Alternative Price Expectations Regimes in Timber Markets

Irma A. Gomez, H. Alan Love and Diana M. Burton*

Abstract

Price expectations play a crucial role in markets for timber and other natural resources. Each period, the resource owner must decide whether to harvest or hold the resource. Since prices in future periods are uncertain, the owner must use a price forecast. Economists have hypothesized alternative mechanisms by which economic agents form expectations. This study develops a dynamic model of individual timber producer behavior to analyze various price expectations mechanisms and determine their role in the timber harvest decision. The model allows for the possibility that producers are risk averse, implying that timber producers must form expectations about both price and price variance. Non-nested hypothesis tests are used to distinguish the expectations regime which best fits market data. The expectations regimes considered are naive and two quasi-rational mechanisms: an exponentially-smoothed model and a nonparametric representation. Data are for hardwood and softwood timber markets in Louisiana.

Keywords: price expectations, price variance, risk aversion, timber markets, timber producers.

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Introduction

Price expectations play a critical role in timber markets. Each period, producers must decide whether to harvest or hold their timber. Since landowners do not know future market conditions with certainty, forecasts of timber prices are required. Economists have hypothesized alternative expectations regimes, from naive expectations to rational expectations. Burton & Love (1996) have recently reviewed the empirical expectations literature.

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This research examines alternative price expectations regimes to determine their acceptance among timber producers. Price expectations formation is assumed to be economically rational (Feige & Pearce, 1976; Arrow, 1978; Grossman & Stiglitz, 1976). A rationally-formed expectation assumes that economically rational agents take into account tradeoffs between additional costs of gathering more information and improved prediction precision. In contrast, Muth's (1961) rational expectations hypothesis treats information like any other production input, but assumes information is scarce yet costless to obtain and process. With positive information costs, the underlying price forecasting model used by producers may be one of a number of expectations regimes.

Previous works incorporating price expectations into timber market models have included particular expectations mechanisms as maintained hypotheses and have not tested across alternative regimes. Examples of these studies are Brännlund's (1988; 1989) analyses of the Swedish roundwood market and the Swedish pulpwood market, respectively, using a first-order autoregressive process for price of sawtimber and naive expectations to represent pulpwood expected price. Brännlund, Johansson & Löfgren (1985), in a study analyzing sawtimber and pulpwood supply in Sweden, model pulpwood supply as a function of current price and expected future prices based on a distributed lag of current and previous prices. They conclude that the effect on supply of an increase in current pulpwood price is diminished by the introduction of explicit expectations of future prices. Buongiorno & Calmels (1988) determine the extent of rational expectations applied to country forecasts of pulp and paper capacity and reject the hypothesis that expectations are fully rational.

This study develops a dynamic model of individual producer behavior to analyze price expectations mechanisms and their role in the harvest decision. The model allows for the possibility that timber producers (landowners) are risk averse. If landowners are risk averse, risk variables may influence the harvest decision. Including risk in timber supply means that producers must form expectations on both price and price-induced risk. Two new price expectation mechanisms are introduced. Non-nested hypothesis test procedures are applied to distinguish which expectation regime best fits market data. This paper begins with a section on timber supply in a dynamic framework, followed by a description of the price expectations mechanisms analyzed and a description of the data. Estimation of expected prices and variances and empirical results are presented. Finally, non-nested hypothesis test results are displayed, followed by the conclusions.

THE MODEL

The landowner's problem is to maximize the expected present value of the utility of profits from timber production. This can be represented as an optimal control problem in continuous time:

$$\text{Max}_{h_p,h_g,g}\ E\left[\int_0^\infty e^{-rt}U\left[p_p h_p + p_s h_s - C\left(h_p, h_s, g, w; k\right)\right]\right] \quad (1)$$

subject to

$$\dot{k} = g - h_p - h_s \quad (2)$$

$$k(0) = k_0. \quad (3)$$

where h_p is pulpwood harvest, h_s is sawtimber harvest, g is growth, $E\,[\cdot]$ is the expectation operator, r is interest rate, t represents time, $U[\cdot]$ is the producer's utility function, p_p is harvested pulpwood price, p_s is harvested sawtimber price, $C(\cdot)$ represents a conditional cost function, w is a variable input price vector, including wages of forest workers and prices of forest machinery, and k is inventory. In particular, $C(h_p,h_s,g,w;k)$ represents a conditional cost function defined as $C(\cdot) = \min_x\{w'x\text{: } F(x,h_s,h_p,g;k) \geq 0\}$ where $\text{F}(x,h_s,h_p,g;k)$ is a production transformation function, x is a variable input quantity vector associated with w. Hence, $C(\cdot)$ represents production costs, excluding inventory holding cost for standing timber and capital costs such as land rent and taxes. The state equation (2) models the net change in inventory at time t as growth less harvest. Equation (3) is the initial condition for inventory.

This representation of the landowner's problem differs from the traditional one of only choosing harvest (e.g., Johansson & Löfgren, 1985). Here, the landowner chooses harvests and growth. Biological growth is incorporated within the technology represented in the conditional cost function. In the current specification, growth can be responsive to managements practices like controlled burns, precommercial thinning, and fertilization. Variable management costs are associated with input prices w. Newman & Wear (1993) and Wear & Newman (1991) model growth and regeneration efforts as choice variables in a static model of timber producer behavior. Most other specifications have treated growth as a function of time and current inventory levels and as unresponsive to management practices (e.g., Newman, 1987; Max & Lehman, 1988). Here growth is represented as a choice variable controlled through management practices.

In this model, the landowner has three controls or decision variables: harvest of pulpwood, harvest of sawtimber, and growth. There is one state variable: inventory level. To maximize expected utility of current and future profits, producers must choose all control variables simultaneously. Given an initial inventory level, inventory is the difference between growth and harvests. Hence, choice of growth and harvests define remaining inventory. By incorporating pulpwood and sawtimber harvests separately, the substitution that might occur between harvest of pulpwood and sawtimber is made explicit (Brännlund, Johansson & Löfgren, 1985).

We assume that a representative producer's mean-variance utility function is represented by

$$E\left[U(\pi)\right]=E(\pi)-\frac{\phi}{2}\sigma_{\pi}^{2}, \tag{4}$$

where ϕ is the risk aversion parameter and σ_{π}^{2} is variance of profit (Hildreth, 1954; Freund, 1956). This utility function, while it assumes constant absolute risk aversion, is simple and results in first-order optimization conditions that are linear in price mean and variance when price alone is uncertain. Variable profit is represented as harvest revenues less variable costs:

$$\pi = p_p h_p + p_s h_s - C\left(h_p, h_s, g, w; k\right). \tag{5}$$

Substituting Equation (5) into (4), that result into (1), and taking expectations, assuming output prices are the only stochastic variables, Equations (1), (2), and (3) form a current value Hamiltonian:

$$H = p_p^e h_p + p_s^e h_s - C\left(h_p, h_s, g, w; k\right) - \frac{\phi}{2}\left(p_p^v h_v^2 + p_s^v h_s^2 + 2h_s h_p \sigma_{ps}\right) + \mu\left(g - h_s - h_p\right), \tag{6}$$

where μ is the shadow price associated with state equation (2) and represents the marginal value to the firm of holding forest inventory, p_p^e is expected pulpwood price, p_s^e is expected sawtimber price, p_p^v and p_s^v are pulpwood and sawtimber price variances, respectively, and σ_{ps} is the covariance of pulpwood and sawtimber prices.

Optimality conditions for Hamiltonian (6) are:

$$H_g = -C_g + \mu = 0, \tag{7}$$

$$H_{h_p} = p_p^e - C_{h_p} - \phi\left(p_p^v h_p + h_s \sigma_{ps}\right) - \mu = 0, \tag{8}$$

$$H_{h_s} = p_s^e - C_{h_s} - \phi\left(p_s^v h_s + h_p \sigma_{ps}\right) - \mu = 0, \tag{9}$$

and

$$-H_k = \dot{\mu} - r\mu = C_k. \tag{10}$$

The equation of motion for the state variable k is

$$\dot{k} = H_\mu = g - h_s - h_p. \tag{11}$$

To obtain the system of equations that solve the landowner's maximization problem, Equations (7) and (8) are combined to get

$$p_p^e - C_{h_p} - \phi\left(p_p^v h_p + h_s \sigma_{ps}\right) - C_g = 0, \tag{12}$$

and (7) and (9) are combined to obtain

$$p_s^e - C_{h_g} - \phi\left(p_s^v h_s + h_p \sigma_{ps}\right) - C_g = 0. \tag{13}$$

Equations (12) and (13) show that, at the optimum, marginal cost of growth, C_g, is equal to expected price of the good less marginal cost of harvesting and risk premium.

Obtaining the last optimality conditions requires several intermediate steps. First, Equation (7) is differentiated with respect to time:

$$H_{gt} = -C_{gt} + \dot{u} = 0. \tag{14}$$

Second, Equations (14), (10) and (7) are combined to get

$$C_{gt} = rC_g + C_k. \tag{15}$$

Finally, the appropriate components are substituted into (15) to get

$$rC_g + C_k - \dot{h}_p C_{gh_p} - \dot{h}_s C_{gh_s} - \dot{g}C_{gg} - \left(g - h_s - h_p\right)C_{gk} = 0. \tag{16}$$

Hence, the system of equations that solves the maximization problem is given by Equations (12), (13) and (16).

We use a generalized Leontief conditional cost function in the empirical model. This function provides a second-order Taylor-series approximation to an arbitrary continuously twice differentiable cost function (Diewert, 1982). Conditional cost is:

$$C\left(h_s, h_p, g, w; k\right) = \gamma_0 + \sum_i^N \sum_j^N \gamma_{ij}\left(z_i z_j\right)^{0.5} + 2\sum_j^N \gamma_j z_j^{0.5}, \tag{17}$$

where $z = (h_p, h_s, g, w, k)$ and γ_i and γ_{ij}, $i, j = p$ (*for* h_p), s (for h_s), g, w, and k, are parameters. Based on Young's theorem, symmetry is imposed as $\gamma_{ij} = \gamma_{ji}$. Additionally, to ensure linear homogeneity in input prices, the cost function is normalized by machinery price. The final form of the estimating equations system is obtained by replacing appropriate derivatives in the necessary conditions. Utility maximization requires the Hamiltonian to be jointly concave in state variable k and controls h_p, h_s and g (Beavis & Dobbs, 1990). Hence, the Hessian matrix has to be negative semidefinite.

PRICE EXPECTATIONS MECHANISMS

Price expectations are assumed to be formed in a economically rational way. Timber producers will use available information to construct expected prices until marginal cost of information equals marginal benefit from additional information measured as improvements in forecast precision. The price expectations mechanisms tested in this paper are naive and two quasi-rational specifications. Using these expectation mechanisms, expected price and expected price variance are modeled as forecasts from auxiliary equations. These forecasts are then substituted into the timber producer's profit equation.

The naive expectation assumes that the best forecast of future price is current price. This expectation mechanism ignores possible producer knowledge of anticipated supply or demand shifts and their effects on price. In the presence of price trends, naive expectations will under- or overpredict future price. The naive expected price variance and covariance for period t are formed using the squared difference between lagged price and the mean price of data from sample beginning through period t–1. Even with its rather poor predictive ability, rational producers may use naive expectations if information collection and processing are costly.

Under the quasi-rational expectation hypothesis, producers form future price forecasts from an optimal statistical predictor and are assumed not to know structural parameters for the entire economic model, as would be required for full rational expectations (Nelson & Bessler, 1992). For this study, two different statistical estimators are postulated: exponential smoothing and a nonparametric estimator.

The exponential smoothing estimator is sometimes described as an adaptive expectations model (Hamilton, 1994). The forecast equation for Holt's linear exponential smoother is $F_{t+m} = S_t + b_t m$ where $S_t = \alpha X_t + (1-\alpha)\,(S_{t-1} + b_{t-1})$ and $b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)\,b_{t-1}$. α and γ are smoothing parameters, m is the number of forecast periods and X_t is a starting value (Makridakis, Wheelwright & McGee, 1983). Exponential smoothing is a unit root process, which allows the intercept of the limiting forecast to change continually with each new observation. Price variances and covariance are computed as $(p_{it} - p_{jt}^{e})^2$ for i, j = pulpwood, sawtimber at each observation. In a timber production context, exponential smoothing is an appealing expectation mechanism since it assumes producers use recent prices to form expectations of future prices. A shortcoming of this procedure is that, like naive expectations, this mechanism does not account for other information available to producers beyond historic prices.

Nonparametric estimation provides a versatile method for exploring a general relationship among variables and gives predictions of observations without reference to a fixed parametric model (Härdle, 1990). In general, this method estimates forecasts by smoothing the data using a statistical function which is 'nearly constant' in a small neighborhood around the explanatory variable. Unlike exponential smoothing, the nonparametric approach models dependent variable response to explanatory data without using any specific functional form. Hence, it does not impose a parametric distribution to explain the data.

A simple way to nonparametrically smooth data is kernel smoothing. A kernel is a continuous, bounded, and symmetric real function K which integrates to one. In this study, we use Nadaraya and Watson's kernel estimator given by:

$$\hat{m}_h(x) = \frac{1}{N}\sum_{t=1}^{N} W_{ht}(x) Y_t, \tag{21}$$

where

$$W_{ht}(x) \equiv \frac{K_h(x - X_t)}{\hat{f}_h(x)}$$

is a sequence of weights that depends on the vector X_t and

$$\hat{f}_h = \frac{1}{N}\sum_{t=1}^{N} K_h(x - X_t),$$

h is bandwidth, X_t is explanatory variables used in the forecast, Y_t is the dependent variable price, sawtimber price or pulpwood price. The shape of the kernel weights is determined by the kernel function and bandwidth h, also called the smoothing parameter, that regulates the size of the neighborhood around x. Small values of h give rougher estimators (with more wiggles) while large values of h result in smoother estimators. In our application, we used the Gauss kernel,

$$K_h(x-X_t)=\left[1/(2\pi)^{1/2}\right]\exp\left(-(x-X_t)^2/2\right).$$

In this study, we selected bandwidth using cross-validation. The cross-validation procedure chooses a smoothing parameter that balances the systematic bias effects with stochastic uncertainty explained by the magnitude of the variance. The smoothing paremeter is found by minimizing average squared error given by

$$1/N\sum_{t=1}^{N}\left(\hat{m}_h(X_t)-m(X_t)\right)^2 W_{ht}(X_t).$$

Variance and covariance forecasts from the Nadaraya-Watson kernel estimator are given by

$$\hat{\sigma}^2(x)=1/N\sum_{t=1}^{N}W_{ht}(x)\left(Y_t-\hat{m}_h(x)\right)^2.$$

(Härdle, 1990). Like exponential smoothing, the nonparametric expectation mechanism is appealing because it assumes producers forecast prices based on recent experience.

ESTIMATION AND HYPOTHESIS TESTING

The empirical model is estimated using the generalized method of moments estimator (GMM) (Hansen, 1982; Hansen & Singleton, 1982). A major assumption of rational expectations models is that errors in expectations are independent of all variables in the information set used by agents in formulating expectations. GMM estimation utilizes instrumental variables to ensure independence of explanatory variables from prediction errors and provides a test for overidentification. As a result, GMM estimation is often used to estimate rational expectations models.

Distinguishing model performance among the different price expectation mechanisms requires use of nonnested tests. Models using GMM estimation cannot be tested using artificially nested regressions, such as the J-test, because the properties of such regressions under GMM have not been adequately developed (Davidson & MacKinnon, 1993; Smith, 1992). Instead, we use a modification of Pollack and Wale's Likelihood Dominance Criterion (1991) test. In models estimated with maximum likelihood estimators, model performance under the alternative hypothesis dominates that under the null hypothesis if and only if the log likelihood value under the alternative is larger than the one under the null hypothesis, given the same number of independent variables in each hypothesis. Davidson and MacKinnon have shown that the minimized value of the criterion function of the GMM estimator is the analog of the log likelihood function for the maximum likelihood estimator when the weighting matrix used in the criterion function is efficient. Hence, Pollak and Wales' test can be used to select the most likely model with the dominant model having the smallest valued GMM criterion function.

Data

The model uses data for stumpage markets in Louisiana provided by the Louisiana Department of Agriculture and Forestry (various years). The state is divided into five timber producing regions. The Northwest, Southwest, and Southeast regions are examined because these regions contain the majority of commercial pine production. Prices are annual average stumpage prices paid for hardwood and softwood by region. Prices used are softwood pine sawtimber price, mixed hardwoods sawtimber price, pulpwood pine price, and mixed hardwood pulpwood price. The Louisiana Department of Agriculture and Forestry also provided yearly data for sawtimber and pulpwood harvests for the period 1964–1991. Sawtimber production is measured in board feet Doyle scale and pulpwood is in standard cords.

Inventory data for hardwood and softwood for 1964, 1974, 1984, and 1991 for all Louisiana parishes and softwood and hardwood growth data are from the U.S. Forest Service (various years). Data are aggregated into the five regions and are measured in million cubic feet. Inventory and growth data for years between surveys are taken from Gomez, Burton & Love (1995). Economic data for wages, machinery price, interest rate, and housing starts are taken from Economic Report of the President (U.S. President, various years). Interest rate and housing start data are used as instrumental variables in estimation. All prices are normalized by machinery price for estimation.

Estimation of Expected Prices and Variances

Implementation of the quasirational expectations mechanism requires estimation of expected prices and variances for the two statistical predictors described above: exponential smoothing and nonparametric. The exponential smoothing estimator is implemented using the Forecast Pro program, an econometric time-series package. Expected prices and corresponding expected price variances for pulpwood and sawtimber for both softwood and hardwood are forecast using only data prior to the forecast year. For example, 1974 price and price variance forecasts use data for the years 1964–1973. Nonparametric forecasts are computed using SHAZAM (White, 1993). This package uses a Nadaraya-Watson estimator and cross-validation to calculate price forecasts and predicted standard errors which are used to form price variance predictions.

Model Estimation

The structural econometric model is estimated using the GMM procedure in TSP 4.3 (Hall, Cummins & Schnake, 1992). Additive error terms are appended to the empirical versions of equations (12), (13), and (16) and appropriate price and price variance and covariance expectations are substituted for p_p^e , p_s^e , p_p^v , p_s^v and σ_{ps}. Two models are estimated for each of the expectations mechanisms: one using hardwood data and another using softwood data. Endogenous variables for each system are pulpwood harvest, sawtimber harvest, and growth. Instrumental variables include timber inventories, wages, machinery price, price and price variance expectations, interest rate, and housing starts. Tests for overidentification for each model and price expectations mechanism did not reject the null hypothesis of a valid instrument set.

RESULTS

Parameter estimates and their asymptotic t-values are reported in Table 1. Regional variables are indicated by abbreviations appended to the variable name. The nonpara-

TABLE 1. MODELS ESTIMATED FOR HARDWOOD AND SOFTWOOD.

	Hardwood			Softwood		
Coefficient	Nonc parametric	Exponential Smoothing	Naive	Non-parametric	Exponential Smoothing	Naive
Constants						
γ_p	−3.57	−0.24	−0.89	−5.81	−8.64	−0.74
	(−17.51)	(−0.56)	(−5.77)	(−1.56)	(−5.50)	(−0.55)
γ_s	−4.20	0.27	−2.69	−18.54	0.75	−15.23
	(−8.11)	(0.06)	(−3.99)	(−6.64)	(1.91)	(−4.72)
γ_g	5.70	0.43	1.29	12.92	14.11	0.71
	(15.25)	(0.96)	(5.08)	(2.26)	(6.16)	(0.66)
γ_k	−1.96	−0.02	−0.65	1.90	6.56	3.74
	(−5.99)	(−0.11)	(−4.02)	(0.68)	(5.20)	(1.04)
Output Coefficients						
γ_{pp}se	0.77	0.38	1.05	3.28	0.80	1.09
	(4.09)	(0.04)	(8.23)	(6.13)	(3.19)	(0.75)
γ_{pp}nw	1.54	0.53	0.39	3.69	1.08	2.49
	(9.85)	(0.06)	(3.94)	(6.79)	(4.32)	(1.91)
γ_{pp}sw	0.65	0.42	0.22	2.02	−1.42	−2.18
	(3.34)	(0.07)	(1.78)	(2.53)	(−3.43)	(−2.39)
γ_{ss}se	7.33	7.39	7.34	13.72	8.67	4.42
	(15.23)	(2.35)	(10.95)	(9.27)	(0.00)	(23.08)
γ_{ss}nw	6.91	5.29	5.70	14.03	7.70	5.04
	(20.60)	(0.52)	(10.61)	(9.55)	(0.00)	(93.08)
γ_{ss}sw	4.24	2.00	4.11	16.74	9.72	10.58
	(6.49)	(0.14)	(5.15)	(9.41)	(1.85)	(7.61)
γ_{gg}se	0.12	0.10	−0.47	1.13	1.07	0.84
	(0.68)	(0.56)	(−3.88)	(2.52)	(6.22)	(1.83)
γ_{gg}nw	−0.72	−0.06	0.16	0.52	0.73	−0.62
	(−4.97)	(−0.25)	(1.81)	(1.15)	(3.78)	(−1.30)
γ_{gg}sw	0.007	0.09	0.19	−1.44	0.98	2.59
	(0.04)	(0.86)	(1.81)	(−1.64)	(2.48)	(3.09)
γ_{kk}se	−0.26	−0.09	0.15	−1.39	−1.63	−0.62
	(−3.04)	(−.27)	(0.32)	(−3.09)	(−8.81)	(−2.34)
γ_{kk}nw	−0.27	−0.10	−0.01	−1.35	−1.61	−0.55
	(−2.89)	(−.12)	(−0.30)	(−3.01)	(−8.69)	(83.97)
γ_{kk}sw	−0.45	−0.15	−0.04	−2.45	−2.74	−0.69
	(−3.38)	(−0.83)	(−0.58)	(−3.18)	(−8.83)	(−0.84)

(continued on next page)

metric price expectations mechanism results for hardwood indicate twenty-four statistically significant coefficients out of twenty-nine. The exponential smoothing mechanism results in only one statistically significant coefficient estimate, while the naive expectations mechanism results in eighteen significant coefficients. The risk aversion parameters

TABLE 1. CONTINUED.

Coefficient	Hardwood Non-parametric	Hardwood Exponential Smoothing	Hardwood Naive	Softwood Non-parametric	Softwood Exponential Smoothing	Softwood Naive
Interaction Terms						
γ_{ps}	0.06	−0.06	−0.02	0.11	0.52	−0.24
	(1.32)	(−0.24)	(−0.49)	(0.39)	(4.45)	(−0.89)
γ_{pg}	−0.13	−0.12	−0.01	−0.46	−0.27	−0.29
	(−6.55)	(−1.83)	(−0.48)	(−3.3)	(−6.55)	(−2.25)
γ_{pw}	1.19	0.07	0.33	3.01	3.24	0.71
	(17.33)	(0.51)	(6.07)	(2.49)	(6.16)	(1.65)
γ_{pk}	−0.05	0.01	−0.04	−0.84	−0.34	−0.23
	(−3.09)	(0.28)	(−3.85)	(−5.66)	(−4.81)	(−1.72)
γ_{sg}	−0.35	−0.06	−0.14	−0.15	0.75	0.19
	(8.86)	(−1.73)	(−5.19)	(−1.10)	(1.91)	(1.27)
γ_{sw}	1.86	0.44	1.30	4.45	5.53	0.55
	(9.02)	(0.23)	(4.83)	(6.69)	(8.43)	(1.74)
γ_{sk}	−0.39	−0.37	−0.36	1.25	1.79	3.97
	(−4.60)	(−1.07)	(−2.77)	(3.22)	(14.41)	(6.26)
γ_{gw}	−1.80	−0.13	−0.39	−3.58	−3.98	−0.23
	(−15.18)	(−1.00)	(−4.88)	(−2.09)	(−5.69)	(−0.68)
γ_{gk}	0.02	0.00	−0.01	−0.39	−0.24	0.01
	(1.00)	(0.03)	(−1.08)	(−2.34)	(−4.24)	(0.33)
γ_{wk}	1.07	0.17	0.27	1.99	0.55	−1.24
	(7.06)	(0.98)	(3.02)	(4.31)	(2.63)	(−2.68)
Risk Coefficients						
ϕse	0.32	−11.68	2.55	0.03	0.19	0.02
	(0.70)	(−0.83)	(2.68)	(3.26)	(1.25)	(0.78)
ϕnw	−7.41	2.87	−0.51	0.11	0.33	0.04
	(−10.03)	(0.42)	(−0.51)	(2.21)	(1.96)	(4.69)
ϕsw	1.25	15.74	3.74	0.09	0.61	0.05
	(2.11)	(1.19)	(1.99)	(2.58)	(0.73)	(0.58)
GMM objective value	4.59	5.78	6.65	6.77	7.54	5.99
Test of over-identification restrictions	78.05	98.31	113.00	115.09	128.22	101.92
p-value	0.99	0.96	0.75	0.70	0.38	0.93
Degrees of freedom	124	124	124	124	124	124

in the nonparametric hardwood model for the Southeast and Southwest regions have the correct sign. Only the Southwest region's risk parameter is statistically significant. The coefficient for the Northwest region has an unexpected sign and is statistically significant. This may result from the relatively low hardwood production in this region. Concavity conditions are met at the means for the Southeast and Southwest regions. The Northwest region does not meet all concavity conditions at the means, probably as a result of the unexpected sign of the large risk parameter.

Parameter estimates for the softwood model are presented in the last three columns of Table 1 for each of the three price expectations mechanisms. Twenty-three coefficients are statistically significant for the nonparametric price expectations mechanism, twenty-two for the exponential smoothing mechanism and twelve for the naive expectations mechanism. The risk aversion parameters for all the regions have the expected sign and are statistically significant in all three models. These coefficients show that landowners are risk averse and thus, measures of these risk variables will influence the harvest decision. Second-order utility maximization criterion are met for all models.

Hypothesis Tests

Three selection criteria are used to determine which price expectations mechanism best reflects the observed data. First, for a maximum, the concavity conditions on the Hessian require that the eigenvectors be nonpositive. Second, the likelihood dominance criterion is used to select the best performing model. Third, in cases where the criterion levels are similar, the model with the largest number of significant parameters is selected.

For hardwood, the lowest criterion function value is obtained by the nonparametric quasirational price expectations mechanism. This expectations mechanism has only one small curvature violation. Each of the other models has larger curvature violations and a higher GMM criterion function value. Hence, the best performing hardwood model utilizes the nonparametric price expectations mechanism and this model appears most consistent with model maintained assumptions.

There are no concavity violations for any of the softwood models. The lowest criterion level value is obtained by the naive forecasting mechanism, being lower than the nonparametric criterion level by 0.8. However, the nonparametric model has a much larger number of significant coefficients than the naive expectations model. Therefore, given the almost equivalent GMM criterion levels, the best performing softwood model is judged to be the model using nonparametric quasirational price expectations.

CONCLUSIONS

This research has examined the harvest decision for landowners in a model which explicitly incorporates both price expectations and price risk. The model permits explicit consideration of risk attitudes among timber producers. The harvest decision is considered in a dynamic, optimal control context with three controls: sawtimber harvest, pulpwood harvest, and growth. Three price expectation mechanisms are examined: naive, exponential smoothing, and nonparametric.

Empirical application of the optimal control model reveals that Louisiana timber producers are indeed risk averse. A non-nested hypothesis test developed by Pollak and Wales and concavity criteria for the Hamiltonian are used to discriminate among the different price expectations mechanisms. Of the price expectations mechanisms examined, nonparametric quasirational expectations are found to be the most likely representation of actual producer behavior. This expectations mechanism conforms closely with risk averse producers predicting prices using recently observed past prices, but assigning differing weights to those prices through time. These findings have implications for better understanding of timber producer behavior for use in policy analysis and in enhanced timber supply forecasting.

ACKNOWLEDGMENTS

This research was supported in part by the Texas Agricultural Experiment Station.

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