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Inventory and Critique of Productivity Estimates In The U.S. Food and Fiber Sector

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Introduction

A major responsibility of The Economic Research Service has been to monitor and evaluate the performance of the segments of the U.S. food and fiber system. Due to increasing interdependence among the various segments of the sector, the agricultural economics profession is giving greater emphasis to developing consistent economic accounts and performance measures across the entire food and fiber sector. For example, a session at the 1974 AAEA summer meetings was devoted to examining strains on our current data system and suggesting improvements. One paper laid out the conceptual foundation for an expanded economic accounting system that would consistently monitor product flows, capital flows, and capital stocks across all segments of the food and fiber sector (Carlin and Handy). The need for an improved economic accounting system carries over to individual performance measures. Most empirical studies of performance are conducted at the firm or industry level of aggregation. Seldom have our conceptual techniques or available data allowed researchers to monitor performance for the entire food and fiber sector.

As part of an effort to improve performance measures, ERS is expanding its research program for measuring and evaluating the efficiency of resource use in the production and marketing of food and fiber products. Plans include expanding productivity measures to industries not presently covered and to ultimately develop a productivity measure covering total outputs and inputs of the entire sector.

The purpose of this paper is to explore alternative methods for developing a total factor productivity measurement system for the food and fiber sector. Such a measure would allow us to monitor changes in the efficiency with which the sector utilizes inputs in producing food and fiber for final demand.

Defining the Sector

Lack of an operational definition of the food and fiber sector has hindered the development of sector performance measures. The profession seems to be converging on a general conceptual definition of the sector as including the farm inputs subsector, the agriculture subsector, and the product market subsector which includes processing, wholesaling, and retailing (USDA, Upchurch; Carlin and Handy; Walters). While this definition helps to identify the broad parameters of the sector, it has not been a particularly useful guide for empirical studies which must determine which establishments, industries or parts of industries are or not included in the sector. The easiest method would be to define certain industries as in the sector on the basis of direct sales to or purchases from agriculture; for example, the work underway by an ERS task force headed by Conrad Fritsch. However, this approach ignores indirect effects, which can be pronounced. For example, agriculture does not purchase products directly from either the crude petroleum and natural gas or the primary iron and steel manufacturing industries. However, a $1 increase in final demand for agriculture causes an increase in demand of 2¢ for the former and 1¢ for the latter (USDA). Certainly a sector definition which is to be used for productivity analysis is suspect if it implies that these two industries are entirely outside of the food and fiber system merely because agriculture does not purchase from them directly. No single definition of the sector will be suitable for all research and policy objectives. (In fact, a realistic definition must change over time.) Nevertheless, a comprehensive definition using consistent descriptors and data sources would allow individual researchers to develop different configurations of industries to meet individual research needs.

The remainder of the paper will survey existing productivity measures and assess their potential use in developing a total factor productivity series for the food and fiber sector. We then evaluate and compare two alternative methods for constructing such a productivity series. Finally, we suggest which methodology, at this stage, seem most promising for achieving our objective.

Applicability of Existing Measures

To what extent can existing empirical studies be aggregated to construct a sectorial productivity measure? Studies by Gossling and Dovring are particularly relevant as guides for developing sector productivity measures (Gossling, 1964; Gossling, 1972; Gossling and Dovring, 1966; Dovring). Since Gossling defines the final output of his "gross output subsystem" at the farm gate, only agriculture and all direct and indirect inputs required to supply agriculture are included in the subsystem. A more detail discussion of Gossling's input-output approach will follow below. Gossling and Dovring use the "gross-output subsystem" approach to measure aggregated labor productivity in U.S. agriculture. Farm output for final demand is divided by the sum of all labor used directly on farms as well as labor used indirectly to produce purchased farm inputs (both durable and non-durable). This methodology provides a much more comprehensive measure of total inputs than conventional productivity studies, but it needs to be extended beyond the farm gate. Most existing measures of productivity are, like the Gossling and Dovring indexes, partial productivity measures in that they relate output to only one input--labor. Partial productivity measures are useful in showing any savings in the use of a particular input over time, but because of factor substitutions, these measures do not reflect changes in the net efficiency of all inputs used.

Input-output tables were also used in a 1966 study by Gale to compute the total output, labor and value added requirements, and labor productivity for the entire "food subsystem." Expanding Gossling's methodology, Gale defined the food subsystem as all direct and indirect requirements of farming, food manufacturing, food distribution, and transportation industries needed to produce the output represented by civilian expenditures for farm food. In essence, Gale uses the I/O inverse transaction matrix, $(I-A)^{-1}$. A major shortcoming of Gale's productivity measure is that it includes only current production requirements omitting capital requirements.

Beyond these studies, there are several productivity measures for individual industries in the food and fiber sector. A selected inventory of such measures, starting with farm inputs and proceeding through distribution follows.

Though no productivity series exists for individual farm input industries, ERS is developing total factor productivity measures for the farm machinery and agricultural chemical industries. The series, which will extend from 1947 on, computes productivity as the ratio of real value added over a linear aggregation of real labor and capital inputs.

Most productivity studies in the food and fiber sector focus on the farm subsector. They include series on net output per person (U.S. Bureau of Labor Statistics) and total factor productivity series based on gross output over total inputs (Loomis and Barton) and on net output or value added over total input (Kendrick, 1961, p. 363 and 1973, p. 78). A review of agriculture productivity measures and concepts is provided by J. Horring in his 1961 book published by O. E. C. D. Besides aggregate farm output, productivity measures are also available for individual commodities. In particular, Dovring has computed productivity indexes for 12 separate commodities (Dovring, pp. 24-58).

Several studies compute productivity series for various industries within the food and fiber processing subsector. Kendrick computes total factor productivity from 1948 to 1966 for food and kindred products and textile manufacturing. ERS also is developing total factor productivity measures for each of nine 3-digit industries within Food and Kindred Products (SIC 20). Remaining studies in the food processing subsector restrict analysis to measures of labor productivity. These include series computed by BLS (index of output per man-hour for seven food processing industries), ERS (output of farm-originated foods per man-hour for eight food processing industries), and Waldorf's study of value-added per man-hour in factories processing farm food products.

Due to conceptual and data problems in measuring output and associated inputs for the distribution subsector, only a few studies attempt to measure productivity in food distribution. The most comprehensive study computes net output (value added) per man-hour in distributing farm-food products (Waldorf and Gale, and updated in Gale and VanHorn). In a 1969 study of real dollar sales per man-hour in retail trade, Schwartzman constructs separate productivity series for eight store types including food stores and eating and drinking places. Finally BLS is developing an annual labor productivity series for food retailing based on the combined gross output per man-hour of grocery stores and specialty food stores. However, this series, as yet, has not been published.

This sampling of the literature reveals that a large number of individual productivity measures are available for many of the individual segments of the food and fiber sector. Conceptually, individual works might be aggregated industry by industry to develop a sector productivity series. Unfortunately, available measures follow no consistent methodology for measuring outputs or inputs and thus, even if a satisfactory weighting system was found for combining existing industry productivity series, lack of consistency makes any aggregation impracticable.

The Ideal Measure

What do we want in a productivity measure? In evaluating the food and fiber system, ERS is concerned with both economic as well as technological productivity. Productivity can be approached from the very broad perspective of economic efficiency, from the narrower and more traditional perspective of technical efficiency, or from the still more narrow perspective of technological change. In addition to the mechanical transformation of factors and materials into intermediate and final products, economic productivity includes utility. How efficiently are inputs into the food and fiber sector transformed into products and services, and how efficiently does this product and service mix yield consumer satisfaction? As a measure of economic efficiency, ERS had developed an Index of Consumer Satisfaction which will be updated periodically (Handy and Pfaff). When this index becomes available for a longer time series (now one year only), it may be interesting to relate it to sector inputs.

The conventional concept of productivity refers to physical productivity or technical efficiency defined as the ratio of real output to real input (Kendrick, 1961, p. 6; Dovring, p. 8). On the other hand, productivity as a measure of technological change refers to the ratio of real output with current technology to what real output would have been with a base period technology (Solow). These two concepts are easily distinguished by considering a growing economy characterized by increasing returns to scale but no technological progress. The latter measure would show a zero advance in productivity whereas the former would show an increase. Traditionally agricultural studies have used the physical productivity concept (Horring, pp. 30-40). That approach may be superior if you take the view that agriculture has been in a chronic disequilibrium state since the measures of technological change must rely on the annual correspondence between factor shares and the elasticity of output with respect to that factor. Still, it seems best to follow whichever methodology is most practicable and bear in mind its limitations.

Though we see the measure of sectoral productivity as important, this does not imply that measurement of productivity by industry and commodity is not. Ideally a productivity measurement system is needed which will yield both the sectoral measure and consistent industry and commodity measures. It seems unlikely that a measure is possible which will yield disaggregation by commodity since, in the process of marketing, commodities often lose their statistical and physical identities. Beyond the distinction between the above three basic approaches to productivity measurement, we need to very carefully distinguish between two different concepts of industry productivity: we are interested in measuring both productivity advance within an industry and the impact of productivity advance on an industry. Thus an industry which produces an increasing quantity of output from a given mix of primary inputs (labour, land, minerals, etc.) and intermediate inputs (machines, structures, etc.) will show productivity advance within itself. But if intermediate inputs are being produced more efficiently elsewhere in the economy, then the measure of productivity advance on the industry will be greater. To measure productivity change within an industry, the industry's output should be related to its use of primary and intermediate inputs. To measure the impact of productivity change on an industry, one should relate the industry's output to all of the primary input used (anywhere within the economy) to produce that output.

Implementing the Ideal

We conceive of there being two basic ways to measure sectoral productivity. The most obvious is to use one of the neoclassical methodologies to measure productivity separately for each of the industries within the sector and to combine these measures with a weighted average. A number of problems with existing neoclassical methodologies will be discussed below, but the principal problem is the interindustry weighting of separate productivity series. In neoclassical works where such weighting schemes are used, an industry is either entirely within or outside a sector. Yet only certain of an industry's activities may fall within the food and fiber sector (food wholesaling in wholesaling) and in many cases only some proportion of some activities (fiber processing is in the sector to the extent that the sector buys processed fiber and to the extent that fiber processing buys natural fiber).

It is possible to avoid the weighting problem by using the input-output approach to productivity. The I/O methodology should start with an n x n matrix of product flows, an n-dimensional vector of final demands, and n-dimensional vectors of all primary good requirements. The food and fiber sector is defined by asking how much agriculture would have to purchase of each of the other industries in order to be fully vertically integrated. 1/ Basically, the total requirements matrix is used to "track down" all of the primary inputs used in producing sector output. Growth in productivity for the food and fiber sector can then be computed in any of several ways, all relating output to primary input. Furthermore, the above data provide all that is needed for separate measures of productivity for each I/O industry.

Several limitations to this approach need to be noted. Seemingly the most severe limitation is one of data. Except for labor, there is little data on primary input by industry. Gossling and Gale handled this problem by assuming that labor was the only primary good. A further data problem is that productivity can only be computed for the seven years in which comparable I/O tables exist. With labor as the only primary input, this latter problem is probably not as significant as it might seem. It is shown (Gossling, 1972, p. 72) that a short cut mthod proposed by Dovring yields a good approximation in non-I/O years. A final data complication is the requirement of data measuring capital stock by I/O industry.

Several limitations to the credibility of the I/O approach are implied by the necessary assumptions. To use I/O, each industry must be assumed to produce a homogeneous output which sells at a unique price. This assumes away the fact that each I/O industry produces non-homogeneous output which is sold in varying mixes to different buyers. A further source of error lies in the assumption that each industry is in a stationary self-replacing state. This latter assumption permits the summation of the current flow matrix and the capital flow matrix to calculate "total flow" and thus completely measure industry interdependence. The notion of measuring productivity with I/O is not new, but it is not well-known. So it is worth noting that the best explanation of this concept was done by Rymes in an article which should become a classic.

We now consider the possibility of measuring productivity industry by industry and aggregating to a measure for the food and fiber sector. Whereas the sector definition was implicit to the I/O approach, it becomes again an open question for industry-by industry aggregation - one for which there is no existing answer.

Beyond the question of sector definition remains the question of how to choose weights for the interindustry aggregation of productivity indices. Unfortunately, no recognized answer exists to this question either.

There is, however, a lucid new treatment of this question in the form of a preliminary report by Hulten (Hulten, 1974). He handles weighting in the context of going from industry measures of productivity to an economy measure. Thus he does not provide an immediate answer to our question, but his work does establish a theoretical basis for approaching the question - one which is destined to receive much further attention, so we shall consider it. 2/

Hulten's main point comes from distinguishing technical change originating in an industry (measured by R_i) from technical change impacting on an industry (Z_i). His formula for measuring R_i is conventional except that it allows for intermediate input. His formula for measuring Z_i is very unconventional, namely

$$Z_i = \overset{*}{Y_i} - \sum_{j=1}^{M} s_j \overset{*}{J_j}$$

where Y_i is delivery to final demand from industry i; J_j is the total input of primary good J used in all industries; s_j is the share of the primary input in national income; and asterisks denote rates of growth. He develops a set of sufficient assumptions for R_i and Z_i to be correct. He then shows that the rate of shift in the social net production possibilities frontier ($\overset{*}{T_i}$) can be measured from weighted sum of either the R_i or Z_i.

Note that Z_i would be very easy to use for our purposes. It involves only data on deliveries to final demand from each industry plus one Divisia indexed measure of primary inputs for the entire economy. More significantly, note that the formula for Z_i could be applied to easily compute productivity for the food and fiber sector merely by defining Y_i as sector delivery to final demand! Unfortunately Hulten makes two crucial and very restrictive assumption which cast doubt on the usefulness of this approach. Essentially, his formula only works if demand is very well behaved so that supply effects dominate in economic change. Thus Hulten assumes that the economy is closed to international trade; that demand functions are constant over the period of analysis; and that each good has a unitary income elasticity of demand. It needs to be noted that agricultural exports are an extremely important, occasionally volatile facet of demand; that an important element of technological change is the creation of new products so that demand functions cannot be constant; and that the income elasticity of demand for food is generally conceded to be less than one. These factors militate against the use of Hulten's Z_i and thus we are left with the use of R_i which is correct even without the restrictive assumptions noted above. There are, of course, some difficulties with the use of R_i. Except for I/O years, not enough data exist on specific intermediate inputs to measure R_i very well. Further, Hulten's interindustry weighting system needs to be extended, as discussed above.

Having raised the issue of industry by industry weighting, there are other topics remaining to be considered.

Whether capital is treated as a primary good or an intermediate good, its treatment is quite unsatisfactory. In agriculture a large portion of the fixed capital stock goes unmeasured - own account capital. An ERS study indicates that, in 1973, $5.5 billion in capital formation is unidentified and $2.6 billion is unrecorded for cattle alone (Dyer). Important own account items are orchards, livestock, and stands of various perennials (hay and alfalfa). Until measures of these capital items are available, all measures of agricultural productivity must be viewed with suspicion.

The traditional measurement of fixed capital is objectionable. It relies on the identity that the current period capital stock is the previous period stock minus depreciation plus investment. Clearly the item of greatest ambiguity is depreciation. The most common measure of depreciation assumes that it is some constant proportion of the previous period capital stock. This assumption has been the subject of recent attack on the basis of empirical studies of investment and profit (Coen; Mendelowitz). Clearly the method may be attacked on the grounds that it fails to make depreciation dependent on the distribution of investment among goods of various service lives. 3/ Another common measure of depreciation, called double-declining balance, assumes that depreciation is at a rate of $\frac{2}{n}$ for a capital good with a service life of n. This method most commonly is assumed to measure the discounted stream of returns to capital. However, it is easy to show that double-declining balance depreciation implicitly assumes very unrealistic time patterns of returns to capital. For example, if the income stream is discounted at a continuous rate of 10%, then double-declining balance depreciation implies that an entrepreneur purchasing a capital asset with a service life of 10 years expects a declining stream of returns over the life of the asset, whereas he expects a constant stream for a 21-year asset, and a continuously increasing stream for any asset with a service life of over 21 years. This feature of declining balance depreciation is indefensible! Rather than assume a particular pattern for the <u>present</u>

value of the stream of profits, it seems safer to simply assume a pattern to the stream of profits. The Economic Research Service has implemented this latter type of analysis and applied it to capital formation in the food and kindred products industry (Howe, Handy, and Traub).

Summary

Based on the above considerations, we can reach some conclusions as to the optimal approach for measuring productivity for the food and fiber system and its components. At this time the I/O approach seemingly has the most to offer for establishing both benchmark measures of productivity and benchmark definitions of the food and fiber sector. As noted, the use of I/O does involve some strong assumptions. However, the validity of any methodology will depend on a definition of the food and fiber sector, and we can conceive of no sector definition which is valid for productivity purposes and which does not use I/O. Hence any methodology will rely on I/O assumptions.

Hulten's aggregation theorem (on aggregating R_is) should be extended to handle the problems discussed above and used to interpolate between I/O year.

Footnotes

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1/ See Gale, pp. 132-133. Gossling analyzes the related question of how much agriculture would have to purchase of each of the other industries in order to be fully integrated on the input side. (Gossling, 1972, pp.-15-29, 165-179). Conceptually there is little trouble extending Gossling's method to arrive at Gale's.

2/ We thank Dr. Hulten for permission to cite his preliminary report.

3/ Jorgenson and Griliches have defended this practice by asserting, with neither citation nor proof, that the distribution of replacements approaches a constant fraction of the capital stock for any "survival curve" and for any initial age distribution of capital (Jorgenson and Griliches, p. 225). Since investment fluctuates with substantial random and nonrandom components, it seems unlikely that this assertion is true.

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