PRODUCTIVITY MODELS OF ECONOMIC GROWTH*

By

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Economic growth generally is conceived in terms of a rising level of consumption or real income per person. Defined in this mnner economic growth can occur as a result of (a) advance in the techniques of production (in technological progress) which results in production of a greater output with the expenditure of a constant aggregate quantity of resources, or (b) as a result of an increase in the quantity of other factors per unit of labor in such a manner that real income per person rises even though the ratio of output to total input remains unchanged or even declines. The significance of technological change for the growth of the less developed countries is that it permits the substitution of knowledge and skill for resources.

Immediately after World War II, development planning was concerned almost exclusively with how to achieve a sufficiently high rate of capital accumulation to permit the achievement of national output targets[1]. Since the mid-1950's, however, efforts to quantify the sources of output growth have led to a growing consensus that tchnological change (more broadly, productivity growth) has played an important role, relative to changes in conventional factor inputs, in accounting for economic growth in the United States and in a number of other rapidly growing economies.[2] A a result, development planners have been giving increasing attention to policies designed to accelerate technological change.

Technological change has been described or measured in many ways—in terms of changes in the blueprints or specifications for individual items of capital equipment; by partial

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productivity measures, such as changes in output per man hour, output per hectare, output per unit of capital (or its reciprocal, the capital coefficient); and by total productivity measures, such as output per unit of total input or some index of change in the aggregate production function.

Historically, it is possible to identify two major stages in the evolution of attempts to quantify technological change. It now seems apparent that a third stage is emerging.

1.0 Partial productivity

During the **first** stage, construction of partial productivity measures received primary attention (1).

(1) $Y_t = T_t X_t$

where: Y_t is an index of physical output (or value added) in a particular industry, sector or economy.

X_t is an index of a particular input, usually labor, but in some cases, land, capital equipment, breeding stock or others.

T_t is a multiplier which can itself be converted into a partial productivity index.

The WPA National Research Project in the 1930's made the first major effort in the field of partial productivity measurement in the United States. The National Bureau of Economic Research and the US Bureau of Labor Statistics carried the work forward in the years immediately preceding and since World War II. The issues involved in the definition of output and input and the problems of index number construction received major attention.[3]

Partial productivity indexes, such as labor land productivity, received rather wide popular acceptance as indicators of technological change. In part, this acceptance reflected the concern with displacement of labor by machinery during the years of high unemployment in the 1930's. Most economists, except perhaps in the field of labor economics, regarded the use of partial productivity indexes as measures of technological change with considerable skepticism. It was pointed out that change in labor productivity clearly results in a biased measure of the contribution of technological change to output growth in any industry where rise in labor productivity has been achieved even partially as a result of a rise in the ratio of capital to labor inputs.[4] Stigler's comment that "not a single theoretical statement of any importance can be made about the average product of factors"[5] is clearly overdrawn. Nevertheless, the use of average partial productivity ratios or indexes, such as the capital-output ratio, output per man-hour or per worker, and output per hectare or other unit of resource input, continues to have a stronger foundation in empirical convenience than in theoretical finesse.

2.0 Total productivity

The second stage began during the early 1950's with the development of total productivity measures.[6] The total productivity approach employs, either explicitly or implicitly, the concept of an "aggregate production function" (2).[7]

(2) $Y_t = g(X_t, U_t, T_t)$

where: Y_t is an index of physical output (or value added) in a particular industry, sector or economy.

X_t is a set of "measurable" inputs, usually indexes of labor and capital although sometimes finer input specifications are employed.

U_t is a random, or short-term cyclical variable such as weather in agriculture or unemployment in manufacturing.

T_t is the total productivity index usually measured as a residual.

$g(\ )$ is the function describing the connection among the variables, usually approximated by a function that is either linear or linear in logarithms.

Within the total productivity approach, two major traditions have developed in the United States. The first, which I shall refer to as the "index number" approach, has emerged out of the work at the National Bureau of Economic Research, the Office of Business Economics of the US Department of Commerce, and the Economic Research Service (and its predecessors) in the US Department of Agriculture. Work in this tradition is essentially an extension of the older partial productivity approach to incorporate a larger set of inputs.[8]

The second tradition, designated the "production function" approach, has develop primarily from the work of economists attached to academic institutions rather than those working at research intitutes or government economic research units. They have emphasized elaboration of the theoretical foundations in order to identify the productivity index more closely with technological change.[9]

The major conceptual issues which continue to receive attention by economists of both traditions are discussed below:

Aggregation: One desirable property of any productivity index is that it be constructed in such a way that the weighted average of the individual industry or sector productivity indexes (or rates of change) should equal the mean index (or rate of change) for the economy as a whole. It also should be possible "to take the economy apart, to aggregate one industry with another, to integrate final products with inputs, and to reassemble the economy once more . . . without affecting the magnitude of the Residual"[10] — the productivity index. It seems clear that both objectives cannot be met simultaneously.[11]

In productivity studies conducted at more than one level of aggregation — when industry productivity indixes (or rates) are aggregated to produce sector productivity indexes (or rates), for example — the aggregate productivity index (or rate) is typically defined as the simple weighted average of the industry or sector rates (or indexes). Double counting, resulting from inter-industry transfers, is usually eliminated by defining output for each industry in terms of "value added" by the industry and inputs in terms of labor, capital (inclusive of depreciation) and land but net of current inputs of raw materials.

For planning purposes, however, it is useful to be able to identify the relative contribution of both (a) conventional inputs, and (b) productivity changes to the output of products measured in conventional physical terms and not by some abstraction, such as "value added" or "sector GNP". For this purpose, the production function should contain all identifiable outputs and inputs, including raw materials, without any arbitrary exclusions from either side. When this "gross" approach is used, the agggregate productivity index becomes the weighted sum of the individual industry indexes.

Aggregate productivity indexes derived from use of the "value added" definitions of input and output are consistent with the first criteria listed above but violate the second. Aggregate productivity indexes derived from the "gross" approach are consistent with the second criteria but violate the first. The design of a system of productivity accounts should permit the construction of industry and aggregate productivity indexes in which raw materials are alternatively included and excluded from the productivity function.

The production function: Practitioners of the production function approach typically have used a Cobb Douglas (linear in the logarithms) production function with the productivity coefficients estimated from relative factor shares, while practitioners of the index number approach usually have employed linear price weighted indexes.[12] In practice, the difference between the two approaches has frequently boiled down to whether the index of total input is to be based on arithmetic or geometric weights. Once the form of production function is specified, the rest of the business comes down to little more than hunting (statistically or otherwise) for an acceptable set of weights. The geometric weighing procedure has the advantage, from the perspective of production economics, of imposing a diminishing rather than constant marginal rate of substitution among inputs. Consistency also would seem to require that outputs also be weighted geometrically.[13]

Use of either individual prices or factor shares as weights in constructing the input index is "correct" only if the sector operates in a perfectly competitive market and is in long run equilibrum. Attempts usually are made, therefore, to select periods of "relative" equilibrum as base periods for weight selection and linkage. Where relative equilibrum cannot be assumed, it would seem reasonable to experiment with statistically derived weights.[14]

Neutrality: If a total productivity index is to serve as an unambiguous index of technological change, the net effect of technological change on the aggregate production function must be "neutral". Shifts in the production function are "neutral" if they leave the productivity coefficients unchanged and simply change the output obtainable from given inputs.[15] When technological change is non-neutral no single indicator, such as a total productivity index or the "constant" term of a production function, can adequately measure technological change.

It is difficult to conceive of any individual invention or innovation that is neutral. At the micro level, technological change almost certainly involves a shift in the relative values of the individual factor productivity coeffcients as well as a shift in the "constant" term of the production function, Fortunately, the neutrality tests that have been attempted, although not conclusive, seem to imply that the net effect of technological change on the aggregate production function has been approximately neutral over relatively long periods.[16]

3.0 Filling the productivity gap.

A major limitation of the total productivity approach for development planning is that it does not provide a clear indication of all of the instrumental variables which must be manipulated to bring about productivity gains. At the micro level, it seems apparent that technology is always "embodied" in particular factors. "....when all the factors are completely specified, the technology is also specified."[17] In order to introduce a new technology, it must be embodied in a set of factors that differs qualitatively from the set formerly employed.

This concern has given rise to a further stage in the development of productivity analysis.[18] [19] A number of economists are making a major effort to account for the sources of output growth which are left unaccounted for by conventional measures of labor, capital, and raw material inputs. These additional sources of output growth are frequently grouped under three headings: (a) changes in the quality of labor inputs; (b) changes in the quality of capital inputs; and (c) a new residual frequently identified as either changes in scale or changes in allocative efficiency.[20]

The efforts to quantify investment in education, to measure its effect on the quality of the human agent, and to identify the effect of such changes on output, clearly have reduced the size of the productivity gap. Efforts to introduce adjustments for the quality of capital equipment directly into the production function point the way toward more effective treatment of the role of capital accumulation and investment in the introduction of technical change into the productive process. It seems rather clear, however, that in large economies or in industries with a large number of firms, scale economies are primarily a phenomenon that accompanies the equilibrating process following the introduction of technological change. In smaller economies, or in industries with few firms, it may be somewhat easier to distinguish scale economies from technological change. It would appear that scale economies, as currently measured, represent little more than (a) the reintroduction of "disembodied" technological change under another name, or (b) a reflection of underutilization of existing productive capacity.[21]

A major issue is whether quantification of the effect of qualitative changes and of inputs contributed by the public sectors on output growth can be expected simply to reduce the manitude of the productivity gap or to eliminate it altogether. Schultz, Solow, and Griliches now appear to assume that the residual should be eliminated completely. But Denison and Salter take the position that a substantial residual or gap will remain even after adjustments for quality changes and that the major analytical task is to identify the relative importance of the several factors that give rise to the productivity gap.[22]

The two positions are not entirely inconsistent. In a functional sense, any change in output must be related to one or more changes in factor inputs and is, therefore, completely accounted for by the change in input. On the other hand, firms find it profitable to replace existing factors by new factors of higher quality only if the value of output rises relative to the value of inputs. The ability to completely identify the sources of output growth is not, therefore, inconsistent with use of a total productivity index to measure the resource savings or output gain resulting from technological change.

4.0 Summary and Conclusions

Initiation of a system of productivity accounting probably should proceed in the following sequence:

(1) Construction of partial productivity series for labor, capital, and raw materials for each major sector of the economy. Particular emphasis should be given to the problem of quality changes in the design of the factor input and product series.

(2) Construction of factor share estimates for each major sector of the economy. The factor share estimates should be consistent with the factor input and product series identified above.

(3) Construction of "net" and "gross" total productivity estimates by sector and for the total economy.

(4) Continuous experimentation with functional approaches; regional and industry disaggregation; and others to reduce or to understand the factors responsible for any positive or negative productivity gaps which emerge.

Each step complements and builds on previous steps. Only when step (3) is completed will it be possible to determine whether the "empty box" represented by the "productivity gap" represents a major problem for further analysis.

The feasibility of introducing a system of productivty accounts depends on the progress that has already been made in a nation's social accounting system. A national income, labor statistics, and price reporting system capable of generating accurate measures of annual changes in both "current" and "real" output and employment by sector is an essential prequisite.

The utility of a system of productivty accounts depends on the manner in which the central government participates in the planning and management of economic activity. Under a system of decentralized management where the government (a) utilizes generalized monetary, fiscal, and commercial, policy to regulate level of economic activity and the rate of economic growth, and (b) concentrates direct public investment primarily in the fields of "social overhead" and on the support of research, development and education, the partial and total productivty trends and input-output ratios generated for broad sectors of economic activity provide useful tools for measuring economic performance and for policy guidance.

Data on the rate of growth of inputs, output, and productivity in agriculture, for example, can provide a guide to the success of agricultural research and extension investments. Such measures also represent essential tools in (a) projecting future raw material, land, and manpower utilization for the agricultural sector, and (b) planning for the absorption of rural workers and new entrants to the labor force from rural areas into the non-farm labor force.

Productivity accounting represents a useful addition to a national social accounting system. It is particularly useful for the exploration of questions dealing with the level of inputs necessary to support alternative rates of economic growth. And it provides many of the elements out of which more complete planning models, which include (a) product demand functions, and (b) factor supply functions in addition to (c) the productivity relationships discussed in this paper, can be built. Economies which have not yet initiated a system of productivity accounts can take advantage of the professional discussion that has been reviewed in this paper. They should be able to avoid many of the limitations, particularly the inadequate treatment of qualitative changes, which have been built into the system of productivity accounts in the US and elsewhere.

Appendix on Aggregation.

Definition of inputs and outputs on a gross rather than a value added basis results in an understatement of the productivity index at the industry or sector level relative to the aggregate or economy level since the productivity index for the economy as a whole becomes the weighted **sum** rather than the weighted **mean** of the individual sector indexes.

Assume for example, an economy consisting of two sectors—agriculture and processing. Asume that all of the product of the agricultural sector is used in the processing sector. The production functions for the two sectors and for the economy as a whole can be represented as follows:

For agriculture:

$$(1)\quad Y_1 = A_1 L_1^{\alpha_1} K_1^{\beta_1}$$

For processing:

$$(2)\quad Y_2 = A_2 L_2^{\alpha_2} K_2^{\beta_2} Y_1^{\gamma}$$

For the economy as a whole:

$$(3)\quad Y_2 = (A_1^{\gamma} A_2)\, L_1^{\alpha_1 \gamma} L_2^{\alpha_2} K_1^{\beta_1 \gamma} K_2^{\beta_2}$$

where:

Y = index of output in physical terms.

A = total productivity index.

L = index of labor input in physical units.

K = index of capital input in physical units.

α = ratio of the value of labor input to the value of output in the base period.

β = ratio of the value of capital input to the value of output in the base period.

γ = ratio of the value of raw materials to the value of output in the base period.

The total productivity index can also be expressed as $A = (1+r)^t$, where: t = is the number of years covered by A and r = is the annual rate of change in A.

If between t_0 and t_1 (a) the productivity index rises from 1.0 to 1.7 in agriculture; (b) from 1.0 to 1.4 in processing; and (c) $\gamma = 0.5$ in the base period, the productivity for the economy as a w hole will be:

$$(4)\ A_E = (A_1{}^{\gamma} A_2) = (1.7)^{0.5}\ (1.4) = (1.3)\ (1.4) = 1.82$$

In this example both of the sector indexes are lower than the index of the economy as a whole. It can be shown that if the processing industry absorbs any of the product of the agricultural sector (that is, if $\gamma > 0$) then $A_E > A_2$ More generally, the index for the total economy will be higher than the index for any sector.

If the output of the processing sector is defined on a net basis—after subtracting the raw materials purchased from the agricultural sector—the production function can be rewritten as:

$$(2.1)\ Y_2' = A_2' L_2^{a_2'} K_2^{a_2'}$$

A_E can be computed as the weighted mean of the A_i of the individual industries or sectors.

$$(4.1)\ A_E = A_1\ (Y) + A_2'\ (1 - Y)$$

Domar states that only the productivity index of (4) is correct. Massell argues (a) that the aggregate productivity index of (4.1) is a measure of the productivity growth due to intra-industry changes in technology, and (b) that the difference between the two indexes $\left[(A_E)_4 - (A_E)_{4.1} \right]$ measures the effect of inter-industry resource shifts on aggregate productivity. I have argued elsewhere (see footnote 11) that A_E as defined in 4.1 is the relevant aggregate productivity index for inter-industry comparisons.

Footnotes:

[1] See, for example, *Measures for the Economic Dvelopment of Underdeveloped Countries*, United Nations, Department of Economic Affairs, New York, May 1951.

[2] E. D. Domar, "On the Measurement of Technological Change," *The Economic Journal*, Vol. 71, No. 284, Dec. 1961, pp. 709-729; "On Total Productivity and All That," *Journal of Political Economy*, Vol. 70, No. 6, Dec. 1962, pp. 597-608; and E. D. Domar, *et al*, "Economic Growth and Productivity in the United States, Canada, United Kingdom, Germany, and Japan in the Post-War Period," *The Review of Economics and Statistics*, Vol. 44, No. 1, Feb. 1964, pp. 33-40. See also the literature for the agricultural sector cited in J. Horring, *Concepts of Productivity Measurement in Agrculture on a National Scale*, Documentation in Agriculture and Food No. 57, Orgonization for Economic Cooperation & Development, Paris, 1961 and by L. B. Lave, "Technological Change in U.S. Agriculture: The Aggregation Problem," *Journal of Farm Economics*, Vol. 46, #1, Feb. 1964, pp. 200-217.

[3] I. H. Siegel, "On the Design of Consistent Output and Input Indexes for Productivity Measurement," in National Bureau of Economic Research (NBER), *Output, Input and Productivity Measurement*, Vol. 25, Studies on Income & Wealth, Princeton University Press, Princeton, 1961, pp. 23-46.

[4] George J. Stigler, "Economic Problems in Measuring Changes in Productivity," in NBER, *Ibid*, pp. 47-63; V. W. Ruttan, *Technological Progress in the Meatpacking Industry*, 1919-1947, USDA, Marketing Research Report #59, Washington, Jan. 1964, pp. 15-28.

[5] Stigler, *op. cit.*, p. 48. See also the response to Stigler's position by T. Scitovsky, *Ibid*, p. 270.

[6] The total productivity approach was suggested by M. A. Copeland and E. M. Martin, "The Correction of Wealth and Income Estimates for Price Changes," (Vol. 2, Studies in Income and Wealth), NBER, New York, 1938, p. 127, and by George J. Stigler, *Trends in Output and Employment*, NBER, New York, 1947, pp. 43-45. Early empirical studies conducted in this framework are G. T. Barton and M. R. Cooper," Relation of Agricultural Production to Inputs," *Review of Economics & Statistics*, Vol. 30, #3, May 1948, pp. 117-126; Jacob Schmookler, "The Changing Efficiency of the American Economy," *Review of Economics & Statistics*, Vol. 34, #4, August 1952, pp. 214-232.

[7] This formulation is from Zvi Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940-60," *Journal of Political Economy*, Vol. 71, #4, August 1963.

[8] For examples of the "Index number" approach, see J. W. Kendrick, *Productivity Trends: Capital and Labor*, NBER, New York, 1956 (Occasional Paper 53); Solomon Fabrican, *Basic Factors on Productivity Change*, NBER, New York, 1959 (Occassional Paper 63); Moses Abramovitz, "Resource and Output Trends in the United States Since 1870," *American Economic Review*, Vol. 46, #2, May 1956, pp. 5-23; R. A.

Loomis and G. T. Barton, *Productivity of Agriculture in the United States, 1870-1958*, Technical Bulletin #1238, USDA, Washington, 1961. (The sries used by Loomis and Barton are published annually by the USDA under the title *Changes in Farm Production & Efficiency*.)

[9] The "production function" approach received its major emphasis with the publication of R. M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics & Statistics*, Vol. 38, #4, August 1957, pp. 312-320. For earlier applications, see D. G. Johnson, "The Nature of the Supply Function for Agricultural Products," *American Economic Review*, Vol. 40, Sept. 1950, pp. 538-564, and V. W. Ruttan, "The Contribution of Technological Progress to Farm Output," *Review of Economics and Statistics*, Vol. 38, Feb. 1956, pp. 61-69. The monumental study by John Kendrick, *Productivity Trends in the United States*, Princeton University Press, Princeton, N.J., 1961, apparently went through an evolution from an "index number" to a "production function" approach. Discussion of the preliminary results by Kendrick, Fabricant, and Abramovitz was clearly in the "index number" tradition.

[10] Domar, *op. cit.* (1961), p. 713.

[11] This discussion draws primarily on (a) B. F. Massell, "Aggregative and Multiplicative Production Functions," *The Economic Journal*, Vol. 74, #293, March 1964, pp. 224-228 and "A Dissaggregated View of Technical Change," *Journal of Political Economy*, Vol. 69. #6, Dec. 1961 pp. 547-557; (b) E. D. Domar, *op. cit.* (1961), pp. 709-729; and (c) V. W. Ruttan, *Technological Progress in the Meatpacking Industry, 1919-1947*, *op. cit.*, pp. 15-28. For a more detailed discussion, see the appendix to this paper.

[12] See the references in 8 and 9 above. Sololw argues that the approach used in his 1957 *RES* article does not require explicit specification of the form of the production function. It is clear from his computational procedure, however, that he is employing a Cobb-Douglas (linear in the logarithms) production function in which the sum of the productivity coefficients is equal to unity. There has also been some experimentation with other production functions, such as the constant elasticity of substitution (CES) production, which includes the Cobb-Douglas function as a special case. See K. Arrow, H. Chenery, B. Minhas, and R. Solow, "Capital-Labor Substitution an Economic Efficiency," *Review of Economics & Statistics*, Vol. 43, #3, August 1951.

[13] For further discussion of geometric vs. arithmetic weighing, see Zvi Griliches, "Specification Bias in Estimates of Production Functions," *Journal of Farm Economics*, Vol. 29, #1, Feb. 1957. pp. 8-20; E. D. Domar, *op. cit* (1961). Sicat's recent work comparing the Cobb-Douglas and the new constant elasticity of substitution (CES) production function has indicated additional support for the use of a function linear in the logarithms even for cross sectional analysis where it would appear to face the greatest conceptual difficulties. See G. P. Sicat "Production Functions in Philippine Manufacturing," *The Philippine Economic Journal*, Vol. II, #2, Second Semester, 1963, pp. 107-113.

[14] Zvi Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940-60," *op. cit.*, pp. 331-346. Solow has,

however, recently demonstrated the tendency for statistical production functions to exhibit increasing returns to scale when none exist. See R. M. Solow, "Heterogenous Capital and Smooth Production Functions: An Experimental Study," *Econometrica*, Vol. 31, #4, Oct. 1963, pp. 623-645.

[15] Solow, *op. cit.* (1957); Ruttan, *op. cit* (1954). For a recent review of neutrality concepts, see A. Asimakopulos, "The Definition of Neutral Inventions," *The Economic Journal*, Vol. 73, #292, Dec. 1963. pp. 675-680.

[16] Existing neutrality tests are, at best, rather weak. Lewis has pointed out exceptions to the Solow test. An alterative "weak" neutrality test can be developed based on the tendency of Laspeyre (base year) quantity indexes to be biased upward while the Paasche (end year) quantitiy indexes are biased downward. The productivity indexes are, of course biased in the opposite direction. If technological change is neutral:

$$A_L \leq A \leq A_P$$

If, however, technological change is strongly non-neutral, it is possible to obtain an apparent reversal of the index number bias and

$$A_P \leq A \leq A_L$$

This point is demonstrated, although the conclusion is not clearly drawn, in Yoram Barzel, "Some Observations on the Index Number Problem," *Ecometrica*, Vol. 31, #3, July 1963, pp. 391-399.

[17] T. W. Schultz, *Transforming Traditional Agriculture*, Yale University Press, New Haven, 1964, p. 135.

[18] Major credit for initiating this third stage must be given to T. W. Schultz. See particularly his presidential address to the American Economic Association, "Investment in Human Capital," *American Economic Review*, Vol. 51 #1, March 1961 and his earlier exchange with Heady: T. W. Schultz, "Reflections on Agricultural Production, Output and Supply," *Journal of Farm Economics* Vol. 38, #3, August 1956, pp. 748-762: E. O. Heady, "Output in Relation to Input for the Agricultural Industry," *Ibid*, Vol. 40, #2, May 1958, pp. 393-405; T. W. Schultz, "Output-Input Relationships Revisited," *Ibid*, #4, Nov. 1958. pp. 924-931; E. O. Heady, "On Output-Input Relations Revisted: A Reply," *Ibid*, Vol. 41, #1, Feb. 1959, pp. 134-136.

[19] The major sustained empirical efforts to reduce the productivity gap have been made by Denison, Griliches, and Solow; E. F. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us*, Committee for Economic Development, 711 Fifth Ave., New York 22, N. Y., 1962; Zvi Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940-60," *op. cit.*, pp. 331-364. The literature dealing with change in the quality of the human agent in the United States is summarized in T. W. Schultz, *The Economic Value of Education*, Columbia University Press, New York, 1963. For an attempt to "embody" changes in the quality of the capital

equipment directly into the production function, see R. M. Solow, "Technical Progress, Capital Formation and Economic Growth," *American Economic Review*, Vol. 52, #2, May 1962, pp. 76-86.

[20] Griliches, *op. cit.* (1963) identifies the new residual as economies of scale. It is identified as a change in allocative efficiency resulting from the movement of factors of production from low productivity to high productivity employment by B. F. Massell, *op. cit.* In "Aggregate Production Function and Medium-Range Growth Projections," *American Economic Review* (forthcoming), R. R. Nelson refers to a third set of factors including "improved effeciency in the allocation of resources, principally the result of movement of factors of production from low productivity jobs and better advantage taken of opportunities for specialization and economies of scale.", p. 11 (mimeo).

[21] Solow, *op. cit.* (1963); Salter, W.E.G., *Productivity and Technical Change*, Cambridge University Press, London, 1960, pp. 140-142.

[22] Denison, *op. cit.*, pp. 234-237, 254-255, 264-274; and "The Unimportance of the Embodied Question," *The American Economic Review*, Vol. 54, #2, Part I, March 1954, pp. 90-04. Salter, *op. cit.*, pp. 1-10.