10-1989

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Discussion Paper 89-3
October 1989

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Acknowledgements

The authors gratefully acknowledge the research assistance of Richard Ledbetter and Dirce Toulan. Allen Fox gave generously of his time and insights in the application of the IMPLAN model in analyzing the effects of structural changes in the wood products industry. The authors are also grateful to the mill managers, employees, union representatives and local government officials for their insights on the causes and consequences of recent changes in the industry. Finally, this study was made possible by the generous support provided by the Ford Foundation.

In 1986 the wood products industry in Oregon was producing more output than in 1979 but with about fifteen percent fewer workers. The employment decline in the wood products industry in Oregon can be traced to a variety of causes, including reductions in timber harvest and changes in output mix between the more labor-intensive plywood production and the less labor-intensive lumber production; but increasing labor productivity in the industry was a major factor. Despite substantial amounts of research regarding such productivity increases, there is still ample room for debate about the specific causes of the observed productivity improvement.

The rapid increase in labor productivity in the industry over the early 1980's is not consistent with trends over the last thirty years; and changes associated with a major recession can lead to mistaken long-term projections. Hence, it is important to determine whether the observed changes in output per worker represented a major structural shift in the industry or there were other factors which explain the change.

The methodology of this study is quite different from most studies of both the wood products and other industries. Previous statistical studies suffer from serious data problems and a wide range of estimates for certain key parameters. Hence, more information about the industry is needed. However, individuals involved in the industry are often unaware of important forces which are affecting them.

Thus, their ability to analyze the changes around them are also limited. This study represents an attempt to combine statistical studies with interviews of managers and workers to get a more accurate description of the changes which have occurred in the wood products industry.

The technique is similar to that used in most econometric model forecasts, where a panel of experts review a forecast to see if the forecasts for specific industries are consistent and reasonable before a final forecast is generated. We started by trying to use existing empirical estimates to determine how much each of several factors had contributed to the observed productivity increases, but wide ranges of estimates for key parameters along with data problems in measuring changes in certain variables made it very difficult to narrow the range of contributions. However, it became clear that there should be some observable differences in major features of the production process if certain factors were primarily responsible for the productivity changes.

In our approach, we identified key information which would allow a choice between various possible explanations and used a structured interview format to get information on these key items from a variety of people in the industry. The structured interview is neither a survey nor an open interview; rather, there are a set of guiding questions which are asked of all interviewees, but there is substantial flexibility for the interviewee to raise issues

or to expand on the topic rather than choosing from a predetermined set of possible answers.

The interview protocols used in this research were designed to elicit information which would be combined with the results of statistical studies to generate a more complete understanding of the changes which have occurred in the timber dependent regions. A series of interviews was then used to determine how people involved in the industry thought about these issues. The information from the interviews is then used to "color" the interpretation of the statistical data.

While the method is neither purely statistical nor purely dependent on information from experts, we do believe that it offers the opportunity to substantially improve our understanding of the industry and the forces affecting it. By combining statistical data with interview information, the study attempts to identify the causes of the previous changes in the industry and the factors which will influence future changes.

In section I we specify the major potential causes of an observed increase in output per worker. We then summarize many of the empirical results which exist relating to these changes. In section II of the paper we discuss which types of information would be useful in sorting out among the different possible causes, and we discuss the interview protocols and their results. Section III then

ends with our conclusions based on the combination of the statistical and interview data.

I. Labor Productivity

The simplest measure of labor productivity is output per unit of labor. However, even such a simple measure creates many problems of measurement and definition. The first problem is that the output which we want to consider is not homogeneous, so it is necessary to either look at the value of the output or to lump together dissimilar items in determining the amount of output produced. Either approach can have serious disadvantages. The use of product value can distort the view of output in an industry where prices fluctuate by a large amount. However, the use of a volume measure often masks differences in the types of output which are aggregated together. This can be a problem, for example, if we must aggregate logs, lumber, plywood, mobile homes and millwork, among other products, as outputs. They use different amounts of labor per unit of output; and the mix of outputs may change over time or over the business cycle. The impact of changes in output mix on employment has been examined in a previous paper (Strathman, Rufolo, Bronfman 1989).

Once a measure of output has been chosen, we have the problem of measuring the labor input. By the simple measure of output per worker, productivity in sawmills and planing mills in the United States increased by 30% between 1979 and 1985 (Bureau of Labor Statistics, 1986). However, there are

many things which could account for such a change in the observed ratio of output to labor input. First, there may be errors in the way in which the labor input is measured. For example, in many industries there has been a substantial increase in the number of workers who are employed by temporary employment agencies and then hired as temporary workers through these agencies.

Typically, workers hired through temporary employment agencies would not be counted as part of an industry's work force. Hence, if an industry has a trend toward more reliance on workers supplied by such agencies, the observed ratio of output to direct employment would change.

Changes in employment associated with using temporary employment agencies would not be limited to shop workers. To the extent that previous clerical and management functions are performed by outside firms or temporary workers, the employment numbers for the industry would be understated relative to past numbers. In addition, if changes in the structure of the industry cause an increase in the use of contract labor relative to direct hires, then the measured labor usage in the industry would decline. Thus, if firms which previously hired accountants directly were to purchase accounting services from an accounting firm, actual employment would remain the same but the accountants would no longer be counted as employees in the original industry. The contracting out of services appears to have increased substantially between 1979 and 1986 (U.S.

Department of Labor, 1987, p. 3), but it is difficult to get information on the extent of the practice in wood products and on any possible increases over this time period.

Another problem arises if the number of hours worked per worker changes substantially. For example, if the measurement is output per person-year and each person starts working ten percent more hours each year, then the observed productivity increase would not be the same as if there were ten percent more output with the same number of hours worked. In addition, if there are rigid work rules, then labor productivity tends to be fairly low. Changes in work rules may cause an increase in labor productivity without any changes in either capital per worker or in the quality of the equipment used. While these changes may lead to an increase in productivity, it is unlikely that such changes can be repeated at regular intervals. Thus, changes in work rules lead to a one-time increase in productivity rather than a change in the trend of productivity improvements. A related effect occurs if management adopts new techniques to use labor more effectively or to better motivate workers. Again, such changes tend to have one-time effects rather than changes in the trend of industry productivity.

For example, vacations, training, absenteeism, or breaks could all affect the observed ratio of output to employment. In difficult economic times, firms might cut back on all of the above and generate an increase in output per worker with no real change in labor productivity.

Alternatively, during good times firms may be able to tolerate restrictive work practices which increase the amount of labor per unit of output. However, if these work practices are changed in response to difficult economic times, the observed level of output per worker may jump even though there is no impact on the industry's trend of productivity increases. Popular discussions of the decline in wages and job security in the industry made it seem likely that some such effects had occurred, but again it was not possible to get good data on the extent of such changes.

The second major set of causes of productivity increases are actual increases in output per worker. These can occur because labor is replaced with machinery or because there are changes in the ability to derive more output from a given level of inputs. The latter change is known as technological progress while the former is factor substitution. Substituting capital for labor is a major cause of increases in the ratio of output to labor. At the extreme, a fully automated plant might require only a few workers to produce the same output that might require hundreds of workers in a less automated plant. Another major cause of increases in output per worker is the use of new methods or new machines which allow each worker to get more work done. For example, the increased use of computers may improve work scheduling so that each worker spends less time waiting or looking for parts.

Most studies find that capital and labor are weak substitutes for each other in the wood products industry. However, the empirical estimates of the rate of substitution between capital and labor cover a very wide range. For example, Stier (1980) reports estimates of the elasticity of substitution between capital and labor in the wood products industry which range from a low of 0.03 to a high of 2.5 (p. 479). This range goes from almost no possibility of substitution to a fairly high degree of substitutability. Such a wide range of estimates mean that the statistics must be used very cautiously. However, they suggest that high and rising labor costs may have induced management to substitute capital for labor.

While the elasticity of substitution between capital and labor is the most important statistical estimate for determining why employment is declining relative to output, there are a variety of other estimates which also provide useful information. An alternative method to determine the relationship between capital and labor is to estimate the effect on labor of an increase in the capital stock. By this method of estimation an increase in the capital stock of one-percent was found to lead to a slight increase in the amount of labor used of 0.18 percent; however, there is an estimated 0.28 percent increase in the amount of lumber produced (Constantino and Haley, 1987). Thus, the capital-labor ratio increases and the output-labor ratio also increases by a small amount. Information on the own price

elasticity of demand for inputs could be coupled with this type of estimate to generate an alternative estimate of the impact of changes in input mixes on the output-labor ratio.

Factor substitution tends to be sensitive to price differences among the factors of production while pure technological progress is not reversed in response to price changes. It is widely acknowledged that labor costs in the wood products industry declined over the early 1980's, especially if fringe benefits are counted as part of costs. Thus, it is important to separate the impact of technological progress from the impact of factor substitution.

Finally, the measured productivity of labor also will depend on choices made about the use of labor in the industry in response to relative prices of inputs and outputs. If the value of output and the cost of timber are high, then it makes sense to recover large amounts of product from each unit of timber which is processed. While this also requires more labor time to produce the additional output, the value of the additional output can compensate for such costs.

Alternatively, if the cost of timber is low then it may be less expensive to purchase more timber inputs and allow more waste of timber to conserve on the use of labor time. Thus, the measure of labor productivity is likely to be sensitive to the cost of other inputs and the price of the output. It is also likely to be sensitive to the quality of

the input. High quality inputs which are used to create valuable end products justify more expenditure on labor to recover as much product as possible and to make sure the quality remains high. However, a low quality input does not warrant the same amount of effort. Constantino and Haley (1987) find that the quality of timber processed in the Pacific Northwest declined between 1957 and 1982. Such declines could affect the relative use of labor either positively or negatively.

A third set of issues are only indirectly related to the measure of output per unit of labor input; but these are topics which must be addressed to fully understand the changes which have been occurring. Among these are the possibility that the skill requirements for the work force are changing over time or that the changing demographics of the work force are affecting measured productivity. In particular, there is usually a pattern of productivity such that workers just entering an industry and older workers are less productive than workers in the middle.

Finally, we cannot ignore the tendency for observed productivity to decline during a recession as output declines more rapidly than employment and to increase during a recovery as output grows more rapidly than employment.

These are topics which generate large amounts of uncertainty based on statistical studies alone; and it is here that the information generated by the surveys of

managers and employees is most needed to supplement the statistical studies.

For example, output per worker could increase because machines replace workers or because both existing machines and workers become more efficient. If the workers are replaced by machines then the relative cost of workers and machines becomes an important determinant of the future rate of change in output per worker. However, if the technological progress is unrelated to the relative cost of the inputs, then there is much less opportunity to change the trend in employment. Hence, more careful analysis of the relationship between productivity improvements and the relative cost of inputs could be important in making projections about future employment.

II. Interview Results

This research is part of a larger project which had several other objectives for the interviews, but the items of interest for determining the causes of changes in labor productivity were primarily contained in interviews with plant managers and workers. The interview responses then provide useful insight into the appropiate ways to use data which is available to measure such changes.

The majority of the interview results to be presented here relate to interviews of plant managers although some results come from interviews with employees. All interviews were done in three southern Oregon counties and were focused on managers and employees of either lumber or plywood mills.

For a more detailed discussion and the protocols used to guide the structured interviews see Rufolo, Strathman, and Bronfman (1988).

The interviews addressed most of the issues related to productivity improvement directly. Managers were asked if they were contracting out more than they had previously, and they were asked a variety of questions about changes in productivity such as whether there had been changes in work rules which allowed more output per worker. Workers were also asked about work rules and other factors which might influence productivity. Thus, the interviews were designed to answer directly whether there had been substantial changes in contracting or work rules.

Questions on stumpage sources and quality were also covered directly in the interviews. The issue of technological changes and the substitution of capital for labor were addressed through a series of questions relating to the perceived current state of technology in the mill relative to other mills and through questions about the timing of major technology improvements.

A majority of the lumber mills surveyed had experienced a slight decline in employment over the last 10 years. The acutal reduction in employment ranged from two people in a small firm to 75 people in one of the largest mills in the survey area. According to the mill managers, the reductions in employment were primarily the result of the introduction of new production technologies into the

facilities. Many managers were of the opinion that while new technology reduced employment in some areas, this was frequently offset by increases in output or by other changes in the use of labor.

Most lumber-mill managers envisioned little change in employment over the next five years except for changes associated with reductions in timber supply or with a decline in demand for output. A notable exception to this were two managers who expected some employment decline and one who perceived that the mill would close within the five-year time frame.

Managers of the plywood mills provided evidence that changes in that industry were more clearly associated with reductions in employment for given levels of output, although this was often offset by increases in production associated with the new technology. Thus, the effect of the changes appeared to be a concentration of production in fewer mills. Mills that had closed in the early 1980's were seen as those which had not made technological changes, and lack of technological improvement was seen as a factor which made a mill more likely to close in the future. In particular, such firms were seen as more vulnerable to changes in log supply since many of the technological changes were associated with the ability to process a wider variety of timber.

Larger mills in the study region have historically relied extensively on their own private forests for input,

but they are increasingly competing with the smaller mills for public timber. Partly, this is because of the continued availability of larger diameter logs from the public lands, although most mill managers did not describe stumpage requirements in terms of old growth versus new growth. Rather, the emphasis was on the diameter of the logs and they noted that many of the logs coming from the public lands were also small diameter.

For most of the mills in the survey, technological upgrading has been a continuous activity since construction. However, the exact timing of the introduction of the new technology has a very wide variance, with some of the most advanced mills having introduced technological innovations ten years or more before some of the others. Of the lumber mills, two were ranked high, four labeled their mills as moderately high; and five considered their mills average to moderately low. Four of the plywood mills were ranked high, three moderately high, three average to moderately low, and two were rated low. Thus, despite the perception of major technological advances in the industry in the 1980's there appear to still be substantial differences in the adoption of such technological change.

While noting the complexity of measuring productivity, nearly all of the mill managers felt that productivity had increased in their mills over the last five years. They cited a variety of indicators, including output per worker or man-hour, increased recovery from raw materials, and

reduced unit cost. The changes in productivity were considered to be the result of specific initiatives undertaken by management to deal with perceived changes in the competitive environment in which the mills operate. The recession of the early 1980's, which saw a number of mills shut down, coupled with competition from alternative products exposed the vulnerabilities of the firms.

Strategies for increasing productivity were variable from one firm to the next, and depended on the firm's perceived position in the market in the future. The adoption of new technology was a major factor in increasing productivity and competitiveness for several firms. For most firms, however, managements's choices over the last few years involved a mix of adopting new machinery, utilizing old machinery in a more effective manner, and striving to "get more work" out of the employee.

Managers were selective in choosing new machinery and software. Strategies focused on workers were also diverse. There were many efforts at improving "communication" between management and workers and many incentives for improved performance.

Finally, a considerable effort has been made to reduce the overall cost of labor. Labor requirements are being reduced by giving workers the training and experience to allow them to move easily from one job to the next routinely. Such a strategy has in some instances involved changing work rules and redefining jobs. Work rules in

several mills have also been changed to reduce absenteeism. Rule changes have also enabled employers to require workers to work on weekends without overtime pay and, in one instance, to use part-time workers for entry level positions. Contract workers are another alternative chosen by most of the mills to reduce overall labor requirements. Employed by an agency that pays their non-wage costs, these individuals fill in on a daily basis at different mills. While their use is limited primarily to temporary replacement of sick or injured workers, their presence in the mills is a recent phenomenon in this region.

Another area which was investigated as part of the study of labor usage in the industry was the mix of workers, especially between the skilled and unskilled segments. A typical effect of technological change or of substituting capital for labor is to increase the use of skilled labor relative to unskilled labor. This would also be consistent with higher than expected increases in output per worker in the industry. Surprisingly, in analyzing the occupational structure of employment in Oregon's wood products industry for the years 1977 to 1985, no support for this hypothesis was found. The gross breakdown of workers between skilled, unskilled, and management showed that there was a slight decrease in unskilled and management workers relative to skilled workers; but this change was of little significance. This characterization is further supported in the interviews, where the nature of the work and training are

not perceived to have changed dramatically in response to new capital equipment. Rather, the perception is that there have been increases in productivity, but no real changes in the skills needed to operate the machinery. If anything, there may be some decreases in skill requirements; but these were not raised as important issue.

Perhaps the most striking finding from the interviews is that despite the major disruption caused by the employment declines from 1979 to 1981, the industry seems to be fairly stable today. While there are substantial concerns about the future availability of timber and the cyclical nature of the industry, major fears about the viability of the wood products industry in Oregon were not found. Further, while there is much talk about new technology and the need to invest in more capital equipment, the industry does not seem poised for further massive substitutions of capital for labor. In fact, there is some concern about the ability to attract workers to meet current labor requirements.

III. Factor Substitution and Productivity Effects

With the perspective gained from the interviews it is possible to go back to the many statistical studies and attempt to reinterpret what has been happening in the industry. During the 1970's real wages in the industry were increasing. This was largely driven by an increase in the demand for workers in the industry. High and rising prices for the output led to increasing competition for the inputs.

The relatively fixed supply of timber caused stumpage prices to rise; and this in turn created demand for additional capital and labor to get the most output from each unit of input.

Capital improvements take time to implement, so the short-run responses to the increased demand for inputs were largely met by increasing the amount of labor used in processing timber. At the same time plans were made for capital improvements, and the data for the late 1970's show substantial net investment in the wood products industry. The tight labor market situation also allowed for workers to avoid repercussions for certain types of unproductive behavior, e.g. frequent absences from work.

The new capital was being brought into production just as the demand for wood products plummeted. Since capital is a fixed cost, the most capital intensive firms tended to operate during the downturn. Thus, the recession hit labor more than proportionately to output. In addition, the slack labor market allowed managers to look more carefully at work rules and worker behavior.

Changes in both management behavior toward workers and in the incentives which were given to workers appear to have increased the productivity of workers. For example, reduced absenteeism would mean that the same amount of work could be done by a smaller number of workers since each worker would work more days per year and since there is less need to have

excess workers to deal with random fluctuations in the number of people showing up for work each day.

Another tactic is for greater use of contract workers. These workers serve when there are short-term increases in demand; and since they do not work directly for the company, the company can have lower total labor costs because of reductions in costs for fringe benefits.

The combination of large capital stock and work rule changes was augmented by reduced need to process low quality inputs. The downturn in the total amount of stumpage being processed meant that purchasers need only purchase the better logs which were available. This also contributed to the reduction in labor per unit of output.

The lower real wages for workers resulting from the recession have increased the cost effectiveness of labor relative to capital; and this has slowed the rate of substitution of capital for labor in the industry. Further, the high demand for output is causing relatively more low quality timber to be processed. Thus, at least two factors are contributing to the recent improvements in the employment picture.

The combination of the interviews and the statistical data seem most consistent with the conclusion that the industry went from a very heated cyclical boom to an extreme cyclical bust in a very short time period. The decline in employment per unit of output is consistent with long term trends associated with the substitution of capital for

labor. This will continue based on the relative prices of labor and capital inputs. The rate of substitution is likely to be slower in the immediate future because of the reductions in inflation adjusted labor costs and the changes in work rules. However, this is not likely to forestall a return to the long term trend lines for long.

Alternatively, the rapid increase in output per worker is not likely to be continued. The severe recession has made producers much more cautious about investment in the industry, so the rapid increase in capital input seen in the late 1970's is not likely to be repeated. Further, the quality decline associated with the input is likely to continue; and this will be at least partially offset by increases in other inputs.

The changes in employment associated with the change in product mix are not as large as those associated with productivity changes, but they may be more of a potential threat in the future. In particular, the region is likely to continue to face increased competition in the production of plywood. Since this is a relatively labor-intensive product, the employment implications are somewhat negative. Also, further increases in export of unprocessed logs is likely to have some small negative employment impact.

On the whole, the employment outlook for the industry is not as negative as the numbers for the early 1980's made it appear. The amount of labor per unit of output is likely to continue to decrease over time, but the rate of decrease

should be in line with historical trends. Perhaps a more pressing concern than the decline in employment opportunities should be the attractiveness of the wood products industry to employees given the cyclical instability which it faces and the reduction in new entrants into the labor force anticipated for the future.

Summary

We addressed the cause of the observed rapid increase in labor productivity in the wood products industry in Oregon. Our conclusion is that it was nothing more than the typical response of the industry to a recession. To be sure, the recession was an unusually severe one for the industry and it followed an unusually high cyclical peak; but there is little evidence of a dramatic change from long-term trend lines for the industry with respect to labor productivity.

In most industries, the downturn in the business cycle leads to a reduction in observed labor productivity because firms are slow to reduce their workforce as demand for ouptut declines. Thus, the industry produces less output with about the same number of workers. Similarly, during an upturn the firms are slow to hire additional workers, so output per worker tends to increase. This typical pattern does not appear to characterize the wood products industry during the period from 1979 on. Rather, the decline in demand in 1979 led to an adjustment which involved closing many individual plants. These closed plants tended to be

the most labor intensive plants in the industry. Thus, output per worker increased rather than decreased.

The output per worker measures were further clouded by the impact of the boom of the 1970's. Prior to 1975 output per worker had bean gradually increasing in Oregon's wood products industry. However, heated demand and high prices induced firms to increase output as much as possible. This involved processing wood which was of relatively low quality and trying to get the greatest amount of output from each log that was possible. Each of these actions required an increase in the amount of labor per unit of output. Thus, the late 1970's saw output per worker decline in the wood products industry by a substantial amount. The simple movement back to the trend line would have meant large job losses for the industry, and the recession caused much more than a movement back to trend.

The declining quality of the timber available is another issue which is often mentioned with respect to the increase in productivity in the industry. The input is often characterized as being divided into the "old growth" timber, which consists of very large diameter, high quality logs versus the "new growth" or "second growth" timber which results from replanting previously logged forests. Since the latter timber is cut at a much younger age, the logs tend to be smaller and more uniform in size. These smaller logs are thought to be more amenable to processing in

automated plants. Thus, the shift to smaller logs would involve less labor per unit of output.

We find that the situation is much more complex then the one just described. While it does appear to be true that the smaller logs are more amenable to automated handling the smaller logs are not as easy to process into wood products. Hence, the labor input per unit of output might increase rather than decrease because of such a shift. Further, the smaller logs appear to be associate with both "old growth" and "new growth" timber. This appears to be because the best and most accessible of the old growth was cut first. Hence, remaining old growth tends to be less accessible and of lower quality than what was cut previously. Each of these factors tends to increase the use of labor to process the logs.

Statistical studies of the industry conclude that most of the improvements in output per worker over time are associated with direct substitution of capital for labor. While there have been increases in the technology available to the industry, they have been more associated with processing a lower quality input than with generating large increases in output per unit of input. These conclusions are largely confirmed by the interviews. Few seem to see major changes in the way in which individual firms process their output. There are ongoing improvements in the capital stock which allow each mill to produce more output with the same number of workers; but these are largely substitutions

of capital for labor rather than major changes in the whole process.

To the extent that there are policy concerns with respect to technological change, they are likely to focus on the changes in ability to process lower quality logs. There are likely to be continued substitution of capital for labor, but this may reduce the amount of physical labor required to work in the industry and increase the potential labor pool.

The final factor with respect to technological improvement is the possibility of devoting more resources to training workers with the skills needed to handle and repair more sophisticated equipment. The interviews indicated that there do not appear to be substantial demands for such workers now; but this may change in the future.

References

Constantino, Luis F. and David Haley, "Trends in Wood Quality for the British Columbia Coast and the United States, Pacific Northwest, Westside," Forest Science 34:1 (1987), 176-89.

Constantino, Luis F. and David Haley, "Wood Quality and the Input and Output Choices of Sawmilling Producers for the British Columbia Coast and the United States, Pacific Northwest, West Side," Canadian Journal of Forestry Research, 18 (1988), 202-08.

Humphrey, David B. J. R. Moroney, "Substitution Among Capital, Labor, and Natural Resource Products in American Manufacturing,: Journal of Political Economy 83:1 (1975), 57-82.

Martinelle, Felice, "Factor Substitution, Technical Change, and Returns to Scale in Canadian Forest Industries," Canadian Journal of Forestry Research, 15 (1985), 116-24.

Merrifield, David E. and Richard W. Haynes, "Production Function Analysis and Market Adjustments: An Application to the Pacific Northwest Forest Products Industry," Forest Science, 29:4 (1983), 813-22.

Rufolo, Anthony M. and James G. Strathman and Lois Martin Bronfman, "Employment Decline in Timber Dependent Regions," Final Report (December, 1988) Center For Urban Studies, Portland State University.

Strathman, James G. and Anthony M. Rufolo and Lois Martin Bronfman, "Structural Change and Employment Decline in Oregon's Wood Products Industry," Discussion Paper 89-2 (October 1989) Center For Urban Studies, Portland State University.

Singh, B.K. and J.C. Nautiyal, "A Comparision of Observed and Long-Run Productivity of and Demand for Inputs in the Canadian Lumber Industry," Canadian Journal of Forestry Research, 16 (1986), 443-55.

Stier, J.C., "Estimating the Production Technology in the U.S. Forest Products Industries," Forest Science, 26 (1980), 471-82.

U.S. Department of Labor, Bureau of Labor Statistics, "Technology and its Impact on Labor in Four Industries," Bulletin 2263, Washington, D.C., U.S. Government Printing Office, November 1986.

U.S. Department of Labor, Bureau of Labor Statistics, "Business Contracting Our Practices," Summary 87-8,

Washington, D.C., U.S. Government Printing Office, November 1987.