Economic Growth and the Theory of Agricultural Revolution

By Joseph A. Swanson

The role of the agricultural sector in economic growth has recently come under study. Numerous articles have appeared on the theoretical aspects (capital formation, increased productivity, etc.) of agriculture's contribution as well as on the numerical magnitude of changes that have taken place. These studies, together with many historical writings on the growth of American agriculture, raise the possibility of several hypotheses about the specific role of agriculture in American economic growth. Recently the work of Rasmussen (9) has presented a hypothesis which deserves examination.[1] Rasmussen finds that the statistical record shows two periods of "revolutionary" change in the agriculture sector: 1850 to 1870 and 1940 to the present time. He notes that these were periods of radical changes in the sources of farm power; they appear as periods of sharp increases in both output and productivity. Specific changes in technology and the nature of demand are shown to have had given effects on the nature of production; hence, upon the structure of the sector. This article examines the theory underlying the concept of "agricultural revolution." That is, the usage of this term, previously and presently, is examined in the light of recent work in the field of development theory and economic history.

AGRICULTURAL HISTORIANS have developed numerous constructs of an agricultural revolution—nearly all of which contradict one another with regard to timing.[2] Schmidt (12) represents the viewpoint of most of these authors. He writes of a "triple economic revolution," marked by the commercialization of agriculture, mechanization of industry, and internationalization of the market—a revolution of 70 years' duration, from 1860 to 1930. Schmidt goes on to isolate causes of the revolution in agriculture: (1) the passing of public lands into private ownership; (2) rapid growth in population and immigration; (3) invention and popularization of improved farm implements and machinery; (4) extension and development of transport facilities; (5) migration of industries from farm to factory; (6) expansion of foreign and domestic markets; and (7) the establishment of agencies for the promotion of scientific knowledge relating to agriculture.

Rasmussen's emphasis upon the changing nature of production relationships puts the problem of defining agricultural revolution in another light. To understand this position we must turn to an analysis of the manner in which output levels are attained. The level of output depends on the existence of given technical relationships (parameters) in the system. The mechanism by which changes in these parameters take place offers a definition of the concept of "agricultural revolution."

Sources of Change in Level of Output

To consider the movement of output through time we need a function which relates the outputs of the agricultural sector to its inputs. In view of our interest in technical change we begin with a production function similar to that developed by Solow (13):

$$(1) \qquad O = A(t)(x_1, x_2, \ldots, x_n)$$

where O = output; $A(t)$ = a scalar, expressed as a function of time to represent technical change; and $(x_1, x_2, \ldots, x_n)$ = a vector of n inputs. For purposes of exposition we will assume that these n inputs may be aggregated so that:

$$(2) \qquad X = \sum_{i=1}^{n} x_i.$$

Or, X is equal to the sum of all production inputs. Since we hold, like Solow, that any technical change that takes place is "neutral," the aggregation of these inputs is not a limiting assumption.[3] Further, it must be assumed that the

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[1] Italic numbers in parentheses refer to items in the Literature Cited. p. 56.

[2] See Rasmussen (9) for a presentation of this group of writers.

[3] Solow's assumption that technical change is "neutral" means that it is not associated with any given input, but rather with their totality.
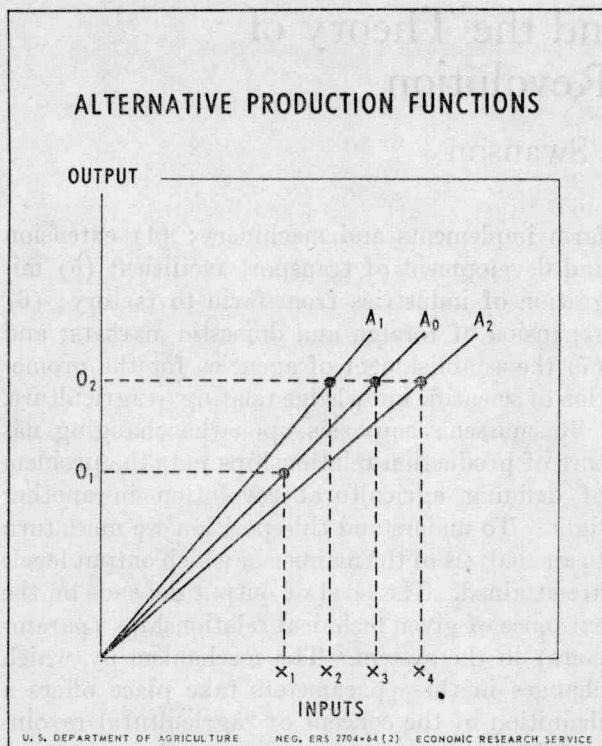
ALTERNATIVE PRODUCTION FUNCTIONS

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FIGURE 1

ratio of any input (x_i) to any other input (x_j) remains constant through time, i.e., $x_i/x_j = k$ for all i and j.

A production function may be specified as

$$(3) \qquad O_t = A_0 X_t.$$

As the subscripts refer to time, output in the tth time period is a linear function of the inputs used in that time period. Inputs are transformed to outputs by a given technical coefficient of production, A; in this case the coefficient A_0. Such a function is presented graphically in figure 1.

In this figure output (O) is given on the y-axis and inputs (X) are given on the x-axis. The technical coefficients of production (A's) are shown as the slopes of lines which connect the x-y intercept with points of optimum output. The subscripts of the A's in figure 1 indicate time.

Output in the first time period (O_1) is the result of the production function

$$(4) \qquad O_1 = A_0 X_1.$$

We may increase production to O_2 by using one of the three following production functions:

$$(5) \qquad O_2 = A_1 X_2$$

$$(6) \qquad O_2 = A_0 X_3$$

$$(7) \qquad O_2 = A_2 X_4.$$

The level of output depends on the level of inputs and on changes in the technical coefficient of production. What we are interested in here, however, is not the means of raising output, but rather the changes which the historical record shows have taken place in input-output relationships. We make use of figure 1, then, to see how closely each of the possible relationships approximates the record of previous development.

The hypothesis to be developed here is that changes in agricultural output in the United States have been due to variations in the ways of combining inputs.[4] For example, the production function

$$(5) \qquad O_2 = A_1 X_2$$

describes the source of output growth in recent decades; a similar phenomenon occurred in 1850–70. With reference to our initial production function (1) we find that the derivative of technical change with respect to time is greater than one, or :

$$\frac{dA(t)}{dt} > 1.$$

Stated another way, output has increased at a faster rate than total input:

$$\frac{O_2 - O_1}{O_1} > \frac{X_2 - X_1}{X_1}.$$

If no change in the technical coefficient (A) occurs, O_2 may be produced by using quantity X_3 of total inputs. Thus the relevant production function is:

$$(6) \qquad O_2 = A_0 X_3.$$

Output has now changed at about the same rate as input:

$$\frac{O_2 - O_1}{O_1} = \frac{X_3 - X_1}{X_1}.$$

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[4] The data used to examine this hypothesis are provided by Towne and Rasmussen (*16*), Loomis and Barton (*8*), and Gallman (*3*).

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Returning to our initial production function we find the derivative of technical change to be as follows:

$$\frac{dA(t)}{dt} = 1.$$

This situation is not unlike the changes which occurred during the decades 1880–90 and 1900–10.

Finally, we may detect decades in which output is increasing at a slower rate than input. For such periods we use the production function

(7) $$O_2 = A_2 X_4$$

as a likely description. For the decades 1870–80 and 1910–20, we have such a proportionate change:

$$\frac{O_2 - O_1}{O_1} < \frac{X_4 - X_1}{X_1};$$

and a derivative of our initial production function (1):

$$\frac{dA(t)}{dt} < 1.$$

Thus, having observed the means by which alternative output levels can be measured and the relationships which these alternatives have with the actual data, we may go on to describe the mechanism of technological change.[5]

Let one more piece of exposition be made by use of figure 1: that the proportionate changes in inputs and output are significant to the analysis of the growth of the agricultural sector. Specifically, let us state that when output growth coincides with a similar, or greater, rate of growth in the volume of input, *extensive* change has taken place in the sector. Under extensive change we may merely be reproducing a given production situation—as was the case of producing the output (O_2) with the production function (6); we did not change the technical coefficient (A_0), but merely the inputs used. Similarly, we achieved the output (O_2) by using production function (7) which implies a less efficient use of inputs.

Salter (*11*) distinguishes "extensive" growth from "growth in depth." In the latter case we have used less input to produce a greater output—

as in producing the output (O_2) by use of the production function (5). "Growth in depth" might be called *intensive* growth.

The movement of the scalar $A(t)$ is the most significant factor in each type of growth; it represents the effect of technical change on the input combinations. We must now raise the questions which bear upon the movement of this coefficient. Let us consider intensive growth in output to be of a "revolutionary" nature and discuss the process of technical change in such growth.

Sources of Technical Change

If we consider only *intensive* shifts in output as being revolutionary, it is necessary to isolate the sources of the shifts. Factors accounting for shifts in the technical coefficient—or, more generally, shifts in productivity—are: (1) changes in the institutional and dimensional structure of the economy; (2) economies of scale that exist at differing periods; (3) changing capacity (or educational levels) of the labor force; and (4) the level of technical knowledge and the nature of its application. Following the chemist's notation, we might write that the reaction of technology and economies of scale is catalyzed by the capabilities of the labor force and the structure of the economy and that this process yields increased output.

In analyzing the role of these productivity-increasing factors, let us first discuss the reactants: economies of scale and technological change. "Economies of scale" is a term used to describe the downward movement of short-run average cost curves over time. It is an economic condition. Conversely, pure technological change is a noneconomic condition. It reflects only the level of the industrial arts within the economy, i.e., the state of technical knowledge, its application to the production process, and the extent of its adoption (*2*, pp. 142–143).

The distinction between economic and noneconomic parameters is that made by Haavelmo (*4*): the former bear specifically on a sector's physical output; the latter contribute only indirectly to output. It should be noted that noneconomic parameters are determined by the movements of economic variables. Clearly, economic decisions rest on each of these conditions and are not exclusive to one or the other.

Of the catalysts designated above, structure and capacity of the labor force, we define the former

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[5] By technical change we mean those factors which affect the input-output ratio, creating more or less efficient utilization of inputs. *Technical change* is distinct from *technological change*, which represents variations in the state of the industrial arts.

TECHNOLOGICAL CHANGE AND THE PRODUCTION FUNCTION

A: Technological Change with an Increase in Capital

B: Increase in Capital Only

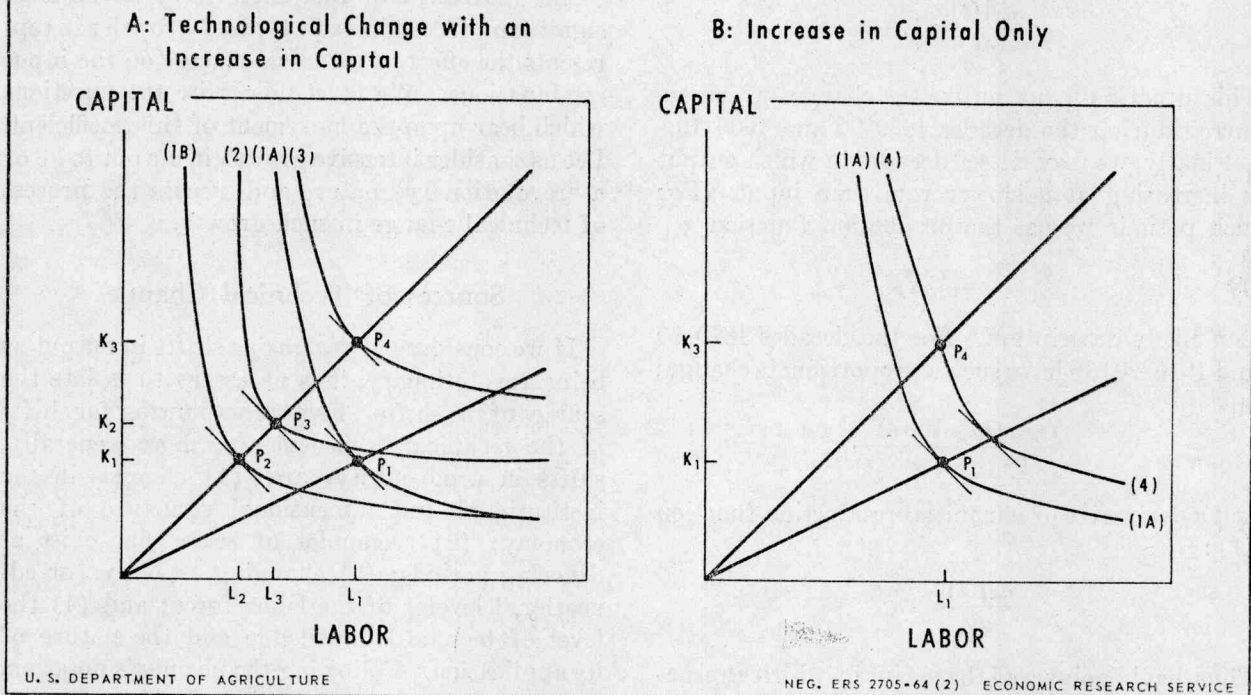U. S. DEPARTMENT OF AGRICULTURE   NEG. ERS 2705-64 (2)   ECONOMIC RESEARCH SERVICE

FIGURE 2

as an economic and the latter as a noneconomic parameter. While these catalytic agents are given here as sources of output growth, they may also be considered as constraints on output growth. The intricate concurrences of these agents is apparent; they are separated here only for purposes of comprehension.

In considering the possibilities of input-output combinations, we discussed "neutral" technical change. This was analogous to shifts in the production function, which do not change the marginal rates of substitution of any of the factors but merely increase output attainable from given factor inputs. We may also have "slope" technical change, where our production function is:

$$(8) \qquad O = f(x_1, x_2, \ldots, x_n; t).$$

Since "slope" changes involve new sets of marginal substitution rates, they are critical to our analysis; they represent technological change within technical change. Changes of technical nature involving "slope" changes are not so easily grasped, for they concern the interaction of capital and technological change.

A method presented by Resek allows us a clearer presentation of this matter (10, pp. 56–57). In figure 2A we begin by considering isoquant 1. This isoquant is split into 1A and 1B: the 1A curve gives an initial production function, and the 1B curve indicates that function after the adoption of a capital-saving innovation. If we allow (total) inputs to remain unchanged, isoquant 2 evolves (i.e., inputs shift from K_1L_1 to K_2L_3). Further, if the price ratios [6] are constant, production point p_4 on isoquant 3 can be reached. Alternatively, production point p_4 could be reached by expanding the initial isoquant 1A out to form isoquant 4—without changing factor proportions in the production function. This is done in figure 2B.

If, then, we give the initial output (isoquant 1A at point p_1) as 100 units and production at point p_2 as the same, the outward (linear) shift caused by employing the same total inputs gives a 30 percent increase in output; the total output at p_3

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[6] These are given by the lines sloping northwest-southeast in figures 2A and 2B.

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is 130 units. Expanding to isoquant 3, production point p_4 becomes 180 units. Again, shifting isoquant 1A to isoquant 4 by increasing the capital input singularly (15 percent) we raise output to 115 units. The total increase in output, 80 units, is the result of a 30 percent increase in technical change, a 15 percent increase in capital, and a 35 percent increase in the interaction of capital and technology.[7]

In summary, "neutral" technological change is that which involves only shifts based on scale changes with marginal rates of substitution remaining constant. "Slope" changes are, conversely, those involving a new set of marginal substitution rates; they have the character of innovation. And the types of innovations which are made are related to input availability within the economy or sector. To achieve a broader view of the innovation process—particularly within the framework of the "agricultural revolution"—we must examine the existing relationships which create such shifts in the production function.

Causes of Technical Change

Turning from the consideration of *sources* of changes in output, we examine a more complex concept, that of *causes* of changes in output. Three dynamic factors in the history of the agricultural sector may be given: the growth of population, changes in the character of demand, and technological change. These factors are interdependent (5, pp. 255–258). We need not concern ourselves with the determinants of these factors; abundant literature exists on their nature. Rather, let us examine the role of these factors in the growth of a given sector.

Increases in a country's population give rise to a number of changes in the structure of the country's economy; savings, input availability, and per capita income are examples. We may take per capita income as a variable which will be instrumental in the development process.[8] In an economy experiencing increases in total population a

similar increase in total production is observed. However, the source of this increased production—improved economic organization, due to the pressures of population growth—is limited by resource availability. The latter may result in decreased per capita production, unless innovations which save factor inputs are adopted. The character of the resultant innovations depends on the nature of demand and on the availablity of inputs and production techniques. This need not imply a narrow approximation of historical events; it offers an approximation of the interrelation of population and resources in the growth process.

Spengler shows the relationship of a population-resources mix to final production as governed by technology and demand (14, p. 137). Technological change is the producer's means of dealing with alternative population sizes and resource availability, while demand change is the consumer's means of adapting to the same alternatives. It follows that variation in population and resource availablity gives rise to changing technology and demand.

Conclusion

The changes in production functions over time do not go a great distance in helping us to understand our growth experience. We have a multiplicity of factors involved, which are not explained by the concept of "agricultural revolution." For example, what relationships do the movements of production functions we have discussed have to the "long swings" found by Abramovitz (1) and Kuznets (6)? Or, what can be said of the changing nature of production with reference to changes in population, labor force, and standards of living in the whole economy and the agricultural sector?

The concept of "agricultural revolution" has been recently used to clarify certain aspects of changes in the structure of the agricultural sector through time. Rasmussen's work (9) has provided a useful approach to the understanding of these changes. Certainly, this work has aptly described the changes in American agriculture for the period since 1940. What of the "first agricultural revolution," dated 1850–70? While we lack detailed data for this period, crude measures of capital and labor inputs can be constructed. And such measures used as divisors for existing output data suggest rapid technical change in this period. Thus, both periods, 1850–70 and 1940–61, have

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[7] These numbers are arbitrary and similar to those used by Resek (10).

[8] Per capita income (or product) is most commonly used as the index of economic development. Presented here is a form of the "income-optimal" population theory, discussed by Spengler (14) and restated by Leibenstein (7).

witnessed revolutionary technical change; i.e., output advanced at a rate much greater than the change in input levels. Although wide variations exist in our estimates of technical change, these two periods may be readily singled out for their dissimilarity with other periods. However, questions about the nature of agriculture in the process of economic growth remain numerous. The study of the historical record can do much to answer these questions.

Literature Cited

(1) ABRAMOVITZ, M.
  1956. RESOURCE AND OUTPUT TRENDS IN THE UNITED STATES SINCE 1870. Nat. Bur. Econ. Res., New York, 23 pp., illus.

(2) DAY, R. H.
  1962. AN APPROACH TO PRODUCTION RESPONSE. Agr. Econ. Res. 14(4): 134–148.

(3) GALLMAN, R. E.
  1960. COMMODITY OUTPUT, 1839–1899. Studies in Income and Wealth, Vol. 24: Trends in the American Economy in the Nineteenth Century. Princeton Univ. Press, pp. 13–67.

(4) HAAVELMO, T.
  1954. A STUDY IN THE THEORY OF ECONOMIC EVOLUTION. North Holland Publishing Co., Amsterdam, 114 pp.

(5) KUZNETS, S.
  1953. ECONOMIC CHANGE. W. W. Norton and Co., New York, 333 pp.

(6) KUZNETS, S.
  1961. CAPITAL IN THE AMERICAN ECONOMY. Princeton Univ. Press, 664 pp., illus.

(7) LEIBENSTEIN, H.
  1957. ECONOMIC BACKWARDNESS AND ECONOMIC GROWTH. John Wiley and Sons, New York, 295 pp., illus.

(8) LOOMIS, R. A., and G. T. BARTON.
  1961. PRODUCTIVITY OF AGRICULTURE, UNITED STATES, 1870–1958. U.S. Dept. Agr., Tech. Bul. 1238, 63 pp., illus.

(9) RASMUSSEN, W. D.
  1962. THE IMPACT OF TECHNOLOGICAL CHANGE ON AMERICAN AGRICULTURE, 1862–1962. Jour. Econ. Hist. 22(4): 578–591, illus.

(10) RESEK, R. W.
  1963. NEUTRALITY OF TECHNICAL PROGRESS. Rev. Econ. and Statis. 45(1): 55–63, illus.

(11) SALTER, W. E. G.
  1960. PRODUCTIVITY AND TECHNICAL CHANGE. Cambridge Univ. Press, London, 198 pp.

(12) SCHMIDT, L. B.
  1930. THE AGRICULTURAL REVOLUTION IN THE UNITED STATES, 1860–1930. Science 75(50): 585–594.

(13) SOLOW, R. M.
  1957. TECHNICAL CHANGE AND THE AGGREGATE PRODUCTION FUNCTION. Rev. Econ. and Statis. 39(3): 312–320, illus.

(14) SPENGLER, J. J.
  1947–48. ASPECTS OF THE ECONOMICS OF POPULATION GROWTH. Southern Econ. Jour. 14(2,3): 124–147, 233–265, illus.

(15) STOUT, T. T., and V. W. RUTTAN.
  1958. REGIONAL PATTERNS OF TECHNOLOGICAL CHANGE IN AMERICAN AGRICULTURE. Jour. Farm Econ. 40(2): 196–207, illus.

(16) TOWNE, M. W., and W. D. RASMUSSEN.
  1960. FARM GROSS PRODUCT AND FARM GROSS INVESTMENT IN THE NINETEENTH CENTURY. Studies in Income and Wealth, Vol. 24: Trends in the American Economy in the Nineteenth Century. Princeton Univ. Press, pp. 255–312.