Total Factor Productivity Trends in the Southern and Western Wood Products Industries

Robert C. Abt  
North Carolina State University

Brian C. Murray  
Research Triangle Institute

Introduction

The theme of the 1992 SOFEW meeting is enhancing productivity. Productivity relates production of outputs to consumption of inputs. As a measure of performance it estimates the efficiency in converting inputs to outputs and as such is an important measure of interregional and international competitiveness. While the notion of relating outputs to inputs is simple, the measures we have traditionally used have serious limitations. Advances in producer theory and index number theory have given us the ability to more accurately measure productivity.

Discussions of productivity in forestry are often centered on site productivity where the emphasis is usually on volume per acre. While technological advances have allowed for increases in volume per acre, economists often find that the focus on this particular measure of productivity leads to questionable financial decisions. Examples might include overly-intensive site preparation or excessive planting densities. Clearly economic efficiency measures should relate the output (volume) to all inputs, rather than one (acres).

Economists may be quick to criticize volume/acre decisionmaking, but unfortunately we have historically had our own version of single input performance measurement. "Productivity" of industries has traditionally been measured as output per employee or manhour. While it is more appropriately referred to as the average product of labor, "labor productivity" suffers from the same disadvantages that volume per acre does as a performance measure. While labor productivity may be higher in one region, this may be more than offset by higher capital productivity in another region.

A correct measure of performance must be able to account for all inputs and outputs. The technical issues in combining input and output quantity measures to measure total factor productivity are described briefly in the next section. That is followed by an application to the lumber and paper industries in the U.S. south and west.

Methodology

To avoid the the arbitrary nature of comparing output to a particular input requires a method for aggregating inputs. One approach to analyzing productivity is to use econometric techniques to estimate the aggregate cost, profit, or production functions. The analysis of aggregate production or profit functions often includes time as a proxy for technical change or productivity shifts.

---

1  Presented at the 1992 Southern Forest Economics Workshop in Mobile AL, April 30, 1992. This research was conducted while Brian Murray was an economist with the USDA Forest Service at Research Triangle Park. It was funded by Forestry Canada and the USDA Forest Service, Forest Products Laboratory.
While this approach is appealing due to the explicit analysis of production, parametric analysis requires either maintained hypotheses about the nature of the production function or an extensive database to be able to use the flexible functional forms that allow these hypotheses to be tested. Analysis of productivity using a time trend variable also imposes constraints on the the nature of production shifts. Usually a constant rate of change is assumed which does not allow measurement of variation over time due to business cycles or other factors.

An alternative approach to measuring productivity is based on index number theory. This non-parametric approach focuses on aggregate indices of input use and production while imposing minimal assumptions about the underlying production process. To the extent that more information about the production function is known (returns to scale, etc.) the indices can be adjusted to be consistent. Total factor productivity is measured by comparing the changes in the aggregate output index with the aggregate input index.

Measures of single and total factor productivity in this paper were computed using the Tornqvist-Theil discrete time approximation of the Divisia index of total factor productivity.

\[
\frac{\text{TFP}_t}{\text{TFP}_{t-1}} = \exp \left( \sum_{i=1}^{n} \frac{1}{2}(S_{i,t} + S_{i,t-1}) \ln \frac{Y_{i,t}}{Y_{i,t-1}} - \sum_{j=1}^{m} \frac{1}{2}(R_{j,t} + R_{j,t-1}) \ln \frac{X_{j,t}}{X_{j,t-1}} \right)
\]

In this equation, \( n \) is the number of outputs, the \( S \)'s represent the shares of the \( i \)'th output in period \( t \), the \( Y \)'s are the output quantities, \( m \) is the number of inputs, the \( R \)'s are the input cost shares, and the \( X \)'s are the input quantities.

Diewart proves that this formulation is the exact index to the translog transformation function. This allows for a flexible representation of the underlying technology with fewer restrictions than other functional forms (e.g., Cobb-Douglas, CES). For this reason, this index is referred to as one in a class of "superlative" indexes.

Though it does not provide a complete measure of productivity, examining single inputs trends relative to output is a useful way to look at production dynamics. In our study, single factor productivities (SFP's) are computed in the same Tornqvist format as above, except that the right term reflects the change in the individual input (not share-weighted), which is subtracted from the share-weighted change of outputs. This yields a measure of the relationship between changes in the individual input and the composite output.

DATA

GENERAL

The basic source of information was the Department of Commerce Census of Manufactures and Annual Survey of Manufactures. The lumber industry was defined as SIC 242, sawmills and planing mills. Alabama, Georgia, and Mississippi were chosen to represent the south based on the size of the industry in these states and the associated availability of data over time. Due to a lack of SIC 26 data for Mississippi, the southern region for SIC 26 consisted of Louisiana, Alabama and Georgia. Since cost of materials data are not available for earlier years, 1964 is
the beginning year of the series. The latest regional data are from the 1987 Census of Manufac-
tures; national 1988 Annual Survey data are available. National growth rates were used to update regional data to 1988, the last year in the series.

SIC 242

State data were not available for the years 1968, 1979, 1980, 1981, 1984, 1985, 1986. For 1968 and 1984-1986 SIC 24 data were available and the interpolated SIC242/SIC24 was used. No regional data are available for the years 1979-1981. For these years the state SIC 242 to national SIC 242 ratio was interpolated to fill the gap. Additional gaps for some series were filled using the SIC242/SIC24 ratios if available, otherwise regional or national trends were used.

SIC 26

For two-digit SIC industries there were gaps in 1968 and 1979-1981. These gaps were filled by trends in the national industry. In some cases gaps from individual states were interpolated by using available data for SIC 26 three digit sub-industries.

LABOR

Labor cost was derived from regional payroll data. Total compensation adjustments were made based on figures for the national SIC 242 and SIC 26 industries. Production and non-production worker quantities were combined to produce a Tornqvist output index weighted by shares derived from payroll and wage data.

MATERIALS

SIC 242

Census year national cost of materials breakdowns were used to determine wood and non-wood material expenditures. These tables are not available for regional industries. Energy was usually less than two percent of the material bill and was not separated from other materials. The wood percent of materials was steady around 80 percent during the 1960's and 1970's and slowly trended upward to 84 percent in 1987. These national percentages were applied to the cost of materials available in each region. Species weighted Tornqvist indices of regional wood prices in the south were used to deflate materials expenditures into an output index. National Forest log price data from the TAMM database was used to create the western log price index which was used to deflate western wood expenditures. The all commodity producer price index was used to deflate non-wood materials in both regions.

SIC 26

Wood, energy and other materials expenditure shares were taken from the Census data as for SIC 242. Wood prices for the south were based on species weighted index of pulpwood prices. Western chip prices were used to deflate western wood expenditures. Energy expenditures were deflated by the processed fuels and lubricants deflator. Other materials were deflated by the SIC 26 producer price index.
Regional data on capital expenditures were available beginning in 1958. National capital expenditure data were available in unpublished BEA reports back to 1890. A perpetual inventory method as described in Bureau of Labor Statistics Bulletin 2034 was applied to regional capital expenditure data. Regional expenditures prior to 1958 were based on national trends. The national machinery/structure proportions were used to categorize regional expenditures. An equipment service life of 13 years and a structure service life of 28 years was assumed based on BEA data. A dispersion of service lives based on a standard deviation equal to one-fourth the service life was incorporated into the analysis. The expenditure deflators were the U.S. machinery and structures investment deflators as reported in the Economic Report to the President.

Rental prices were derived from a "tax-free" simplified formula based on the Griliches and Jorgenson. The rate of return was set to the AAA bond rate; depreciation was derived from the perpetual inventory model; capital gains were based on average price appreciation over the previous three years. Capital cost shares were derived by applying the rental price to the real stock derived with the PIM model.

Due to a lack of historical expenditure data, the "value-added" approach as described in Ghebreemichael, Roberts and Treheway was used to estimate capital stock. This approach treats value-added as returns to capital and deflates these returns with the rental price of capital to yield a quantity measure of capital stock. The resulting stock estimates are more volatile and less reliable than those obtained with the perpetual inventory method. The rental price was based on the above formula, where depreciation was based on the double-declining balance method with an assumed service life of 16 years for equipment and 31 years for structures.

Output quantities were estimated by deflating shipments data by Tornqvist indices of output prices. Data on output shares by category were available for the national SIC 242 industry for each year in the period. These shares were used to separate output into hardwood/softwood proportions which were then deflated by regional species-weighted Tornqvist lumber price indices. SIC26 output was derived by deflating shipments by the SIC 26 producer price index.

Results

Lumber industry

Figures 1-15 show lumber industry trends in prices, quantities, and productivity measures. Wood is the largest single factor input into the production of lumber, accounting for between 50 and 62 percent of total costs in both regions throughout the period. Capital accounts for the smallest share of input costs, averaging around 7 percent in both regions. Part of the reason for the small capital share may be due to the simplified way in which capital service prices are computed.
Capital accumulation rises steadily through the 1970's and early 1980's in both regions. Capital stock in the South has leveled off since the 1982 recession, while net divestment of the capital stock since 1982 is occurring in the West. The average annual growth for capital is 3.18% and 1.35% respectively for the South and West. SFP measures for capital indicate negative growth in both the West and South, as capital growth has exceeded output growth.

Labor input has declined in both regions, but most notably in the West where there is an average decline in the labor force of 1.18% per year, compared to a 0.41% decline in the South. Labor prices have increased faster in the south. SFP measures show that average productivity gains are higher for labor than for other inputs: 3.14% in the South and roughly 2% in the West.

Wood use has declined over time in the West (-0.48%), while having risen steadily in the South (2.47%). This corresponds with productivity gains in the use of wood in the West (1.33% per year) that are not matched in the South (0.67%). The interregional trends in both wood use and the productivity of wood conversion to lumber are consistent with results from the TAMM market model (Adams ands Haynes) used by the U.S. Forest Service. Different trends in wood productivity between regions might be attributable to the conversion of old-growth forests in the West to managed forests, or perhaps to the increasing importance of mill chips and residues as an output component in the West.

The average annual growth in TFP is nearly identical for both regions. This is particularly interesting in light of the fact that the components of the TFP measure (e.g., output growth, capital accumulation, etc...) are generally quite different for each region. This is indicative of an industry characterized by competing regional markets that adapt efficiently to the factor markets particular to each region.

Paper and Allied Products

Figures 16-30 show pulp and paper industry trends in prices, quantities, and productivity measures. Since the industry as defined here includes significant secondary processing, the trends do not necessarily reflect performance of the primary wood-using sector.

Materials are the largest component of input costs in the paper industry, followed by capital and then labor. The capital share is significantly larger in the paper industry than in the lumber industry, partly due to the different methods used to compute capital costs (value-added method rather than the perpetual inventory method), but largely due to the technological nature of paper production.

Capital accumulation shows a steady growth rate in both regions, but particularly in the South (5.14% per year average). Labor growth averages less than 1%, while materials and energy use grow steadily but not as strong as capital in either region.

SFP measures indicate that average capital productivity declines significantly in both regions, where labor productivity rises sharply and materials and energy productivity growth is moderate. This substantial surge in capital accumulation at a rate substantially faster than output growth yields measures of TFP that are very slightly negative for both regions (-0.03% and -0.20%). Because the measure of capital stock is not as reliable using the value-added method, comparisons of TFP should be made with caution.
Literature Cited


Lumber Industry Trends.

Figure 1

Southern Input Prices

Western Input Prices

Figure 2

Wood Prices

Labor Prices

Figure 3

Figure 4

Output Quantities

Western Input Quantities

Figure 5

Figure 6
Lumber Industry Trends (continued).

Figure 7

Southern Input Quantities

Figure 8

Single Factor Productivities

South

Figure 9

Single Factor Productivities

West

Figure 10

Wood Productivity

Figure 11

Labor Productivity

Figure 12

Capital Productivity
Lumber Industry Trends (continued).

Figure 13

Figure 14

Figure 15
Pulp and Paper Industry Trends (continued).

Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

Figure 27
Pulp and Paper Industry Trends (continued).

**Figure 28**

**Total Factor Productivity**

*Pulp and Paper South*

**Figure 29**

**Total Factor Productivity**

*Pulp and Paper West*

**Figure 30**

**Total Factor Productivity**

*Pulp and Paper*

---

82