REGIONAL ECONOMIC ANALYSIS OF THE LOGGING INDUSTRY IN THE SOUTHEAST

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Abstract: Recent environmental regulations in the Pacific Northwest under Option 9 have the potential to cause a large shift in the logging industry to other regions of the country. The Southeast has a large timber resource base and could see a significant increase in production in the coming decade. To help understand what impacts could result in the Southeast, it is important to understand characteristics of the production structure in the industry. A nonhomothetic translog cost function with two variable inputs, labor and capital, was employed to estimate the underlying production structure of the logging industry in the Southeast from 1963 to 1992. The analysis found that labor and capital were substitutes but that the substitution possibilities were limited. This could greatly affect industry employment if a large portion of the industry shifted from the Pacific Northwest to the Southeast. Increased harvest levels in the region will cause either the number or size of existing firms to increase. Because of the limited substitution possibilities, greater production levels cannot be accomplished by increased capitalization alone. Employment in the region's logging industry would have to increase.

Introduction

The logging industry (SIC 2411) in the United States represents an important sector of the nation's economy. In 1992 for example, the industry had shipments of over 13 billion dollars and directly employed 83,000 individuals (U.S. Department of Commerce 1995). This industry is also crucial to the survival of the other forest products industries. Without the logging industry, industries such as lumber and pulp and paper would be unable to obtain roundwood materials needed for production. Despite the relative importance of the industry, little is known about its production structure.

Regional differences exist in most if not all forest products industries in the United States. Supply inputs for the various forest products industries, such as labor and raw materials, differ among the various regions of the country. As a result, different manufacturing technologies have evolved within regions to efficiently process production inputs. These manufacturing differences could lead to possible regional variations in the cost structure of an industry. However, these important regional differences become lost in national aggregation and are preserved only in studies incorporating regional data.

The need for regional studies has increased dramatically in recent years. Forest products industries in the Pacific Northwest, which rely heavily on timber from federally owned land, have seen production reduced due to increased environmental regulation. Harvest in the region from federal lands is expected to decrease by 76 percent over the next ten years compared the harvest levels in the 1980s (Tuchmann 1995). Restrictions on available wood raw material resources have caused significant shifts in production in all forest industries to other regions of the country. To evaluate the nature of these impacts, knowledge of regional differences in the production structure of the industry is essential.

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The objective of this analysis is to estimate certain characteristics of production for the logging industry in the Southeast from 1963 to 1992 and to evaluate possible effects of a large shift of the logging industry to the Southeast. This study will focus on the elasticity of substitution between labor and capital in the industry as well as the own- and cross-price elasticities of factor demand.

**Methods**

For any industry, its underlying production function shows the relationship between output and inputs for a given state of technology. In this analysis, a two input production function is used to characterize the logging industry in the Southeast. Mathematically, this function can be expressed as follows:

\[
Q = f(I_L, I_K, T)
\]

where \( Q \) is total industry output for the region, \( I_L \) and \( I_K \) are input levels of labor and capital, respectively, and \( T \) is a time trend representing the current state of technology.

For every industry production function, there exists a dual cost function when the objective of the firm is to minimize costs. If certain conditions are met, then under the theory of duality characteristics of industry production can be estimated by its corresponding dual cost function. For the theory of duality to hold, the industry must be characterized by cost minimization, exogenous factor prices and exogenous industry output.

A general nonhomothetic translog function was employed in this study to represent the cost structure of the logging industry in the Southeast. This flexible form does not impose restrictions on elasticity of substitution or returns to scale, nor does it force the industry to be homothetic or homogeneous with respect to output. Equation (2) is the exact specification of the cost function used in this investigation:

\[
\ln C = \alpha + \beta_L (\ln P_L) + \beta_K (\ln P_K) + \beta_Q (\ln Q) + \beta_T (T) + 1/2 [\beta_{LL} (\ln P_L)^2 + \beta_{KK} (\ln P_K)^2 + \beta_{QQ} (\ln Q)^2 + \beta_{TT} (T)^2] + \beta_{LT} (\ln P_L)(\ln P_K) + \beta_{KQ} (\ln P_K)(\ln Q) + \beta_{QT} (\ln P_L)(\ln Q) (2)
\]

where \( C \) is total cost, \( Q \) is aggregate industry output, \( P_L \) and \( P_K \) are the input prices of labor and capital, and \( T \) is a time trend to represent the current state of technology.

To preserve symmetry of the cross partial derivatives and to assure that the function is homogeneous of degree one with respect to input prices, the following restrictions are imposed:

\[
\beta_{LK} = \beta_{KL} \quad \text{for} \quad L \neq K
\]

\[
\beta_L + \beta_K = 1 \quad \beta_{LL} + \beta_{KK} = \beta_{LT} + \beta_{KT} = \beta_{LQ} + \beta_{KQ} = 0 \quad (4)
\]

Taking the first derivative of the cost function (2) with respect to input prices and applying Sheppard's lemma results in the following input demand equations (5) (6):

\[
S_L = \beta_L + \beta_{LL} (\ln P_L) + \beta_{LK} (\ln P_K) + \beta_{LQ} (\ln Q) + \beta_{LT} (T) \quad (5)
\]
where $S_L$ and $S_K$ represent the share of total cost attributed to labor and capital.

**Estimation Techniques**

Since the share equations sum to one, residuals across the two equations sum to zero at each observation. The result is a singular variance-covariance matrix. To prevent this, one share equation has to be dropped to allow for estimation of the desired parameters. The labor cost share equation (6) was arbitrarily chosen as the deleted equation in this analysis. In implementing restrictions (3) and (4), the price of capital is divided by the deleted price of labor. According to Stier (1980), the coefficient $\beta_{LK}$ can be recovered by the restriction $\beta_{LK} = -\beta_{KK}$.

Most of the parameters of interest in this study can be obtained from the cost share equation without considering the total cost function in equation (2). However, joint estimation of the total cost function and factor share equation leads to more efficient estimates of all parameters (Christensen and Greene 1976). The disturbance terms of the two equations are assumed to be correlated to each other in a given period, but are assumed to be independent across time. The Maximum Likelihood Estimation technique in LIMDEP, Version 7.0 (Econometric Software, Inc.), was used to estimate the parent cost function (2) and the capital share (6). Such estimation is invariant to which cost share is dropped and provides estimates that are asymptotically equivalent to maximum likelihood estimates (Greene 1993). Information from the deleted labor share equation was recovered using the restrictions in (3) and (4).

**Elasticity of Substitution**

Allen-Uzawa partial elasticities of substitution (Allen 1938, Uzawa 1962) have been used in numerous studies to show the degree in which input factors can be substituted in production for a given state of technology. The equations for the own- (7) and cross-Allen-Uzawa partial elasticities (8) are as follows:

$$\sigma_{i}^{A} = S_i - 1 + \beta_{i} / S_i$$  \hspace{1cm} (7)

$$\sigma_{ij}^{A} = S_j + \beta_{ij} / S_i$$  \hspace{1cm} (8)

where $\sigma_{i}^{A}$ and $\sigma_{ij}^{A}$ are the own- and cross Allen-Uzawa partial elasticities of substitution, respectively. Although the Allen partial elasticities were once the dominant measure of substitution, they were calculated in this study only to develop the Morishima elasticities and price elasticities for factor demand in the region.

Blackorby and Russell (1989) believe that the Allen-Uzawa partial elasticities are not a measure of the ease of substitution, and they do not provide a measure of the curvature of the isoquant. The authors suggest that a better measure is provided by the Morishima elasticities of substitution. To calculate the Morishima elasticities, the own- and cross-Allen-Uzawa elasticities for the industry must be known. The Morishima elasticities (9) are then estimated in the following manner:

$$\sigma_{ij}^{M} = S_j (\sigma_{ij}^{A} - \sigma_{i}^{A})$$  \hspace{1cm} (9)

where $\sigma_{ij}^{M}$ represents the Morishima elasticity of substitution between input i and input j for the particular industry.
Own- and Cross-Price Elasticities of Factor Demand

The Allen-Uzawa partial elasticities can also be used to determine the own- and cross-price elasticities for factor demand. The own- and cross-price elasticities are important in assessing the impacts of price changes of inputs on the production process. Own-price elasticity of factor demand shows the change in quantity demanded of an input given a change in the price of that input. Cross-price elasticity, on the other hand, measures the change in the quantity of an input demanded in response to change in the price of another input. Own- and cross-price elasticities can be calculated by the following transformation of the Allen-Uzawa partial elasticities (10):

\[ \xi_y = S_j \sigma y^j \]  

(10)

Since the factor shares, \( S_L \) and \( S_K \), vary by observation, the Allen-Uzawa partial elasticity, Morishima elasticities and price elasticities for each region were calculated using the mean of the respective factor shares.

Tested Restrictions

The nonhomothetic translog cost function does not assume the logging industry is homothetic, homogeneous, or time invariant. However, these restrictions can be tested statistically to determine if they apply to the region. This is accomplished by estimating additional sets of equations nested within the original model. The validity of the restrictions is tested by comparing twice the difference of the log-likelihood statistic to a \( \chi^2 \) critical value with degrees of freedom equal to the number of restrictions (Ball and Chambers 1982). In the study, three nested models were estimated with the following restrictions:

1. \( \beta_{KQ} = 0 \)
2. \( \beta_{KQ} = \beta_{QQ} = 0 \)
3. \( \beta_T = \beta_{TT} = \beta_{KT} = \beta_{QT} = 0 \)

The first restriction forces the function to be homothetic and therefore separable into input prices and quantities. If the function is homothetic then the isoquants of the industry are radial blowups of the unit isoquant. Therefore, the slopes of the isoquants are dependent only on the ratios of input prices and not the quantity of industry output. The second set of restrictions forces the function to be homogenous. A homogeneous function is characterized by a constant elasticity of cost with respect to output. If this restriction holds and \( \beta_Q \) is equal to one then the industry can be characterized by constant returns to scale. The last set of restrictions tests whether costs have changed significantly over time. If the homothetic and homogeneous restrictions are rejected then specifying the underlying production structure as a Cobb-Douglas or CES function would be inappropriate.

Data

Annual data on the logging industry (SIC 2411) for the Southeast were collected for the years 1963 to 1992. Data on labor and capital expenditures were obtained from various issues of the Census of Manufacturers and the Annual Survey of Manufactures. All prices, expenditures and costs were deflated using the GDP implicit price deflator for all items (base year 1987).

A regional data set was developed by combining state level data based on geographic location and data availability. The states of Mississippi, Georgia, Florida, South Carolina, Arkansas, and Louisiana were used to develop the Southeastern data set. Due to the lack of Gross Book Value data for Alabama, the state could not be included in the analysis. Therefore, the Southeastern data set did not represent a contiguous region, but the combination of two subregions. Data on Logging Camps and Contractors (SIC 2411) and Lumber and Wood Products (SIC 2400) for individual states were not
published in 1979, 1980 and 1981. Additionally, for 1968, 1984, 1985, and 1986 only data for SIC 2400 for individual states were available. Some additional observations were not reported for certain individual states. Missing observations were interpolated using a ratio of state SIC 2411/national SIC 2411 for the years 1979 through 1981. All other missing observations in the series were interpolated using a ratio of state SIC 2411/state SIC 2400.

To calculate returns to capital, the amount of physical capital stock of the industry in each region must be known. However, such data are not available for the logging industry on a regional or state level. Therefore, data on gross book value (GBV) of depreciable assets for SIC 2411 on the national aggregate level were used to develop a capital series for Southeast. Data on GBV were collected from various issues of the Census of Manufactures and Annual Survey of Manufactures from 1958 to 1992 for national SIC 2411. Missing years in the series were estimated using the perpetual inventory method developed by Christensen and Jorgenson (1969). The GBV series was then regressed using a time trend, new capital expenditures, and gross book value from the previous period as explanatory variables.

GBV of SIC 2400 for individual states was reported in the 1958 Census of Manufactures. This value was multiplied by a ratio of national GBV for SIC 2411/national GBV for SIC 2400 to estimate the share of the GBV attributed to logging in each state. The calculated GBV for SIC 2411 for the states in 1958 was used as a starting benchmark for the capital series. After adjusting the constant and time trend coefficient, the regression equation from the national series was used to estimate the GBV for logging in each state. The predicted GBV for individual states was combined to form the GBV series for the region.

Returns to capital for the logging industry in each region were calculated by dividing gross quasi-rent (value added minus payroll) by capital stock. The wage rate for the industry in the region was calculated by dividing total payroll by aggregate total man-hours. Nonproduction workers were assumed to have worked 2,000 hours annually. The labor share for each region was calculated by dividing total payroll by value added. Since returns to capital and labor are assumed to exhaust value added for the industry, the capital share was calculated as one minus the labor share. Total regional industry output was determined by dividing value of shipments by PPI for Crude Materials Except Fuel from July editions of the Producer Prices and Price Indexes. Total industry cost was calculated as the summation of industry expenditures on payroll, material and new capital.

Results and Discussion

Four systems of equations were estimated for the logging industry in the Southeast. Estimation results of the nonhomothetic, homothetic, homogeneous and time invariant models are in Table 1. Included in the table are the estimates of the coefficients and their standard errors as well as the log-likelihood statistics for each model. The nonhomothetic model for the Southeast was checked to see if it was locally well behaved. Fitted share estimates were less than one and greater than zero for all observations thereby satisfying the positivity requirement. Concavity of input prices was satisfied by negative values of the own-price elasticities for labor and capital for all observations.

The calculated Morishima elasticity of substitution for the Southeast was 0.470. This indicates that labor and capital are substitutes in the logging industry in the Southeast but substitution possibilities are limited. Low substitution elasticities could, however, benefit the Southeast in terms of employment. As stated by Sedjo (1995) one area likely to experience an increase in harvest from environmental regulations in the Pacific Northwest is the U.S. South. Increased harvest in the Southeast would mean that the current size or number of logging firms in the area would have to
Table 1. Estimation results of nonhomothetic, homothetic, homogeneous and time invariant functions
for the logging industry in the southeast.

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Nonhomothetic*</th>
<th>Homothetic*</th>
<th>Homogeneous*</th>
<th>Time Invariant*</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>-17.412</td>
<td>-16.767</td>
<td>11.717</td>
<td>-0.632</td>
</tr>
<tr>
<td></td>
<td>(27.363)</td>
<td>(27.597)</td>
<td>(1.823)***</td>
<td>(77.734)</td>
</tr>
<tr>
<td>$\beta_L$</td>
<td>0.315</td>
<td>0.409</td>
<td>0.381</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.256)</td>
<td>(0.114)***</td>
<td>(0.115)***</td>
<td>(0.316)</td>
</tr>
<tr>
<td>$\beta_K$</td>
<td>0.685</td>
<td>0.591</td>
<td>0.619</td>
<td>0.992</td>
</tr>
<tr>
<td></td>
<td>(0.257)***</td>
<td>(0.114)***</td>
<td>(0.115)***</td>
<td>(0.316)***</td>
</tr>
<tr>
<td>$\beta_T$</td>
<td>-0.129</td>
<td>-0.117</td>
<td>-0.154</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.125)</td>
<td>(0.116)</td>
<td></td>
</tr>
<tr>
<td>$\beta_Q$</td>
<td>6.689</td>
<td>6.553</td>
<td>-0.804***</td>
<td>2.475</td>
</tr>
<tr>
<td></td>
<td>(7.007)</td>
<td>(7.071)</td>
<td>(0.237)</td>
<td>(20.212)</td>
</tr>
<tr>
<td>$\beta_{LQ}$</td>
<td>0.058</td>
<td>0.059</td>
<td>0.059</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>(0.021)***</td>
<td>(0.028)***</td>
<td>(0.029)***</td>
<td>(0.048)**</td>
</tr>
<tr>
<td>$\beta_{KQ}$</td>
<td>0.058</td>
<td>0.059</td>
<td>0.059</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>(0.021)***</td>
<td>(0.028)***</td>
<td>(0.029)***</td>
<td>(0.048)**</td>
</tr>
<tr>
<td>$\beta_{TT}$</td>
<td>-0.003</td>
<td>-0.003</td>
<td>-0.003</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.001)***</td>
<td>(0.001)***</td>
<td>(0.001)***</td>
<td></td>
</tr>
<tr>
<td>$\beta_{QQ}$</td>
<td>-0.956</td>
<td>-0.951</td>
<td>-</td>
<td>-0.402</td>
</tr>
<tr>
<td></td>
<td>(0.898)</td>
<td>(0.906)</td>
<td></td>
<td>(2.626)</td>
</tr>
<tr>
<td>$\beta_{LQ}$</td>
<td>0.019</td>
<td>-</td>
<td>-</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td></td>
<td></td>
<td>(0.041)</td>
</tr>
<tr>
<td>$\beta_{LT}$</td>
<td>-0.003</td>
<td>-0.0001</td>
<td>0.004</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.001)***</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>$\beta_{KQ}$</td>
<td>-0.019</td>
<td>-</td>
<td>-</td>
<td>-0.053</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td></td>
<td></td>
<td>(0.041)</td>
</tr>
<tr>
<td>$\beta_{KT}$</td>
<td>0.003</td>
<td>-0.0001</td>
<td>-0.004</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.001)***</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>$\beta_{QT}$</td>
<td>0.027</td>
<td>0.028</td>
<td>0.032</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.016)**</td>
<td>(0.017)**</td>
<td>(0.015)**</td>
<td></td>
</tr>
<tr>
<td>Log-like</td>
<td>86.5529</td>
<td>78.4486</td>
<td>77.9158</td>
<td>43.4592</td>
</tr>
<tr>
<td>Restrictions</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

* Standard errors are in parentheses below the parameter estimates.

* Significant at the 10% level, two tailed test.
** Significant at the 5% level, two tailed test.
*** Significant at the 1% level, two tailed test.
Table 2. Own- and cross-price elasticities calculated at the mean of the factor shares for the logging industry in the Southeast.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Labor</th>
<th>Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>-0.453</td>
<td>0.165</td>
</tr>
<tr>
<td>Capital</td>
<td>0.107</td>
<td>-0.304</td>
</tr>
</tbody>
</table>

increase. Because substitution between the inputs is limited, increased harvest levels could not be accomplished by increased capitalization alone. The labor force of the industry would have to be increased. However, production shifts from the Pacific Northwest are likely to occur in other regions of the world, and therefore the aggregate U.S. logging industry could see a reduction in employment.

Table 2 contains the own- and cross-price elasticities of factor demand for the logging industry in the Southeast. The own-price elasticities are negative, and input demand curves are therefore downward sloping. All of the own-price elasticities are inelastic and according to Seldon and Bullard (1992) indicate that the suppliers of the inputs have little market power. The authors state that if left to the suppliers they would price the input in the elastic portion of the demand curve. Labor appears more responsive to price changes than capital in the Southeast. The cross-price elasticities are positive, indicating as before that the inputs labor and capital are substitutes.

Tests were performed to evaluate whether more restrictive functions such as homothetic, homogeneous or time invariant models would be appropriate for the logging industry in the Southeast. A test statistic of twice the difference of the log-likelihood statistic was compared to a χ² critical value with degrees of freedom equal to the number of restriction imposed on the model. For the Southeast the calculated test statistics for the homothetic, homogeneous and time invariant models were 16.21, 17.27 and 86.19. These test statistics were compared to χ² critical at the 5 percent significance level with 1, 2, and 4 degrees of freedom, respectively. Test statistics for the homothetic, homogeneous and time invariant model easily exceeded the χ² critical values of 3.84, 5.99 and 9.49 and therefore the null hypothesis that the restrictions hold can be rejected. The rejection of the homothetic and homogeneous models implies that functions such as the Cobb-Douglas or CES that restrict the function to be homothetic and homogeneous would be inappropriate for the logging industry in the Southeast. Rejection of the time invariant model implies that technology shifts over time had a significant influence on the industry.

**Literature Cited**


