

This study was made to compare marginal resource productivities in the different marketing services rendered by Kansas country elevators of modern construction in terms of departure from equilibrium conditions, to predict the effect of varying resource combinations on the value of output, and to measure the returns to scale for the different marketing services as well as the plant function.

Labor had the highest marginal productivity in both sidelines and total plant functions. In the storage function, operating expenses gave the highest marginal return followed by capital services. The marginal productivity for labor in storage indicated optimum use. The marginal productivities were not significantly different from zero in grain merchandising.

Consequently, efficiency could have been increased in sidelines as well as total plant operation by adding labor inputs relative to operating and capital service inputs. Efficiency in storage operations could have been furthered by increasing operating expenses and capital services.

Transfers of resources between the different elevator operations would not have increased over-all efficiency.

The productivity of capital in both operating expenses and capital services corresponded to capital cost.

Additional labor inputs in the sidelines function would have increased the marginal productivity of labor even without a simultaneous increase of operating expenses and capital services.

The addition of capital services and operating expenses with labor inputs as given would have caused the greatest absolute increase in labor productivity in storage and the least absolute increase in labor productivity

in grain merchandising.

More efficient combinations of labor and capital than mean combinations would have been possible. These least-cost combinations could have been brought about by increasing labor and decreasing capital in the sidelines and plant functions and decreasing labor and increasing capital in the storage function.

Expansion in sidelines and storage operations would have been profitable. Grain merchandising and total plant operations indicated constant returns to scale.

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LITERATURE CITED

Bronfenbrenner, M. "Production Functions: Cobb-Douglas, Interfirm, Intrafirm." Econometrica, January 1944, 12:35-44.

Bronfenbrenner, M. and Paul H. Douglas. "Cross-Section Studies in the Cobb-Douglas Function." Journal of Political Economy, December 1939, 47:761-785.

Chamberlin, Edward Hastings. The Theory of Monopolistic Competition. Cambridge: Harvard University Press, 1950. 314 p.

Cobb, Charles W. and Paul H. Douglas. "A Theory of Production." American Economic Review, March 1928, 18 (Part I, Supplement):139-164.

Douglas, Paul H. "Are There Laws of Production?" American Economic Review, March 1948, 38 (Part I):1-41.

Durand, David. "Some Thoughts on Marginal Productivity, With Special Reference to Professor Douglas' Analysis." Journal of Political Economy, December 1937, 45:740-758.

Ferguson, John M. Landmarks of Economic Thought. New York: Longmans, Green and Co., 1938. 295 p.

Fienup, Darell F. Resource Productivity on Montana Dry-Land Crop Farms. Montana State College, Agricultural Experiment Station's mimeographed Circular 66. June 1952.

Gunn, Grace T. and Paul H. Douglas. "The Production Function for American Manufacturing in 1919." American Economic Review, March 1941, 31:67-80.

Harries, Hu. "Development and Use of Production Functions for Firms in Agriculture." Scientific Agriculture, Agricultural Institute of Canada, October 1947, 27:487-493.

Heady, Earl O. "Production Functions from a Random Sample of Farms." Journal of Farm Economics, November 1946, 28:986-1004.

__________. Economics of Agricultural Production and Resource Use. New York: Prentice-Hall Inc., 1952. 850 p.

Heady, Earl O. and Schalk du Toit. "Marginal Resource Productivity for Agriculture in Selected Areas of South Africa and the United States." Journal of Political Economy, December 1954, 52:494-505.

Heady, Earl O. and Russell Shaw. "Resource Returns and Productivity Coefficients in Selected Farming Areas." Journal of Farm Economics, May 1954, 34:243-257.

Hoover, Leo M. and John H. McCoy. Economic Factors That Affect Wheat in Kansas. Kansas Agricultural Experiment Station's Bulletin 369. January 1955. 24 p.

Kansas Agricultural Experiment Station. Country Elevator Study. Unpublished Report. 1953.

Kelley, Paul L., Henry Tucker and Milton L. Manuel. Resource Returns and Productivity Coefficients in the Kansas Cooperative Grain Elevator Industry, Contribution No. 225, Dept. of Agricultural Economics and No. 22, Statistical Laboratory, Kansas Agricultural Experiment Station, Manhattan.

Larson, A.L. and H.S. Whitney. Relative Efficiencies of Single-Unit and Multiple-Unit Cooperative Elevator Organizations. Oklahoma Agricultural Experiment Station's Bulletin 426. June 1954. 31 p.

Marschak, Jacob and William H. Andrews Jr. "Random Simultaneous Equations and the Theory of Production." Econometrica, July-October 1944, 12:143-205.

Mendershausen, Horst. "On the Significance of Professor Douglas' Production Function." Econometrica, April 1938, 6:143-153.

__________________ vs. Grace T. Gunn and Paul H. Douglas. "On the Significance of Another Production Function." American Economic Review, September 1941, 31:563-569.

Norton, L.J. Business Policies of Country Grain Elevators. Illinois Agricultural Experiment Station's Bulletin 477. 29 p.

Robinson, Joan. "What Is Perfect Competition?" Quarterly Journal of Economics, November 1934, 49:104-111.

Ruggles, Richard. "The Concept of Linear Total Cost Output Regressions." American Economic Review, June 1941, 31:332-335.

Shepherd, Geoffrey S. Agricultural Price and Income Policy. Third edition. Ames: Iowa State College Press, 1952. 288 p.

Tintner, Gerhard. Econometrics. New York: John Wiley & Sons, Inc., 1952. 370 p.

______________. "A Note on the Derivation of Production Functions from Farm Records." Econometrica, January 1944, 12:26-34.

U.S. Department of Agriculture. Kansas State Board of Agriculture. Office of Agricultural Statistician. News Releases of June 25, 1951, and November 1, 1954.

APPENDICES

Appendix A

Table 1. Income items excluded from total income Y, 22 Kansas country elevators, 1951.

Elev. No.	Item excluded	Amount
1	Telephone	$ 16.20
	Sale of junk	199.16
	Insurance	85.96
3	Patr. ref., FUJA[1], 1952	2,190.81
	Patr. ref., FUJA[1], 1951	400.14
	Patr. ref., CCA[2], 1952	291.79
	Int. on stock, FUJA[1]	36.30
4	Patr. pror., FCCCo[3]	4,292.52
	Patr. pror., CCA[2]	90.51
	Patr. pror., KFSA[4]	397.61
	Stock int., FCCCo[3]	207.00
	Interest	21.91
5	Combining wheat and milo	873.98
	Interest income-notes	127.87
	Patr. ref., FCCCo[3]	11,194.98
	Patr. ref., CCA[2]	9,062.01
	Ninnescah Coop. Cred. Un. Div.	.50
	Stock div., FCCCo[3]	207.00
9	Purchase discount earned	384.43
	Patr. ref., FCCCo[3]	3,309.72
	Patr. ref., CCA[2]	2,699.66
	Patr. ref., FUJA[1]	.30
	Stock div., FCCCo[3]	213.00
	Stock div., Coop. Refining	6.00
	Stock div., Equity Un. Grain Co.	1.00
	Old checks cancelled	23.09
	Sale of junk	50.00
10	Patr. ref., FCCCo[3]	9,441.93
	Patr. ref., CCA[2], 1952	2,651.98
	Patr. ref., CCA[2], 1951	113.66
	Kansas Farmers Service Ass'n.	50.00
	Stock div., FCCCo[3]	234.00
	Stock div., FUJA[1]	3.00
11	Interest	85.90
14	Patr. ref., FCCCo[3]	3,403.91
	Patr. ref., CCA[2]	1,159.16
	Stock int., FCCCo[3]	168.00
	Recovery of old debts	13.51

(cont'd)

(Table 1, cont'd)

Elev. No.	Item excluded	Amount
15	Patr. pror., FCCCo[3]	15,123.42
	Patr. pror., CCA[2]	352.50
	Patr. pror., Rolla Coop. Ass'n.	21.88
	Stock div., FCCCo[3]	258.00
	Stock div., Rolla Coop. Ass'n.	1.00
	Old notes collected	5.00
16	Patr. pror., FCCCo[3]	9,528.36
	Patr. pror., CCA[2] (Stock)	6,775.00
	Patr. pror., CCA[2] (Deferred)	6,794.60
	Stock div., FCCCo[3]	300.00
	Stock div., Pawnee Coop. Fed. Cred. Un.	12.40
	Int. on gov. bonds	400.00
	Other interest	189.47
18	Interest	3,412.43
19	Interest	604.87
	Recoveries on bad debts	427.26
	Misc. income	6.15
20	Interest notes	59.93
	Rental-dwellings	660.00
	Sale on scrap	21.00
	Rental-Advertising Sign	10.00
	Patr. ref., FCCCo[3]	19,206.99
	Patr. ref., FUJA[1]	10.56
	Patr. ref., CCA[2]	382.89
	Stock div., FCCCo[3]	300.00
	Stock div., FUJA[1]	6.00
	Disposal of 1946 Chevy	575.00
	Sale of scales, old feed elevator	100.00
21	Recovery, charge-off account	343.05
	Patr. ref., FCCCo[3]	5,073.69
	Patr. ref., FUJA[1]	1.91
	Patr. ref., CCA[2]	5,407.66
	Stock div., FCCCo[3]	276.00
	Stock div., FUJA[1]	9.00
	Stock div., CCA[2]	40.00
	Net savings-locker operation	794.22
22	Patr. pror., FCCCo[3]	16,362.60
	Patr. pror., CCA[2]	771.48
	Patr. pror., Cimarron F. Coop. Oil Company	8.42
	Stock div., FCCCo[3]	300.00
	Sale of iron junk	74.50
	TOTAL	$148,815.74

[1] FUJA = Farmers' Union Jobbing Association
[2] CCA = Consumer Cooperative Association
[3] FCCCo= Farmers' Cooperative Commission Company
[4] KFSA = Kansas Farmers' Service Association

Table 2. Items of "Other Income" excluded from sidelines income.

Elev. No.	Item Excluded	Amount	Remarks
1	Storage and handling	$ 5,162.10	
2	Storage and interest	2,718.62	
3	FUJA[1] financial account, wheat	4,244.01	Sales on commission basis; included in grain merchandising
	FUJA[1] financial account, milo	2,923.12	
	Storage and handling	1,185.10	
4	Storage	4,109.52	
5	Storage and handling	9,019.98	
8	Storage	2,250.00	
9	Storage and handling	6,089.61	
10	Storage	5,888.23	
11	Storage and handling	15,312.79	
12	Storage	22,642.04	
13	Storage	22,400.00	
14	Storage	25,054.20	
15	Storage and handling	18,478.88	
16	Handling grain	679.88	
18	Wheat handling	18,286.03	
	Milo handling	929.58	
	Dockage income	924.88	
	Railroad claims	2,764.42	Included in grain merchandising because freight claims on grain assumed to constitute the bulk of this amount
19	Storage income	85,212.83	
20	Storage and handling	25,683.13	
21	Storage and handling	58,099.81	
22	Storage	31,203.82	
	Handling	496.47	
	Freight claims	1,675.00	Included in grain merchandising because freight claims on grain assumed to constitute the bulk of this amount
	TOTAL	$373,434.05	

[1]FUJA = Farmers' Union Jobbing Association

Appendix B: Detailed Classification of Input-Output Variables

Total Function

Gross Income Y:

1) The total value of goods and services sold and ending inventory less the total value of goods and services purchased and beginning inventory; excluding items listed in Appendix A, Table 1.

2) Other income; excluding items listed in Appendix A, Table 2.

Labor Services X_1:

The sum of labor services listed under sidelines, storage, and grain merchandising functions.

Operating Expenses X_2:

The sum of operating expenses listed under sidelines, storage, and grain merchandising functions.

Capital Services X_3:

The sum of capital services listed under sidelines, storage, and grain merchandising functions.

Sidelines Function

Gross Income Y:

1) The total value of sidelines merchandise sold and ending inventory less the total value of sidelines merchandise purchased and beginning inventory.

2) Other income; excluding items listed in Appendix A, Table 2.

Labor Services X_1:

Salaries	Employee pensions
Wages	Social security
Commissions	Employee insurance
Directors' fees	Work compensation

Operating Expenses X_2:

Office supplies incl. postage	Freight, express, drayage

(Sidelines, cont'd)

Operating Expenses X_2: (cont'd)

Plant (elev.) supplies
Travel and convention expenses
Subscriptions, dues, periodicals
Advertising, incl. calendars
Donations, flowers, contributions, collections
Advertising and memberships
Telephone and telegraph
Dues and memberships
Seed test
Grading and gravel
Dig ditch
Combing expense
Weed cutting
Scale testing and service
Feed mill expense
Adding machine service
Ice and floor sweep
Store supplies and expenses
Office machine service
Service station supplies and expenses
Christmas presents and expense
Station supplies and repairs
Hauling trash
Delivering gravel
General supplies
Locker supplies
Station uniforms
Memberships

Capital Services X_3:

Maintenance and repairs
Water
Light
Power or electricity
Gas and oil (truck)
Depreciation-bldg.
Depreciation-equip.
Rent
Railroad lease
Motor service supplies and expenses
Gas, water, ice
Fuel (coal, gas, or propane)
Water and fuel
Water line
Truck power
Machines
Transformer rental
Truck and car expenses

Storage Function

Gross Income Y:

Bushel months stored, multiplied by rate of payment for storage (1 cent per bushel month).

Labor Services X_1:

Salaries, incl. directors fees, wages, incl. regular, social security, employee insurance, work compensation.

Operating Expense X_2:

Office supplies
Plant (elev.) supplies
Travel and convention
Telephone and telegraph
Insect control
Scale test and service

(Storage cont'd)

Operating Expense X_2: (cont'd)

Subscriptions, dues, periodicals
Advertising, donations, flowers, gifts, collection, Christmas expenses
Hauling trash
Hauling dirt
Freight and express
Car coopering
Freight and hauling
Testing grain
Rodent and bird control
Grading and gravel
Dues and memberships
Sand and dirt
Adding machine service
Weed cutting
Crop report
Filling in scale pit
Weighing expense
Ice and floor sweep
Memberships
Office machine service
Moving wheat

Capital Services X_3:

Maintenance and repairs
Office utilities (fuel, light, oil, water)
Depreciation-bldg.
Water line
Depreciation-equip.
Lease-rent
Electricity
Truck gas and oil
Truck and car expense

Grain Merchandising Function

Gross Income Y:

Total gross income less storage and sidelines income.

Labor Services X_1:

Salaries, incl. directors fees, wages, incl. regular social security, employee insurance, work compensation.

Operating Expenses X_2:

Office supplies
Plant (elev.) supplies
Travel and convention expenses
Subscriptions, dues, periodicals
Advertising, donations, flowers, gifts, collection, Christmas expenses
Hauling trash
Hauling dirt
Telephone and telegraph
Insect control
Scale test and service
Grading and gravel
Dues and memberships
Sand and dirt
Adding machine service
Weed cutting
Crop report
Testing grain
Rodent and bird control

(Grain Merchandising, cont'd)

Operating Expenses X_2: (cont'd)

Freight and express
Car coopering
Moving wheat
Freight and hauling
Office machine service
F'lling in scale pit
Weighing expense
Ice and floor sweep
Memberships

Capital Services X_3:

Maintenance and repairs
Office utilities, (fuel, light, oil, water)
Depreciation-bldg.
Water line
Depreciation-equip.
Lease-rent
Electricity
Truck gas and oil
Truck and car expense

RESOURCE PRODUCTIVITY STUDIES IN TWENTY-TWO KANSAS COUNTRY ELEVATORS OF MODERN CONSTRUCTION

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1954

AN ABSTRACT OF A THESIS

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The purpose of this study was to compare the marginal productivities of resources employed in Kansas country elevators of modern construction in terms of departure from the optimum efficiency conditions, to predict the effect of varying combinations of resources on output, and to measure returns to scale in elevator operations.

The sample of 22 elevators was drawn from a sub-population of a universe of western and central Kansas elevators with a licensed storage capacity from 95,000 to 850,000 bushels and with uniform construction. The elevators in this sub-population kept similar records, had been built during the 1947-51 period, and were willing to co-operate. The sub-population was stratified into four size groups. The elevators in each stratum were picked at random. The data for the 1951 wheat crop year were collected by personal interview and inspection of office records.

The elevator firms were assumed to operate in a perfectly competitive market where distribution of income and basic organization of industry and primary production were given. According to the marginal productivity theory, the maximum efficiency under these conditions would be reached when the "net values" of all marginal resource productivities are zero. This situation can be reached by adding factor units to the point where they just pay for themselves. Each firm would tend to carry its scale of operations to the point of constant returns where the total product will be exhausted if the claims of each factor are met.

Cobb-Douglas type production functions which are linear in logarithms were fitted to sidelines, storage, and grain merchandising operations as well as for total plant operation.

The statistical method of least squares, commonly called the multiple regression analysis, was used to derive estimates of the elasticities of production. The dependent variable in the regression equation was gross income. The three independent variables were labor services, operating expenses, and capital services. All variables were measured in dollars. The significance of the regression equations was tested by means of t-tests and analysis of variance.

The elasticities of production and the geometric means of the input-output variables were used to derive marginal-productivity, rate-of-substitution, and returns-to-scale estimates.

The estimated marginal productivities indicated that efficiency could have been increased in sidelines and total plant by adding labor inputs relative to operating expense and capital service inputs, and in storage by increasing operating expenses and capital services. The marginal productivity for labor in storage indicated optimum use.

Tests of inter-function differences indicated that transfers of resources between the different functions would not have increased over-all efficiency.

Tests of efficiency in factor pricing provided evidence that the productivity of capital corresponded to its cost in both operating expenses and capital services.

It was found that the marginal productivity of labor in sidelines could have been increased by additional labor inputs even if capital services and operating expenses were held fixed.

Labor-capital substitution schedules indicated that least-cost combinations could have been brought about by increasing labor and decreasing capital in sidelines and total plant operations, and decreasing labor and increasing capital in storage.

Tintner's test for the hypothesis of constant returns to scale indicated that expansion in sidelines and storage would have been profitable.

This analysis is static and applies only in the short run. It is limited by the accuracy of the original data as well as normality and independence of observations. The entrepreneurial factor has been excluded. The analysis applies to the "average" elevator, not to the "individual" elevator. It is directed to those who are responsible for public policy formation and thus concerned with the average situation in the elevator industry.