An Econometric Study of the Hardwood Stumpage Market in the South Central United States:
Preliminary Results

by
Venkatarao Nagubadi and Ian A. Munn

Abstract
This study investigates the supply and demand structure of the hardwood stumpage market in the South Central United States for the period 1981-1996. Three stage least squares regression is used to estimate parameters in a simultaneous equations model of pulpwood and sawtimber stumpage markets for mixed hardwoods, oak, and total hardwoods. Stumpage prices are generally non-significant. Hardwood pulpwood is a gross complement in sawtimber production, but there is no evidence of substitution of sawtimber for pulpwood production or hardwood pulpwood for pine in pulp production. The wage rates and interest rates have reduced the demand for hardwood pulpwood. Final good prices have a positive influence and wage rates have a negative effect on the demand for hardwood sawtimber. Price and inventory elasticities are estimated.

INTRODUCTION
The South Central United States occupies a key position with 23% of the inventory, 29% of net annual growth, and 32% of annual removals in the U.S. hardwood stumpage market (Powell et al. 1993). Timberland is predominantly private with 70% in nonindustrial private forest (NIPF) ownership. Non-timber objectives of NIPF landowners significantly influence their production behavior and available timber supplies (Newman and Wear 1993).

The hardwood market has experienced several changes in recent times. Hardwood lumber production increased nearly 50% from 1979 to 1995. Hardwood lumber exports, as a percent of total hardwood lumber production in the United States, increased from 2.3% in 1960 to 8.5% in 1996 (West and Hansen 1997). Technological developments have increased the use of hardwoods as a substitute for softwoods in pulpwood production and in structural panels such as oriented strand board. Consequently, real hardwood pulpwood prices increased at an annual compound rate of 6.3% compared to 1.5% for softwood pulpwood during 1977-96 (Nagubadi and Munn 1997). Haynes et al. (1995) project that real hardwood sawtimber prices will increase between 1.0 and 2.4% annually during 1991-2040, reflecting the increase in demand.

Although the hardwood annual growth to removals ratio is 1.5:1 compared to 0.99:1 for softwoods, and the inventory to annual removals ratio for hardwoods is 48:1 versus 18:1 for softwoods, the actual difference in available stumpage is much less. Much of the hardwood resource is grown in bottomlands, coastal areas, or steep slopes in mountain areas. Increasing environmental restrictions imposed on wetlands have restricted the hardwood stumpage supply. Further, hardwoods grow in mixed-age, mixed-species stands in contrast to primarily even-age, single species softwood stands. For these reasons, the supply and demand structure of hardwood stumpage markets is sufficiently different from softwoods to deserve a separate look.

Researchers have studied the supply and demand structure of softwood lumber and stumpage markets (Robinson 1974; Adams 1977; Newman 1987). However, no studies examined the supply and demand structure of the hardwood stumpage market. The supply and demand responses to stumpage price

1 Approved for publication as Journal Article No. F O-098 of the Forest and Wildlife Research Center, Mississippi State University.

2 Graduate Research Assistant and Assistant Professor, Forestry Department, Mississippi State University, Box 9681, Mississippi State, MS 39762.
changes for hardwood pulpwood and sawtimber are important for policy and planning purposes. Substitution elasticities for hardwood pulpwood and sawtimber, and for hardwood and softwood pulpwood are also important.

The objective of this study is to estimate the supply and demand structure of the hardwood stumpage market in the South Central region of the United States comprising Alabama, Arkansas, Louisiana, Mississippi, Tennessee, and Texas. The study evaluates substitution possibilities between hardwood pulpwood and sawtimber, and between hardwood and softwood pulpwood. Price and inventory elasticities are estimated.

THEORETICAL MODEL
The demand for hardwood stumpage is derived from hardwood lumber which is primarily used in the production of pallets, skids, furniture, and hardwood flooring. Therefore, hardwood stumpage demand can be derived from the production functions of these final hardwood lumber products. Assuming a twice continuously differentiable production function for hardwood products, the production function of firms using hardwood stumpage products is written as (Brannlund et al. 1985; Newman 1987):

\[ Y = F(L, K, S) \]

where \( Y \) is the quantity of final goods produced from hardwood stumpage, \( L, K, \) and \( S \) are the quantities of labor, capital, and hardwood stumpage (as raw material) used by the firm. The profit function, \( V \), can be written as:

\[
\max (w, r, p_s): V = P_H F(.) - wL - rK - p_s S
\]

where \( P_H \) is the price of final good made from hardwood stumpage products, \( w, r, p_s \) are prices of labor, capital, and hardwood stumpage respectively. Using Hotelling= lemma, by differentiating the profit function with respect to the stumpage price, \( p_s \), the firms= demand (\( S^d \)) for hardwood stumpage can be derived:

\[
\frac{\partial V}{\partial p_s} = S^d(p_s, P_H, w, r).
\]

The regional hardwood timber demand function can be found by aggregating all the individual firms= demand functions.

The supply of hardwood stumpage is assumed to be a function of hardwood stumpage price, harvesting costs, and the inventory of hardwood stumpage:

\[
S^s = S^s(p_s, HC, I)
\]

where \( S^s \) is the quantity of hardwood stumpage supplied, \( p_s \) is the price of hardwood stumpage, \( HC \) is harvesting cost, and \( I \) is hardwood stumpage inventory.

Finally, assuming market clearing conditions, supply equals demand, \( S^s = S^d \), and the hardwood stumpage market can be represented by simultaneous supply and demand equations.

PREVIOUS STUDIES
Previous studies have focussed on softwood stumpage, softwood lumber, and hardwood lumber. Robinson (1974) estimated the own-price supply elasticity for Douglas-fir stumpage at a low 0.11. Brannlund et al. (1985) estimated supply elasticities for aggregate sawtimber and pulpwood in Sweden at 0.6 and 0.7 respectively during 1953-81. Newman (1987) estimated supply elasticities for softwood sawnwood at 0.55 and for softwood pulpwood at 0.23 for the period 1950-80. These studies indicate an inelastic supply function for stumpage products in general. The supply price elasticity for hardwood stumpage is, therefore, anticipated to be low because most of the hardwood resource is controlled by NIPF landowners.

The empirical evidence concerning the effect of interest rates on stumpage supply is mixed. Robinson (1974) included interest rates in the supply function for Douglas-fir stumpage. The coefficient was significantly negative implying supply will decrease with increases in the interest rate. However, Hultkrantz and Aronsson (1989) questioned this and argued that according to economic theory as interest rates increase the cost of holding forest inventories increases. They found interest rates to be significantly positive which contradicted Robinson’s (1974) results.

Newman (1987) included the interest rate as the user cost of capital in demand equations and found a significantly negative effect on softwood pulpwood demand. In this study, the interest rate is included as an indicator of overall market activity in the demand functions of hardwood stumpage products.
EMPIRICAL MODEL AND DATA

The empirical model for hardwood markets is estimated for the South Central region of the United States for the period from 1981 to 1996. The empirical specification of the model is:

**Hardwood Pulpwood:**

**Demand:**

\[
Q_{HP} = a_0 + a_1 P_{HP} + a_2 P_{SP} + a_3 P_P + a_4 W + a_5 R
\]

**Supply:**

\[
Q_{HP} = b_0 + b_1 P_{HP} + b_2 P_{SP} + b_3 P_P + b_4 HC_{HP} + b_5 I_{HP}
\]

where: 
- \(Q_{HP}\) = removals of hardwood pulpwood,
- \(Q_{HS}\) = removals of hardwood sawtimber,
- \(P_{HP}\) = price of hardwood pulpwood,
- \(P_{SP}\) = price of softwood pulpwood,
- \(P_P\) = price of paper,
- \(HC_{HP}\) = harvest cost of hardwood pulpwood,
- \(I_{HP}\) = inventory of hardwood pulpwood,
- \(a_i, b_i, \gamma_i, \delta_i\) = respective coefficients.

Hardwood pulpwood and sawtimber are produced simultaneously and production decisions affect each other. Therefore, three stage least squares regression is used to obtain parameter estimates in a simultaneous equations model.

**Data**

*Stumpage prices:* Stumpage price data are taken from Timber Mart-South (TMS 1981-96). Weighted average prices for the South Central region are calculated using statewide removals as weights. Pulpwood prices are in dollars per standard cord. Separate prices for oak pulpwood are not available, therefore, mixed hardwood pulpwood prices are used as a proxy. Oak and mixed hardwood sawtimber prices are in dollars per Mbf (Doyle). Real stumpage prices are calculated using the Producers Price Index (PPI) for all commodities (1982=100).

*Harvesting cost:* This is calculated as the difference between the delivered price and stumpage price of the respective commodities. Harvesting cost is deflated using the PPI. The average harvesting cost is calculated using state removals as weights.

*Removals:* Annual removals data are estimates developed from the Southern Timber Resource Inventory Projection System (STRIPS) developed by McDill and Braze (1997). Removals for six states are computed in million cubic feet (mcf). Pulpwood removals are derived by subtracting sawtimber removal volumes from total removal volumes for the respective commodities.

*Inventory:* Inventory data in billion cubic feet (bcf) are obtained from McDill and Braze (1997). Pulpwood inventories are calculated by subtracting sawtimber inventories from total inventories of respective commodities.

*Lumber price:* Red oak lumber (green only) prices for first and seconds (FAS) obtained from the Hardwood Market Report (Memphis, TN) are used as a proxy for final good price for hardwood sawtimber. These prices are deflated using the PPI.

*Paper price:* The producer price index for paper (code: WPU 0913) from the Bureau of Labor Statistics (U.S. Department of Labor) is used as a proxy for the final good price of hardwood pulpwood. The paper price index (1982=100) is deflated using the PPI.

*Wage rate:* Average hourly earnings for logging camps (SIC code: 241) national data from the Bureau of Labor Statistics (U.S. Department of Labor) is used. Nominal earnings are deflated by the consumer price index (1982-84=100) to generate real earnings.

*Interest rate:* First mortgage interest rates for single family homes are used in the analysis (Bureau of the Census, U.S. Department of Commerce).

RESULTS AND DISCUSSION

Separate models for mixed hardwood, oak, and total hardwood stumpage are estimated. The analysis is restricted to the period 1981-96 as annual removals and inventory data are not available for Tennessee prior to 1981. The preliminary results for these three models are presented below.

**Mixed Hardwood Model**

The parameter estimates for the mixed
hardwood model are presented in Table 1. In the demand equation for mixed hardwood pulpwood, the coefficients for wage rate and interest rate are negative and significant. In the supply equation for hardwood pulpwood stumpage, the coefficient for the inventory variable is significant and positive.

For mixed hardwood sawtimber, the coefficients for wage rate and final good price in the demand equation are significant at 1% level of probability and have the expected signs. In the supply equation, the coefficient for inventory is significant and positive. No other coefficients are significant.

*Oak Model*

For oak pulpwood stumpage, the coefficients for the wage rate and interest rate in the demand equation are significant and negative as expected (Table 2). In the supply equation, the coefficient for harvesting cost is negative and significant and the coefficient for inventory is positive and significant.

In the demand equation for oak sawtimber stumpage, the coefficient for the wage rate variable is significant and negative and that for final good price is significant and positive. The coefficient for oak sawtimber stumpage price in the demand equation is significant at the 10% level of probability, but the sign is positive contrary to theoretical expectation. The
Table 1 Estimates of coefficients for mixed hardwood stumpage market in the South Central U.S.: 1981-96.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>660.71</td>
<td>-473.87</td>
<td></td>
<td>Intercept</td>
<td>1737.10</td>
<td>-850.38</td>
<td></td>
</tr>
<tr>
<td>HST price</td>
<td>-0.06</td>
<td>0.53</td>
<td>HST price</td>
<td>0.19</td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPW price</td>
<td>1.70</td>
<td>1.41</td>
<td>HPW price</td>
<td>-</td>
<td>-0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPW price</td>
<td>1.70</td>
<td>-</td>
<td>Wage rate</td>
<td>-146.78***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wage rate</td>
<td>-21.97***</td>
<td>-</td>
<td>Interest rate</td>
<td>6.85</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate</td>
<td>-10.51***</td>
<td>-</td>
<td>HST harv. cost</td>
<td>-</td>
<td>-0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPW harv. cost</td>
<td>-</td>
<td>0.16</td>
<td>HST inventory</td>
<td>-</td>
<td>49.48***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPW inventory</td>
<td>-</td>
<td>47.62***</td>
<td>Lumber price</td>
<td>0.76***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper price</td>
<td>0.66</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.95</td>
<td>0.96</td>
<td>R-Squared</td>
<td>0.96</td>
<td>0.96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* HST= mixed hardwood sawtimber, HPW= mixed hardwood pulpwood, PPW= Pine pulpwood. *, ** and *** indicate significance at 10, 5, and 1% level.

Table 2 Estimates of coefficients for oak stumpage market in the South Central U.S.: 1981-96.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Oak Pulpwood</th>
<th>Demand Eq.</th>
<th>Supply Eq.</th>
<th>Variable</th>
<th>Oak Sawtimber</th>
<th>Demand Eq.</th>
<th>Supply Eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1075.40</td>
<td>-744.35</td>
<td></td>
<td>Intercept</td>
<td>780.83</td>
<td>-69.03</td>
<td></td>
</tr>
<tr>
<td>OST price</td>
<td>-</td>
<td>1.10**</td>
<td>OST price</td>
<td>0.27*</td>
<td>1.04***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPW price</td>
<td>4.73</td>
<td>-3.74</td>
<td>HPW price</td>
<td>-</td>
<td>-4.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPW price</td>
<td>-3.58</td>
<td>-</td>
<td>Wage rate</td>
<td>-74.36***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wage rate</td>
<td>-28.12***</td>
<td>-</td>
<td>Interest rate</td>
<td>5.48</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate</td>
<td>-15.86***</td>
<td>-</td>
<td>OST harv. cost</td>
<td>-</td>
<td>-0.46***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPW harv. cost</td>
<td>-</td>
<td>-1.98**</td>
<td>OST inventory</td>
<td>-</td>
<td>38.32***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPW inventory</td>
<td>-</td>
<td>159.17***</td>
<td>Lumber price</td>
<td>0.34***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper price</td>
<td>0.47</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.95</td>
<td>0.96</td>
<td>R-Squared</td>
<td>0.98</td>
<td>0.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* OST= oak sawtimber, OPW= oak pulpwood. *, ** and *** indicate significance at 10, 5, and 1% level.

coefficient for oak sawtimber stumpage in the supply equation is positive and significant. As expected, the harvesting cost has a significant negative effect on the supply of oak sawtimber, while inventory has a significant positive effect on oak sawtimber supply.

Total Hardwood Model

The results for total hardwoods are similar to mixed hardwood model with the exception that the coefficient for sawtimber price in the pulpwood demand equation is significant and positive at the 10% level of probability (Table 3). As in the mixed hardwood model, the coefficients for wage rate and interest rate are significant and negative in the pulpwood demand equation and the coefficient for the inventory variable is positive and significant in the total hardwood pulpwood supply.

Similar results are obtained for total hardwood sawtimber as in the case of mixed hardwood sawtimber. The coefficients for wage rate and final good price in the demand equation are significant and as expected. The inventory variable has significant positive influence on the supply of total hardwood sawtimber.
Elasticities

Elasticities for total hardwood model are calculated at mean levels of variables (Table 4). Except for inventories of total hardwood pulpwood and sawtimber in supply equations and wage rate in the demand equation for total hardwood sawtimber, the
Table 3  Estimates of coefficients for total hardwood stumpage market in the South Central U.S.: 1981-96.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total hardwood pulpwood</th>
<th>Variable</th>
<th>Total hardwood Sawtimber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand Eq.</td>
<td>Supply Eq.</td>
<td>Demand Eq.</td>
</tr>
<tr>
<td>Intercept</td>
<td>1003.90</td>
<td>-635.14</td>
<td>Intercept</td>
</tr>
<tr>
<td>TST price</td>
<td>-</td>
<td>1.02*</td>
<td>TST price</td>
</tr>
<tr>
<td>HPW price</td>
<td>-2.86</td>
<td>-3.67</td>
<td>HPW price</td>
</tr>
<tr>
<td>PPW price</td>
<td>2.21</td>
<td>-</td>
<td>Wage rate</td>
</tr>
<tr>
<td>Wage rate</td>
<td>-34.99***</td>
<td>-</td>
<td>Interest rate</td>
</tr>
<tr>
<td>Interest rate</td>
<td>-14.34***</td>
<td>-</td>
<td>TST harv. cost</td>
</tr>
<tr>
<td>HPW harv. cost</td>
<td>-</td>
<td>-0.89</td>
<td>TST inv</td>
</tr>
<tr>
<td>TPW inv</td>
<td>-</td>
<td>47.18***</td>
<td>Lumber price</td>
</tr>
<tr>
<td>Paper price</td>
<td>1.13</td>
<td>-</td>
<td>R-Squared</td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.95</td>
<td>0.96</td>
<td>R-Squared</td>
</tr>
</tbody>
</table>

* TST= total hardwood sawtimber (mixed hardwood+oak), TPW=total hardwood pulpwood. *, ** and *** indicate significance at 10, 5, and 1% level.

Table 4  Estimates of elasticities in the total hardwood stumpage market in South Central U.S.: 1981-96.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Hardwood Pulpwood</th>
<th>Variable</th>
<th>Total Hardwood Sawtimber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand</td>
<td>Supply</td>
<td>Demand</td>
</tr>
<tr>
<td>HPW price</td>
<td>-0.028</td>
<td>-0.036</td>
<td>TST price</td>
</tr>
<tr>
<td>PPW price</td>
<td>0.049</td>
<td>-</td>
<td>HPW price</td>
</tr>
<tr>
<td>Wage rate</td>
<td>-0.453***</td>
<td>-</td>
<td>Wage rate</td>
</tr>
<tr>
<td>Interest rate</td>
<td>-0.211***</td>
<td>-</td>
<td>Interest rate</td>
</tr>
<tr>
<td>Paper price</td>
<td>-0.211***</td>
<td>-</td>
<td>Lumber price</td>
</tr>
<tr>
<td>TST price</td>
<td>-</td>
<td>0.126*</td>
<td>TST harv. cost</td>
</tr>
<tr>
<td>HPW harv. cost</td>
<td>0.196</td>
<td>-0.049</td>
<td>TST inventory</td>
</tr>
<tr>
<td>TPW inventory</td>
<td>-</td>
<td>1.874***</td>
<td></td>
</tr>
</tbody>
</table>

*, ** and *** indicate significance at 10, 5, and 1% level.

results show the highly inelastic nature of the hardwood stumpage market. Own price supply elasticity for total hardwood sawtimber is 0.082. Supply elasticity of inventory is higher for pulpwood than sawtimber. The elasticities of demand with respect to final good price are higher for total hardwood sawtimber than pulpwood indicating higher demand response to price changes in hardwood sawtimber.

Discussion

The supply and demand of hardwood stumpage is generally unresponsive to stumpage prices. An exception is a significant supply response to oak sawtimber prices. This is probably due to generally higher prices of oak furniture and oak flooring. The own price elasticities for the hardwood stumpage market in the South Central region are lower than those observed by Newman (1987) for softwood stumpage market in the southern U.S.

Judging by the non-significant coefficients for pine pulpwood prices in all pulpwood demand equations, there is no significant substitution of hardwoods for pine in pulp production in response to increasing pine pulpwood prices. There is no evidence
for substitution of sawtimber for pulpwood in response to increases in pulpwood prices in the hardwood stumpage production. However, significant positive coefficients for sawtimber prices in the pulpwood supply equations in oak and total hardwood models indicate hardwood pulpwood is a gross complement to sawtimber production.

Wage rates and interest rates are significant factors for pulpwood demand in all models. Increases in wage rates and interest costs will increase the manufacturing costs of final goods and reduce the demand for mixed hardwood pulpwood stumpage. With respect to sawtimber demand, wages are negative and significant, however interest rates are non-significant in all models. Harvesting costs have a significant negative effect on the supply of oak stumpage products specifically, but not on the supply of hardwood products in general.

Inventory is a major factor in the supply of hardwood stumpage products in all models. Inventory response is elastic for both hardwood sawtimber and pulpwood products contrary to Newman’s (1987) finding of an inelastic response of inventory for softwood sawnwood supply. The supply response to inventory changes is greater for pulpwood than sawtimber.

The effect of final good price varied for pulpwood and sawtimber. Lumber price has a significant positive effect on sawtimber demand, but paper price has no effect on pulpwood demand in all models.

SUMMARY
In this paper, the supply and demand structure of hardwood stumpage market in the South Central United States comprising six states, viz., Alabama, Arkansas, Louisiana, Mississippi, Tennessee, and Texas is investigated, for the period 1981-1996. Three stage least squares regression is used to obtain the parameter estimates in a simultaneous equations model of pulpwood and sawtimber supply and demand equations. Separate models are estimated for mixed hardwoods, oak, and total hardwoods stumpage products.

Stumpage prices are generally non-significant. Inventory is positively related to the supply of hardwood pulpwood and sawtimber stumpage. For oak pulpwood and oak sawtimber stumpage, increases in harvesting costs decrease supply. The relationship between hardwood sawtimber and pulpwood stumpage is complementary and there is no evidence that sawtimber is a substitute for pulpwood or hardwood pulpwood is a substitute for pine pulpwood.

The major factors in the demand for hardwood pulpwood stumpage are the wage rate (-) and interest rate (-). The major factors in the demand for hardwood sawtimber stumpage are prices of final goods (+) and the wage rate (-).

Literature Cited


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