Determinants of Pulpwood Supply and Demand in Alabama

Maksym Polyakov\textsuperscript{1}  
Larry Teeter\textsuperscript{2}  
John D. Jackson\textsuperscript{3}

Abstract

This paper presents an econometric analysis of the pulpwood market in Alabama. The market is modeled as a partial equilibrium one where the equality of supply and demand determines price. Estimation of the parameters was done using two-stage least squares. The price elasticity of supply was found to be relatively low, but higher than previously reported for the US South (Newman 1987). The complementary role of sawtimber in pulpwood supply corresponds with findings for Sweden and the US South (Brännlund 1985, Newman 1987). Regression results explain 80\% of the dependent variable variation, are consistent, and can be used for prediction purposes.

Key words: supply, demand, pulpwood, US South.

\textsuperscript{1} School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849-5418 USA 334-844-1053, polyama@auburn.edu  
\textsuperscript{2} School of Forestry and Wildlife Science, Auburn University, Auburn, AL 36849-5418 USA 334-844-1045, teeter@auburn.edu  
\textsuperscript{3} Department of Economics, Auburn University, Auburn, AL 36849 USA 334-844-2926, jjackson@business.auburn.edu
Determinants of Pulpwood Supply and Demand in Alabama

Introduction

The Southern timber market is the major source of both softwood and hardwood pulpwood in the US. In 1997, three-fourths of total US pulpwood production was produced in the region (USDA Forest Service 1999, p. 38). Currently, 97 mills are operating and drawing wood from the 13 Southern States. Southern mills’ pulping capacity of 134 thousand tons per day accounts for more than two-thirds of the nation’s total pulping capacity (Johnson 2001). Alabama leads the South in total production, number of mills, and pulping capacity.

A number of projections made in the 1970s and 1980s predicted an increasing share for the US South both in timber growth and removals (Haynes and Adams 1985). According to the 2000 RPA Forest Resources Assessment (USDA Forest Service 2001), however, by the year 2050 about 56 percent of nation’s harvested wood is predicted to come from the US South, which is comparable with the current share. Furthermore, the RPA predicts a constant proportion (30%) of roundwood used to produce wood pulp, which is explained in part by increases in utilization of recycled paper and wood processing residuals.

The constant interest in timber supply and environmental issues calls for more efforts to improve analyses and projections of forest resource trends. Furthermore, in the recent years there is a growing interest in information on timber supply in specific regions (states or parts of the states) and how it is affected by mill expansions, land use changes, and urbanization (Abt, Cubbage and Pacheco 2000).

The determinants of wood supply and demand are important elements of timber inventory projection models. This paper attempts to estimate demand and supply elasticities as well as other determinants for the Alabama pulpwood market.

Literature review


The theoretical part of most empirical studies of timber markets is commonly based on contemporary neoclassical microeconomic theory. Supply and demand are considered simultaneously, therefore methods are employed which allow for systems of simultaneous equations. Common approaches include two stage least squares (2SLS)
regression, or three stage least squares (3SLS) regression for the cases when sawtimber and pulpwood markets are considered simultaneously (Brännlund et al. 1985, Newman 1987, Carter 1992).

Leuschner (1973) conducted an econometric study of the aspen pulpwood market in Wisconsin based on data covering 1948 to 1969. He assumed that demand for pulpwood is not affected by price and is shifted by changes in pulpmill capacity. Supply is affected by price and shifted by the quantity sold in Wisconsin and imports during the previous year. The linear model of two stage least squares regression was used. All equation coefficients were found to be significant and had signs consistent with the underlying theory. The elasticity of supply with respect to own price was estimated to be 2.6.

Brännlund et al. (1985) analyzed Swedish pulpwood and sawtimber markets based on time-series data covering 1953 to 1981, and assumed that the equality between demand and supply determine price in the sawtimber market, and that pulpwood prices are exogenously determined (because of the specific features of the Swedish pulpwood market). A log-linear model was used. All coefficients of the supply curves had signs that are consistent with the underlying theory, and most were statistically significant. The own supply price elasticity of pulpwood was estimated to be approximately 0.7.

Newman (1987) presented an aggregate regional model of the southern US softwood solidwood (lumber + plywood) and pulpwood stumpage markets. This analysis considered direct substitution in output between these two products. A simple theoretical framework of the stumpage market allows the derivation of stumpage demand and supply within a profit maximization framework. Three-stage least squares regression techniques provided simultaneous parameter estimation of the market system. The linear specification was used. The study quantified substantial asymmetries between the pulpwood and solid wood market structures with respect to both supply and demand. Price coefficients in the pulpwood supply and demand equations were significant and had signs consistent with the theory. The own price supply and demand elasticities for the pulpwood market were estimated to be 0.23 and −0.43 respectively.

Carter (1992) presented a dynamic model of the Texas pulpwood stumpage market for the period 1964–1986. The ridge regression form of three-stage least squares was used in order to address problems of collinearity. Large significant income elasticity was found, larger then own price elasticity. The estimates of own supply and demand price elasticities using three-stage least squares were equal to 0.59 and −0.42 respectively.

All of the listed above previous studies dealt with softwood pulpwood (Carter, 1992), softwood solidwood (pulpwood + lumber) (Brännlund et al., 1985; Newman, 1987), or pulpwood hardwood (Leuschner, 1973) markets. As to our knowledge, no attempts were made to analyze the interaction between softwood and hardwood pulpwood demands. This is one of the goals of the present article.
Conceptual model

The basic economic assumption used in the model is that of equality of supply and demand for both softwood and hardwood pulpwood:

\[ Q_t^S = Q_t^{Sd} = Q_t^{Ss} \]  
\[ Q_t^H = Q_t^{Hd} = Q_t^{Hs} \]

where \( Q_t^S \) is the quantity of softwood pulpwood stumpage in year \( t \), and \( Q_t^{Sd} \) and \( Q_t^{Ss} \) are respectively the quantities demanded and supplied in year \( t \); \( Q_t^H \) is the quantity of hardwood pulpwood stumpage in year \( t \), \( Q_t^{Hd} \) and \( Q_t^{Hs} \) are respectively the quantities of hardwood pulpwood demanded and supplied.

Stumpage demand is derived from its use to produce pulp. Pulpmills have high fixed costs and mill managers have a significant incentive to ensure that mills operate continuously. That is why it is rational to include mill capacity in the list of explanatory variables. The influence of capacity is expected to be more significant in models of smaller regions (e.g., state as opposed to region or nation). The sign of pulpmill capacity is expected to be positive. At the aggregate level, pulpmills purchase both softwood and hardwood pulpwood. It is assumed that the proportion of each can vary within a limited range, therefore softwood and hardwood pulpwood can be alternative inputs. The sign of own price is expected to be negative, the sign of the price of alternative input is expected to be positive. Thus, demands for softwood and hardwood pulpwood are specified as

\[ Q_t^{Sd} = F(P_t^{Spw}, P_t^{Hpw}, C_t), \]  
\[ Q_t^{Hd} = F(P_t^{Hpw}, P_t^{Spw}, C_t), \]

where

- \( Q_t^{Sd} \) – demand for pine pulpwood stumpage in year \( t \);
- \( Q_t^{Hd} \) – demand for pine pulpwood stumpage in year \( t \);
- \( P_t^{Spw} \) – softwood pulpwood stumpage price in year \( t \);
- \( P_t^{Hpw} \) – hardwood pulpwood stumpage price in year \( t \);
- \( C_t \) – daily pulping capacity of Alabama pulp industry in year \( t \).

It is more difficult to derive the supply equation for pulpwood than demand equations. The individual production cost data are not readily available (Brännlund at al. 1985, Newman 1990) and expenses connected with production are distant in time. Pulpwood supply is a function of the revenues of forest management through own price and price of alternative products (sawtimber). The own price variable is expected to have a positive sign while the coefficients for alternative product prices are unclear; they depend on the possibility to switch to and from alternative products and on the dynamics of alternative
product prices. It is reasonable to use standing softwood inventory as in (Newman 1987), but data are only available at approximately ten-year intervals, and interpolation does not make much sense. Another consideration which could be made is that stumpage is bought, harvested, and sold to the pulp mills by a large number of small contractors who have limited financial resources and managerial skills. The volume sold in previous years can affect current year’s supply, because high sales in a previous year provide contractors with an incentive to stay in business in the current year and expand capacity (Leuschner 1973). Therefore, we assume a positive relationship between current year supply and previous year quantity. Finally, the quantities supplied are specified as

\[ Q_t^{SS} = F(p_t^{Spw}, p_t^{Sst}, Q_{t-1}^{SS}) \]  

(5)

\[ Q_t^{HS} = F(p_t^{Hpw}, p_t^{Hst}, Q_{t-1}^{HS}) \]  

(6)

where

- \( Q_t^{SS} \) – supply of softwood pulpwood stumpage in year \( t \);
- \( p_t^{Spw} \) – softwood pulpwood stumpage price in year \( t \);
- \( p_t^{Sst} \) – softwood sawtimber stumpage price in year \( t \);
- \( Q_t^{SS} \) – harvest of softwood pulpwood in previous year;
- \( Q_t^{HS} \) – supply of hardwood pulpwood stumpage in year \( t \);
- \( p_t^{Hpw} \) – hardwood pulpwood stumpage price in year \( t \);
- \( p_t^{Hst} \) – hardwood sawtimber stumpage price in year \( t \);
- \( Q_t^{HS} \) – harvest of softwood pulpwood in previous year.

**Data**


**Stumpage quantity** \( (Q_t^S \equiv Q_t^{SD} \equiv Q_t^{SS}, Q_t^H \equiv Q_t^{HD} \equiv Q_t^{HS}) \)

The quantity of pine pulpwood stumpage is the total quantity of pine roundwood in thousand cords, used for pulp production in Alabama. The sources of data are reports from the USDA Forest Service Southern Research Station.

**Stumpage prices** \( (p_t^{Spw}, p_t^{Sst}, p_t^{Hpw}, p_t^{Hst}) \)

Timber Mart South stumpage price data were used for the analysis. Annual prices were obtained by averaging statewide quarterly data. The price units used were US Dollars per cord for pulpwood, and US Dollars per board foot for sawtimber.
Pulping Capacity (C_t)

Data are annualized daily pulping capacities of Alabama's pulp and paper industry in thousand tons. Sources of data are annual reports "Southern Pulpwood Production" from the USDA Forest Service Southern Research Station.

Econometric model

The model utilized here is a system of four simultaneous linear demand (3, 4) and supply (5, 6) equations with equilibrium constraints (1, 2). Supply and demand equations contain two endogenous variables — prices of softwood and hardwood pulpwood. Furthermore, the supply equations contain lagged dependent variables. In this situation, the ordinary least squares (OLS) method provides inconsistent estimates of the coefficients (Gujarati 1988, p. 563). Both demand and supply equations are overidentified, which allows us to use two stage least squares (2SLS) regression, as it produces consistent (but biased) parameter estimates for the system of simultaneous equations.

In order to perform 2SLS, it is necessary to create instrumental variables by regressing $P_t^{Spw}, P_t^{Hpw}$ on all the exogenous variables ($C_t, P_t^{Sst}, Q_{t-1}^S, P_t^{Hst}, Q_{t-1}^H$), and use predicted values $\hat{P}_t^{Spw}, \hat{P}_t^{Hpw}$ in the following system of linear structural regression equations:

\begin{align}
Q_t^S &= \alpha_1 + \alpha_2 \hat{P}_t^{Spw} + \alpha_3 \hat{P}_t^{Hpw} + \alpha_4 C_t + \epsilon_{1t}, \\
Q_t^H &= \beta_1 + \beta_2 \hat{P}_t^{Hpw} + \beta_3 \hat{P}_t^{Spw} + \beta_4 C_t + \epsilon_{2t}, \\
Q_t^S &= \gamma_1 + \gamma_2 \hat{P}_t^{Spw} + \gamma_3 P_t^{Sst} + \gamma_4 Q_{t-1}^S + \epsilon_{3t}, \\
Q_t^H &= \delta_1 + \delta_2 \hat{P}_t^{Hpw} + \delta_3 P_t^{Hst} + \delta_4 Q_{t-1}^H + \epsilon_{4t},
\end{align}

where the $\alpha_t, \beta_t, \gamma_t, \delta_t$ are estimated coefficients and the $\epsilon_{it}$ are residuals from the estimation.

Both linear and log-log models were tested. Both provide comparable goodness of fit and significance measures. The linear results were used because they accommodate the theoretical model (the effects are mostly additive) and because the linear model is reported to generally perform better in this kind of situation (Newman 1987).

Regression results

The matrix of correlation coefficients between all of the variables used in the model is presented as Table 1. High correlation between explanatory variables $P_t^{Sst}, P_t^{Hpw}$, and
\( P_t^{Hst} \) (higher than between each of them and \( Q_t^S \) or \( Q_t^H \)) suggests the possible presence of near-multicollinearity.

**First stage equation**

The \( R^2 \) value in the first stage regression is high (exceeds 0.8), therefore the 2SLS estimate should approach classical OLS estimates (Gujarati 1988, p. 606). This also implies that standard errors of the second-stage regression need not be corrected and can be taken as the true estimates (Gujarati 1988, p. 621).

The regression results for the structural (second stage) equations are presented in Table 2. The table also contains elasticities calculated at the mean of the data.

**Demand equation**

The goodness of fit (as indicated by \( R^2 \)) is high (although its use as a measure of goodness of fit is not fully appropriate because in 2SLS it is not bounded in [0, 1]). The presence of heteroscedasticity was tested using White's tests. Tests failed to reject the null hypothesis of homoscedasticity at reasonable levels of significance in both demand equations. In order to test for autocorrelation the Durbin-Watson statistic was calculated. The value of the statistic lies within the indeterminate interval (\( d_l = 1.08 \) and \( d_u = 1.66 \) for \( N=23 \) and \( k = 3 \)). The conclusion is that no serious autocorrelation problem exists. However, because values of the Durbin-Watson statistic are very close to \( d_l \), Newey-West autocorrelation consistent covariance estimate (Greene, 2000, p. 464) was conducted, and corrected errors are recorded in Table 2.

The own price coefficients and alternative input price coefficients in the demand equations are not significant and have signs opposite to that expected. This corresponds with previous studies implicitly assuming own price elasticity equal to zero (Leuschner 1973). The coefficients of pulp mill capacity have the expected signs. In the hardwood pulpwod equation the coefficient is significant at the 1% level and in the softwood pulpwood equation it is significant only at the 10% level. Relatively low significance of \( C_t \) in this case could be explained by high correlation between explanatory variables in the equation.

**Supply equations**

The regression estimates are characterized by a high goodness of fit. The White's test failed to reject the null hypothesis of homoscedasticity at the 5% level. The conclusion was made that there is no heteroscedasticity. Because of the presence of a lagged dependent variable in the supply equations, the Durbin-Watson \( d \) statistic is not valid; therefore the Durbin \( h \) statistic was calculated. The value of the statistic suggests presence of autocorrelation in both softwood and hardwood pulpwood supply equations. The Newey-West autocorrelation consistent covariance matrix was calculated, and those standard errors are the ones that appear in Table 2.
Coefficients of all the regression coefficients of the supply equations are significant at the 1 percent level and higher, except coefficients for own price and lagged supply in the hardwood pulpwood supply equation. All the signs are consistent with underlying theory — coefficients of pulpwood prices and lagged pulpwood quantities are positive, and coefficients of sawtimber prices are negative. The softwood pulpwood own price elasticity is 0.82, this is slightly higher than elasticities estimated by Brännlund at al. (1985), Newman (1987), Carter (1992), but lower than that reported by Leuschner (1973).

Conclusion

The paper presents an econometric analysis of pulpwood supply and demand for Alabama. It uses two-stage least squares regression techniques for the system of four supply and demand equation.

The price elasticity of softwood pulpwood supply was found to be relatively low, but higher than previously reported for the US South (Newman 1987, Carter 1992). Price elasticity of hardwood pulpwood supply was comparable with the one of softwood pulpwood. The complementary role of sawtimber found both for softwood and hardwood pulpwood supply corresponds with findings for Sweden and US South (Brännlund at al. 1985, Newman 1987, Carter 1992).

The insignificance of pulpwood stumpage prices for pulpwood demand could be explained by the argument that the mills' pulping capacity is the most important factor influencing pulpwood demand. Data used in the analysis do not support the hypothesis of a substitute role for softwood and hardwood pulpwood stumpage prices in pulpwood demand. A limitation of the analysis here is that no account has been taken of the import of pulpwood from and export to the neighboring states. This could account for the failure concluding the substitute relationships between softwood and hardwood pulpwood demands.

Literature cited


Table 1. Correlation matrix.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$Q_{t-1}^S$</th>
<th>$Q_t^H$</th>
<th>$Q_{t-1}^H$</th>
<th>$P_t^{Spw}$</th>
<th>$P_t^{Sst}$</th>
<th>$P_t^{Hpw}$</th>
<th>$P_t^{Hst}$</th>
<th>$C_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_t^S$</td>
<td>0.894</td>
<td>0.757</td>
<td>0.781</td>
<td>0.804</td>
<td>0.774</td>
<td>0.880</td>
<td>0.789</td>
<td>0.850</td>
</tr>
<tr>
<td>$Q_{t-1}$</td>
<td>0.677</td>
<td>0.789</td>
<td>0.682</td>
<td>0.769</td>
<td>0.841</td>
<td>0.790</td>
<td>0.759</td>
<td></td>
</tr>
<tr>
<td>$Q_t^H$</td>
<td>0.916</td>
<td>0.554</td>
<td>0.448</td>
<td>0.792</td>
<td>0.594</td>
<td>0.936</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Q_{t-1}^H$</td>
<td>0.543</td>
<td>0.534</td>
<td>0.817</td>
<td>0.678</td>
<td>0.924</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_t^{Spw}$</td>
<td></td>
<td>0.856</td>
<td>0.805</td>
<td>0.871</td>
<td>0.658</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_t^{Sst}$</td>
<td></td>
<td></td>
<td>0.790</td>
<td>0.905</td>
<td>0.563</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_t^{Hpw}$</td>
<td></td>
<td></td>
<td></td>
<td>0.907</td>
<td>0.864</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_t^{Hst}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.707</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. The results of two stage least squares regression and price elasticities of the Alabama pulpwood stumpage market 1977–1999

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Value</th>
<th>Std. Error</th>
<th>$t$-value</th>
<th>$p$-value</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand $Q_t^s$</td>
<td>Intercept</td>
<td>623.382</td>
<td>1002.076</td>
<td>.622</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Spw}$</td>
<td>71.358</td>
<td>45.541</td>
<td>1.567</td>
<td>0.11</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Hpw}$</td>
<td>58.372</td>
<td>50.886</td>
<td>1.147</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$C_t$</td>
<td>0.105</td>
<td>0.061</td>
<td>1.707</td>
<td>0.09</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.839</td>
</tr>
<tr>
<td></td>
<td>Durbin-Watson $d$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.183</td>
</tr>
<tr>
<td></td>
<td>White's $NR^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.181</td>
</tr>
<tr>
<td>$Q_t^h$</td>
<td>Intercept</td>
<td>-405.564</td>
<td>1635.336</td>
<td>-2.248</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Hpw}$</td>
<td>26.746</td>
<td>52.075</td>
<td>.514</td>
<td>0.60</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Spw}$</td>
<td>-77.097</td>
<td>68.244</td>
<td>-1.130</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$C_t$</td>
<td>0.239</td>
<td>.048</td>
<td>5.025</td>
<td>0.00</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.868</td>
</tr>
<tr>
<td></td>
<td>Durbin-Watson $d$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.273</td>
</tr>
<tr>
<td></td>
<td>White's $NR^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.742</td>
</tr>
<tr>
<td>Supply $Q_t^s$</td>
<td>Intercept</td>
<td>-1173.996</td>
<td>429.033</td>
<td>-2.736</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Spw}$</td>
<td>191.894</td>
<td>23.681</td>
<td>8.103</td>
<td>0.00</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>$P_t^{Sst}$</td>
<td>-6.133</td>
<td>2.311</td>
<td>-2.654</td>
<td>0.01</td>
<td>-0.25</td>
</tr>
<tr>
<td></td>
<td>$Q_t^{Ss}$</td>
<td>0.700</td>
<td>.120</td>
<td>5.859</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>Durbin $h$</td>
<td>-1.822</td>
<td></td>
<td></td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>White's $NR^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.867</td>
</tr>
<tr>
<td>$Q_t^h$</td>
<td>Intercept</td>
<td>1819.576</td>
<td>657.866</td>
<td>2.766</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\hat{p}_t^{Hpw}$</td>
<td>160.974</td>
<td>70.071</td>
<td>2.297</td>
<td>0.02</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>$P_t^{Hst}$</td>
<td>-20.031</td>
<td>7.472</td>
<td>-2.681</td>
<td>0.01</td>
<td>-0.38</td>
</tr>
<tr>
<td></td>
<td>$Q_t^{Hs}$</td>
<td>0.455</td>
<td>.251</td>
<td>1.811</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.835</td>
</tr>
<tr>
<td></td>
<td>Durbin $h$</td>
<td>3.249</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>White's $NR^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.048</td>
</tr>
</tbody>
</table>