MODELLING TIMBER PRICE FORECASTS AND STUMPAGE MARKET EXPECTATIONS IN FINLAND 1900-1995

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ABSTRACT

The forecasting of real stumpage prices is analyzed both in the ex-ante and ex-post sense. The data consist of yearly observations of roundwood stumpage prices and the cost of living index in Finland 1900-1995. Optimal ex-ante forecasts for real prices are derived consistent with the rational expectations hypothesis. The empirical results show that real price expectations are not formed optimally and informational efficiency is not obtained. Orthogonality conditions are violated and ex-post real price changes can be explained by real price forecast errors. The results suggest that in Finland this century past stumpage prices have had predictive power but that markets have not used this information efficiently. The methodology proposed helps overcome conceptual problems encountered in testing timber market efficiency based on stationarity tests.

Keywords: forecasting, market efficiency, rational expectations, real timber prices.

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INTRODUCTION

Studying the efficiency and price forecasting of timber markets is important from an individual landowner's point of view, because if markets are not efficient, there are gains that the landowner can make by utilizing the timber price information more efficiently. Also, in that case, there might be policy incentives to provide publicly available price information to the market participants. Furthermore, under inefficiency of timber markets, public or government timberland owners could have a role in stabilizing timber markets by adjusting their timber sales according to market situation.

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The informational efficiency and price formation of the timber markets have been studied since the early l990s. Washburn & Binkley (1990) reported some evidence that stumpage markets actually may exhibit rational expectations, suggesting that the markets are efficient. Haight & Holmes (1991) pointed out to aggregation or averaging of price data as potential reasons for results which support efficiency, and found that timber prices follow autoregressive stationary process, an indication of inefficiency. Hultkrantz (1993) rejected the proposition of nonstationarity using pooled quarterly timber price data. Provencher (1995) rejected the rational expectations hypothesis to explain the harvesting behavior of forest owners, and Yin & Newman (1996) accepted stationarity of timber prices as a weak form of informational inefficiency of the stumpage markets. Furthermore, Hultkrantz (1995) studied the efficiency of Swedish timber markets with long annual timber price data. His results indicated inefficiency of the markets. However, recently Prestemon & Holmes (2000) reported results from the U.S. south indicating that the timber markets are in fact functioning efficiently.

Hultkrantz's work is important in this context. He argues that depending on the assumed model both the nonstationary and stationary timber price processes are valid presentations of the weak form of the (information) efficient market hypothesis. The pure asset exchange economy with risk-neutral agents entails the martingale price process. However, if we allow for risk-aversion and production economy with storage, typical features in the forest sector, a rational expectation equilibrium may imply a stationary price process. The nature of price process is important for the optimal harvesting. Under non-stationary prices harvesting is independent of current prices whereas in the stationary case reservation price rule matters. Thus, testing the weak form of the efficient market hypothesis on timber markets is complicated by conceptual problems that are not present in the pure asset markets.

In response to these problems we propose an alternative way of testing rational expectations hypothesis that uses only market price and general price level information to derive optimal real price expectations. If the real timber price expectations are not formed optimally, then both the asset market and the reservation price model ask too much as they both assume that agents do not make systematical pricing errors in real terms for their forest assets. We build a testable stumpage real price model consistent with rational expectations hypothesis. Based on this model we then study the forecasting process and efficiency of timber prices. Additionally we extend the scope of the study beyond the informational efficiency point of view. More specifically, our interest lies in the practical question of how market information could be used to improve the informational efficiency and hence the forecasting of timber prices.

Our analysis is similar to Hultkrantz's in that we use long time series of annual timber prices. Hultkrantz used Swedish data from 1909–1990, we use data from Finland in years 1900–1995. Unlike the previous literature related to stumpage market efficiency, we employ both nominal and real timber prices to test for the informational efficiency. This gives two benefits. First, we can decompose the forecasting errors into nominal and real ones, or into those emanating from sector-wise and economy-wise shocks. Second, we can judge how good of a hedge forest assets are against inflation. Generally, investments in timber assets are considered to be a good protection against inflation (Redmond & Cubbage, 1988).

Our data first give evidence that both timber prices and cost of living index are non-stationary unit root series. Based on this we build a rational expectation model, in which timber sellers form their real timber price forecasts from nominal timber prices and cost of living index forecasts. The forecast results derived from this model do not, however, support the rational expectations hypothesis, or efficiency of price information usage. Next, the stationarity of the forecasting errors leads us to study whether, in ex post, forecasting errors could be used to improve the timber price forecasts. This is done by using a signal extraction model.

In the second section of this paper, we first present the rational expectations model with ex ante real price expectations. In our model forest owners are interested in predicting real timber prices. In this context, the pricing decisions by timber sellers are based on expectations on how the nominal stumpage and general price levels will evolve in the future. The key question in the rational expectations hypothesis is the requirement that an economic agent uses all the relevant information in forming his or her expectations.

The used data and time-series properties of the analyzed nominal and real timber prices, and general price index, are described and determined in the third section. This leads to a choice of model for optimal estimation of expectations of the price series; a base to test the rational expectations hypothesis. This is presented in the fourth section. In the fifth section, the informational contents of expectations errors are analyzed in the ex post context by testing whether expectation errors can be used to improve forecasts for real timber prices changes. Finally, the sixth section gives the conclusions with some discussion over the results obtained.

EX-ANTE REAL PRICE EXPECTATIONS AND THE RE HYPOTHESIS

The basis of forecasting real stumpage price expectations exploits the fact that the real prices are not known before the nominal prices and some general price index are known. Thus, by definition

$$\ln r_t \equiv \ln p_t - \ln i_t, \tag{1}$$

where r_t is the real price calculated from observed nominal prices p_t and the general price index i_t. However, a more interesting and important question in the economic sense is the correct pricing rule ex-ante. Naturally the participants in stumpage markets are interested in relations such as

$$\ln r_t^e = \ln p_t - \ln i_t^e \tag{2}$$

or

$$\ln r_t^e = \ln p_t^e - \ln i_t^e \tag{3}$$

where the superscript refers to expectation. They try to minimize the forecast errors $\ln r_t - \ln r_t^e$. If the participants do not know the true real price r_t at period t, then it means that they do not know either p_t or i_t or both at that period. They must form expectations (i.e. forecasts) on the values of p_t and i_t. One approach to this problem is to use the rational expectation hypothesis (RE) which can be written as

$$\ln p_t = \ln p_t^e + \varepsilon_t, \quad \varepsilon_t \sim \mathrm{NID}\left(0, \sigma_\varepsilon^2\right) \tag{4}$$

$$\ln i_t = \ln i_t^e + \upsilon_t, \quad \upsilon_t \sim \mathrm{NID}\left(0, \sigma_\upsilon^2\right) \tag{5}$$

with $\mathrm{cov}(\varepsilon_t, \varepsilon_{t-j}) = 0$, $\mathrm{cov}(\upsilon_t, \upsilon_{t-j}) = 0$ for $j \neq 0$ and $\mathrm{cov}(\varepsilon_t, \upsilon_t) = 0$. This model assumes that the agent can form optimal expectations in the sense that expectation errors on average will be zero, i.e. $\mathrm{E}[\ln p_t - \ln p_t^e] = 0$ and $\mathrm{E}[\ln i_t - \ln i_t^e] = 0$. Naturally, the condition $\mathrm{E}[\ln r_t - \ln r_t^e] = 0$ is valid because

$$\begin{aligned} \ln r_t^e &= \ln p_t^e - \ln i_t^e = \left(\ln p_t - \varepsilon_t\right) - \left(\ln i_t - \upsilon_t\right) \\ &= \ln r_t - \left(\varepsilon_t - \upsilon_t\right). \end{aligned} \tag{6}$$

The RE hypothesis says that the agent uses all the relevant information in forming expectations. However, the question of how this information is obtained is often left open. Tautologically, one can give the normative (rational) rule that all the relevant information has been obtained when the RE hypothesis is realized. Empirically, the question is more subtle than this and various approaches have been used to test the RE hypothesis (see Pesaran, 1992; Holden *et al.*, 1985). In what follows, we use the time series approach, i.e., we use the information contained in past p_t and i_t to derive the optimal forecasts of p_t^e, i_t^e, and r_t^e.

We assume that all participants in the timber markets have access to the past values p_t and i_t, but we do not know how efficiently they use this information in forming real price expectations. In this respect, our approach differs from the approach used by Washburn & Binkley (1990) for example. They form an efficient asset market model under the RE hypothesis. However, their results are not definite

(Hultkrantz, 1993; Washburn & Binkley, 1993). In comparison, we do not specify any equilibrium asset market model explicitly. Instead we derive the optimal forecasts by time series methods and analyze their implications for the RE hypothesis.

DATA SELECTION AND TIME SERIES PROPERTIES

The data analyzed consist of yearly observations of roundwood stumpage prices (P_t) and the cost of living index (CLI_t) in 1900–1995 in Finland. Both series are expressed in 1960 prices and analyzed in logarithms, i.e., $\ln P_t$ and $\ln CLI_t$. The ex-post real stumpage price, $\ln R_t$, is defined as $\ln R_t = \ln P_t - \ln CLI_t$.

The frequency and the span of data suit our intentions well. The average rotation time is about 70 years for standing timber in Finland. The median time of subsequent harvesting is about three years. This means that a single forest owner does not base his selling decisions on continuous

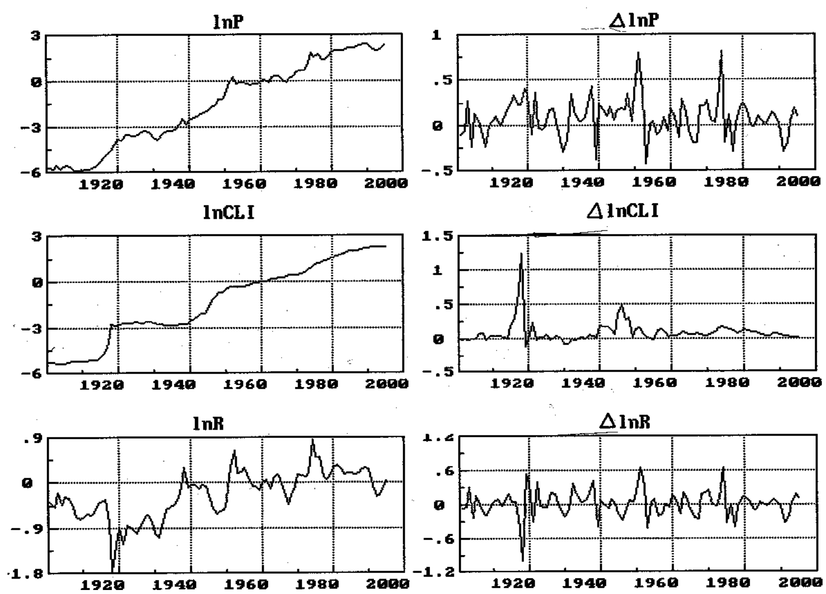

FIGURE 1. ROUNDWOOD STUMPAGE PRICES ($\ln P_T$), COST OF LIVING INDEX ($\ln CLI_T$), AND EX-POST REAL STUMPAGE PRICES ($\ln R_T$) AND FIRST DIFFERENCES ($\nabla \ln P_T$,$\nabla \ln CLI_T$,$\nabla \ln R_T$) IN 1960 PRICES. TIME PERIOD IS 1900–1995 (96 OBSERVATIONS).

price records. The selling decision occurs in discrete time intervals. Furthermore, the stumpage trade practice in Finland is such that the timber stand buyer has two years during which he can collect the sold timber. The payments are also distributed over this period, suggesting that short-term price data such as monthly series may be inappropriate for analyzing the harvesting decisions of timber sellers (see also Yin & Newman, 1996). Hence the yearly observations of nominal prices and the general price level constitute a valid information base for modelling price expectations and forecasts.

Figure 1 gives the series and their first logarithmic differences ($\nabla \ln x_t = \ln x_t - \ln x_{t-1}$). All level series show a trending behaviour but the differenced series are probably stationary. The series exhibit some abnormal behavior in the years 1917–1919 and 1946–1952. The former period was the time of the Finnish Civil War, when the roundwood markets were badly disrupted. In the latter period, Finnish forest product exports started their continuing upward trend. The rapid inflation after World War II and Korean boom in the 1950s had their impact on stumpage prices during this period as well.

Table 1 gives the summary statistics and correlations between the differenced series. The most important finding is that the mean of yearly differences of the ex-post real price, $\nabla \ln R_t$, is positive, with a value of 0.0039. On the average the nominal stumpage prices have grown faster than inflation this century. However, the variability of $\nabla \ln R_t$ is larger than for nominal price changes or inflation.

Another interesting finding is the negative correlation between inflation and real stumpage price changes (–0.492). This means that the real stumpage prices do not immediately record the inflation effect. Note that the correlations were also negative between one year lagged and one year ahead real stumpage prices and inflation. No formal testing of correlations was done because of the non-normality of the series.

The non-normality found in Table 1 is caused by the factors applying to 1917–1919 and 1946–1952. Observe that the stumpage price change minimums are much smaller than the inflation minimum. The inflation maximum is almost twice that of the maximums of stumpage price changes.

TABLE 1. SUMMARY STATISTICS AND CORRELATIONS.

	$\nabla \ln P_t$	$\nabla \ln CLI_t$	$\nabla \ln R_t$
Mean	0.083	0.079	0.0039
Median	0.081	0.040	0.0209
Std.Dev.	0.206	0.160	0.231
Skewness	0.45	4.57	-0.46
Ex.Kurtosis	1.70	27.31	3.46
Minimum	-0.41	-0.12	-0.99
Maximum	0.79	1.22	0.64
Normality	11.26*	440.10*	28.36*

$\chi^2_N(2)$- test: 5% critical level 5.991

CORRELATIONS

	$\nabla \ln P_t$	$\nabla \ln CLI_t$	$\nabla \ln R_t$
$\nabla \ln P_t$	1.000		
$\nabla \ln CLI_t$	0.224	1.000	
$\nabla \ln R_t$	0.737	-0.492	1.000
	$\nabla \ln P_{t-1}$	$\nabla \ln CLI_t$	$\nabla \ln R_{t-1}$
$\nabla \ln P_{t-1}$	1.000		
$\nabla \ln CLI_t$	0.204	1.000	
$\nabla \ln R_{t-1}$	0.737	-0.108	1.000
	$\nabla \ln P_{t+1}$	$\nabla \ln CLI_t$	$\nabla \ln R_{t+1}$
$\nabla \ln P_{t+1}$	1.000		
$\nabla \ln CLI_t$	0.268	1.000	
$\nabla \ln R_{t+1}$	0.737	-0.054	1.000

Obviously comparing medians and means reveals that the distribution of inflation series is positively skewed. The distribution of nominal stumpage price changes is symmetric, but for real prices the distribution is negatively skewed. Thus inflation has not been paced by similar changes in stumpage prices. This is an indication of nominal price rigidity. The asymmetric behavior in inflation and real price movements are the reverse, indicating that real price movements are more sensitive to nominal changes than to inflation.

The next important question is the series stationarity. The trending behavior is evident in the level series. The possible non-stationarity (in the unit root sense) was analyzed by ADF (Dickey & Fuller, 1981) and KPSS tests (Kwiatkowsky *et al.*, 1992). The former assumes that the series has a unit root, but the latter uses stationarity as a null hypothesis. The autocorrelations and stationarity testing do not reject the unit root behavior for the level series but the differenced series are clearly stationary. Appendix 1 gives more detailed information on the time series properties of the series.

Generally this means that our series can be modelled by ARIMA(p,1,q) models, i.e.

$$\Phi(B)\nabla \ln y_t = \theta(B)\mu_t. \tag{7}$$

$\Phi(B)$ is the stationary AR polynomial of order p, $\theta(B)$ is the MA polynomial of order q, and μ_t are the NID(0,σ^2) errors. Different models were estimated to find parsimonious ARMA models for differenced series. Akaike's information criteria (AICC) was used to determine the best model. Appendix 2 gives the detailed results of the various model alternatives. The following models turned out to be the best (standard errors in parenthesis).

$\ln P_t$: IMA(1,1)

$$\nabla \ln P_t = \underset{(0.023)}{0.0843} + \mu_t + \underset{(0.101)}{0.182}\mu_{t-1} \tag{8}$$

$\ln CLI_t$: IMA(1,1)

$$\nabla \ln \mathrm{CLI}_t = \underset{(0.0312)}{0.0795} + \mu_t + \underset{(0.104)}{0.471}\mu_{t-1} \tag{9}$$

$\ln R_t$: IMA(1,2)

$$\nabla \ln \mathrm{R}_t = \underset{(0.0017)}{0.0039} + \mu_t - \underset{(0.109)}{0.036}\mu_{t-1} - \underset{(0.122)}{0.335}\mu_{t-2}\ . \tag{10}$$

The results indicate that all three original series are random-walk series with a drift, disturbed by correlated innovations. From the forecasting point of view this is good news, since IMA-processes, although adaptive in the strict sense, permit deriving forecasts optimally. As shown by Muth (1960, 1961), the expectations are in fact fully rational if

$$y_t = \mu_t + \theta \sum_{i=1}^{\infty} \mu_{t-i},$$

so that $\nabla y_t = \mu_t + (\theta - 1)\mu_{t-1}$. That is, if y_t is generated by a moving average of i.i.d. random variables, then the agent's best forecasts of y_t depend only on y_{t-1} (for more details see Nerlove & Schuermann, 1995 or Pesaran, 1992).

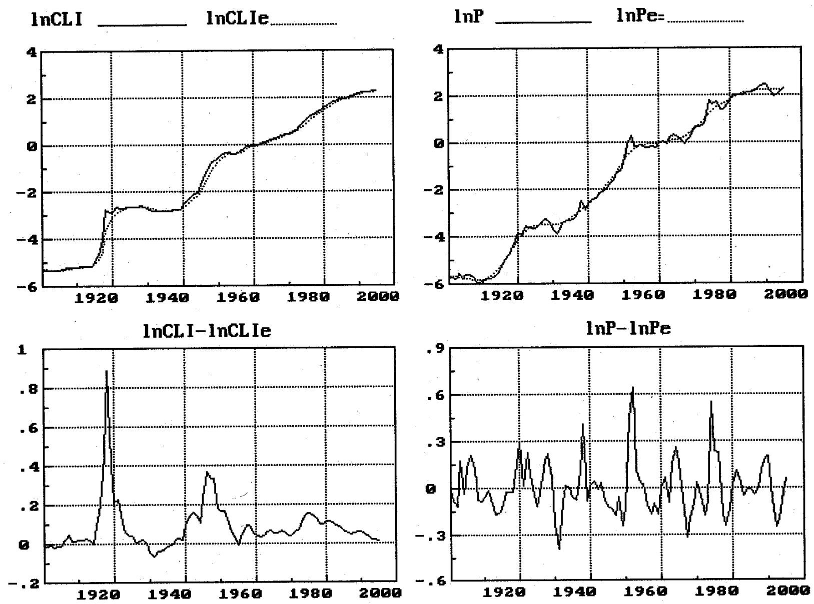

FIGURE 2. TIMBER PRICE SERIES LNP_T, GENERAL PRICE LEVEL lnCLI_T AND OPTIMAL FORECASTS $\ln \hat{P}_t^e$, $\ln C\hat{L}I_t^e$, AND FORECAST ERRORS.

OPTIMAL ESTIMATION OF EXPECTATIONS OF GENERAL PRICE AND TIMBER PRICE LEVELS

We next adopt the point of view of an individual market participant in roundwood markets in predicting future prices. The pricing decision by a single agent is based on expectations of the nominal stumpage and general price levels. After calculating forecasts for these, the agent can evaluate the real prices ex-ante $\ln R_t^e = \ln P_t^e - \ln CLI_t^e$. Optimal estimators of $\ln P_t^e$ and $\ln CLI_t^e$ (in MMSE-sense, see Whittle, 1963; Pesaran, 1992; Muth, 1960), based upon information until time t–1, are then

$$\hat{y}_2^e = (1-\theta)y_1 \tag{11}$$

$$\hat{y}_t^e = (1-\theta)\sum \theta^i y_{t-1-i} = \theta \hat{y}_{t-1}^e + (1-\theta)y_{t-1}, \quad (t>2),$$

where y_t is $\ln P_t$ or $\ln CLI_t$ and θ the MA(1) parameter from the above IMA(1,1) models. Forecasts are thus obtained with the exponentially weighted moving average (EWMA) algorithm, the smoothing parameter being $(1-\theta)$.

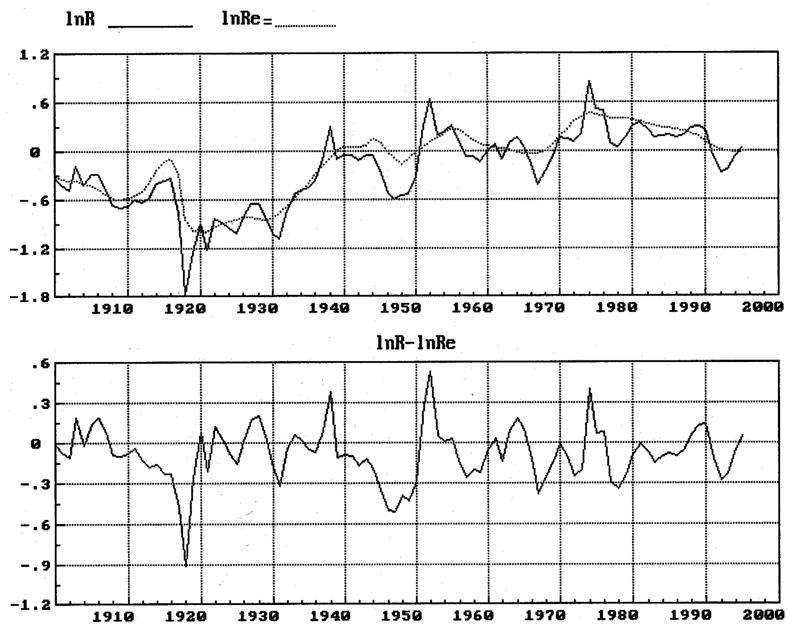

FIGURE 3. REAL TIMBER PRICE SERIES $\ln R_T$ AND OPTIMAL FORECASTS $\ln \hat{R}_t^e$ AND FORECAST ERRORS $\ln R_t - \ln \hat{R}_t^e$.

Figure 2 gives the optimal forecasts for $\ln P_t$ and $\ln C\hat{L}I_t$ with corresponding forecast errors (i.e. $y_t - \hat{y}_t^e$). We see that both $\ln CLI_t$ and $\ln P_t$ forecasts track the true series quite well except some years of rapid changes. The real price expectations can now be calculated from $\ln \hat{P}_t^e$ and $\ln C\hat{L}I_t^e$. Figure 3 gives the real stumpage price forecasts, $\ln \hat{R}_t^e$. These are upward biased and the forecast errors are quite large for all periods.

Table 2 gives the summary statistics of the forecast errors. The errors are biased in the mean and median sense, and they are stationary but autocorrelated. Non-normality is also found. Generally, these results reject the RE hypothesis. Note that the mean and median of forecast errors for nominal stumpage prices are close to zero, suggesting that timber market participants have been using price information in expectation formation in an optimal way. However this is not a sufficient indication of informational efficiency in stumpage markets, because forecast errors are autocorrelated. Note that Washburn & Binkley (1990) obtain market efficiency results with yearly observations for some US states in the period 1950–1987.

TABLE 2. SUMMARY STATISTICS OF FORECACSTS ERRORS.

	$\ln P_t - \ln \hat{P}_t^e$	$\ln CLI_t - \ln C\hat{L}I_t^e$	$\ln R_t - \ln \hat{R}_t^e$
Mean	–0.0014	0.0892	–0.0901
Median	–0.0262	0.0579	–0.0951
Std.Dev.	0.171	0.125	0.206
Skewness	1.03	3.40	–0.35
Ex.Kurtosis	1.99	16.68	2.31
Minimum	–0.39	–0.06	–0.92
Maximum	0.63	0.89	0.52
Normality	14.233*	178.74*	18.59*
χ_N^2 (2)-test: 5% critical level 5.991			
Autocorrelations			
Lag 1	0.44	0.77	0.53
2	–0.05	0.52	0.11
3	–0.25	0.34	–0.03
Stationarity:			
ADF(1) test with constant	–7.00*	–3.98*	–5.93*
5% critical level	–3.504		

EX-POST EXPECTATIONS AND FORECASTS

Shifting the question of predicting the real prices from the ex-ante viewpoint to analysis of realized outcomes gives an opportunity to analyze the information content of expectation errors. Do they contain information that could be used in updating the real prices and their movements? This is the question that can be analyzed in the ex-post sense when real prices have been realized. Generally, if expectation errors explain the true series, then this directly rejects rational expectation hypothesis. In that case the analysis will reveal in what direction the expectation formation has been biased and potentially how it can be improved.

From the previous analysis we know that true errors in the model for $\nabla \ln R_t$ are autocorrelated (see Equation 10) and a constant τ exists in the sense that $E[\nabla \ln R_t] = \tau$. The conditional expectations of real price movements with real price expectation errors can be written as

$$
\begin{aligned}
& E\left[\nabla \ln R_t \middle| \ln R_t - E\left[\ln R_t \middle| \Omega_{t-1}\right]\right] \\
& = E[\nabla \ln R_t] + \beta\left[\ln R_t - E\left[\ln R_t \middle| \Omega_{t-1}\right]\right] \\
& = \tau + \beta\left[\ln R_t - \ln R_t^e\right] \\
& = \tau + \beta\left[\left(\ln P_t - \ln P_t^e\right) - \left(\ln CLI_t - \ln CLI_t^e\right)\right] \\
& = \tau + \beta\left[\varepsilon_t - \upsilon_t\right] = \tau + \beta\Gamma_t. \qquad (12)
\end{aligned}
$$

where Ω_{t-1} is the information set from the previous period that gives the optimal forecasts. We can thus express the conditional expectation of $\nabla \ln R_t$ conditioned on real price forecast errors as a linear function of the expected real price change τ and the difference between the RE forecast errors in nominal prices ε_t and the general price index υ_t (see Equation 6 above). This gives the signal extraction interpretation to the RE model, where τ is the unobserved expected state disturbed by measurement errors Γ_t.

This relation has some interest as long as the observed $\nabla \ln R_t$ and $\hat{\Gamma}_t$ are correlated, i.e., the difference of observed forecast errors contains some information about real price movements. Note that the equation above must be balanced with respect to the stationarity conditions of variables involved and (ε_t, υ_t) must not be correlated. In this case we know that $\nabla \ln R_t$ and $\hat{\Gamma}_t$ are stationary (see Appendix 1 and Table 2). The correlation between $\hat{\varepsilon}_t$ and $\hat{\upsilon}_t$ is negligible (0.055).

By regressing the observable $\nabla \ln R_t$ on constant and observed real price expectation errors $\hat{\Gamma}_t$, one can see whether the forecast errors contain information that predicts $\nabla \ln R_t$. The question is not about forecasting $\nabla \ln R_t$, since it is already known, but about testing the rational price information usage in stumpage markets. We also regressed $\nabla \ln R_t$ on $\hat{\varepsilon}_t$ and $\hat{\upsilon}_t$ separately in order to detect possible sources of informational inefficiency.

Basically Eq. 12 is a static one in which the variables are drawn from bivariate normal distributions. We know

TABLE 3. OLS ESTIMATES OF AUGMENTED MODELS OF ΔLNR 1900–1995 (96 OBSERVATIONS, t-VALUES IN PARENTHESIS).

Constant	0.061	0.033	0.019	0.023
	(2.80)	(1.51)	(1.05)	(0.96)
$\hat{\Gamma}_t$	0.522			
	(5.11)			
$\hat{\varepsilon}_t$		0.609	0.602	
		(5.58)	(5.55)	
$\hat{\upsilon}_t$		−0.169		−0.055
		(−0.82)		(−0.053)
D	0.409	0.617		−0.701
	(2.89)	(3.34)		(−3.32)

Models include a dummy variable D taking values 1 for 1917–1919.

Diagnostics:

S.E.	0.185	0.183	0.182	0.194
R^2	0.385	0.409	0.405	0.207
AR(2)	1.86	1.78	1.56	0.76
χ^2_N (2)	5.76	2.42	2.42	5.22
W-HET	0.21	3.29	1.36	2.02
ARCH(1)	0.67	0.47	0.57	4.45*

AR(2): residual autocorrelation test.
χ^2_N (2): residual normality test.
W-HET: residual heteroskedasticity test.
ARCH(1): residual autoregressive heteroskedasticity test.

however that $\nabla \ln R_t$ and $\hat{\Gamma}_t$ are not drawn from a bivariate normal distribution. Equation 12 is empirically approximated by a model containing a dummy variable corresponding to the exceptional observations in 1917–1919.

The results in Table 3 show that the forecast errors of real prices $\hat{\Gamma}_t$ can improve the $\nabla \ln R_t$ forecasts. We can reduce the standard error of real price forecast errors by some 10% (1–0.185/0.206). The parameter estimate 0.522 for variable $\hat{\Gamma}_t$ is significantly different from zero. In other words, if the agent forecasts the real stumpage prices optimally and uses the forecast errors as predictors of the real stumpage price changes then these predictors have some predictive power. The results also reveal that the forecast errors of the general price index do not have predictive power in the model for $\nabla \ln R_t$. $\hat{\upsilon}_t$ does not enter significantly into the model. The predictive power of $\hat{\Gamma}_t$ lies only in the forecast errors of the nominal stumpage prices $\hat{\varepsilon}_t$. Note that the results in Table 3 correspond to the violation of the orthogonal assumption of the RE hypothesis that demands that $E[\nabla \ln R_t \mid \Gamma_t] = 0$. This means that participants in timber markets in Finland have not succeeded in forming expectations of real prices correctly.

Conclusions

The forecasting of real stumpage prices were analyzed both in ex-ante and ex-post sense with annual observations of roundwood stumpage prices and cost of living index in Finland in the years 1900–95. Optimal ex-ante forecasts for real prices were derived under the rational expectations hypothesis. Expectations for nominal and general price level were calculated with exponential smoothing algorithm. However, the forecast errors were biased and autocorrelated invalidating the rational expectations hypothesis. The methodology proposed helps overcome conceptual problems encountered in testing timber market efficiency based on stationarity tests.

We found high correlation between nominal and real timber prices but low correlation between nominal timber prices and the cost of living index in the Finnish data. This implies that the nominal timber prices in Finland during the period have been sluggish in following the general price movements. This points to sector wise factors in determining the nominal timber price movements, both on the timber demand and supply side. It also implies that, at least in the short run, timber assets do not provide a safe protection against general inflation.

The real timber prices are both in ex-ante and ex-post sense determined more by nominal timber prices and less by general price level. Ex-ante forecast errors of nominal prices can be used as predictors for ex-post real price movements. Generally the results show that agents do not derive optimally their real price expectations and some information contained in nominal timber prices is not fully updated in expectation formation.

There are several questions that can be raised based on the results arrived and the analysis carried out in this study. In the analysis we rely heavily on the assumption that forest owners (or more generally timber market participants) form their real timber price expectations by first forecasting nominal timber prices and the index of living cost. Whether this is the true expectations formation pattern, cannot be judged based on our results. Another question relates to the type of timber price data we use. It can be legitimately asked whether Finland forms a single, well-defined market for stumpage. However, it is interesting to note, that in our analysis the data first appear non-stationary, but that this efficiency result is later 'dis-illusioned' by the stationarity and non-orthogonality of the forecast error series. This compares to the results in earlier studies according to which the efficiency of averaged or aggregated data has been removed by disaggregation.

The implications of our results are fairly straightforward. The results indicate that price responsive models or capital asset models may be utilized to improve the expected returns of timber selling. Furthermore, the results indicate that the public forestland owner in Finland, the Forest and Park Service, which owns substantial areas of forestland in the country, could serve as a price stabilizing agent on the timber markets by exercising price-responsive timber selling practices.

Why the timber markets exhibit inefficiency can be due to several imperfections of stumpage and related markets in Finland during the study period. These include various price arrangements, liquidity constraints of the nonindustrial forest owners leading to non-market determinants in timber supply decisions, oligopsonistic features especially in the pulpwood markets, and until recently (1998) regulated forestland markets.

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APPENDIX1

Time series properties of series used.

	AUTOCORRELATIONS (ACF and PACF)						
	Lags						
	1	2	3	4	5	10	20
$\ln P_t$	0.975	0.949	0.923	0.898	0.869	0.708	0.390
	0.945	−0.049	−0.010	0.009	−0.086	−0.023	−0.027
$\ln CLI_t$	0.973	0.943	0.911	0.877	0.843	0.664	0.352
	0.973	−0.068	−0.042	−0.048	−0.031	−0.023	−0.048
$\ln R_t$	0.873	0.738	0.662	0.602	0.575	0.513	0.183
	0.873	−0.103	0.175	0.013	0.126	0.077	−0.035
$\nabla \ln P_t$	0.157	−0.068	−0.045	0.036	0.090	0.043	−0.046
	0.157	−0.095	−0.019	0.042	0.072	0.029	−0.065
$\nabla \ln CLI_t$	0.419	0.149	0.158	−0.009	0.004	−0.111	−0.006
	0.419	−0.032	0.130	−0.147	0.072	−0.036	−0.095
$\nabla \ln R_t$	0.036	−0.230	−0.067	−0.123	−0.037	0.090	−0.120
	0.036	−0.231	−0.052	−0.183	−0.062	0.028	−0.110

STATIONARITY TEST

ADF test

H_0 hypothesis: y_t is nonstationary (unit root series).

	Aux. Variables		
	Trend and Constant	Constant	–
$\ln P_t$	−2.40 (ADF(1))	−1.58 (ADF(0))	
$\ln CLI_t$	−3.40 (ADF(3))	−1.47 (ADF(1))	
$\ln R_t$	−3.98* (ADF(1))	−2.41 (ADF(0))	
$\nabla \ln P_t$		−7.68* (ADF(0))	−7.20* (ADF(0))
$\nabla \ln CLI_t$		−5.86* (ADF(0))	−3.21* (ADF(2))
$\nabla \ln R_t$		−7.96* (ADF(1))	−8.33* (ADF(1))
5% critical levels	−3.46	−2.89	−1.95

KPSS TEST

H_0 hypothesis: y_t is stationary.

	Aux. Variables					
	Trend and Constant			Constant		
Lags:	KPSS(1)	KPSS(4)	KPSS(10)	KPSS(1)	KPSS(4)	KPSS(10)
$\ln P_t$	0.275*	0.117	0.096	4.821*	1.681*	0.951*
$\ln CLI_t$	0.189*	0.076	0.062	4.730*	1.659*	0.953*
$\ln R_t$	0.231*	0.116	0.096	2.803*	1.119*	0.694*
$\nabla \ln P_t$				0.082	0.086	0.084
$\nabla \ln CLI_t$				0.076	0.051	0.053
$\nabla \ln R_t$				0.031	0.057	0.094
5% critical levels		0.146			0.463	

APPENDIX 2

ARIMA(p,1,q) models with p and q = 1,2

Series	AR(1)	AR(2)	MA(1)	MA(2)	ARMA(1,1)
$\nabla \ln P_t$	0.157	−0.171	0.182	0.166	−0.156
	(0.101)	(0.102)	(0.101)	(0.103)	(0.410)
		−0.092		−0.048	0.336
		(0.106)		(0.100)	(0.381)
AICC	−28.24	−26.21	−28.65	−26.74	−26.65
$\chi^2(1)$	1.58	0.03	1.00	0.22	0.33
$\nabla \ln CLI_t$	0.417	0.429	0.471	0.471	0.039
	(0.092)	(0.114)	(0.101)	(0.100)	(1.443)
		−0.007		−0.008	0.429
		(0.100)		(0.101)	(1.483)
AICC	−91.12	−90.21	−92.95	−90.78	−90.79
$\chi^2(1)$	1.58	3.04	1.00	3.14	3.08
$\nabla \ln R_t$	0.036	0.039	0.065	−0.036	not causal
	(0.102)	(0.099)	(0.134)	(0.109)	
		−0.228		−0.335	
		(0.099)		(0.121)	
AICC	−4.54	−7.56	−4.64	−9.70	
$\chi^2(1)$	4.98*	0.48	4.86*	1.06	

$\chi^2(1)$: Portmanteau test for residual randomness, 5% critical level 3.84