# An Econometric Analysis of Pine Pulpwood Market in the Southern US

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**Abstract:** This paper examines the determinants of pine pulpwood supply and demand in the southern US using annual data from 1950 to 2002. A structural simultaneous system of equations (SSE) model is used to estimate short-run price elasticities with three-stage least squares (3SLS) regression techniques. The results show that price elasticities of supply of and demand for pine pulpwood are relatively small, but similar to those reported for the US South. The results also show that the cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11, which is consistent with the previous finding. The significant substitution between pulpwood stumpage and energy use was found with elasticity of -0.35.

**Keywords:** Energy use, pine pulpwood market, simultaneous system of equations, market equilibrium

## Introduction

More than 83% of softwood pulpwood production in the United States came from the South (Howard 2003, p.6) and some 72% of timberland in the South was owned by nonindustrial private forest (NIPF) landowners in 2002 (Smith et al. 2004). These landowners supply stumpage to loggers or wood-dealers whereas paper processors produce final product combining processing inputs (such as capital and labor) with the log materials delivered by the loggers or wood-dealers. In 2004, 89 southern pulpmills were operating and pulping capacity of 125 thousand tons per day accounts for more than 70 percent of the Nation's total pulping capacity (Johnson and Steppleton 2004, p.7).

Understanding the characteristics of the stumpage market has been an important aspect in modeling exercises or forecast efforts, public policy and management plan. For example, Adams and Haynes (1980), Newman (1987), and Carter (1992) emphasize timber supply and demand issues and give insights into the determinants of quantity supplied and demanded, and price. Another example is supply and demand elasticities of stumpage play significant roles in measuring welfare impacts (e.g., Li and Zhang 2006). Modeling the stumpage market is also useful for assessing the effects of cost-sharing and technical assistance on reforestation (e.g., Royer 1987, Hyberg and Holthausen 1989, Zhang and Pearse 1996, and Zhang and Flick 2001).

Timber market models are extensively used to estimate short-run elasticity for forest landowners (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992, and Polyakov et al. 2005); however,

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few studies consider energy use in pulpwood market in the US South (Liao 2007). Most of previous studies have small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to its specification and even inconsistent (Wooldridge 2000). In addition, most of previous studies pay little attention to energy used in the production of paper and allied products. Energy use among US pulp, paper, and paperboard mills accounts for about 12% of all energy used in the domestic manufacturing sector and shares production cost by 13% within the paper mills (NAF 2002, Brown and Zhang 2005). Moreover, most of previous studies often ignore recycled paper, which is an increasingly significant input for environment reasons. The wastepaper utilization accounts for 42% for newsprint, 10% for printing/writing paper, 60% for tissue paper, and 15% for packaging paper, respectively (Brown and Zhang 2005).

Therefore, this study is to estimate pine pulpwood supply and demand using structural SSE approach in the Southern US because this approach has its own advantages. First, a structural SSE is a partial equilibrium model based on economic theory. Variable choices make economic sense. Second, an advantage of a structural SSE over non structural vector autoregression (VAR) model is that it estimates multiple equations simultaneously and enables us to obtain the price elasticities in the short run.

The paper is organized as follows. First, the theoretical models of pine pulpwood stumpage supply and demand are presented. Then, the data sources are presented and the empirical estimation using three-stage least squares (3SLS) follows. Next, the regression results are interpreted. The study ends with summary and conclusion.

**Theoretical Framework**

Demand for stumpage derives from its use as a raw material in the production of paper and paperboard products. Paper and paperboard firms purchase the stumpage in the market along with other inputs (e.g. labor, capital) to provide their particular output. Following the early authors' framework (Newman 1987, Brown and Zhang 2005), the production function for a competitive firm $i$ is assumed to be twice continuously differentiable. Thus,

$$\mathrm{Q}_{\mathrm{it}} = q_i(L_{it}, K_{it}, E_{it}, W_{it}, D_{it}) \qquad (1)$$

where $i$ = 1,..., $N$; $t$ = annual observations (1950, …, 2002) for pulpwood; $Q_{it}$ is the quantity of paper and paperboard production by firm $i$ in period $t$; and $L_{it}$, $K_{it}$, $E_{it}$, $W_{it}$,and $D_{it}$ are the quantities of labor, capital, energy, wastepaper, and raw material that firm $i$ uses in period $t$.

The paper and paperboard products trade in national markets, and as such, the final good price ($FP$) is exogenous to the region. The profit function for firm $i$ in period $t$ is:

$$\text{Max } \pi_{\mathrm{it}} = FP_{it} q_{it}(L_{it}, K_{it}, E_{it}, D_{it}) - w_{it}L_{it} - i_{it}K_{it} - e_{it}E_{it} - r_{it}W_{it} - PP_{it}D_{it} \qquad (2)$$

where $w_{it}$, $\mathrm{i}_{it}$, $e_{it}$, $r_{it}$, and $PP_{it}$ are for the particular industry, the respective prices of labor, capital, energy, recycled paper and pine pulpwood stumpage.

Applying Hotelling's lemma, the firm's derived demand for stumpage in period *t* is a function of market price and the prices of all inputs in production. The demand function for stumpage $D_i$ is found by taking the first derivative of the profit function (Varian 1978, p.31). Thus,

$$\partial \pi_{\text{it}} / \partial PP_{it} = D_{it}(\underset{+}{FP_{it}}, \underset{?}{w_{it}}, \underset{?}{i_{it}}, \underset{?}{e_{it}}, \underset{?}{r_{it}}, \underset{-}{PP_{it}}) \tag{3}$$

where the signs below the variables represent the expected effects on stumpage demand given an increase in output price or stumpage input costs. The signs for the wage, capital, and energy are uncertain because they depend on whether stumpage is a technical complement or substitute with other inputs (Newman 1987).

If all the firms in the southern region have the same production function and face the same input prices, the regional stumpage demand equation can be obtained by aggregating the N individual firm's demand functions. Thus,

$$\mathrm{D_t}(\mathrm{FP_t}, \mathrm{w_t}, \mathrm{i_t}, \mathrm{e_t}, \mathrm{r_t}, \mathrm{PP_t}) = \sum_{i=1}^{N} D_{it}(FP_{it}, w_{it}, i_{it}, e_{it}, r_{it}, PP_{it}) \tag{4}$$

This equation serves as the theoretical model for the analysis.

The aggregated roundwood supply is assumed to be a function of the received price for roundwood and the harvesting costs suggested by Newman (1987). There are several reasons for the assumption. First, the differentiated ownership and management structure of forestland in the South complicates the aggregation of individual roundwood supply functions as was done by Brännlund et al. (1985) and Kuuluvainen (1986). If owner-specific data is available, a complete production function specification is possible, though still problematic (Brännlund et al. 1985). Second, numerous factors influence the individuals output of roundwood such as multiple potential outputs (sawlog, pulp and paper log, poles), long delay between production decisions and the presence of government regulation. These concerns recommend hypothesizing a simplified supply function that still accounts for the returns and costs from forest management (Newman 1987). The amount of standing softwood pulpwood inventory serves as an inverse proxy for harvesting costs. Pine sawtimber stumpage might influence the output of pine pulpwood suggested by Newman (1987). Thus, the supply specification is as the following:

$$\mathrm{S_{jt}} = S_j(\underset{+}{PP_{jt}}, \underset{?}{SP_{jt}}, \underset{+}{v_{jt}}) \tag{5}$$

The own price for the pulpwood supply function is positive while the sign on sawtimber price is uncertain. Timber inventory has a positive effect on the output because the marginal harvesting costs decrease as inventory increases. If all the forest owners in the region maintain the same production, the regional stumpage supply specification can be found by aggregating the N individual forest owner's production functions. Thus,

$$S_t(PP_t, SP_t, v_t) = \sum_{j=1}^{N} S_{jt}(PP_{jt}, SP_{jt}, v_{jt}) \tag{6}$$

The equation serves the theoretic model for this analysis and shows that the stumpage supply of pine pulpwood depends on owen price, sawtimber price, and inventory.

Finally, a market clearing assumes that the quantity of supply and demand should be equal. Thus:

$$S_t(PP_t, SP_t, v_t) = D_t(FP_t, w_t, i_t, e_t, r_t, PP_t) \tag{7}$$

Keep in mind, transportation costs are assumed a relatively constant fraction of the stumpage price and do not affect the short-run supply and demand in the region.

The SSE model satisfies the order condition for identification because there are two endogenous variables (Dem and PP) and more than two excluded exogenous variables (PPI, w, i, r, e, t) in the demand equation. Likewise, there are two endogenous variables (SUP and PP) and more than two excluded exogenous variables (V and SP) in the supply equation. The SSE model was estimated with three-stage least squares (3SLS) because it is consistent and asymptotically more efficient than two-stage least squares (2SLS) in overidentified systems (Wooldridge 2000, p516). It is clear that ordinary least squares (OLS) is inconsistent for the SSE model. In the empirical estimation, EViews 5.1 is used.

**Data Sources**

Data sources are described in Table 1. Softwood stumpage is the total quantity of pine pulpwood of the 13 southern states covered by the Southeastern and Southern Forest Experiment Stations of the USDA Forest Service. The softwood roundwood imports from and exports to the region are ignored because both are relatively small quantities. The average volume-weighted stumpage price of southern pine pulpwood for 1977-2002 is from Timber Mart-South and for 1950-1976 from Ulrich (1989). Likewise, the average volume-weighted stumpage price of southern pine sawtimber for 1977-2002 is from Timber Mart-South and for 1950-1976 from Ulrich (1989). The US bank prime loan is used as the opportunity cost of capital (www.federalreserve.gov/releases/h15/data). The producer price index of the paper and allied products is employed as the final product price from the Bureau of Labor and Statistics (BLS). Wage rate is from the BLS. The producer price index of waste or recycled paper is also obtained from BLS, which serves as a proxy for the wastepaper price. Annual data for electricity is also taken from the BLS index for industrial electric power. Standing timber inventory for 1950-1985 is from Adams (1988) and for 1986-2002 from Smith et al. (2004). The missing data is found based on the formula from Newman (1987). The formula is specified as the following: $v_t = v_{t-1} + [G^* - (S_t - S^*)$, where $G^*$ is the average annual net growth between survey years and $S^*$ is the average stumpage production between survey years. All data are annual and the time series cover the period from 1950 to 2002 (53 observations). The deflator is the Producer Price Index used for all prices from the US Department of Commerce (1982=100) and the Consumer Price Index is used for wage rate from the US BLS (1982=100).

## Empirical Results

Both linear and log-linear forms are explored to estimate the SSE model. The log-log form results are reported here because it outperforms better than linear form in terms of coefficient significant. In addition, the logarithmic transformation can partly overcome exponential trends of these time series and the coefficients have an interpretation as elasticity. The White's tests indicate that no heteroscedasticity is present in the SSE model. Following the procedure from a special case of the White test (Wooldridge 2000, p. 260), we obtain the *F*-values (2.12 for the demand equations and 0.53 for the supply equations). Both of them are less than the value of $F_{2,50}$ distribution at the 5% level ($F_{2,50}$ =3.19), indicating we fail to reject homoskedasticity. The low values for the Durbin Watson (DW) statistic in the SSE model reveal a problem of serial correlation in the system. However, the statistical package in this study cannot correct the serial correlation for the system equations (Newman 1987). Alternatively, one treatment is to calculate serial correlation-robust standard error, while keeping other results of the SSE model, following the framework of Newey-West (Wooldridge, 2000, p.395). However, the SC-robust standard errors may be poorly behaved when there is substantial serial correction and the sample size is small. In addition, the OLS used in the system can be very inefficient.

Table 2 presents the regression results for pine pulpwood supply and demand. Overall, the explanatory variables significantly explain the dependent variables because the $R^2$ values are high. The coefficients have the expected sign and most of them are significant.

On the demand side, the own price elasticity is significantly negative at the 5% level, but very inelastic with an estimated value of 0.22. On contrary, the final good price (paper and allied products) is significantly positive with an elasticity of 0.37, unlike previous studies where the final good price is not significantly different from 0. After a careful examination, we find that some degree of complements exists between stumpage and capital, while stumpage and energy are technical substitute. Both of these coefficients are significant at the 5% level. However, neither labor shows significantly positive relationship with stumpage, or recycled paper shows significantly negative relationship with stumpage.

On the supply side, the own price elasticity is significantly positive at the 1% level, but very inelastic with an estimated value of 0.35. The inventory elasticity is significantly positive at the 1% level and close to 1, which means that a 10% increase in the growing stock tends to increase pulpwood production by 8.9 %. The cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11.

The estimated elasticities in this study can only be partially compared with existing values in the literature because of difference in methodology, data sources and regional focus. Table 3 compares price and inventory elasticities from this study and other studies for the US South. The price elasticities of softwood pulpwood demand and supply were found to be relatively small in this study, but similar to those reported for the US South (e.g. Newman 1987, Carter 1992, and Polyakov 2005).

## Concluding Remarks

The primary objective of the paper is to provide an up-to-date econometric analysis of pine pulpwood supply and demand in the South. To that end, a structural SSE model is developed and three-stage least squares regression techniques were used for that model. The results show that price elasticities of supply of and demand for pine pulpwood are relatively small, but similar to those reported for the US South (e.g. Newman 1987, Carter 1992). The results also show that the cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11, which is consistent with the finding by Newman (1987). Finally, the significantly substitution between pulpwood stumpage and energy was found with elasticity -0.35.

The study makes two contributions to the U.S. timber supply and demand literature. First, a five-factor demand specification for pine pulpwood stumpage is employed, while previous studies often ignore recycled paper and energy uses. Second, on the supply side, the complementary role of sawtimber in pulpwood production for the US South is found to be similar in Sweden (Johansson and Löfgren 1985), while it does not hold for Texas (Carter 1992).

The finding in this study may have implications on paper industry processors, landowners, and public policymakers. Paper industry processors should aware that any policy change in increasing capital investment may result in demand increase for pulpwood. Landowners who pursue profits from pulpwood production may consider the complementary role of sawtimber because sawtimber generates more revenue than pulpwood. The apparent substitution between wood and energy use produces a possible dilemma for environmental policymakers. If a hypothetical environmental tax is imposed on industrial electricity use, it may increase natural resource consumption. Further research is needed to examine pine pulpwood production by different ownerships so that a complete production function could be specified. In addition, the long-run relationship among the variables could be examined.

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Table 1. Data description and sources.

| Variable (Abbreviation) | Measurement | Source |
|---|---|---|
| Pine pulpwood demand (DEM) | Million cord | Southern Forest Experiment Station |
| Pine pulpwood supply (SUP) | Million cord | Southern Forest Experiment Station |
| Stumpage price of pine pulpwood (PP) | US$/Standard cord | 1977-1999 from Timber Mart-South, 1950-1976 from Ulrich (1989) |
| Stumpage price of pine sawtimber (SP) | US$/Thousand board feet (Scribner) | 1977-1999 from Timber Mart-South, 1950-1976 from Ulrich (1989) |
| Paper and allied products (FP) | Index (1982=100) | US Bureau of Labor Statistics |
| Inventory (v) | Million cubic feet | 1950-1985 from Adams et al (1988), 1986-2002 from Smith et al. (2002) |
| Wage rates (w) | U.S.$ per hour | US Bureau of Labor Statistics |
| Capital cost (i) | % | US Federal Reserve |
| Recycled paper (r) | Index (1982=100) | US Bureau of Labor Statistics |
| Energy (e) | Index (1982=100) | US Bureau of Labor Statistics |
| Technical change (t) | Integer | From 1 for 1950 to 53 for 2002 |
| U.S. Consumer Price Index (CPI) | 1982=100 | US Bureau of Labor Statistics |
| U.S. Producer Price Index (PPI) | 1982=100 | US Bureau of Labor Statistics |

Table 2. 3SLS estimates of softwood pulpwood stumpage demand and supply for the US South, 1950-2002.

| | Dem | | Sup | |
|---|---|---|---|---|
| Variable | Coefficient | Std. Error | Coefficient | Std. Error |
| Intercept | 9.13 | 0.64** | -0.87 | 0.56 |
| Pine pulpwood price | -0.22 | 0.11** | 0.35 | 0.07** |
| Inventory | | | 0.89 | 0.07** |
| Pine sawtimber price | | | 0.11 | 0.05** |
| Paper and allied products | 0.37 | 0.20** | | |
| Wage rate | 0.21 | 0.20 | | |
| Capital | 0.27 | 0.06** | | |
| Recycled paper | -0.04 | 0.05 | | |
| Energy | -0.35 | 0.10** | | |
| Technical change | 0.02 | 0.01** | | |
| No. of observations | 53 | | 53 | |
| Adjusted-$R^2$ | 0.92 | | 0.93 | |

Note: ** indicates significant at the 5% level.

Table 3. Elasticity estimates from this study and other studies of the stumpage market for the US South.

| Equations and variables | This study | Newman (1987) | Carter (1992) | Polyakov et al. (2005) |
|---|---|---|---|---|
| Dem | | | | |
| PP | -0.22** | -0.43* | -0.42** | -0.77** |
| FP | 0.37** | 0.12 | 0.05 | |
| w | 0.21 | 0.68** | | |
| i | 0.27** | -0.15** | | |
| r | -0.04 | | | |
| e | -0.35** | | | |
| t | 0.02** | | | |
| Sup | | | | |
| PP | 0.35** | 0.23** | 0.59** | 0.35** |
| v | 0.89** | 1.20** | 3.60** | |
| SP | 0.11** | 0.08** | -0.07 | |

Note: ** and * denote significances at the 5% and 10% levels.

We compared our proposed biomass thinning regime with a traditional management regime.Â  Following the biomass thinning, traditional harvest of pulpwood and timber products would be conducted. The feasibility analysis of incorporating biomass thinning as a potential product for a biomass market was examined for Piedmont and Coastal Plain site scenarios in Alabama.Â  The development of cellulosic ethanol markets will contribute to the use of small diameter, understory trees and harvesting residues in loblolly pine (Pinus taeda) plantations in the South ( Perlack & Stokes, 2011 , Rummer et al., 2012 ), leading to a higher level of silvicultural activities in young forest stands in terms of additional thinning and final harvests. Modeling and forecasting pine sawtimber stumpage prices in the US South by various time series models. Canadian Journal of Forest Research, Vol. 40, Issue. 8, p. 1506.Â  Approaches and methods for the econometric analysis of market power: a survey and empirical comparison. Journal of Economic Surveys, Vol. 31, Issue. 1, p. 303.Â  Structural Changes on Pulpwood Market in the US South: Wood Pellets Investments and Price Dynamics. Forest Science, Vol. 65, Issue. 6, p. 675.