DYNAMICS OF LONG-TERM FOREST PRODUCTS SUPPLY AND POLICY IMPLICATIONS

BY

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ABSTRACT

Timber markets are characterized as having excess demand because real price continues to escalate. Counter measures designed to alter the increasing real price should center on activities which augment a long-term supply response. The unresolved and underlying question is the identification of the optimal mix of market incentives and public interventions. Specification of this mix of interventions requires that both the pure market solution and the solution resulting from a mix of market and public interventions be accurately specified. To accomplish this, precise identification of the supply response must be accomplished. Transfer function analysis is a superior method for this purpose. Transfer functions were used to determine the underlying market characteristics for three forest products. Long-term supply of hardwood sawlogs was found to be dependent on interest rate (opportunity returns) but not on market price, as previously conjectured. Pine pulpwood supply was found to be dependent on paper board production but not price, and hardwood pulpwood was found to be independent of all classical exogenous drivers.

INTRODUCTION

Inspection of Arkansas' available timber inventory and real price through time confirms that the market demand continues to exceed market supply. Declining inventory reflects the net effect of a decrease in total acreage concurrent with a decline in stocking levels. The mix of timber lands has declined in both quality and distribution. For an extensive discussion of the Arkansas forest resource base see Kluender and Willett, 1989.

The timber market is characterized as having excess demand when the real price continues to escalate. The presence of an upward trend in the real price and inadequate supply has significant public policy implications. An increasing real price obstructs the achievement of housing policy objectives and increases the real cost of other products using timber as an input.

If the present market conditions continue, then two outcomes are possible. First, following classical economic theory, the increasing real price will be reflected in above average returns attracting new entry so that the long term supply increases and future price escalations are moderated.

The second outcome is that the continuous real price increases do not attract entry. Absent a supply response, classical economic theory holds that real price increases lead to detrimental effects on public policy objectives.

Counter measures designed to alter the increasing real price usually center on activities which augment a long-term supply response. The search for optimal policies prompting a supply response requires that the market process be accurately described. A prerequisite to designing supply-side stimuli is the correct identification of the variables prompting supply-side decision makers to react. Once the variables are identified, policy makers use interventions to alter the market conditions. A recent text (Boyd and Hyde, 1989) offers an exhaustive treatment of forestry sector intervention. A correctly specified supply curve pinpoints the variables that must be targeted by policy instruments.

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Previous research statistically estimated the supply curves for pine sawlogs (Kluender and Pickett, 1988). The results of that effort identified the independent variables in the supply equation and their corresponding elasticities of supply. Knowing the responsiveness of supply to changes in each independent variable permits a benefit-cost analysis to be completed for each policy instrument. The final selection of the mix of policy variables is made from the results of the benefit-cost analysis and the available budget.

Observing the increasing real price of timber and declining timber acreage in the southern U.S. suggests the market is not responding as the classical model predicts. Modern investment theory holds that entrepreneurs respond to above average returns by expanding supply so that the return earned on investments in timber equals the return earned on the next best alternative. The model concludes that the response by entrepreneurs acts to augment long-run supply moderating any increase in the real price of timber.

When market data reveal that the classical results are not achieved, economists appeal to the doctrine of 'market failures' to explain deviations from the expected findings. Market failures are impediments preventing the market from achieving the classical solution. The public policy response to the observed market failures is the adoption of interventions which overcome or countermand the impediments so that the competitive solution results.

The unresolved and underlying question has to do with the identification of the optimal mix of market incentives and public interventions (Boyd and Hyde, 1989). The determination of the optimal mix requires that a clear and precise measure of decision-makers' supply and demand responses be known. An erroneous determination of either wastes scarce resources. In an effort to promote the design of optimal public policy expenditures, this paper has two purposes. The first is to suggest techniques that are helpful in identifying the supply response. Given the successful completion of the first, the second purpose is to suggest targets for public interventions.

Specification of the optimal mix of market incentives and public interventions requires that both the pure market solution and the solution resulting from a mix of market and public interventions be accurately specified. All analyses begin by determining whether or not an unfettered market yields the neoclassical solution. However, the identification of a pure market is difficult because interventions are already in place in most markets. Knowing this, the analysis proceeds and omits the consideration of specific preexisting interventions.

The statistical estimation of the market supply curve usually applies ordinary least squares (OLS) methodology to time-series data. The level of sophistication varies from simple single equations to complex simultaneous equation models. A careful review of the results from applying OLS techniques to time series data from the forest sector reveals that grave reservations exist about the typical OLS results. The doubts exist because attempts to verify the assumptions underpinning OLS estimation techniques usually fail. If OLS assumptions are not satisfied, then inferences based on the estimators are invalid. That is, interventions based on an incorrect estimation of the market process squander scarce public resources.

To achieve the first purpose, we suggest techniques which overcome the deficiencies in OLS so that an accurate specification of the market supply curve results. Given the accurate specification of the market supply curve, this paper also identifies the important policy implications revealed by the correctly specified supply curve.

METHODS

DATA: This analysis investigates the supply function in three of Arkansas' forest product markets for the 108-month period January 1977 through December 1985. The first is the supply of hardwood sawlogs. Monthly data[1] on price expressed as dollars per 1000 board feet were obtained from Timber

Mart-South (Timber Mart- South, 1986). The monthly hardwood sawlog quantity supplied is expressed as 1000 board feet per month (MBF/mo.) was derived from severance tax data maintained by the Arkansas Forestry Commission (Arkansas Forestry Commission, 1986). The discount rate consists of monthly observations for a 10-year constant maturity U.S. treasury note and obtained from Citibase (Citibase, 1989).

The second analysis investigates the supply of pine pulpwood. The same 108-month time-span is considered. The price data are expressed as dollars per thousand cords and obtained from Timber Mart-South. The quantity data are obtained from severance tax data maintained by the Arkansas Forestry Commission expressed as thousands of cords per month. The series on paperboard production is expressed as thousands of short tons and obtained from the Survey of Current Business (U.S. Dept. of Commerce, 1989).

The third supply function examined is for hardwood pulpwood. The same 108 month interval is considered. The price data are expressed as dollars per thousand cords and obtained from Timber Mart-South. The quantity data are obtained from severance tax data maintained by the Arkansas Forestry Commission expressed as thousands of cords per month. The series on paper production is expressed in thousands of short tons and was obtained from the Survey of Current Business.

ASSUMPTIONS: The use of comparative statics requires that the criteria used to choose the appropriate model be specified. This analysis uses two criteria. The first is that all underlying assumptions underpinning the analysis be satisfied. The five underlying assumptions address properties of the residuals. The assumptions assure that estimators are the best linear unbiased estimates of their true values. The well known assumptions are that (1) the expected value of the residuals is zero, (2) they have constant variance, (3) they are normally distributed, (4) they are independent, and (5) the independent variables are not related to them. The second criteria is that the functional form between the dependent and independent variables be correct. Note these differ from the usual criterion of maximizing R^2. (See Ramanathan, 1989)

ORDINARY LEAST SQUARES: Ordinary least squares (OLS) methods originated as a methodology to summarize the statistical relationships among cross-sectional data. When time series data are analyzed with OLS methods a host of difficulties arise. The difficulties are classified into two groups. One is that the assumptions relevant to the residuals are not satisfied, and the other is the difficulties encountered when attempting to pre-specify the model form. When either difficulty arises, the researcher enters the cycle of reformulation, transformation, re-estimation, diagnosis, and inspection. Two recent texts (Belcha, 1989 and Ramanathan, 1989) devote extensive discussions to the method to overcome the deficiencies inherent in using OLS techniques for the analysis of time series. The econometric industry devotes extensive efforts to the repair of OLS deficiencies. While many are effective, superior methods are available for the estimation of the relationships among time series variables. Adoption of the preferred techniques usually bequeaths the analyst an insight into the dynamics of the market process.

TRANSFER FUNCTIONS: The most powerful statistical methodology for the analysis of single equation time series data is transfer function analysis (Vandaele, 1983). It results in parameter estimates where all the underlying assumptions are satisfied and the equation is the correct functional form. Thus, the most general expression for all econometric models is a transfer function.

Transfer function models have great theoretical appeal (Pickett, 1988). 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 an examination of the variables' auto-correlation, partial auto-correlation, and cross correlation functions (Automatic Forecasting Systems, 1986). The research methodology used to identify the correct model form and the nonlinear estimation techniques result in models which are superior to those estimated by OLS techniques. In summary, transfer function analysis overcomes regression bias inherent in most OLS models of economic time series.

This paper reports the estimates developed by transfer function models for each of the three Arkansas forest sectors.[2] The models will be evaluated, and the policy implications of each will be identified. We conclude by demonstrating that the correct estimation of the market process reveals the correct targets of the forest policy initiatives.

RESULTS

Hardwood Sawlog Market

The supply curve for hardwood sawlogs:

$$QHL_t = f(PHL_t, I_t, e_t) \tag{1}$$

where:
QHL = Quantity supplied of hardwood logs.
PHL = Price of hardwood logs.
I = Interest rate.
e = Residuals

The estimation of the transfer function (TFM) for hardwood sawlogs is:

$$(1\text{-}B)(1\text{-}B^{12})QHL^{0.0}{}_t = \underset{(3.2)}{1.12}(1\text{-}B)(1\text{-}B^{6})I^{-1.0}{}_{(t-2)} \tag{2}$$

Mean square error = .01, R^2 = .95
T-value is shown in parenthesis.

The transfer function deletes the price variable as insignificant. The differencing operators and the power (Box-Cox) transformations insure that all variables are stationary. Both of these techniques assure that the residuals will have constant variance. Also, the time dependencies between changes in the opportunity cost and changes in supply are clearly evident by the group delay required by the t-2 lag on the interest rate variable. Finally, an analysis of the residuals concludes that all assumptions are satisfied.

The transfer function may be expanded and written as a traditional right hand side regression equation. Table 1 expresses the model as a regression equation.

The regression equation may be used to calculate the elasticity of hardwood log supply with respect to changes in the interest rate. Figure 1 portrays the monthly elasticity values. The elasticity values are quite low and not constant through time.

Figure 2 shows the three dimensional surface linking the original data series for hardwood sawlog volume, the interest rate, and time. Such a complex surface is difficult to model with linear (in parameters) OLS models. When nonlinear OLS estimation techniques are used, the difficulties shift to insuring that the functional form is correct.

Figure 3 shows the three dimensional surface modeled with a transfer function. The vertical axis graphs the estimated values--Y-hat. The interest rate B-J axis graphs the values estimated with the series' univariate model. Since the transfer function analysis uses nonlinear estimation techniques and follows rules resulting in the correct functional form, it estimates surfaces very close to the original.

Table 1. The Box-Jenkins transfer function for hardwood sawlogs expressed as a regression equation.

TIME PERIOD	COEFFICIENTS It	COEFFICIENTS QHLt
CONSTANT = .000		
T=- 1	.00000	1.000
T=- 2	1.1218	.0000
T=- 3	-1.1218	.0000
T=- 8	-1.1218	.0000
T=- 9	1.1218	.0000
T=- 12	.00000	.4726
T=- 13	.00000	-.4726
T=- 14	.59167	.0000
T=- 15	-.59167	.0000
T=- 20	-.59167	.0000
T=- 21	.59167	.0000
T=- 24	.00000	.2492
T=- 25	.00000	-.2492
T=- 26	.31205	.0000
T=- 27	-.31205	.0000
T=- 32	-.31205	.0000
T=- 33	.31205	.0000
T=- 36	.00000	.1315
T=- 37	.00000	-.1315
T=- 38	.16458	.0000
T=- 39	-.16458	.0000
T=- 44	-.16458	.0000
T=- 45	.16458	.0000
T=- 48	.00000	.6933E-01
T=- 49	.00000	-.6933E-01
T=- 50	.86798E-01	.0000
T=- 51	-.86798E-01	.0000
T=- 56	-.86798E-01	.0000
T=- 57	.86798E-01	.0000
T=- 60	.00000	.3656E-01
T=- 61	.00000	-.3656E-01
T=- 62	.45778E-01	.0000
T=- 63	-.45778E-01	.0000
T=- 68	-.45778E-01	.0000
T=- 69	.45778E-01	.0000
T=- 72	.00000	.1928E-01
T=- 73	.00000	-.1928E-01
T=- 74	.24143E-01	.0000
T=- 75	-.24143E-01	.0000
T=- 80	-.24143E-01	.0000
T=- 81	.24143E-01	.0000
T=- 84	.00000	.1017E-01
T=- 85	.00000	-.1017E-01
T=- 86	.12733E-01	.0000
T=- 87	-.12733E-01	.0000
T=- 92	-.12733E-01	.0000
T=- 93	.12733E-01	.0000
T=- 96	.00000	.5364E-02
T=- 97	.00000	-.5364E-02
T=- 98	.67156E-02	.0000
T=- 99	-.67156E-02	.0000
T=- 104	-.67156E-02	.0000
T=- 105	.67156E-02	.0000

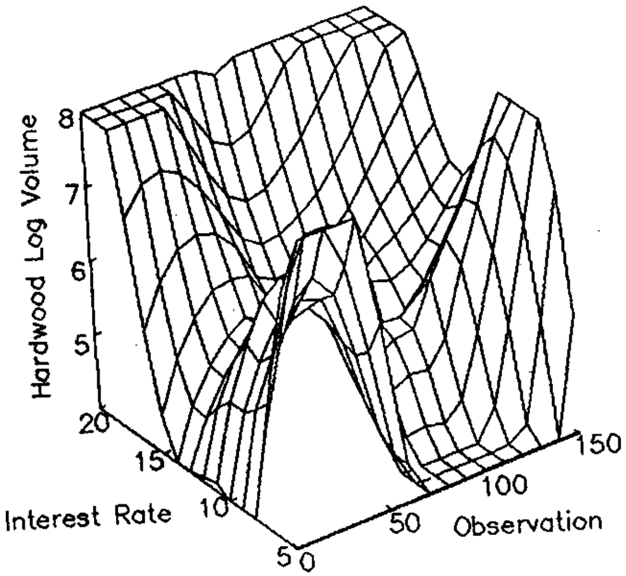

Figure 1. Uncorrected hardwood sawlog supply over time with respect to interest rate.

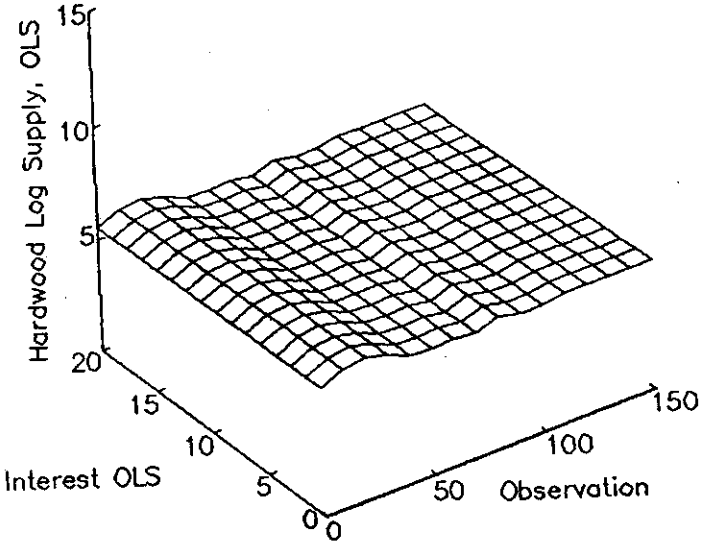

Figure 2. Ordinary least squares fit of hardwood sawlog supply over time with respect to interest rate.

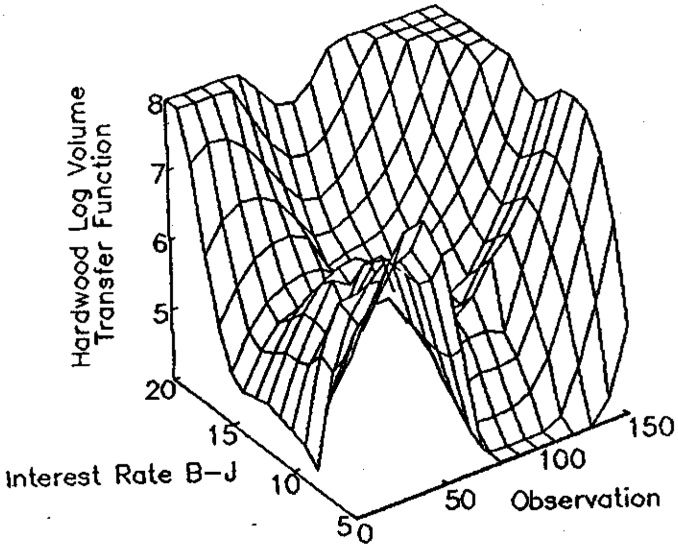

Figure 3. Transfer function fit of hardwood sawlog supply over time with respect to interest rate.

Policy Implications: Classical micro-economic theory suggests the hardwood sawlog price is an important determinant of the supply. However, transfer function analysis concludes that price is not statistically significant and the opportunity cost (or return) is important. In addition, the elasticity of supply with respect to the interest rate is very low (Figure 4).

The policy implications of the supply curve estimated with transfer functions suggests that the supply of hardwood logs is not responsive to changes in price and only slightly responsive to changes in the opportunity costs. These conclusions support those expected from traditional forest investment theory. Conventional theory holds that if the return earned on alternative investments increases above the return earned on the present investment, then profit maximization requires that the decision maker exit the low return and enter the high return opportunity. However, one of the dominant characteristics of investment in timber stands is its long horizon and illiquidity. The investment horizon is 40-60 years. Implicit in the long-term horizon is the negligible impact of short-term (monthly) fluctuations in the opportunity cost of capital. The low elasticity of supply with respect to the interest rates confirm this.

Investments in timber resources are made after comparing the return earned during the life of the asset to returns earned on alternative investments during the same interval. If alternative returns are higher than the return earned on timber investments, then exit from the timber industry occurs. For capital investments held as timber stands, the shift out of timber can be accomplished only by harvesting the resource. Transfer of the asset would simply shift the burden to an investor with a lower opportunity cost while remaining in timber.

The policy implication is clear. Investment in hardwood timber resources is stimulated by programs which increase the return earned on these investments. Specifically, the programs should target all parameters in the investment function except the selling price of the timber.

An additional implication is evident from an inspection of the surface of Figure 3. If a slice of the surface is taken at low and at high interest rates parallel to the time axis, the two dimension curves will appear very different. This suggests that the policy initiatives should be quite different at low and high levels of interest rates.

Pine Pulpwood Market

The supply curve for pine pulpwood may be written as:

$$QPP_t = f(PPP_t, I_t, QB_t, e_t) \qquad (3)$$

where:

QPP = Quantity supplied of pine pulpwood.
PPP = Price of pine pulpwood.
I = Interest rate
QB = Quantity of paperboard production.
e = Residuals

Pine pulpwood is a key input in paperboard production. As paperboard production increases, the demand for all inputs increases, pine pulpwood included. Hence, the necessity to include paperboard production as an independent variable.

Figure 5 shows the original surface of QPP, QB, and time. Note the surface takes an unusual shape. However, the time dependencies are not constant through time as noted by undulating peaks and troughs when moving along an axis.

The transfer function estimation of the pine pulpwood equation includes only QB as a significant variable. The equation is:

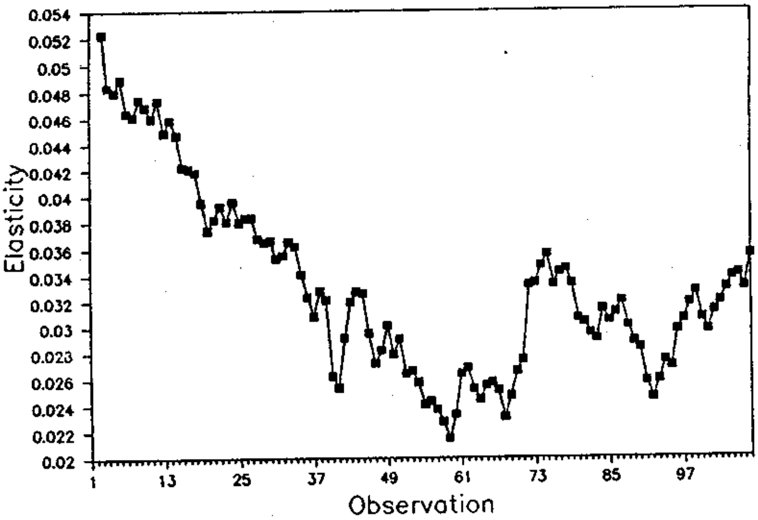

Figure 4. Hardwood sawlog supply elasticity over time with respect to interest rate.

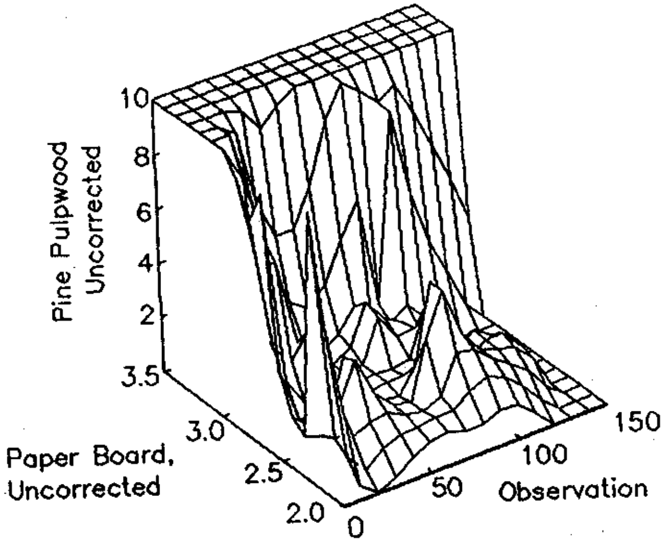

Figure 5. Uncorrected pine pulpwood supply over time with respect to paper board production.

$$\underset{(3.3)}{(1\text{-}B)(1\text{-}B^{12})QPP^{1.0}_t} = \underset{(11.2)}{.07(1\text{-}B^{12})(1\text{-}B^3)QB^{1.0}_{t\text{-}1}} + (1\text{-}.83B^{12})a_t \qquad (4)$$

Mean square error = .001, R^2 = .94
T-values are shown in parenthesis.

The transfer function deletes the insignificant price and interest rate variables. The differencing operators insure that all variables are stationary. Also, the time dependencies between changes in the quantity of paperboard production and changes in supply are clearly evident by the group delay noted by the t-1 lag on the independent variable. Finally, an analysis of the residuals concludes that all assumptions are satisfied.

The transfer function may be expanded and written as a traditional right-hand side regression equation. Table 2 expresses the model as regression equation.

Figure 6 shows the three dimensional surface modeled with a transfer function. The vertical axis graphs the fitted values for the dependent variable. The paperboard, B-J axis graphs the values estimated with the series' univariate model. Transfer function techniques extract and reveal the underlying process handily. The elimination of the significant time dependencies embedded within each series unveils the surface linking the two variables through time. Absent the power of the transfer function methodology, the traditional researcher remains trapped when attempting to model this surface.

The elasticities of pine pulpwood supply with respect to paperboard production are presented in Figure 7. These elasticity values are low and exhibit a strong seasonal pattern.

Policy Implications: The market supply of pine pulpwood is influenced by the total U.S. production of paperboard. The policy implications of the supply curve estimated with transfer functions suggests that the supply of pine pulpwood is independent of both its price and the opportunity returns available to the owner. The absence of price as an important determinant of the quantity supplied conforms to the theory of factor supply when the buyer faces many competitors for inputs, i.e., the supply curve is perfectly elastic at the prevailing market price. As paperboard production increases, the demand curve for pine pulp shifts to the right intersecting the horizontal supply curve at a higher level of output. The market price of pine pulpwood remains the same regardless of quantity offered on the market.

Other right-hand side variables may have been omitted from the supply function. Six percent of the variance in pine pulpwood quantity remains unexplained by the current and lagged values of paperboard production and lagged values of the dependent variable.

The policy implication of the one independent variable is clear. It is unlikely that a policy instrument can be identified that will affect the quantity of pine pulpwood supply which operates through the paperboard production variable. Given the inability to pinpoint a policy variable, analysts know that the failure of price to explain the variance in the quantity supplied eliminates it as a policy tool candidate. Therefore, public policy should target all parameters in the investment function except the price of pine pulpwood.

Again, the two dimensional surface created by slicing at low and high levels of paper production parallel the time axis results in markedly different line graphs. The implication is the different policy initiatives are required for times of low and high paperboard production.

Table 2. The Box-Jenkins transfer function for pine pulpwood expressed as a regression equation.

TIME PERIOD	COEFFICIENTS	
	PBt	QPPt
CONSTANT =0.0		
T=- 1	.69392E-01	1.000
T=- 4	-.69392E-01	.0000
T=- 12	.00000	.1708
T=- 13	-.11851E-01	-.1708
T=- 16	.11851E-01	.0000
T=- 24	.00000	.1416
T=- 25	-.98270E-02	-.1416
T=- 28	.98270E-02	.0000
T=- 36	.00000	.1174
T=- 37	-.81487E-02	-.1174
T=- 40	.81487E-02	.0000
T=- 48	.00000	.9738E-01
T=- 49	-.67571E-02	-.9738E-01
T=- 52	.67571E-02	.0000
T=- 60	.00000	.8075E-01
T=- 61	-.56031E-02	-.8075E-01
T=- 64	.56031E-02	.0000
T=- 72	.00000	.6696E-01
T=- 73	-.46462E-02	-.6696E-01
T=- 76	.46462E-02	.0000
T=- 84	.00000	.5552E-01
T=- 85	-.38527E-02	-.5552E-01
T=- 88	.38527E-02	.0000
T=- 96	.00000	.4604E-01
T=- 97	-.31947E-02	-.4604E-01
T=- 100	.31947E-02	.0000

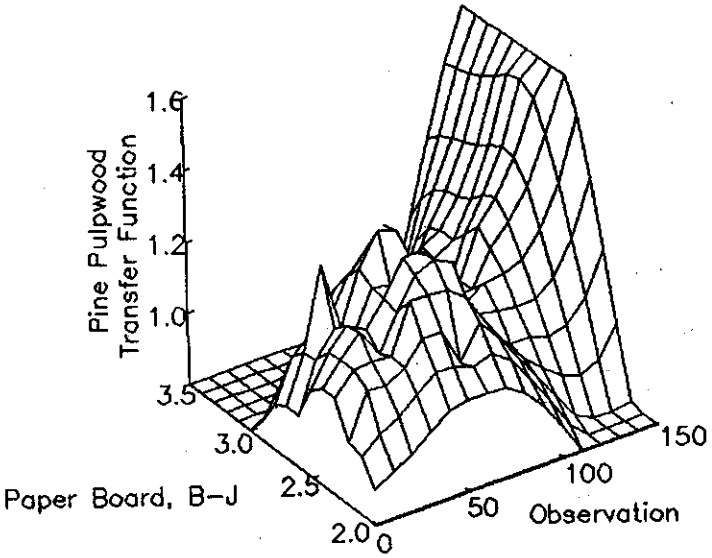

Figure 6. Transfer function fit of pine pulpwood supply over time with respect to paper board production.

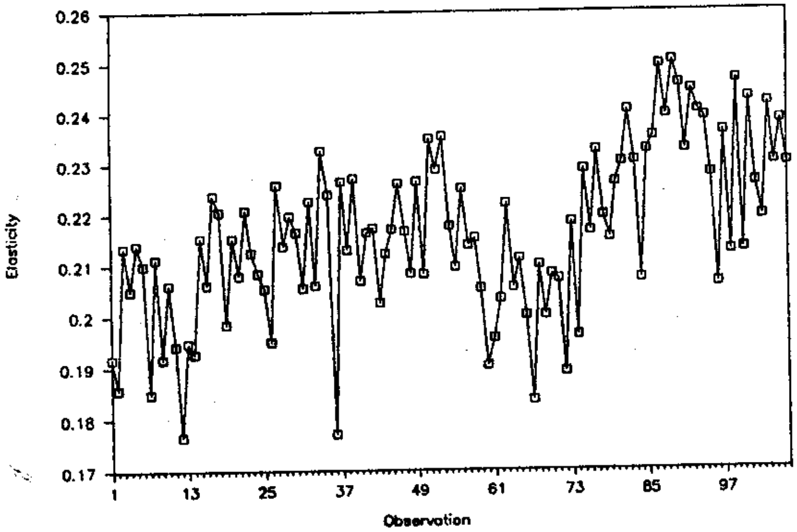

Figure 7. Pine pulpwood elasticity with respect to paper board production over time.

Table 3. The Box-Jenkins univariate model for hardwood pulpwood expressed as a regression equation.

TIME PERIOD	COEFFICIENT QHPt
Constant	.00000
T= - 1	1.0000
T= - 12	.80449
T= - 13	-.80449
T= - 24	.74237
T= - 25	-.74237
T= - 36	-.59723
T= - 37	.59723
T= - 48	-.55111
T= - 49	.55111
T= - 60	.44336
T= - 61	-.44336
T= - 72	.40912
T= - 73	-.40912
T= - 84	-.32914
T= - 85	.32914
T= - 96	-.30372
T= - 97	.30372

Hardwood Pulpwood Market

The supply curve for hardwood pulpwood may be written as:

$$QHP_t = f(PHP_t, I_t, QP_t, e_t) \qquad (5)$$

where:

QHP = Quantity supplied of hardwood pulpwood.
PHP = Price of pine pulpwood.
I = Interest rate
QP = Quantity of paper production.
e = Residuals

Hardwood pulpwood is a key input in the production of paper. As paper production increases, the demand for all inputs increases, hardwood pulpwood included. Hence, the necessity to include paper production as an independent variable.

Estimation of the transfer function reduces to a simple univariate model. None of the proposed independent variables are significant. The univariate model is:

$$(1-B)QHP^{1.0}_t(1 - \underset{(32)}{.79}B^{12}) = (1 + \underset{(-30)}{.9}B^{24})a_t \qquad (6)$$

Mean square error = .001, R^2 = .91
T-values are shown in parenthesis

An examination of the residuals reveals that all assumptions are satisfied. The failure of all proposed independent variables, particularly paper production, is unexpected. While 91 percent of the variance in the dependent series is explained by a distributed lag of its previous values, the amount remaining unexplained suggests one or more independent variables have been overlooked. Subsequent research will focus on identifying the omitted variables. The univariate model is written as a regression equation in Table 3.

Figure 8 offers some insight into the functional relationship among the supply of hardwood pulpwood supply, paper production, and time. All series are filtered with their univariate model before plotting. Note the surface alters significantly during the sample period. While the surface appears to relate the quantity supplied to paper production, paper is not statistically significant at 95 percent.

Policy Implications. The policy implications of a univariate model without any independent driving variables is clear. Absent any independent variables, there are no targets for policy initiatives. The alternative targets are the variables in the cost component of the equation calculating the internal rate of return.

ENDNOTES

1. A complete listing of all data series and statistical reports are available on a floppy diskette. Send a blank 5.25" floppy diskette with the mailing address attached to Prof. John C. Pickett, Dept. of Econ. & Finance, UALR, 2801 S. University, Little Rock, AR 72204.

2. See Kluender and Pickett, 1988 for an expanded statement applying transfer functions in the analysis of forest sector supply curves.

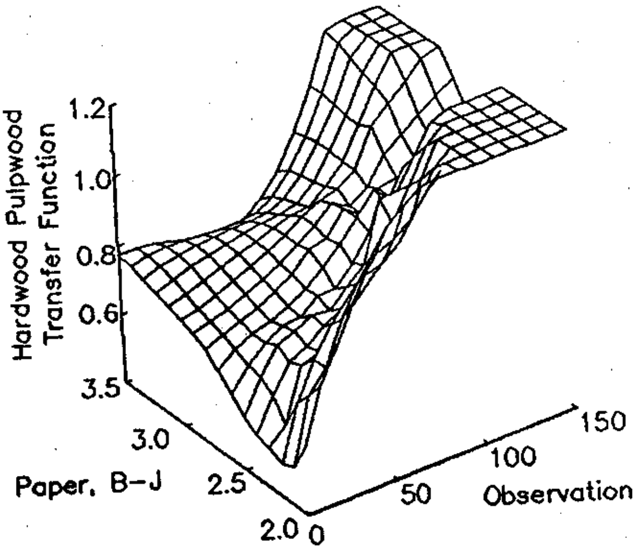

Figure 8. Transfer function fit of hardwood pulpwood supply over time with respect to paper produciton.

LITERATURE CITED

Arkansas Forestry Commission. 1986. Severance Tax Data. Division of Special Collections. Arkansas Forestry Commission, Little Rock.

Automatic Forecasting Systems, Inc. 1986. AUTOBOX: The User's Guide. Automatic Forecasting Systems, Inc. Hatboro, PA.

Blecha, Betty J. 1989. Econometric Sourcebook Wadsworth Publishing Company. Belmont, CA.

Boyd, R.G. and Hyde, W.F. 1989. Forestry Sector Intervention. Iowa State University Press. Ames.

Citibase, Citibank, N.A., 120 Wall Street, New York, NY 10043

Kluender, R.A. and Pickett, J.C. 1988. Estimating the Pine Sawlog Supply Curves Using Transfer Functions. Proceedings of the 1988 Southern Forest Economics Workshop. University of Florida.

Kluender, R.A. and Willett, R.L. 1989. Arkansas' Fourth Forest: Alternatives for the Future. Arkansas Agricultural Experiment Station. Special Report 133. University of Arkansas. Fayetteville.

Pickett, J.C. 1988. Autobox--An Advanced Time Series Program for Microcomputers. Readings in Business and Economic Research. Center for Business and Economic Research, University of Alabama, Tuscaloosa. February 1988.

Ramanathan, Ramu. 1989. Introductory Econometrics with Applications. Academic Press. New York.

Timber Mart-South. 1986. Stumpage Price Series for Arkansas. Data Resources International. McGraw-Hill, Inc. Boston.

U.S. Department of Commerce. 1989. Survey of Current Business. Government Printing Office, Washington.

Vandaele, R. 1983. Applied Time Series Analysis and Box-Jenkins Models. Academic Press. New York.