Concepts of Gross and Net Productivity

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by

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Comprehensive productivity measures are often regarded as superior to the more special ones such as labor productivity. In the words of Solomon Fabricant, "The best measure is one that compares output with the combined use of all resources" (Fabricant, p. 6). The economic meaning of productivity measurement is a complex problem to which I will return toward the end of this paper. It is not the intention to repeat here the whole debate about index-number problems and their bearing on productivity measurement. The focus of the following is instead a problem which has received relatively little attention: how index numbers of productivity may be affected by the level of aggregation on which the analysis is carried out: the whole economy, major industry groups, individual industries, individual firms or individual enterprises.

For this discussion, a distinction will be maintained between gross and net productivity. Gross productivity is defined as the ratio of output over all inputs. Net productivity is the ratio of value added over internal factors of production (labor and capital internal to the industry or firm). The two concepts coincide at the level of the whole national economy, but when the economy is disaggregated into industry groups, etc., the two concepts begin to differ and they generally differ more, the more disaggregated the analysis. A third term, "total factor productivity," is less tractable. It might seem to obey Fabricant's advice, to consider all resources, but it does that only at the level of the national economy. At the industry level, "total factor productivity" as often used (e.g. by Kendrick, 1961 and 1973) becomes a misnomer because intermediate products have been excluded. In addition, the term sometimes also covers other concepts than value added over labor and capital--it is for instance also made to mean <u>output</u> over labor and capital (thus, e.g., Kendrick, 1973, p. 256). Such multiple use of technical terms should of course be avoided.

Net productivity has prevailed in most analyses to date. When gross productivity has begun to attract more attention in recent years (Christensen;

Howe and Handy), this is due to more than a stricter adherence to Fabricant's advice. The problem which gross productivity should answer better than net productivity is that of assigning credit for productivity gains among the several factors which jointly generate these gains (Griliches, Pasinetti, Hulten).

A major problem with gross productivity is the fact that the apparent rate of productivity change is in some measure dependent on the level of aggregation chosen for analysis. The more disaggregated the treatment (the lower the level of aggregation), the slower becomes the apparent rate of productivity change, as will be shown in schematic examples below. This has been observed before (Ruttan, Dovring, p. 64). Gross productivity of an industry (or whatever the aggregation level) is never comparable with that of the economy as a whole.

For some schematic examples, let us first think of an industry (Industry 1) which for simplicity we treat as a closed system (no intermediate products are considered, although there always are such in the real world), and which may be disaggregated into two sub-industries (Industry 1a and Industry 1b) which together comprise all the activities of Industry 1. Then let productivity, over some arbitrary time span, increase by 10%. For Industry 1, we obtain

$$\frac{110\ O_1}{100\ I_1} = 110 \qquad (1)$$

Suppose further that Industry 1a has half of the outputs and inputs of Industry 1, again maintaining the fictitious assumption of a closed system. For Industry 1a the equation becomes

$$\frac{55\ O_{1a}}{50\ I_{1a}} = 110 \qquad (2)$$

Industry 1b, which represents a later stage of production, absorbs the entire output of Industry 1a as input, along with its own internal factors of production, and turns out as its output the same final goods as Industry 1.

Then we obtain

$$\frac{55\ O_{1a} + 55\ O_{1b}}{55\ O_{1a} + 50\ I_{1b}} = \frac{110}{105} = 104.76 \qquad (3)$$

It now becomes obvious that rates of change in gross productivity are not comparable between units of analysis which represent different levels of aggregation (1b versus 1), or which absorb external inputs in their factor mix in different proportions (1b versus 1a). The larger the external inputs are as a proportion of total turnover, the lower will be the apparent rate of change in gross productivity.

By contrast, net productivity changes are comparable irrespective of the level of aggregation. Netting out the factors absorbed from Industry 1a, we obtain for Industry 1b

$$\frac{55\ O_{1b}}{50\ I_{1b}} = 110 \qquad (4)$$

How far gross productivity indexes differ from net indexes, and from each other, depends on two things: the level of aggregation and the rate of change. Level of aggregation may be expressed as the ratio of value added to total output, or Value Added Ratio (VAR). The smaller this ratio, the lower the level of aggregation. The ratio is 100 at the highest level of aggregation, that is the entire national economy, where all intermediate products are netted out and there are no "external" factors of production. The VAR is lower, the larger the "throughput" of external factors and can be quite low on highly specialized enterprises such as chicken farms and petroleum refineries. If industry 1b had only 10% instead of 50% of value added in its gross output, then its gross productivity index would come to only 100.92.

The higher the rate of productivity change, the larger will be the discrepancies we are discussing. If the index for Industry 1 were 200 instead of 110, then with 50% value added, Industry 1b would have an index of 133.33; with 10% value added, it would drop to 105.56. Note that these cannot be aggregated even by exponential reckoning: 1.333 is less than the square root of 2, and 1.056 is less than the tenth root of 2. This will cause some minor difficulty with time series data, when the value-added ratio varies over time.

How dramatic the consequences may be from such differences can be shown, for instance, on the American poultry industries where purchased feed dominates the inputs and represent a very large part of the output value. It is common knowledge that productivity in poultry production rose spectacularly in the 1950s and 1960s, yet their gross productivity rose quite slowly (Dovring, p. 35 sq.). The sharp drop in the relative prices of eggs and chicken meat is thus in no way related to gross productivity.

Different types of index, such as the gross, the net, or other descriptions, may not be comparable between themselves, but neither are they entirely out of touch with each other as long as they reflect some of the same realities. Work on aggregated-labor productivity in American agriculture showed that a long-run productivity trend from the early 1920s to the early 1960s reflected an acceleration factor of 3 1/2% (of the rate of productivity change) per year, and the same acceleration factor can be traced also in the otherwise widely differing indexes of both gross and net productivity (Dovring, pp. 15 sqq.).

As shown above, gross productivity indexes are basically not comparable with each other, unless the level of aggregation (in the sense of the value-added ratio) happens to be the same, which is often not the case. To compound the difficulty, even the same industry may have varying value-added ratios over time, in which case even the same index series is not fully comparable between parts of itself. Such is the case of the index of gross productivity in U.S. agriculture.

Gross productivity may be measured for a variety of reasons, but the most convincing of these is the desire to explain observed changes in productivity--to assign credit to the several factors. Such analysis will require complete specification of factors of production, and net productivity measurement does not do that--it leaves out some factors, and this omission has different impact, depending on how important the omitted factors are. But even the causal analysis based on all factors, as in gross productivity measurement, is less than satisfactory unless we also can compare that which we endeavor to explain, and here gross productivity fails for the reasons developed above. It now appears that gross productivity indexes can be reduced to a comparable scale by translating them into net productivity indexes which, as also shown above, are comparable in the sense that they can be aggregated into larger segments, and into the whole economy, without difficulty. Provided the value-added ratio (VAR) is known, we can start from equations (3) and (4) above, where gross productivity was changed into net by removing the external factors from both sides of the expression. Consequently, external inputs can be computed as the difference between the gross index and the gross index multiplied by the VAR, and the internal inputs as difference between all inputs and the external ones. We then write

$$\frac{\text{Gross index x VAR}}{1-(\text{Gross index - Gross index x VAR})} = \text{net index} \qquad (5a)$$

or, in simpler notation

$$\frac{\text{VAR}}{\frac{1}{\text{Gross index}} - (1\text{-VAR})} = \text{net index}. \qquad (5b)$$

Applying this to the above treated case of Industry 1b with 50% VAR,

$$\frac{.50}{\frac{1}{1.0476} - (1-.50)} = \frac{.50}{.45456} = 1.10 \qquad (6)$$

which is the expected rate of net productivity change.

As an instance, we may look at the productivity index of U.S. agriculture for the years 1940-57. According to Loomis and Barton, p. 1, in those years "agricultural productivity increased at an average annual rate of 1.6 percent, compared with 2.3 percent for the economy as a whole." In net productivity terms, however, agriculture always comes out with higher rates than the national economy (thus Kendrick 1961, p. 364, 3.2% per year 1940-57 for agriculture, idem, p. 330: 2.1% for the national economy, and p. 113: 2.3% for the private domestic economy, all in 1929 prices; Kendrick 1973, pp. 236-255 also shows agriculture consistently ahead of the national economy, in 1958 prices.

The comparison cited from Loomis and Barton is not only misleading as stated. It also misses a very essential point about U.S. agriculture in the period described and after: by rapid productivity gains the industry was weakening its own terms of trade.

Contrary to widespread assumptions, rapid productivity gains are not by themselves conducive to higher incomes in the sector where they occur. It may sometimes seem that way, if the productivity gain was a concomitant of vigorous expansion in goods with high demand elasticities. Wage manipulation also sometimes leaves the same impression, but market forces left unhampered would normally lower the relative prices of the goods being produced under lowered real costs. This is why U.S. agriculture in the 1950s and 1960s needed price supports: with productivity running ahead of that of the whole economy, the relative income of farmers was under downward pressure. Sluggish productivity would have protected these incomes better, but U.S. agriculture is too competitive an industry for that kind of strategy.

The above analysis leads to the question, what do gross and net productivity indexes really mean? Net productivity describes gains in social account but explains very little and has no direct contact with price formation. Measures in constant prices do not directly concern the rate of profit, nor the problem of resource saving which must be judged by the varying prices through which the market reflects varying resource scarcities. Gross productivity is better for analysis of cause and effect, but since it is seldom entirely comprehensive, the data for such explanations continue to be incomplete; and this incompleteness, like the gross-productivity index, varies with the level of aggregation.

These continuing conceptual difficulties with comprehensive productivity measures should redirect our attention toward single-factor productivity analysis, which can be more directly addressed to distinct problems. Use of aggregated-labor productivity (Dovring) did elude most of the index-number problems and showed some economically meaningful relation to trends of relative prices. Before 1973, the price of labor--the distribution of national product between persons--was the single most important issue for which productivity analysis could be undertaken. For the future, we should also envisage comprehensive energy-productivity analysis as a tool to explore what has now become a survival issue in industrial economies. The energy-productivity performance of the food and fiber complex should be an important component in this work, and can be pursued by similar techniques as aggregated-labor productivity analysis.

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