EXPLORING THE IMPACTS OF PRICE EXPECTATIONS AND INTEREST RATES ON THE SOUTHEASTERN SOFTWOOD STUMPAGE MARKET

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ABSTRACT

This paper reports estimates of a simultaneous system of stumpage market equations that include adaptive expectations and market interest rates. The estimated coefficient of stumpage price expectations is negative and significant. The estimated coefficient of market interest rates is positive and significant. The elasticities of stumpage price expectations and market interest rates are inelastic. Further research work will concentrate on improving the underlying database and will use a rational price expectations approach to estimating stumpage price expectations using Generalized Method of Moments (GMM) estimators.

INTRODUCTION

Recent projections of the Southern forest economy by Adams and Haynes (1991) indicate that sawtimber stumpage prices will rise sharply over the period to 2015. Economic theory suggests that an increase in current stumpage price encourages producers to increase output and bring more marginal timberland into production, while rising stumpage price expectations will shift producers' harvest to the future as long as the marginal benefit from delaying the harvest is greater than the marginal opportunity cost of the delay.

Previous studies (Robinson (1974), Adams and Hayes (1980), Newman (1987), Hetemäki and Kuuluvain (1992), and Ovaskainen(1992)) analyze how the changes of current stumpage price affect timber supply, but few explicitly examine price expectations. This paper reports estimates a Southeastern softwood stumpage supply model that includes both price expectations and market interest rates. Both stumpage demand and supply are derived within a profit maximization framework. The model's demand structure is similar to the stumpage market model derived by Newman (1987). Demand is modeled as a function of stumpage price, final product price, labor wage rate, and capital rental rate. Supply for stumpage is a function of stumpage price, inventory level, expected price, market interest rate and lagged quantity.
THEORETICAL FRAMEWORK

We assume a three input production function that models output as a function of capital, labor, and stumpage to produce solidwood products such as lumber and plywood. For each firm i, the production function is as follows:

\[ q_{it} = q_{it} ( L_{it}, K_{it}, S_{it} ), \]

where

- \( i = 1, \ldots, N \) firms,
- \( t = 1964, \ldots, 1988 \),
- \( q_{it} \) = quantity of solidwood produced by firm \( i \) in period \( t \),
- \( L_{it} \) = quantity of labor consumed by firm \( i \) in period \( t \),
- \( K_{it} \) = quantity of capital consumed by firm \( i \) in period \( t \),
- \( S_{it} \) = quantity of stumpage used by firm \( i \) in period \( t \).

Total revenue, \( TR \), is the amount paid by consumers for solidwood products. That is:

\[ TR_{it} = p_{lut} q_{it} ( L_{it}, K_{it}, S_{it} ) \]

where \( p_{lut} \) is the price of lumber or plywood in period \( t \). Total cost, \( TC \), is the sum of production cost by firm \( i \). That is:

\[ TC_{it} = p_{lt} L_{it} + p_{kt} K_{it} + p_{st} S_{it}, \]

where

- \( p_{lt} \) = wage rate of labor in period \( t \),
- \( p_{kt} \) = rental rate of capital in period \( t \),
- \( p_{st} \) = stumpage price in period \( t \).

The objective of firm \( i \) is to maximize its potential profit (\( \pi_{it} \)). That is:

\[ \text{Max} \quad \pi_{it} = p_{lut} q_{it} ( L_{it}, K_{it}, S_{it} ) - p_{lt} L_{it} - p_{kt} K_{it} - p_{st} S_{it}. \]

Applying Hotelling's lemma, by differentiating the profit function with respect to stumpage price, we can get firm \( i \)'s derived demand function for stumpage. That is:

\[ \delta \pi_{it} / \delta p_{st} = S_{i}^d ( p_{st}, p_{lut}, p_{lt}, p_{kt} ) \]

The supply function for stumpage includes stumpage price, inventory level, expected stumpage price, the market interest rate and the lagged quantity of stumpage. Expected stumpage price and interest rate are proxies for the opportunity cost of holding growing
stock. The inventory level has traditionally been considered a proxy for harvesting cost since an increase in inventory level implies a decrease in the marginal harvesting costs. Lagged quantity supplied reflects partial adjustment in production process. As a result, the aggregate supply function for stumpage is as follows:

\[ Q^s = Q^s(p_{st}, I_t, p_{t+1}, r_t, Q_{t-1}) \]

where \( p_{st} \) = stumpage price in period t,

\( I_t \) = inventory level in period t,

\( p_{t+1} \) = expected stumpage price in period t+1,

\( r_t \) = market interest rate at period t,

\( Q_{t-1} \) = quantity harvest in period t-1.

Market clearing implies:

\[ Q^s(p_{st}, I_t, p_{t+1}, r_t, Q_{t-1}) = Q^d(p_{st}, P_{lubt}, P_{lt}, P_{kt}) \]

To investigate expectations, we first estimated a distributed lag model by including the the last five years of stumpage prices. The OLS regression results showed that only the coefficient of the first period lag of stumpage price is statistically significant, therefore, the distributed price expectations model uses the first period lag of stumpage price.

DATA AND METHODS

This analysis uses time series data from 1964 to 1988. Price variables are adjusted to the common base year of 1967 by means of the Total Industrial Commodities Producer Price Index in the Economic Report to the President (1993).

(i) Standing timber inventory and stumpage quantity in million cubic feet are from USDA Forest Service (Adams et al. 1988) and current FIA data. Linear interpolation is used between survey years.

(ii) Stumpage prices are from USDA Forest Service (Adams et al. 1988) and Timber Mart-South (1977-1988).

(iii) The Real producer price index for lumber and woods products serves as the final goods price variable. A national price index is used for deflation. The lumber and wood products price index is from Department of Labor, Bureau of Labor Statistics 1993.

(iv) Annual interest rates are from U.S. Treasury Bills as reported in the Economic Report to the President (1993).

(v) Labor costs were derived from regional payroll data. The wages and salaries paid to each type of labor are divided by their respective quantities to obtain average implicit labor prices. However, wages and salaries do not include the supplemental labor incomes received by worker and paid by the industry (e.g., unemployment insurance and
pension funds). Consequently, 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. Base data is from the U.S. Department of Commerce Census of Manufactures.

(vi) Capital service prices are derived using Christensen and Jorgensen's method (1969, p. 302). The service price of capital asset \( I \) at time \( t \) is given by

\[
P_{i,t} = Q_{i,t-1} \left( r_i - z_{i,t} \right) + Q_{i,t} d_{i,t}
\]

where \( Q_{i,t} \) is the time \( t \), acquisition price of capital asset \( i \); \( r_i \) is the Moody's AAA bond rate for the U.S.; \( d_{i,t} \) is the annual rate of depreciation (i.e., capital consumption allowance divided by the 1-year lag of the net stock), and \( z_{i,t} \) is the annual rate of capital gain loss (i.e., the annual rate of change in the asset acquisition price). The data is derived from the U.S. Department of Commerce Census of Manufactures.

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1 For more detailed derivation of labor costs, see Abt. 1984. Regional production structure and factor demand in the U.S. lumber industry. PhD dissertation, University of California, Berkeley, CA.


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ECONOMETRIC ESTIMATION AND RESULTS

Since quantity supply and derived demand for stumpage are determined simultaneously in the stumpage market, a simultaneous equations system was estimated using iterative three stage least squares (IT3SLS) regression to obtain asymptotically efficient and unbiased coefficients. The identified endogenous and exogenous variables are shown in Table 1.

Both linear and logarithmic formations of the equations system were tested, but the logarithm formation results are presented because they generally performed better. Another advantage of the logarithmic formulation is that the elasticities are estimated directly as the coefficients.

The estimated structure of logarithmic regression system for the softwood stumpage is:

\[
\ln Q^s_{st} = \alpha_0 + \alpha_1 \ln p_{st} + \alpha_2 \ln I_t + \alpha_3 \ln p_{s,t+1} + \alpha_4 \ln r_t + \alpha_5 \ln Q_{t-1} + \varepsilon_1
\]

\[
\ln Q^d_{st} = \beta_0 + \beta_1 \ln p_{st} + \beta_2 \ln P_{hbt} + \beta_3 \ln I_t + \beta_4 \ln p_{kt} + \varepsilon_2
\]

Where the \( \alpha_i \) (\( i = 0,...5 \)) and \( \beta_j \) (\( j = 0,...4 \)) are the estimated intercept terms and
coefficients and the $\varepsilon_i$ ($i = 1,2$) are the residuals from the estimation. Iterative three stage least squares (IT3SLS) regression is used to estimate the structural model. The results are reported in table 2. The fit of the model over the estimation period is shown in Figure 1.

<table>
<thead>
<tr>
<th>Simultaneous equations system</th>
<th>$Q_1^s = \alpha_0 + \alpha_1 p_{st} + \alpha_2 I_t + \alpha_3 p_{st+1} + \alpha_4 r_t + \alpha_5 Q_{t-1} + \varepsilon_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Q_1^d = \beta_0 + \beta_1 p_{st} + \beta_2 p_{lubt} + \beta_3 p_{lt} + \beta_4 p_{kt} + \varepsilon_2$</td>
</tr>
<tr>
<td></td>
<td>$Q^s_1 = Q^d_1$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>$Q_t = \text{sawtimber stumpage output in period } t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$p_t = \text{sawtimber stumpage price in period } t$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exogenous variables</th>
<th>$I_t = \text{inventory level in period } t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$p_{t+1} = \text{expected sawtimber stumpage price in period } t+1$</td>
</tr>
<tr>
<td></td>
<td>$r_t = \text{market interest rate in period } t$</td>
</tr>
<tr>
<td></td>
<td>$Q_{t-1} = \text{sawtimber stumpage output in period } t-1$</td>
</tr>
<tr>
<td></td>
<td>$p_{lubt} = \text{lumber price in period } t$</td>
</tr>
<tr>
<td></td>
<td>$p_{lt} = \text{labor wage rate in period } t$</td>
</tr>
<tr>
<td></td>
<td>$p_{kt} = \text{capital rental rate in period } t$</td>
</tr>
</tbody>
</table>
Table 2. IT3LSL results: 1964-1988.

<table>
<thead>
<tr>
<th>variable</th>
<th>$Q^2_{st}$</th>
<th>$Q^0_{st}$</th>
<th>$p_{st}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>intercept</td>
<td>-4.87**</td>
<td>5.96***</td>
<td>28.67</td>
</tr>
<tr>
<td>$p_{st}$</td>
<td>0.10**</td>
<td>0.11</td>
<td>-</td>
</tr>
<tr>
<td>$I_t$</td>
<td>0.94***</td>
<td>-</td>
<td>-3.70*</td>
</tr>
<tr>
<td>$p_{s,t+1}$</td>
<td>-0.29***</td>
<td>-</td>
<td>-0.31</td>
</tr>
<tr>
<td>$r_t$</td>
<td>0.10***</td>
<td>-</td>
<td>0.33**</td>
</tr>
<tr>
<td>$Q_{t-1}$</td>
<td>0.53***</td>
<td>-</td>
<td>0.34</td>
</tr>
<tr>
<td>$P_{ubt}$</td>
<td>-</td>
<td>-0.09</td>
<td>1.55**</td>
</tr>
<tr>
<td>$P_{lt}$</td>
<td>-</td>
<td>0.31***</td>
<td>0.53</td>
</tr>
<tr>
<td>$P_{kt}$</td>
<td>-</td>
<td>0.06***</td>
<td>-0.05</td>
</tr>
<tr>
<td>d.f.</td>
<td>18</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>DW</td>
<td>0.987@</td>
<td>0.772</td>
<td>1.76</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.9656</td>
<td>0.9656</td>
<td>0.8790</td>
</tr>
<tr>
<td>CV</td>
<td>0.5428</td>
<td>0.6737</td>
<td>2.2898</td>
</tr>
<tr>
<td>$F$</td>
<td>183748***</td>
<td>95592***</td>
<td>16.6***</td>
</tr>
</tbody>
</table>

* Significant at the 0.10 probability level
** Significant at the 0.05 probability level
*** Significant at the 0.01 probability level
@ Durbin h statistic
Figure 1. Observed and estimated real stumpage prices.

CONCLUSION

All the coefficients in the supply function are significant at the 5 percent level. The elasticity of stumpage price expectations is -0.29 and significant at 1 percent level. The coefficient of interest rate is 0.10 and significant at 1 percent level. Both the elasticities of stumpage price expectations and market interest rate are inelastic. Estimates of stumpage price and inventory are consistent with the previous studies. The own price elasticity is inelastic (0.10) and significant at 5 percent level. The elasticity of inventory is nearly unity (0.94).

In the derived demand function, the coefficients of stumpage price and lumber price are wrong sign but insignificant. The small positive coefficients of labor and capital costs indicate that labor, capital and stumpage inputs are substitutes. Comparison with previous studies is presented in Table 3.
Table 3. Comparison of the previous stumpage elasticities

<table>
<thead>
<tr>
<th>Source</th>
<th>Regions and species</th>
<th>Supply elasticities $p_s$ $I$ $p_{t+1}$ $r$</th>
<th>Demand elasticities $p_s$ $p_{lubt}$ $p_l$ $p_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montgomery et al. (1975)</td>
<td>Georgia: softwood</td>
<td></td>
<td>-.13</td>
</tr>
<tr>
<td>Adams and Haynes (1980)</td>
<td>Southeast: softwood</td>
<td>.447 1.0 (FI)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.30 (NIPF)</td>
<td></td>
</tr>
<tr>
<td>Daniels and Hyde (1986)</td>
<td>NC: softwood</td>
<td>.267 .62</td>
<td>-.033 .516</td>
</tr>
<tr>
<td>Our results (1995)</td>
<td>Southeast: softwood</td>
<td>.10 .94 -.29 .10 .11 -.09 .31 .06</td>
<td></td>
</tr>
</tbody>
</table>

This paper provides empirical support for examining price expectations and market interest rates. Further research work will concentrate on improving the underlying database and will take a rational price expectations approach to estimating stumpage price expectations using Generalized Method of Moments (GMM) estimators for both softwood and hardwood and for different ownership categories.

LITERATURE CITED


