STUMPAGE MARKET IMPACTS OF SOUTHERN PINE BEETLE EPIDEMICS

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ABSTRACT — The Southern Pine Beetle (SPB) is one of the most damaging pests of southern pine forests. SPB epidemics occur periodically and result in large volumes of timber killed over wide geographical areas. The primary purpose of this study is to test the hypothesis that SPB epidemics, and the resultant timber salvage effort, influence stumpage prices for sawlogs and pulpwood. The empirical analysis is based on a bivariate time series model of unidirectional causality known as the transfer function-noise model. The experimental setting is southeast Texas during the 1983–1986 epidemic. Results are obtained regarding the magnitude and duration of market disturbances and some general conclusions are provided regarding changes in economic welfare.

INTRODUCTION

Cut and remove, or timber salvage, is the predominant means of controlling Southern Pine Beetle (SPB) outbreaks (Thatcher et al. 1981.) During years when SPB populations are endemic, the market effect of salvage is probably negligible. During SPB epidemics, however, it is plausible that a measureable shift occurs in the timber supply curve. If a shift does in fact occur, then the economic welfare of timber sellers and buyers is affected.

A general conceptual model of the welfare effects of a major SPB epidemic is presented in Figure 1. In this figure, market supply prior to the disturbance is represented as $S_1$ and market demand is represented as $D$.

The postulated effect of a major epidemic is an increase in timber supply elasticity, rotating the supply curve to $S_2$. A multiplicative form for the disturbance is postulated since (1) landowners' willingness-to-sell probably increases, and (2) landowners who actively manage their timber face higher marginal costs and are more likely to salvage damaged timber than are low-cost "passive" landowners.

The welfare effects of the postulated change are immediately apparent. Producer surplus decreases, from area $cbf$ to $edf$ in Figure 1. The drop in price from $c$ to $e$ clearly results in lower rents per unit of timber harvested. Consumer surplus, on the other hand, increases from $abc$ to $ade$. The net welfare change is positive, with consumers theoretically able to compensate producers for their loss.

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Figure 1. Welfare effects of SPB epidemic

If data were available on timber price, quantity, demand elasticity, and supply elasticity for S1 and S2, an estimate of the welfare effects of a SPB epidemic could be computed. Unfortunately, an estimate of the change in supply elasticity is not available. The more modest objective of this study is to test the hypothesis that a measureable price impact is felt in the stumpage market. If this hypothesis is rejected, then the more ambitious goal of estimating changes in welfare is unnecessary. If, on the other hand, the hypothesis is not rejected, a call for further research may be warranted.

To the extent that the behavior of stumpage market participants is myopic, expectations of future market conditions do not influence the level of current harvests. If price decreases are anticipated, however, rational resource owners optimally adjust harvests prior to the fall in price (Clark 1976.) It is reasonable to hypothesize, then, that infestation detection programs play a role in the formation of market expectations. This further hypothesis is tested below.

EXPERIMENTAL SETTING

Two criteria were used to select a geographic area for hypothesis testing. First, a major epidemic must have occurred in the area. Second, stumpage price reports must be available for the area before, during, and after the epidemic.

Southeast Texas satisfied both of these criteria and was chosen as the experimental setting. Between 1960 and 1980, two peaks in the periodic cycle of SPB killed timber occurred in 1962 and 1976 (Price and Doggett, 1982.) In 1985, however, east Texas experienced the largest epidemic on record when an estimated 330,400 MBF of sawtimber was killed. This volume represents more
than one-third of the volume of softwood lumber sawn in Texas during that year.

Stumpage prices for southeast Texas were obtained from Timber Mart South (TMS). Since monthly stumpage and delivered prices have been reported in TMS since 1977, only the 1983–1986 epidemic could be studied. The monthly price series used for analysis are: (1) southern yellow pine sawtimber stumpage ($/MBF Scribner log rule) for Texas region 2, and (2) pine pulpwood stumpage ($/standard cord) for Texas region 2. To capture the price impact over an entire beetle population cycle, prices were used from January, 1980 through December, 1987. Thus, 96 observations were used for hypothesis testing.

Monthly sawtimber stumpage prices are shown in Figure 2 and monthly pulpwood prices are shown in Figure 3. Also shown in the figures are prices for the entire southeast region.

Examination of Figure 2 and Figure 3 reveals a dramatic and abrupt fall in sawtimber and pulpwood stumpage prices during the spring of 1985. This is precisely when rapid SPB spot growth, and subsequent salvage/control effort, would be incipient preceding the major epidemic to follow during the summer and fall months. As can be seen, both sawtimber and pulpwood stumpage prices exceeded the southwide price preceeding the spring of 1985 and were less than the southwide price for a number of months after a precipitous decline.

A simple method of calculating the impact of an epidemic on stumpage prices would be to subtract the low price during the epidemic from the price prevailing before the epidemic. Such a method, however, is deficient for two reasons. First, stumpage prices are clearly stochastic and a method of accounting for the stochastic process is warranted. Second, stumpage prices represent the interaction of supply and demand forces. Falling stumpage prices could result from a change in demand conditions as well as a change in supply.

**EMPIRICAL MODEL**

Methods for analyzing time series data can be grouped into univariate and multivariate models. Univariate models attempt to describe the stochastic process generating observed values but do not address the issue of identifying causal factors. Granger’s (1969) definition of causality is quite general in that it allows testing for one-way and two-way causality between two (or more) time series. Data limitations cause us to consider a modified version of the Granger causality model. Since the causal factor is measured as a dummy variable, we use a bivariate model of unidirectional causality introduced by Box and Tiao (1975) known as the transfer function-noise model.

In its simplest form, the transfer function-noise model can be written:

\[ Y_t = f(x_t) + N_t \]  \hspace{1cm} (1)

where \( Y_t \) = dependent variable at time \( t \)
\( f \) = transfer function
\( x_t \) = event at time \( t \)
\( N_t \) = noise at time \( t \).
The noise term is modeled by a mixed autoregressive moving average process which, in our case, describes the stochastic price generating process:

$$N_t = (\theta(B)/\phi(B))\eta_t$$  

where  
- $B$ = the backshift operator  
- $\eta$ = white noise  
- $\theta$ = moving average polynomial  
- $\phi$ = autoregressive polynomial

While the event term $\xi_t$ in the transfer function could be any exogenous time series, for our purpose $\xi_t$ is an indicator variable that takes the value 1 and 0 to indicate the occurrence or nonoccurrence of an event. It is analogous to a dummy variable in standard regression analysis in that it is used to capture a shift in the stochastic process. Specification of the transfer function is provided by a flexible functional form:

$$f(\xi_t) = (\omega(B)/\delta(B))\xi_t$$  

where $\omega$ and $\delta$ are transfer function parameters.

In general, the transfer function can be used to model changes in a stochastic process which are abrupt and temporary, abrupt and permanent, gradual and temporary, and gradual and permanent. Permanent changes in the level of a process are modeled using a step indicator $\xi_t = S_t$ where $S_t = 0$ before the occurrence of the event and 1 thereafter. Temporary changes are modeled using a pulse indicator $\xi_t = P_t$ where $P_t = 1$ at the point an event is initiated and 0 during all other periods.

As with univariate time series models, specification of the noise term is driven by the data. The usual Box–Jenkins method of model identification, estimation, and diagnostic checking was used to specify $N_t$ (Pindyck and Rubinfeld 1981.) The transfer function, on the other hand, must be specified \textit{a priori} for the results to be confirmatory rather than exploratory (McCleary and Hay 1980.) To test the hypothesis that market participants behave myopically as opposed to responding to expectations, \textit{a priori} specification of the onset of the event was set at two points: (1) the summer of 1985, and (2) the spring of 1985.

The transfer function–noise model represented in equations (1) through (3) was used to estimate the price generating process of four time-series: (1) southeast Texas southern yellow pine sawtimber stumpage (TR2SAW), (2) southeast Texas pine pulpwod (TR2PULP), (3) southwide southern yellow pine stumpage (SRSAW), and (4) southwide pine pulpwod (SRPULP). Parameters were estimated with the SORITEC integrated econometric and statistical analysis system using maximum likelihood methods.

RESULTS

Regression results are presented in Table 1. In general, the results present evidence of a statistically significant market impact resulting from the SPB epidemic beginning in the spring of 1985.
Table 1. Parameter estimates for the transfer function-noise model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>TR2SAW</th>
<th>TR2PULP</th>
<th>SRSAW</th>
<th>SRPULP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega_1$</td>
<td>$-45.12^{***}$</td>
<td>$-3.17^{***}$</td>
<td>$-22.68^{***}$</td>
<td>$-0.09$</td>
</tr>
<tr>
<td></td>
<td>(-4.29)</td>
<td>(-3.37)</td>
<td>(-5.50)</td>
<td>(-0.84)</td>
</tr>
<tr>
<td>$\omega_2$</td>
<td>19.61</td>
<td>14.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.55)</td>
<td>(2.79)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta_1$</td>
<td></td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.33)</td>
<td></td>
<td></td>
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<tr>
<td>$\phi_1$</td>
<td>0.85</td>
<td>-0.13</td>
<td>0.85</td>
<td>-0.23</td>
</tr>
<tr>
<td></td>
<td>(14.95)</td>
<td>(-2.61)</td>
<td>(14.26)</td>
<td>(-2.28)</td>
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<tr>
<td>$\theta_1$</td>
<td></td>
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| $R^2$ | 0.89 | 0.86 | 0.88 | 0.83 |
| $Q(k-20)$ | 11.7 | 33.6 | 28.8 | 16.3 |

NOTE: t-statistics in parentheses. *** denotes significance at the 0.01 level. ** denotes significance at the 0.05 level.

The parameter estimate $\omega_1$ in column two indicates that sawtimber prices in southeast Texas abruptly fell $45.12$/MBF in the spring of 1985. This step change exceeds the fall in price over the entire southern region ($\omega_1 = -22.68$). Under the assumption that the sole cause of the southern region price decline was decreasing demand, a conservative estimate of the Texas price decline due to the SPB is the difference of $22.44$/MBF.

The parameter estimate $\omega_2$ in column two indicates that sawtimber prices in Texas abruptly increased as the market cleared the inventory accumulated during the epidemic. The point at which the market cleared was found experimentally and occurred twenty-five months after the onset of the epidemic. In Texas, the price of sawtimber increased $19.61$ at this point in time (although this result is not quite significant at the 0.10 level), and the overall price level in the southern region increased $14.30$. Under the assumption that the cause of price inflation in the southern region was due to an outward shift in demand, a conservative estimate of the Texas price increase due to SPB-killed timber clearing the market is the difference of $5.31$. That Texas prices did not shift all the way back to pre-epidemic levels suggests that the Texas market had not fully regained an equilibrium position by the end of 1987.

The parameter estimate $\omega_2 = -3.17$ in column three provides evidence that the Texas pulpwood market experienced a statistically significant drop in price in the spring of 1985. Regardless of specification, no significant price decline could be found for the southeast region as a whole. The parameter estimate $\delta_1 = 0.74$ indicates that the price effect in the pulpwood market gradually decays over time and that after twelve months, the price impact is $0.10$, after thirteen months it is $0.075$, and so forth.
Diagnostic checking was performed using the Q-statistic. The hypothesis that
the residuals were not white noise was rejected at the 0.99 confidence level
in all cases, suggesting that the model specifications were acceptable.

CONCLUSIONS

Based on the study results, we cannot reject the hypothesis that large SPB
epidemics cause prices to fall in stumpage markets. While the market impact
is clearly transient, we discovered that pulpwood markets apparently clear
faster than sawtimber markets. This may reflect the fact that SPB outbreaks
are more likely to occur in stands with high basal areas and large, over-
mature trees. To the extent that such stands are used for recreation, the
fall in stumpage value represents an opportunity cost of recreational use.

While we tested various specifications for the form of transfer function, the
analysis suggested that the market impact occurred abruptly. Since the
epidemic actually began building as early as 1983, it might be supposed that a
gradual market impact would be more likely than an abrupt change. The
empirical evidence suggests, however, that it wasn't until the spring of 1985
that the market realized that a major epidemic was underway. That prices fell
abruptly in the spring rather than during the peak of the SPB spot
growth/salvage season suggests a market adjustment based on expectations of
future market conditions.

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