Structural Change in Southern Softwood Stumpage Markets

by

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Abstract

The potential for structural change in southern stumpage market models has impacts on not only our basic understanding of those markets, but also on harvest, inventory and price projections, and related policy. In this paper, we test for structural change in both sawtimber and pulpwood softwood stumpage markets in the U.S. South over the period 1950-1994. Test results strongly reject structural stability in both sawtimber and pulpwood supply over the period. However, stability in stumpage demand can not necessarily be rejected Using a new technique, Flexible Least Squares (FLS), a series of varying elasticity models are estimated. Results of the FLS procedure show that both pulpwood and stumpage price supply elasticities have been trending upward over time. The degree of this trend depends upon whether a linear or log-linear model is specified.

INTRODUCTION

This paper addresses structural stability and the potential for time-varying price elasticities in southern softwood stumpage markets. The specific purposes of this paper are first, to test for structural stability in southern softwood sawtimber and pulpwood stumpage markets, and second, to estimate a flexible parameters model that examines how structural change might be embodied in stumpage price elasticities over time.

The question of structural change in stumpage markets is a concern because it impacts our basic understanding of those markets. Our understanding is generally embodied in a set of parameter values such as price and inventory elasticities, and functional form Concerns also rest with the methods used to estimate market parameters.

Often, parameters are estimated using limited time-series data. Estimates based on historical data are only good in the sense that they measure the "average** market structure over the estimated time period. In many cases, this may not necessarily represent a problem. If. though, one is interested in obtaining a more precise estimate of the market parameter as it now exists, because this 'true" parameter is important for making good policy, then using historical data to measure the parameter may give poor results. This is especially true if the market structure is trending in a particular manner over time, or if there is an abrupt structural change in the market.

A brief example might help to show why understanding structural change in markets may be of interest. Let us assume that if structural change is occurring in southern stumpage markets for instance, tbat this could manifest itself through changing demand or supply price elasticities. Consider using the Timber Assessment Market Model (TAMM; Adams and Haynes 1980, 1996) to project future harvest, inventory, and price changes under both an "'average" sawtimber stumpage supply elasticity parameter based on historical data and a "true" parameter that reflects the current (and future) elasticity.

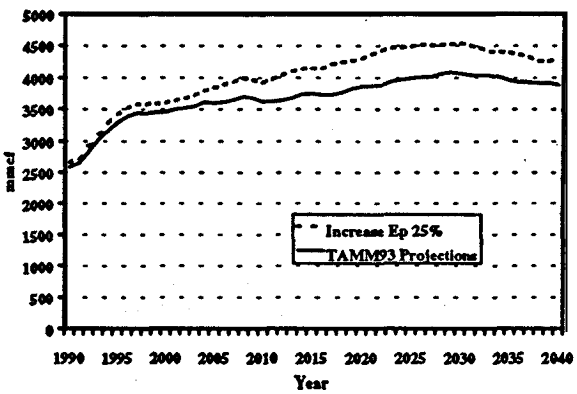

Figure 1. Softwood saw-timber harvest.

Figures 1-3 illustrate the sensitivity of TAMM (1993 version) softwood sawtimber harvest, softwood inventory, and sawtimber price projections for the U.S. South to an increase in softwood sawtimber supply price elasticities (Ep) by 25% above currently simulated levels (for example, from 30 to .375). Such a scenario might prove plausiile if, for instance, elasticities were rismg over time, but TAMM used the average elasticity

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estimated with historical data. Both graphs illustrate what one might expect-au increasing supply elasticity makes timber more available to the market (Figure 1), thereby reducing inventory levels (Figure 2) but also reducing stumpage prices (Figure 3). Differences iu projections because of unrecognized structural changes could have meaningful policy impacts.

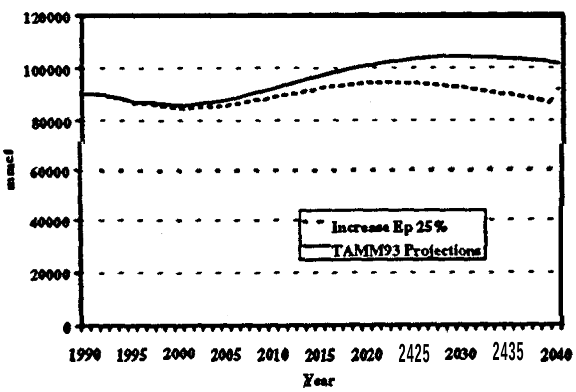

Figure 2. Softwood growing stock inventory.

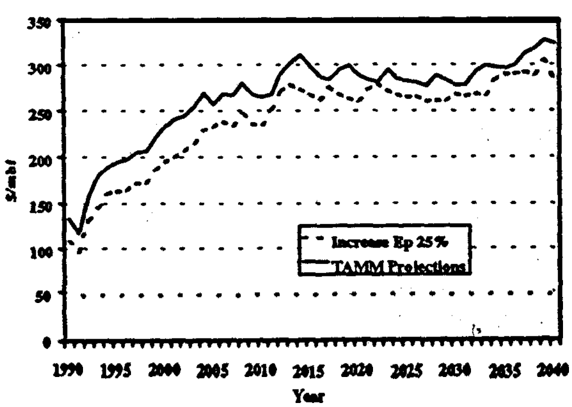

Figure 3. Sawtimber softwood stumpage prices.

Another area where elasticity estimates in particular are important is in the estimation of consumer aud producer welfare changes. In Newman (1990). changing assumptions about tbe magnitude of demand and supply stumpage price elasticities had an important effect on the distribution of benefits to producers and consumers from shifting inventories over time. Indeed, Newman (1990, pg 715) states that "Comparing these results implies that greater concern for the precision of the price elasticities is needed when the distributional consequences of supply shifts are examined".

METHODS AND RESULTS

Market Equations-To analyze potential structural change in southern softwood stumpage markets, it is first necessary to specify the form of the supply and demand functions that allegedly represent the structure of those markets. It makes some sense to test the hypothesis of structural change employing model forms that are most commonly represented in the literature.

Previous work (e.g., Adams and Hayues 1980, 1996, Newman 1987) has presumed aggregate stumpage supply (Q_t^s) to be in general a function of own price (p_t), inventory (I_t), and other supply shifters (Z_t):

$$Q_t^s = \alpha_0 + \alpha_1 p_t + \alpha_2 I_t + \alpha_3 Z_t \qquad (1)$$

This is Newman's (1987) specification except that substitute product prices were also included (e.g., sawtimber in pulpwood supply). Adams and Haynes (1980) estimated the supply functions for industrial and non-industrial ownerships separately using the following structure:

$$Q_t^s / I_t = \beta_0 + \beta_1 p_t + \beta_2 Z_t \qquad (2)$$

An important distinction between (1) and (2) is the form of the dependent variabie (quantity to inventory ratio), which iu the Adams and Haynes (1980) and subsequent formulations in TAMM (e.g., Adams and Haynes 1996) restricts the inventory elasticity to unity. Interest rate (for industrial) and income variables (for non-industrial owners) were also included. Updated versions of TAMM supply equations now presumably include substitute product prices and the dependent variable lagged one period. Both Adams and Haynes (1980, 1996) and Newman (1987) utilized strictly linear (compared to log-linear) model forms. Elasticities are thus estimated indirectly. In this paper we consider the following specifications of the supply function for industrial and non-industrial ownerships combined to test for structural change in supply:

$$a)\ Q_t^s = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t' + \alpha_3 I_t$$
$$b)\ \ln Q_t^s = \alpha_0 + \alpha_1 \ln p_t + \alpha_2 \ln p_t' + \alpha_3 \ln I_t$$

and (3)

$$c)\ Q_t^s / I_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t'$$
$$d)\ \ln Q_t^s / I = \alpha_0 + \alpha_1 \ln p_t + \alpha_2 \ln p_t'$$

where Q_t^s is softwood stumpage quantity supplied (pulpwood or sawtimber), p_t is own price, p_t' is substitute price and I_t is total softwood growing stock inventory.

Structural change in softwood stumpage demand is examined using the following equations which are slight modifications of the specifications proposed by Newman (1987):

$$a)\ Q_t^D = \gamma_0 + \gamma_1 p_t + \gamma_2 f_t + \gamma_3 w_t + \gamma_4 Q_{t-1}^D$$

and (4)

$$b)\ \ln Q_t^D = \gamma_0 + \gamma_1 \ln p_t + \gamma_2 \ln f_t + \gamma_3 \ln w_t + \gamma_4 \ln Q_{t-1}^D$$

where Q_t^D is softwood stumpage quantity demanded (pulpwood or sawtimber), p_t is own price, f, represents final goods price and w_t represents labor costs. Here, capital is treated as a quasi-fixed input and hence lagged quantity demanded is included instead of a price for capital.

Data-Data for this analysis covers 12 southern U.S. states from Texas to Virginia. The data is annual and ranges the period 1950 to 1994. Sawtimber harvest quantities and growing stock inventory were supplied by Dr. Darius Adams and represent unpublished Forest Service data constructed for use in the latest RPA Assessment. Pulpwoodroundwood harvest and residue values were obtained from Howard (1997) and Ulrich (1989). Tbe real producer price index for pulp, paper, and allied products was used as a final goods price for pulpwood. The real producer price index for all lumber was used as a final goods price for sawtimber (Ulrich 1989, Howard 1997). Wages for SIC 24 and SIC 26 are real hourly wages derived (i.e., total wages divided by hours worked) from the U.S. Department of Commerce, Survey of Manufacturers (various issues).

Up through 1976, sawtimber stumpage prices are average real stumpage prices for sawtimber sold from National Forests (Ulrich 1989). After 1976, real Timber Mart South average prices are used. Pulpwood stumpage prices are an average of midsouth and southeast real southern pine pulpwood stumpage prices (Ulrich 1989). less real estimated logging and transportation costs. After 1987, these prices were derived using annualpercentagechanges in Timber Mart South average pulpwood stumpage prices.

Testing Structural Change-Structural change manifests itself in the instability of regression coefficients over time. Two basic procedures are used to test the bypothesis of structural stability in the supply and demand equations. Each of these are in some manner based on the stability of least squares residuals. Tbe tests used are:

- Chow test (two and three period).
- Test proposed by Ploberger and Kramer (1996) (P&K).

Chow tests examine the stability of regression coefficients over different data subsets. In our case, there is no *a priori* method for determining what subsets should be tested (i.e., where the structural shift takes place). Recognizing this, we test stability using both two period (1950-1972, 1973-1994) and three period (1950-1965, 1966-1980, 1981-1994) subsets. The P&K test is nongraphical version of the CUSUM test (see Greene 1997) and is considered more powerful in the presence of trending data. Since both of these are single equation methods, we utilize instrumental variables where potential endogeneity is a concern.

Results of each test are presented in Tables 1 and 2, respectively. Using the Chow test (Table 1), for both two and three period comparisons, structural stability is rejected in all supply model formulations, as well as in sawtimber demand models. Only in the pulpwood demand model formulations was stability not rejected.

Table 1. Chow structural change test results.

Supply Equations	Pulpwood 2 Per.	Pulpwood 3 Per.	Sawtimber 2 Per.	Sawtimber 3 Per.
y=Q/I				
Linear	9.04*	4.53*	22.0*	19.6*
Log	10.2*	5.03*	23.1*	21.3*
y=Q				
Linear	2.75**	8.20*	18.4*	18.9*
Log	2.92**	7.76*	27.1*	24.9*
Demand Equations	**Pulpwood 2 Per.**	**Pulpwood 3 Per.**	**Sawtimber 2 Per.**	**Sawtimber 3 Per.**
Linear	.56	136	2.06***	3.93***
Log	.42	1.28	3.65*	5.11*

* p<.01
** p<.05
*** p<.10
critical values based on relevant F-test

P&K structural change tests also strongly reject structural stability in supply overall (Table 2). All supply equations, using quantity to inventory (Q/I) as the dependent variable, are rejected at the 1% level. However, using only quantity as the dependent variable, stability is not rejected for the log pulpwood model but is for the linear pulpwood model at the 10% level. Both sawtimber supply models are rejected. We are unable to reject stability of demand equations at any meaningful level of significance. The inability to reject stability in demand equations may be due to the fact that the demand equations were relatively less robust when compared to the supply equations, and they included a lagged variable. This might lead one to question whether or not including a lagged variable in our supply equations would alter the outcome of the structural change tests. Inclusion of a lagged dependent variable in supply indeed improved the stability of those equations. Still, stability could be rejected in several instances. The inclusion of a Jagged dependent variable in supply however appears to have a weaker theoretical justification than it does in the demand model.

Table 2. P&K structural change test results.

Supply Equations	Pulpwood	Sawtimber
y=Q/I		
Linear	1.33*	1.24*
Log	1.34*	1.25*
y=Q		
Linear	.39***	1.14*
Log	.30	1.19*
Demand Equations	**Pulpwood**	**Sawtimber**
Linear	.04	.07
Log	.06	.06

* p<.01
*** p<.10
for critical values, see Ploberger and Kramer (1996).

These results provide fairly powerful evidence of structural instability over time in timber supply, as traditionally model& in southern softwood stumpage marketsover theperiod 1950 to 1994. In thepulpwood supply models, instability may be more pronounced in the Q/I dependent variable formulation. Structural instability in demand is less demonstrable overall, but some evidence points to instability in sawtimber demand as well.

Flexible Least Squares-One method for exploring the nature of parameter instability is to hypothesize that the underlying varying parameter model takes the form:

$$y_t = x_t\beta_t + \varepsilon_t, \qquad t = 1,2,\ldots,T \qquad (5)$$

where

$$\beta_t = \beta_{t-1} + v_t, \qquad t = 2,3 \quad ,\ldots, \quad T \qquad (6)$$

Note that the k parameter vector β_t is allowed to vary over time. There are two sources of stochastic variation in this model. The first is a normal stochastic variation on y_t, and the second is a dynamic error on β_t, which is aliowed to vary slowly over time.

The method used to estimate this model is relatively new, is termed Flexible Least Squares **(FLS),** and Was developed by **Kalaba and** Tesfatsion (1989). The FLS estimator **is:**

$$\underset{b_t}{Min}\ L = \sum_{t=2}^{T} (b_t - b_{t-1})'\psi(b_t - b_{t-1})$$

$$+\sum_{t=1}^{T} (y_t - x_t b_t)'(y_t - x_t b_t) \qquad (7)$$

$$= \sum_{t=2}^{T} \hat{v}_t'\psi\hat{v}_t + \sum_{t=1}^{T} \hat{\varepsilon}_t'\hat{\varepsilon}_t,$$

where $\psi = \begin{bmatrix} \mu_1 & 0 & \cdots & \cdots & 0 \\ 0 & \mu_2 & 0 & \ddots & \vdots \\ \vdots & 0 & \ddots & 0 & \vdots \\ \vdots & \ddots & 0 & \mu_{k-1} & 0 \\ 0 & \cdots & \cdots & 0 & \mu_k \end{bmatrix}$ isakxkdiagonal **matrix, and where** μ_k **lies** on the interval $0 < \mu_k < \infty$ **. The FLS estimator is made up of two** components. The second component in **(7)** is simply the sum of squared **residual** errors--however b_t may fluctuate over time. The first component is the sum of squared residual dynamic errors, scaled by the matrix ψ . One may allow **some** or all model **coefficients** to vary over time depending upon the weights **prescribed in** ψ .

Minimization **with** emphasis on the second component (i.e., small ψ) is equivalent to a fully random coefficients estimator. **Minimization** with respect to the **first** component (i.e., large ψ) is equivalent to producing the OLS estimator. FLS is a single equation estimator. In order to reduce simultaneitybias wemodifytheprocedureviatheuseof instrumental variables, thereby giving rise to our **IV_FLS** estimator.

In this paper we make the simplifying assumption that **structural** change is embedded in the own price elasticity. This assumption is only really critical in one interesting **respect.** Early **optimizations** indicated that. there was a (nearly) direct tradeoff between thevariation in theownprice elasticity and the inventory elasticity. This might lead one to believe that **structural** change **manifests itself primarily** in the inventory elasticity. However, the **inventory** elasticity **appears to be a function of the price elasticity. That is,** inventory changes are **endogenous.** This makes it difficult to **separate** supply responses that result from real changes in inventory and supply responses that result from changes in price. For that reason, the inventory elasticity is held fixed over time. Surprisingly, the inventory elasticity tends to migrate to a unitary elasticity (from what it otherwise would be in a purely fixed **coefficient** model) when the price elasticity is allowed to vary. This would tend to support the TAMM **specification** of the supply model.

IV_FLS Results--Price elasticities (Ep) for sawtimber and pulpwood supply models are presented in Figures 3 and 4. There are dramatic differences in elasticity trends between linear and log models, but the form of the dependent variable (Q or Q/I) makes little practical difference. This may also support the assumption of a fixed inventory elasticity.

It tends to matter rather dramatically whether one assumes a log or linear model when discussing the effects of structural change in **stumpage** supply models. **Figure** 3 shows that, using a linear model, sawtimber price elasticities have varied substantially over time. In the log model the variation is much less, and might be **considered** by some to represent relative stability. In **Figure 4,** pulpwood elasticities also vary much more using **the linear model form. In all** cases, however, there is evidence that elasticities have been rising over time (for sawtimber, since the early **1960s).**[2]

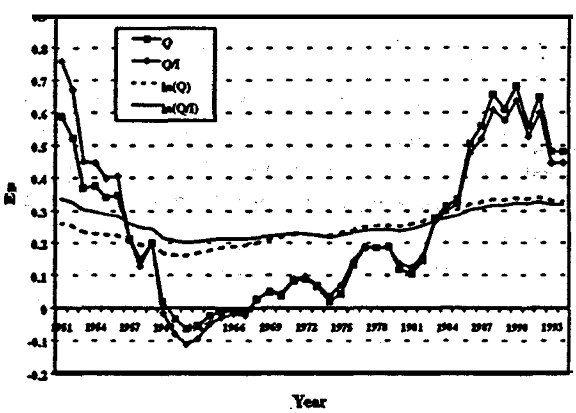

Figure 3. Sawtimber supply own price elasticities.

[2] In **the linear model,** elasticities are generated indirectly using average values of the sampledata. .

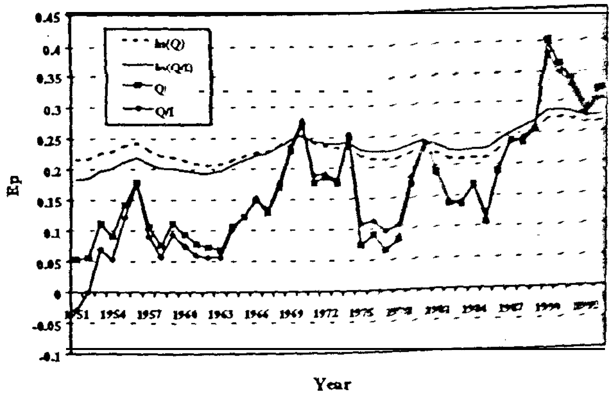

Figure 4. Pulpwood supply own price elasticities.

CONCLUSIONS

The purpose of this paper has been to test the hypothesis of structural stability over time in southern pulpwood and sawtimber stumpage markets. Using traditional model specifications of these markets, we were able to reject structural stability on the supply side in favor of structural change. On the other hand, we can not necessarily reject structural stability on the demand side.

The nature of the structural change was hypothesized to reside in the landowner's response to own price changes. Using the techniques of FLS, time-varying stumpage price elasticities were estimated. Results show that supply elasticities have generally been rising. This result is much more dramatic in the linear model than in the log model. Still, the rises are potentially significant for both from a modeling perspective.

Structural change indeed has ramifications for timber supply modeling. If supply elasticities are rising, this portends lower inventories and in the short to medium term, perhaps lower stumpage prices than currently projected for southern stumpage markets.

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