Sources of Productivity Change in the U.S. Forest Products Industries

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Abstract.—Productivity growth is an important component of long-term economic growth. It has been estimated that historically, productivity increases have accounted for as much as one-third of the growth rate in the United States. At the aggregate and sector level, productivity measures are used as indicators of the health of industry and the economy. This paper explores the sources of productivity change in the U.S. forest products sector. The potential sources of productivity change are analyzed through a review of the literature and a nationwide mail survey of plant and mill managers. Survey results were analyzed to (1) identify the important factors involved in productivity change; and (2) assess the relative importance of these factors among industry groups and geographical regions. Results indicate that regions do differ in the sources of productivity change.

Keywords: Technological change

Introduction

Productivity increases have historically been an important source of economic growth. It has been estimated that productivity increases have accounted for as much as a third of the growth rate in the United States (Jorgenson, 1980). Economists have noted a recent alarming slowdown in the rate of productivity growth. From 1950 to 1973, the U.S. economy grew at an average annual rate of 2.1 percent, dropping to an average annual rate of 0.3

1


This research was supported by the USDA Forest Products Laboratory, Madison, WI Cooperative agreement USDA-FP-81-0325 and the University of Minnesota Computer Center.


92
Figure 1. Breakdown of geographical regions
percent from 1973 to 1977 (Denison 1979). Part of the decline in the aggregate productivity growth rate has been attributed to significant changes in the composition of output. The rapid expansion of the services sector, which has traditionally exhibited low rates of productivity growth, is often cited as a major factor in the decline. However, declines in productivity growth are evident at the sectoral level as well. Productivity for U.S. manufacturing increased at an average annual rate of 2.2 percent between 1973 and 1979 compared with an average annual rate of 2.7 percent between 1947 and 1973 (American Productivity Center 1980).

This paper explores the sources of productivity change in the U.S. forest products sector. In the first section, the potential sources of productivity change are analyzed through a review of the literature. In the second section, differences in the sources of productivity change between industries comprising the primary forest-based sector and differences across geographical regions were examined by means of a nationwide survey. The sector was grouped into eight product categories: (1) softwood lumber, (2) hardwood lumber, (3) softwood plywood, (4) hardwood plywood and veneer, (5) particleboard, (6) structural particleboard, (7) pulp, paper, and paperboard, and (8) fibreboard, hardboard, and medium density fiberboard (MDF). The sector was further broken down into three geographical regions: the west, midwest, and south. (figure 1).

**PRODUCTIVITY CONCEPTS**

Productivity is defined conceptually as the ratio of outputs to factor inputs. Productivity change in an economic sense is the relative efficiency of production over time. Economic production is an amorphous term that implies some process where raw materials and other inputs are transformed into goods and services that can be used by society. The relationship between inputs and outputs is a purely mathematical one. Productivity change is measured by establishing an input-output relationship for some base period. Then future output, predicted using the base period input-output relationship, is compared with the actual output level. The residual—output that cannot be explained with the base period input-output relationship—represents productivity change. Table 1 provides a sample of productivity growth estimates for the forest-based sector.

The productivity growth estimates reported in table 1 vary substantially. In some cases the reported averages are taken over different time intervals and for different components of the forest products sector. The empirical measures, however, are often very sensitive to the manner in which the variables are constructed. For example, the Jorgenson estimates are adjusted for demographic and educational changes in the labor force over time and the Kendrick estimates are not. The estimates in table 1 represent average trends only. Depending on the level of aggregation and the characteristics of the individual industries that comprise the group for which the estimate was made, these results may provide little insight into productivity change at the industry or regional level. These types of problems may be especially pronounced for the forest products sector because of the regional nature of some forest products industries and the diversity of the sector in terms of
products and manufacturing processes. The general lack of published data at a regional and industrial level only exacerbates the measurement problems.

Table 1. Alternative estimates of the average annual rate of productivity change in the U.S. forest products industries.

<table>
<thead>
<tr>
<th>Annual Productivity Change (percent)</th>
<th>Time Interval</th>
<th>Industry</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>1948 - 66</td>
<td>paper &amp; allied products</td>
<td>Kendrick (1973)</td>
</tr>
<tr>
<td>3.4</td>
<td>1948 - 66</td>
<td>lumber &amp; wood products</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1948 - 66</td>
<td>paper &amp; allied products</td>
<td>Jorgenson (1980)</td>
</tr>
<tr>
<td>-0.6</td>
<td>1948 - 66</td>
<td>lumber and wood products</td>
<td></td>
</tr>
<tr>
<td>1.75</td>
<td>1949 - 70</td>
<td>lumber &amp; wood products</td>
<td>Robinson (1975)</td>
</tr>
<tr>
<td>2.89 - 4.54</td>
<td>1958 - 81</td>
<td>paper</td>
<td>De Borger &amp; Buongiorno (1985)</td>
</tr>
<tr>
<td>1.00</td>
<td>1958 - 81</td>
<td>paperboard</td>
<td></td>
</tr>
<tr>
<td>3.10</td>
<td>1958 - 76</td>
<td>logging camps &amp; contractors</td>
<td>Risbrudt (1979)</td>
</tr>
<tr>
<td>1.80</td>
<td>1958 - 76</td>
<td>sawmills &amp; planing mills</td>
<td></td>
</tr>
<tr>
<td>2.40</td>
<td>1958 - 76</td>
<td>pulpmills</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td>1958 - 76</td>
<td>papermills, no building paper</td>
<td></td>
</tr>
<tr>
<td>3.95</td>
<td>1951 - 73</td>
<td>lumber &amp; wood products (LABOR)</td>
<td>Greber &amp; White</td>
</tr>
<tr>
<td>-0.51</td>
<td>1951 - 73</td>
<td>lumber &amp; wood products (CAPITAL) (1982)</td>
<td></td>
</tr>
</tbody>
</table>

SOURCES OF PRODUCTIVITY CHANGE

Sources of productivity change can be broadly grouped into two categories -- environmental factors and technological change factors. The environment is broadly defined to include all cultural, legal and institutional, and economic factors that determine a firm's (and an industry's) structure and the conditions under which it functions. In the broadest context, technological change refers to the process by which the environment is changed or modified over time in response to needs or opportunities. The linkages between these two sources of productivity change are indicated below.
The distinction between the two categories, the environment and technological change, as described here is primarily temporal. Technological change is a continuous process involving the creation and adoption of new techniques by industry and the public sector. In some cases the new products and processes are adopted to replace existing ones. In general this process of adoption, the critical step in productivity change, is often slow, averaging 10 to 15 years in the U.S. (Mansfield 1963). In the present study, a static viewpoint was taken with regard to the environment, and such a "snapshot" view presupposes a given state of technology. The two categories, technological change and the environment, are inexorably linked because the environment acts as a constraint on the integration of new technology and the integration of new technology in turn results in changes in the environment. (Binswanger and Ruttan 1978).

Environmental Factors and their Impact on Productivity

Changes in the environment under which a forest products firm operates can directly influence productivity. Decisions about plant size, equipment, organization, and other production matters are made given existing environmental conditions and expectations about future operating conditions. The ability to adapt to unexpected changes, both positive and negative, determine the degree to which productivity is affected. Some examples of environmental change include new government regulations on environmental quality, tax law changes, demand and supply changes for raw materials resulting in significant price changes and quality changes in the wood resource. The degree to which forest products firms can respond to these changes depends on the nature of the production technology, specifically the degree of possible factor substitutions and the productive nature of the input itself. The better a firm can substitute factors, the better it can respond to changes in input supplies and the less productivity is affected. At a more aggregate level, changes in the environment may lead to changes in the structure of the industry, in the degree of competition, for example.

For forest products firms, commercial innovation can be conceptually separated into two broad categories -- product innovations and process innovations. Product innovations include all new products; those that are substitutes for existing products and those that have entirely new uses. Process innovations involve changes in the production process itself,
modifications to both existing manufacturing processes and entirely new processes. Here, "manufacturing process" includes the entire scope of production including management, organization, and marketing functions in addition to the mechanical process. Product innovations give rise to new products and industries. New industries are often characterized by the relatively rapid adoption of new processes (Hill and Utterback 1980). And these process innovations contribute to productivity growth (Boretsky 1980).

The process of commercial innovation is critical to forest products firms because this process can lead directly to increases in productivity. Commercial innovation occurs primarily as a firm's response to its operating environment (Hill and Utterback 1980). One important factor is a changing relative price structure of production inputs and outputs. Changing relative prices of outputs and inputs can adversely affect earnings and hence profits. The importance of changing relative factor prices in the commercial innovation process in agriculture has been documented by Binswanger and Rutten (1978). The adoption of new industrial processes to utilize wood residues for energy in the pulp and paper industry is an example of an industry's response to changing relative prices of inputs. In this case the need was precipitated in an energy intensive industry by a rapid increase in the price of fossil fuels.

In addition to changes in economic conditions, the commercial innovation process for forest products firms can be initiated because of government intervention. Federal, State, or local regulations may require the firms in an industry to modify some part of their production process. Pollution controls are one example of this type of legislation. Of course, the effect of this type of control depends on how strongly the regulation is enforced.

Research, both basic and applied, is also an important component of the innovation process for forest products firms. It has been argued that the level of research and development activity by firms has been too low (Nelson 1959). Terleckyj (1980), in investigating the role of industrial research and development in the productivity growth of the manufacturing sector, found that privately financed industrial research and development had a significant effect, but that government funded research did not.

Environmental changes may also result in inputs not being utilized to their highest technological potential. As Leibenstein (1966) points out, "People normally operate within the bounds of a great deal of intellectual slack." Striking examples of this phenomenon include many labor force problems. The key, according to Leibenstein, is utilizing the labor input to its fullest extent is motivation. This point is especially relevant today because changes in our social and cultural environment together with reluctance on the part of producers to adapt to these changes, have made us more aware of the relationship between worker motivation, worker attitudes, and productivity (Rozen 1982). Over the past decade there have been significant changes in the labor force, most notably the increasing average educational level of workers and the rapid influx of women into the labor force (Kerr 1979). In addition, there has been a substantial increase in the demand for what Kerr terms good jobs, jobs leading to personal self-fulfillment and political rights in the
work place. These demographic and cultural changes in the labor force may manifest themselves in three basic forms: skill deficiency, overvalued self-evaluation, and job deficiency (Rozen 1982). Two basic approaches to these labor force motivation problems are apparent in the literature -- modifying the work organization to explicitly include incentive systems, both monetary and political, and employing only those workers most likely to be satisfied with a given job. The choice of group incentive systems as a solution to worker motivation problems derives from the public goods aspects of the work environment. Examples of this include safety conditions, lighting, heating, speed of production, firm policies regarding layoffs, work sharing, and formal grievance procedures. All employees are affected by these factors and cannot be excluded from their benefits. With public goods, the individual incentive to express preferences concerning the amount of a factor desired is reduced so collective decision making is necessary to achieve optimum amounts of these factors (Freemand 1978).

McCord (1975) has shown the importance of motivation in a study of financial incentive systems in the pulpwood industry of Georgia. McCord tested three incentive systems and their effects on production. Of the incentive systems studied, Plan A, a guaranteed hourly wage plus a premium tied to actual production, yielded the highest level of production. Plan C, a base rate plus a system of non-monetary compensation (coupons redeemable for merchandise), resulted in no increase in previous output levels. Plan B, a straight piece rate also resulted in increases in the level of output. Greene and Podsakoff (1978), in a case study in two large paper mills, found that output level and work satisfaction declined dramatically after eliminating a performance contingent pay plan. With regard to specific firms, Reed-Forestville achieved increases in labor productivity of 60 percent after instituting a financial incentive system where bonuses were paid for production over set monthly quotas for timber harvesting (Anvik 1979). Great Lakes Paper reported savings of $3/cord as a result of instituting a group performance incentive system for operators and mechanics in timber harvesting operations (Bartholomew 1977).

A SURVEY OF IMPORTANT FACTORS IN PRODUCTIVITY CHANGE

A mail survey was used to further study productivity change in forest products firms. A list of specific factors was developed from discussions with industry representatives and from a review of the research literature (Strees, 1984). Respondents were asked to indicate how important they perceived each item (or factor) to be in the situation described in each part of the survey by checking one of the four listed "levels of importance" -- very important, moderately important, slightly important or not important and to rank the five factors they perceived as most influential.

The survey questionnaire was sent to plant and mill managers from the eight industry product categories. The sample was obtained from plant and mill listings from the 1982 Directory of Forest Products Industry and the 1982 Lockwood's Directory. Of the 738 questionnaires, 451 were returned for an overall response rate of 61 percent.
The list of factors from part I of the survey -- factors contributing to the decline in the rate of productivity growth -- are listed in table 2. Resource quality factors such as decreasing average log size and the increasing proportion of inexperienced unskilled workers in the labor force can result in productivity growth declines if firms cannot compensate. Unskilled and/or inexperienced workers may not be able to handle complex production equipment as efficiently as their skilled counterparts. Likewise, productivity growth rate declines are probable where production equipment is being utilized to handle smaller logs than for which it was designed.

Legal factors such as environmental and worker safety regulations have required firms to divert some otherwise productive resources in order to comply. Adversary labor-management relations can result in significant resource diversions as well (Clark 1980). These diversions of otherwise productive resources can decrease the potential for productivity growth.

Factors such as government harvesting policies on public lands, rapid increases in the price of fossil fuels, and cyclical markets can disrupt supply and adversely affect productivity growth when production processes cannot accommodate these disruptions. Inputs can only be substituted within the constraints of existing production technology.

The factors listed under technological change indicate possible sources of inefficiency in the innovation process. Because many forms of technological change in the forest products industries are developed outside the industry and are manifested as new equipment, the factors listed under this category are concerned with problems encountered in the transfer and adoption of new capital embodied technology.

The list of factors from part II of the survey, factors stimulating an increase in the rate of productivity growth, are also listed in table 2. These factors generally relate to different aspects of the innovation process.

Survey Results

Each factor in parts I and II of the questionnaire was analyzed separately. Statistical relationships between the levels of importance for each factor, industry group, and geographical region were analyzed using a categorical data analysis approach (Fienberg 1981). For each factor, a three dimensional contingency table was constructed with importance level cross-classified by industry group and geographic region. Of the three categorical variables-- importance level, industry group, and geographic region-- industry group and geographic region can be thought of as explanatory variables and importance level as a response variable. Three model types were considered to explain the relationships among the variables -- joint independence, conditional independence, and no three-factor-independence. For the joint independence model, industry group and geographical region are
Table 2. Productivity change factors from the Forest Industry Productivity Growth Study questionnaire.

Part I. Factors contributing to the decline in the rate of productivity growth.

**Environmental Factors**

- Decreasing average log size
- Increased proportion of inexperienced unskilled workers in the labor force
- Adversary labor (unions) - management relations
- Cost of complying with environmental regulations
- Cost of complying with worker safety regulations (OSHA)
- Tax laws
- Government harvesting policies on publicly owned timber lands
- Rapid increases in the price of fossil fuels
- Plants operating at less than full capacity as a result of volatile product markets (cyclical markets)

**Technological Change**

- Limited commercial availability of new technology and equipment
- Cost of new equipment
- Finance cost of capital
- Inadequate expenditure on research and development

Part II. Factors stimulating an increase in the rate of productivity growth

- Developing and implementing specialized employee training programs
- Establishing financial incentives programs for employees
- Establishing company-wide productivity improvement programs
- Increased mechanization induced by an inadequate labor supply
- Availability of new (or better) processing equipment
- Development of computer-based process control equipment
- Increased expenditures for research and development by private firms
- Increased federal (state) expenditures for research
- Cooperative research and development programs between companies
jointly independent of importance level, implying no statistical relationship between the variables. Two conditional independence models were considered: (1) for a given industry group, importance level is independent of geographic region; and (2) for a given geographic region, importance level is independent of product group. The no three-factor independence model involves two sets of pairwise relations between the variables, Importance level - product group and importance level - geographic region. Each pair of interactions is independent of the excluded variable. Survey data for each factor in parts I and II were fitted to each of the four models.

Table 3 provides a regional breakdown of the five most important factors contributing to productivity change from parts I and II of the survey. Among the most important sources cited for the declines in the rate of productivity growth, both across industries and geographical regions, are: the cost of new equipment, the finance cost of capital, and plants operating at less than full capacity as a result of volatile product markets. A key factor is the reduction in plant utilization rates as a result of cyclical product markets. Lower plant utilization rates must be considered when estimating the benefits from adopting and installing new technology and equipment, and these benefits must be weighed against the costs. A profitable innovation could conceivably become unprofitable under conditions of excess plant capacity. Increasing interest rates add unsteadiness to many of the forest industry product markets in addition to increasing the opportunity cost of financial resources. Again, the result is an increase in the cost of new or replacement equipment.

Although there were few explicit factors concerning labor quality in part I of the survey, it was evident from both the additional factors listed by many survey participants and the results from the labor related factors listed in part II that the apparent decline in labor quality is believed to be an important factor contributing to the decline in the rate of productivity growth for all industries sampled. Survey responses suggest that declines in labor quality are not the result of an increased proportion of inexperienced, unskilled workers in the labor force, because this factor was listed as relatively unimportant by all sampled groups.

However, industry groups differed in their views on solving labor quality problems. Developing and implementing specialized employee training programs was cited as an important factor by the hardwood plywood and veneer, the pulp, paper and paperboard and the fibreboard, hardboard, and MDF product groups while the softwood and hardwood lumber groups favored substituting capital for labor (as expressed in the high rankings for the factor: increased mechanization induced by an inadequate labor supply) and, to a lesser degree, establishing financial incentives programs for employees. There are regional variations in these factors as well. Financial incentive programs are favored in the west region while specialized employee training programs are favored in the midwest and south regions.

In the softwood and hardwood lumber product groups the labor input has the largest share of the total product cost. Past productivity gains have occurred largely as a result of the substitution of capital for labor through
Table 3. Regional productivity change factors.

Part I. Factors contributing to productivity declines

West
1. Finance cost of capital
2. Plants operating at less than full capacity as a result of volatile product markets
3. Government harvesting policies on publicly owned timber land
4. Cost of complying with environmental regulations
5. Cost of new equipment

Midwest
1. Finance cost of capital
2. Cost of new equipment
3. Plants operating at less than full capacity as a result of volatile product markets
4. Rapid increases in the price of fossil fuels
5. Adversary labor (unions) - management relations

South
1. Finance cost of capital
2. Cost of new equipment
3. Plants operating at less than full capacity as a result of volatile product markets
4. Rapid increases in the price of fossil fuels
5. Decreasing average log size

Part II. Factors stimulating productivity increases

West
1. Establishing company-wide productivity improvement programs
2. Availability of new (or better) processing equipment
3. Development of computer-based process control equipment
4. Establishing financial incentives programs for employees
5. Developing and implementing specialized employee training programs

Midwest
1. Availability of new (or better) processing equipment
2. Establishing company-wide productivity improvement programs
3. Developing and implementing specialized employee training programs
4. Increased mechanization induced by an inadequate labor supply
5. Increased expenditures for research and development by private firms

South
1. Availability of new (or better) processing equipment
2. Establishing company-wide productivity improvement programs
3. Development of computer-based process control equipment
4. Developing and implementing specialized employee training programs
5. Increased mechanization induced by an inadequate labor supply
labor-saving technological change (Greber and White 1982). It is not surprising then that firms in these product groups would advocate the continued substitution of capital for labor. Labor required for these product groups is generally unskilled. Therefore, financial incentive programs are likely to be more effective in generating productivity increases in these product groups than specialized employee training programs.

Decreasing average log size was cited as an important factor by the softwood and hardwood lumber and the hardwood plywood and veneer product groups. Rapid increases in the price of fossil fuels is an important consideration in the pulp, paper and paperboard product group -- a particularly energy intensive industry.

Government harvesting policies on publicly owned timber lands were cited as important sources of declines in the rate of productivity growth in the west region where much of the public timber is located. Environmental restrictions on timber harvesting practices on public lands such as restrictions on the maximum size of clear cuts and the placement of and methods of constructing logging roads can add greatly to the cost of the wood resource.

Among the most highly ranked factors stimulating an increase in the rate of productivity growth is the availability of new (or better) processing equipment. This factor, considered together with the important factors contributing to the decline in the rate of productivity growth: cost of new equipment and the finance cost of capital, tends to suggest that the lack of new equipment and technology is not the limiting factor (in fact this factor was rated among the least important in part I). Instead, economically feasible new equipment and technology must be used to stimulate an increase in the rate of productivity growth. New technology may exist but economic conditions together with the characteristics of that technology (i.e. size of investment, complexity, etc.) may preclude adoption. This may also explain why survey respondents perceived increased research and development as unimportant. Another possible explanation for the lack of interest in research and development is that technological change in many forest products industries comes as a result of the adoption of new technology developed outside the sector (i.e. from equipment manufactures) rather than as a result of inventive activity from within the sector (Bentley 1970). Scherer (1982), in a study of inter-industry technology flows, estimated that 45 percent of the technological innovations in the lumber and wood products industry (in terms of dollars of research) originated from outside the sector. Therefore, research and development may not be viewed by some forest products industries as an important component in their technological change process.

CONCLUSION

This study answers important questions concerning productivity change in the forest-based sector. From the survey results, the important sources of productivity change can be grouped into three categories -- those dealing with the capital input, those dealing with the labor input and those dealing with
the resource input. The labor and resource categories of factors exhibit regional and product group variation. With regard to the capital input, the survey results suggest that lack of new economically feasible equipment and technology is a limiting consideration. The results also suggest that this is an economic phenomenon resulting from unstable demand brought on to some extent by high interest rates. Labor quality problems were identified as an important factor, but the variety of potential solutions advocated by different industry groups and across geographical regions suggests certain inter-industry differences in the manufacturing process and work organizations. Further work is needed, however, to fully understand changes in forest industry productivity. We need to better understand how much these factors have influenced productivity. To develop effective ways to prevent productivity slumps, this study does show that a variety of factors need to be analyzed in order to understand changes in forest industry productivity.
LITERATURE CITED


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