NATURAL RESOURCES JOURNAL

Volume 29
Issue 3 *Summer 1989*

Summer 1989

Public Policy Implications for the Supply of Pine Sawlogs

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ABSTRACT

Use of transfer function analysis, the most powerful current statistical methodology for analysis of single equation time-series data, reveals that previous analyses have significantly over-estimated pine sawlog supply curve elasticity. This analysis shows that internal rate of return of forest investments is the single most important factor in determining long-term forest supply. Traditional policy incentives encouraging forest investment are inadequate. Front-end cost of forest investments must be lowered in order to bring additional lands into forest production or to induce landowners to do a better job of regenerating forest lands after harvest.

INTRODUCTION

Declining global timber reserves confirm that demand continues to exceed supply, improved management practices notwithstanding. When demand exceeds supply, the real price of timber increases, so that the market clears at a higher price. If excess demand causes real timber price increases, then public policy objectives tend to be thwarted by the marketplace. This is a market characterized by excess long-term demand.

An alternative to the market clearing at higher real prices is to increase the supply of timber, causing the real price to decline. Public policy debate includes the use of the market mechanisms to increase the supply of timber. However, observation reveals that timber markets are not competitive. Increasing real prices should attract sufficient new producers and the associated increased output causing real price decline, but this has not happened.

This paper focuses on the public policy implications for long-term pine sawlog supply developed by an analysis of the estimated supply curve of pine sawlogs. This paper demonstrates that previous public policies have been inadequate to insure adequate long-run supply. Accordingly, without significant policy changes, long-term supply will continue to fall short of demand and real price appreciation will continue. An advanced

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methodology particularly appropriate for identifying the true supply curve is employed. Arkansas data are used in the statistical analysis, but the research methodology and policy implications have much broader applications.

MODELS AND PROBLEMS

The factors potentially affecting long-term sawlog supply are traditional time-series variables. When time-series are analyzed using ordinary least squares regression (OLS) modeling techniques, the estimated equations will frequently exhibit regression bias. Biased results exist when the residuals violate the fundamental assumptions underlying OLS regression.[1] In addition, OLS methodology requires that the analyst specify the functional form of the estimated equation. Forest economics research has given us an appreciation of the variables potentially affecting forest investment. However, research methodology associated with modeling supply relations is not as well defined.

In economic policy research, two errors are often present. These arise from improper methodology in developing statistical models. First, variables may be included solely because of their ability to reduce the unexplained variance of the dependent variable.[2] This is inadequate model specification and is usually denoted by the inclusion of variables whose presence in the model are not structurally supported. The second error is caused when the assumptions of OLS regression are not fully satisfied. This error results in parameter estimates not being the best linear unbiased estimates (BLUE) of their true values. Accordingly, inferences drawn from incorrect models may not be valid.

Analysts versed in time-series analysis are alert to these problems. Moreover, econometric literature is replete with examples of standard remedies to repair violations of the underlying assumptions. However, researchers are often trapped in the formulation, estimation, checking, and fix-up cycle. When an examination of the error terms indicates that the assumptions are not satisfied, models are reformulated, or new variables introduced. Often, however, the corrections lie deeper than conventional remedies can accomplish.

Given the enormous implications of incorrect public policy choice, this research: 1) reports a superior analytical technique for the analysis of time-series; 2) applies the technique to estimate the sawlog supply curve using Arkansas data; 3) calculates elasticity of supply with respect to price and the interest rate; and 4) suggests the public policy implications implicit from the elasticity estimates.

1. J. Neter & W. Wasserman, Applied Linear Statistical Models 842 (1974).
2. Lovell, *Data Mining*, 65 Rev. of Econ. & Stat. 1 (1983).

TRANSFER FUNCTIONS

The most powerful statistical method for the analysis of single equation time-series data is transfer function analysis.[3] It yields parameters where all the underlying assumptions are satisfied, and the equation is the correct functional form. Transfer functions are multivariate time-series models, and have great theoretical appeal.[4] The functional form among the dependent and independent variables does not require *a priori* specification. In transfer function analysis, the correct functional form is revealed by examination of the variables' autocorrelation, partial autocorrelation, and cross correlation functions. When the transfer function is the correct form, then the error terms and each driving variable are independent. If dependence between the errors and the driving variables exists, then an incorrect model form is indicated, prompting further identification and estimation until independence results.

In summary, transfer function analysis overcomes regression bias inherent in most OLS models of economic time-series. The statistical properties of transfer function models suggest that they are a powerful analytical tool useful in the analysis of time-series data.

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3. Pickett, *Autobox: An Advanced Time Series Program for Microcomputers*, in Readings in Business and Economic Research 98 (D. Hamilton ed. 1988).

4. To understand a transfer function model, recall the distributed lag model. In a distributed lag model, the current value of Y(t) is represented as a function of a number of past values of X(t).

$$Y(t)=v(0)X(t)+v(1)X(t-1)+v(2)X(t-2)+e(t) \quad (1)$$
$$\text{or } Y(t)=v(B)X(t),$$

where B is the backshift operator.

Conventional Box-Jenkins or univariate time-series notation express Y(t) as a function of its previous values.

$$Y(t)=\frac{(1-\theta(\lambda)B)}{(1-\phi(\lambda)B)}a(t). \quad (2)$$

The 'v' weights are called impulse response weights, where:

$$v(B)=\frac{\Omega(\lambda)(B)(\lambda)}{\delta(\Gamma)(B)(\Gamma)}. \quad (3)$$

This structure allows for a delay before X affects Y.

The error terms may be expressed as a conventional autoregressive integrated moving average (ARIMA) process:

$$e(t)=\frac{\theta(B)}{\phi(B)}a(t). \quad (4)$$

and by substitution, the general expression for a transfer function is:

$$Y(t)=\frac{\Omega(\lambda)(B)(\lambda)}{\delta(\Gamma)(B)(\Gamma)}X(t-b)+\frac{\theta(B)}{\phi(B)}a(t). \quad (5)$$

Thus, the most general expression for all econometric models is a transfer function, and each econometric model may be written as a restricted transfer function equation. For example, the familiar bivariate regression model is the transfer function where in (5) above the:

$$\delta(\Gamma)(B)(\Gamma)=1$$
$$\Omega(\lambda)(B)(\lambda)=\Omega(0) \quad (6)$$

and no parameters on the error term.

STUDY METHODS

Normally, timber supply demonstrations are performed in the traditional price-quantity space. One additional variable, the discount rate, was selected as a component of our model to capture the dynamic nature of supply over time as it responded to other market factors.

The price data (P) used in the analysis are the monthly price paid for Arkansas pine sawlog timber stumpage. The price is expressed as dollars per 1000 board feet ($/MBF). This series was obtained from Timber Mart-South.[5] The monthly pine sawlog quantity supplied (Q) was derived from severance tax data maintained by the Arkansas Forestry Commission.[6] The quantity is expressed as 1000 board feet per month (MBF/mo). The discount rate consists of monthly observations for a ten year constant maturity U.S. Treasury note. These data were obtained from CITIBASE.[7]

The analysis uses data for the period January 1977 through December 1985. Figures 1 and 2 graph the price and quantity used in the analysis. From mid-1976 until July 1981, pine sawlog mills expanded production and grew at a rate faster than the long-term industry growth rate.[8] After July 1981 pine sawlog production declined below the long-term growth trend.

The first research task was to estimate the pine sawlog supply curve using transfer function analysis as the research method.[9] Given the estimated supply function, the second research task was to separately identify movements along the supply curve and shifts in the supply curve. The third task was to calculate the elasticities of supply with respect to price and interest rate. The final task was to formulate effective public policy that will insure sufficient long-term supply of pine sawlogs.

RESULTS OF ANALYSIS

The Supply Curve

The supply curve written in transfer function notation from equation (5) in footnote (4) above is:

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5. Data Resources International, Timber Mart-South 1984 Yearbook 49 (1986) (stumpage prices for Arkansas).

6. Arkansas Forestry Commission, Severence Tax Data (1986) (available from the Arkansas Forestry Commission, Division of Special Collections, Little Rock, Ark.).

7. Citibank, Long-term Discount Rates 1977-1985, Citibase (1987) (data diskette). All data series, program output, the regression equation in tabular form and elasticities may be obtained by sending a blank, double sided, double density, 5.25 inch diskette to Prof. John C. Pickett, Dept. of Economics and Finance, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, Ark. 72204.

8. R. Kluender, W. McCoy, & J. Easterling, The Arkansas Forest Products Industry, 41 (Arkansas Agricultural Experiment Station, Bulletin No. 908, 1988).

9. The software program Autobox Plus, estimated the equation. Automatic Forecasting Systems, Inc., Autobox:Plus, Version 2 (1988).

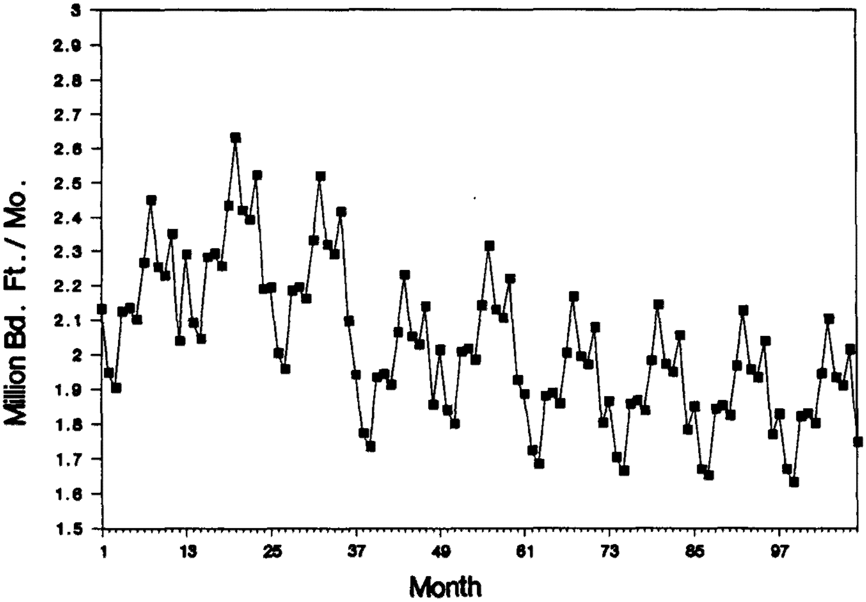

FIGURE 1. Pine sawlog supply in Arkansas from January 1977 to December 1985.

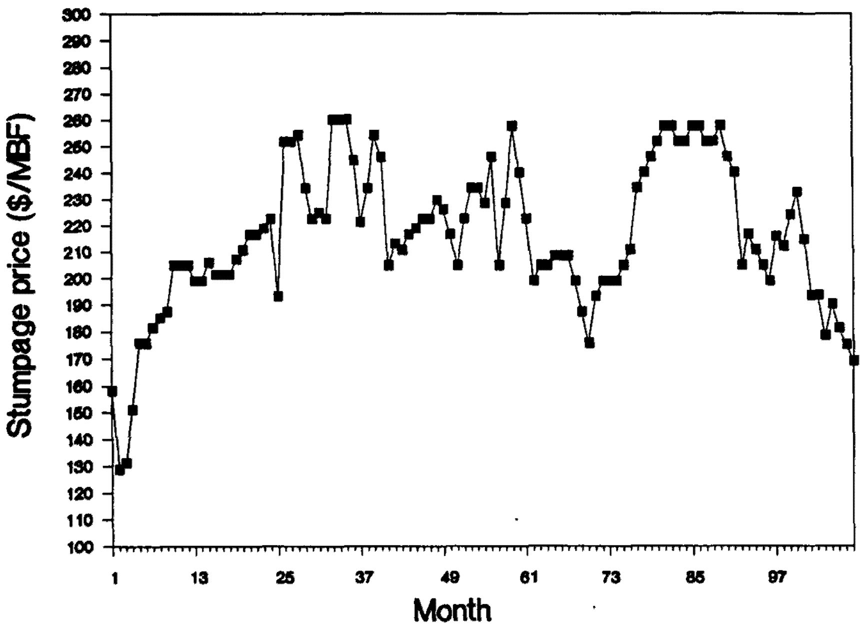

FIGURE 2. Pine sawlog stumpage price in Arkansas from January 1977 to December 1985.

$$(1-B)(1-B^{12})LnQ_t = \underset{(2.08)}{.0269}(1-B)P_t + \frac{(1.48)-.65}{(1 + \underset{(-7.07)}{1.89}B + \underset{(-4.40)}{.802}B^2)}(1-B)I^{-1}_{t-2} + (1-\underset{(7.06)}{.615}B^{12})a_t \cdot$$

Mean square error = .0019, $R^2 = .959$

T-values are shown in parentheses.

A posteriori testing the assumptions on the error terms reveals that all are satisfied. The familiar backshift operators, (1–B) and $(1-B^{12})$, and the Box-Cox transformation parameters insure the series are stationary. The extended transfer function written in regression format contains 109 terms and is not repeated here for brevity. It is, however, the expression from which the traditional supply curve is derived. The form is that of a distributed lag equation as suggested in equation 4, footnote 4, above. The lags operate on all variables and extend to the $t = -107$ period suggesting that suppliers of sawlogs are influenced by previous observations of price and interest rates up to nine years.

The regression equation is used to calculate the supply function. Figure 3 depicts the supply curve existing in December of alternate years. Observe that the supply curve exhibits significant shifts through time. This constantly shifting supply curve demonstrates the dynamic market process. Transfer function analysis captures the changes.

Shifts in Supply

Transfer function analysis estimates pine sawlog supply curves mirroring the structural dependencies identified by economic theory. The law of supply is verified in the Arkansas pine sawlog market. As price increases, suppliers increase the quantities placed on the market.

However, the identification of a dynamically shifting supply curve prompts further consideration of the process driving sellers to place sawlogs on the market. For overall supply to be expanded harvest rates must increase. Accordingly, if the forest land base is fixed, then the length of time that the forest stands are held must decrease. Alternatively, forest utilization must increase or new forest long-run investment must be initiated.

Most forest holding-length models have great intuitive appeal. They can be used to explain the effects of varying forest product values, costs, discount rate, and length of time a forest stand should be held before harvest. For all commonly accepted models, stands will be held longer as the discount rate declines because investment holding cost, or opportunity cost, decreases while investment value growth continues. However, in the face of rising interest rates some forest holdings will be liquidated

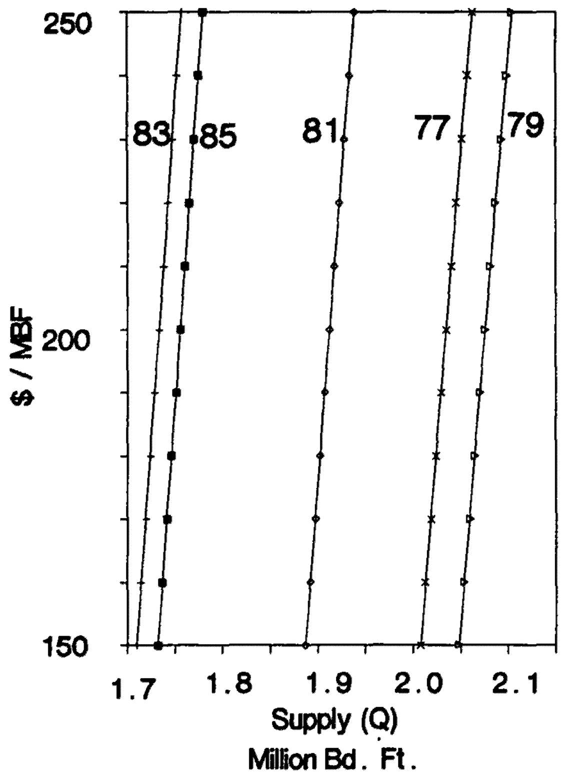

FIGURE 3. Pine sawlog supply curve for December of alternating years, 1977 to 1985.

because the investor is better off shifting his capital to a higher yielding investment.

Forest stand holding-length affects the long-term forest harvest rate, which affects the volume of sawlogs supplied at any given time. While a variable for forest stand holding-length is not explicitly included in the supply model, the developed supply equation does include the interest rate variable. It proxies both the opportunity cost and the forest stand holding-length. Traditional forest economics theory says as alternative returns increase, investors shift out of forest investments into higher yielding investments.

Just as an increase in the forest stand holding-length reduces the quantity of sawlogs available for harvest, high opportunity costs decrease stand holding-length. The offer and withdrawal of marketable timber stands is equivalent to changes in the number of suppliers causing shifts in the supply curve. As owners of timber stands face higher opportunity

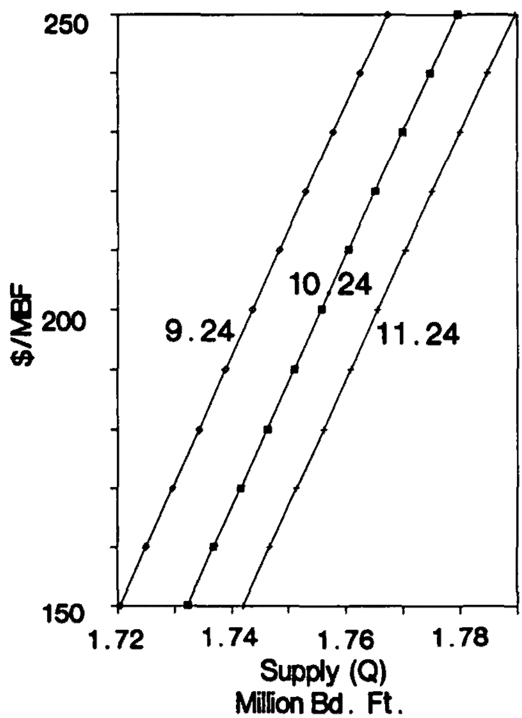

FIGURE 4. Pine sawlog supply curve for December 1985 for three different discount rates.

returns, their response is to shorten the forest stand holding-length. The shortening is accomplished by increasing harvest rates at all prices; hence, the short-term supply curve shifts to the right providing greater quantity supplied at all prices. Transfer function analysis efficiently estimates the dependencies among the quantity supplied, price and interest rate as described by conventional forest economic theory.

Figure 4 graphically demonstrates the shift in the supply curve for December 1985 which would have occurred in response to a change in the interest rate. The actual interest rate was 10.24 percent. If the interest rate had been 11.24 percent, the supply curve would shift to the right and become more inelastic. If the interest rate had been 9.24 percent, the supply curve would shift to the left and become more responsive.

Elasticities of Supply

Timber markets traditionally have been classified as imperfect in the southern United States.[10] Low estimates of elasticity of supply are prof-

10. F. Cubbage & R. Haynes, Evaluation of the Effectiveness of Market Responses to Timber Scarcity Problems 87 (USDA Forest Service. Marketing Research Report No. 1149, 1988).

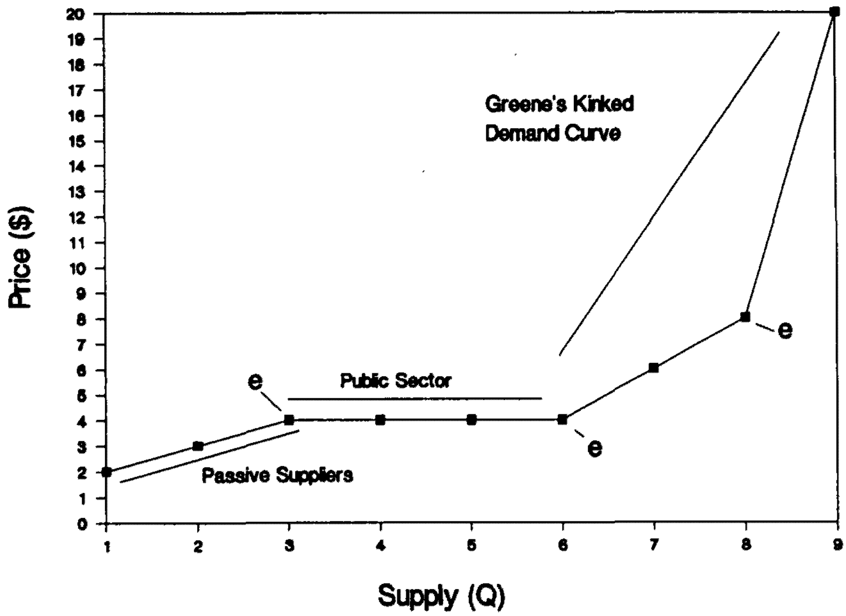

FIGURE 5. Hypothetical segmented supply curve showing market entry points (e) for various supplier groups. After Gregory (1972, 1985) and Greene (1977).

fered as evidence of markets not being truly competitive. Supply elasticities are estimated to equal 0.4.[11] Regardless of the reasons for the imperfections, long-term timber supply has never been particularly responsive to price.

Gregory[12] and Greene[13] hypothesize a multiple supply-sector curve, the aggregate of several supplier groups. Each group offers quantities on the market at different threshold prices (Figure 5). In contrast to the supply-sector hypothesis which presumes quantity supplied is responsive to changes in price, this analysis of the Arkansas data suggests that new suppliers enter the market in response to changes in opportunity costs. The supply-sector model suggests that movement *along* the supply curve is the fundamental market mechanism. However, our analysis of the Arkansas data suggests the fundamental market mechanism consists of two separately identifiable processes. The first is the traditional movement along a supply curve in response to changes in the price of sawlogs. The second is a shift in the supply curve in response to changes in the opportunity returns.

11. USDA Forest Service, The South's Fourth Forest 514 (Forest Resource Report No. 24, 1987).

12. G. Gregory, Resource Economics for Foresters 476 (1987); G. Gregory, Forest Resource Economics, 546 (1972).

13. J. Greene, Propositions for Oral Defense 43 (1972) (M.S. defense, West Virginia University) (available from J. Greene, University of Arkansas, Monticello, Ark.).

Greene[14] argues for a private sector supply curve characterized by abrupt and pronounced changes. This hypothesized supply curve is strongly unresponsive in its upper end. This conforms to the estimated supply curves in Figure 3. In the supply-sector model, the market clearing price is located high on the upper end of Greene's kinked curve. The similarity between the two hypotheses is that supply is inelastic at the market clearing price. The differences are that (1) we find shifts in supply are stimulated by changes in opportunity returns, and (2) the price and interest rate elasticities of supply are extremely low.

The supply equation permits supply price and interest rate elasticity to be calculated at all months of the sample period. Figure 6 depicts supply price elasticity for the 108 months of the analysis period. Inspection of Figure 6 reveals an important supply phenomenon: pine sawlog supply curves are much more price inelastic (.06) than reported by other researchers.[15] The price elasticities portrayed here represent the responsiveness existing at each month during the period of analysis.

Figure 7 depicts the supply interest rate elasticity. This elasticity takes values ranging from .043 to .090. The interest elasticity of supply is of the same magnitude as the price elasticity. The sign of the interest rate elasticities is positive, as expected from equation 7.

POLICY IMPLICATIONS

The broad policy issue is to identify methods to increase the long run supply sufficient to meet market demand at constant real prices. Figure 3 suggests that a large percentage increase in price will have a very small effect on increasing quantity supplied. Recent literature does not dwell on shifts in the supply curve in response to changes in opportunity costs. Few long run public policy objectives are achieved by an increase in the interest rate. Efforts to increase the supply of pine sawlogs by increasing either the price or the opportunity returns will not stimulate any significant change in the quantity of timber placed on the market.

Classical investment analysis portrays investors choosing among alternatives. Typically, comparison is made between a candidate and an alternative opportunity return such as an interest-bearing security. Investors elect to initiate or continue with an investment if the rate of return of the candidate is greater than the alternative. However, shifts in opportunity returns do not bring significant new supplies of pine sawlogs into the market, as evidenced by the extremely low interest rate responsiveness of supply. Therefore, neither price nor the interest rate are effective policy instruments.

14. *Id.* at 13.
15. *See, e.g.*, Cubbage & Haynes, *supra* note 11, at 29.

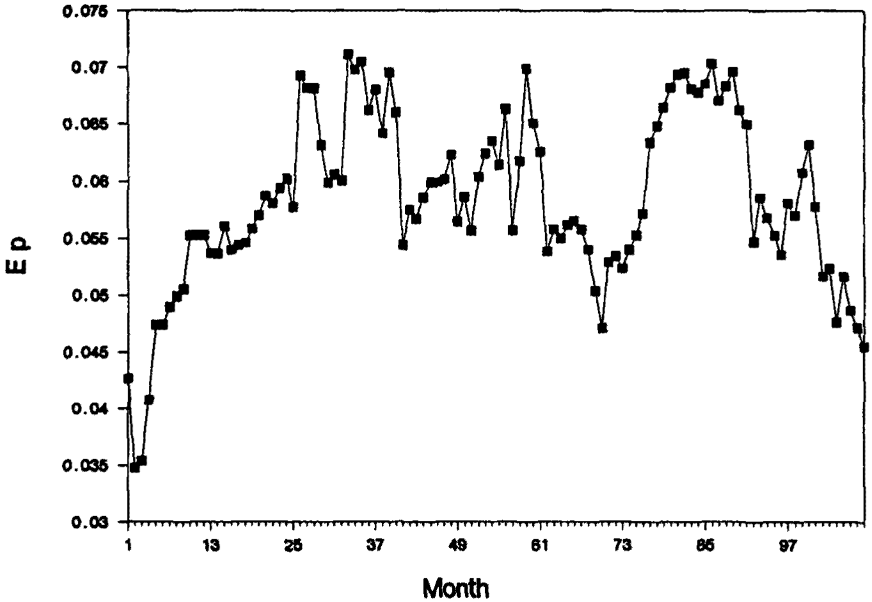

FIGURE 6. Supply elasticity with respect to price for pine sawlogs in Arkansas, January 1977 to December 1985.

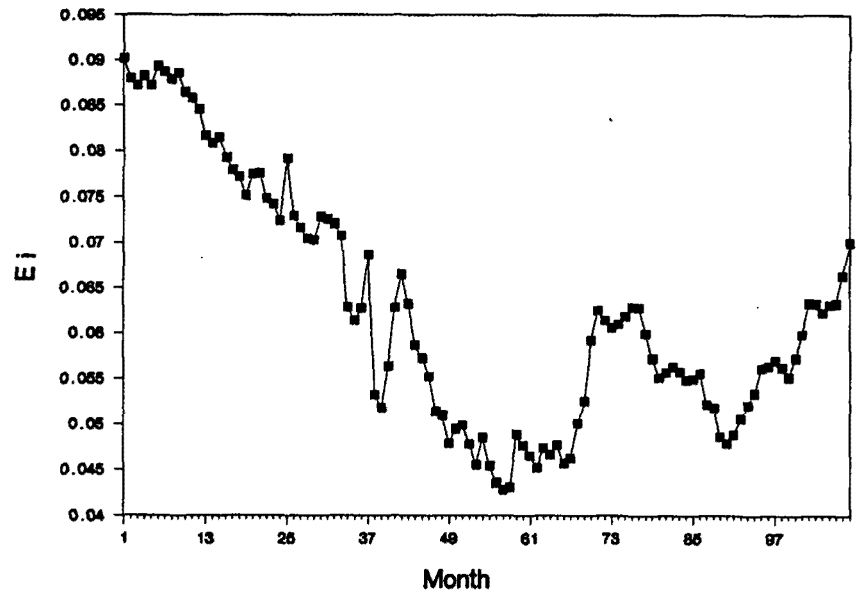

FIGURE 7. Supply elasticity with respect to discount rate for pine sawlogs in Arkansas, January 1977 to December 1985.

There are other policy tools which may affect the supply of sawlogs. The theory of forest stand holding-length describes how increasing supplies can be maintained only if total forest investment is increased. Consequently, schemes to increase long-term supply must make forest investment more attractive. The internal rate of return to forest investment is governed by the investment duration, the biological growth rate, expected future returns, and the cost of establishing the forest investment. While there is some latitude in the process, investment duration and biological growth rate are essentially fixed for the production of sawlogs. The failure of price to bring significant additional quantities on the market suggests that expected future returns is an ineffective investment motivator. Favorable taxation treatment for timber falls into this category since increased after-tax revenues equates to higher expected returns. In a similar way, investments made in anticipation of real price appreciation do not provide sufficient supply increases to nullify real price escalation. Thus, only if the initial cost of forest investments can be lowered can the real rate of return be raised. If supply were responsive to price, then customary arguments that preferential taxation treatment of timber sales spawns additional forest investment would be valid.

Schemes to lower the initial cost of forest investments consist of technical solutions and incentives. Industry has relied on technical solutions, while nonindustrial landowners have depended heavily on incentives. Technical solutions include lower intensity site-preparation, spacing treatments over time, and new technology. An example of the last is the replacement of mechanical competition control operations with herbicide control techniques.

Incentives divide into direct aid (educational, extension, and technical assistance), or indirect aid (tax incentives and cost sharing). Direct aid solutions assume technical ignorance on the part of the landowner. The expense of supplying direct aid includes salaries, expenses, and support staff costs as a surrogate for the landowner's management costs. Direct aid costs are not borne by the landowner, but rather by other private interests or by society. Indirect aid, such as the Forestry Incentives Program (FIP),[16] use of the reforestation provisions of the Packwood Amendment,[17] and investment tax credits increase the internal rate of return earned on investment in timber by lowering the front-end cost.

16. The Agriculture and Consumer Protection Act of 1973. Aug. 10, 1973. 93rd Cong., 1st Sess. §§ 1009, 87 U.S. Stat. 45. The 1974 Forestry Incentives Program (FIP) of P.L. 93-86 authorizes the Secretary of Agriculture to share the cost of forestry practices with nonindustrial, private forest landowners. The program is administered at county level by the U.S. Department of Agriculture, Soil Conservation Service, Agricultural Stabilization Committee.

17. Title III. P.L. 96-451. Reforestation Expenses. Oct. 14, 1980. 96th Cong. 2nd Sess. §§ 301, 94 U.S. Stat. 1989. Title III (The Packwood Amendment) of P.L. 96-451 amends Part VI of subchapter B of Chapt. 1 of the Internal Revenue Code of 1954 (itemized deductions for individuals and corporations). The Tax Reform Act of 1986 left these reforestation provisions in place. The Packwood Amendment allows up to $10,000 of capitalized reforestation costs each year to be eligible for a 10 percent investment tax credit and a 7-year amortization of invested capital funds.

Increasing the supply of timber resources is difficult given the minimum discount rate assigned by most investors and the low biological growth rate. The difficulty is compounded when prevailing opportunity costs rise above the internal rate of return earned on forest investments. When short-term harvest rates increase, the timber capital providing for harvest in future periods is consumed, thus decreasing long-term supply.

CONCLUSION

Transfer function analysis rather than conventional regression techniques is a superior method for the analysis of economic time series. The application of this method to estimate the supply curve for Arkansas' pine sawlogs reveals that the price and interest rate elasticities are much lower than previously reported in the literature.

In contrast to the segmented curve hypothesis, this analysis demonstrates that changes in the opportunity returns measured by interest rate cause a shift in the supply curve of pine sawlogs. This analysis concludes that the dynamic adjustment process is manifested both by shifts in the supply curve and movements along a supply curve. The estimated supply curves have low elasticities with respect to both price and interest rate.

The evidence that the dynamic market is characterized by supply shifts and movements along a supply curve has explicit policy implications. Higher prices will not significantly increase the number of sawlogs offered on the market. An increase in the opportunity returns will trigger approximately the same increase in the number of sawlogs offered on the market as an increase in price. However, both are short-term responses.

Long-term increases in the quantity of sawlogs offered on the market will be dependent on schemes to raise the internal rate of return earned on investments in timber above the return earned on alternative investments.