Forecasting the price of lumber and plywood: econometric model versus futures markets

Joseph Buongiorno
F. Mey Huang
Henry Spelter

Abstract

Three methods of forecasting the price of lumber and plywood were compared: 1) the FORSIM model of Data Resources Inc., 2) the futures markets, with prices of contracts for future delivery used as forecasts of cash prices, and 3) a naive model where the predicted price is equal to the last known cash price. The comparisons used data for the period 1974 to 1981. For lumber forecasts of the current quarter and one quarter ahead there was no significant difference in accuracy between the FORSIM and futures market. For two and three quarters ahead, FORSIM was better. For all horizons, FORSIM and the futures market were more accurate than the naive model. For plywood forecasts, of the current quarter and one of three quarters ahead, there was no significant difference between FORSIM and the futures market. For two quarters ahead, the futures market was better. The naive model was as accurate as FORSIM for forecasts one and two quarters ahead, and as accurate as the futures market for the current quarter. Turning points of lumber prices were predicted best by the naive model. Most of the prediction errors of FORSIM and the lumber futures market were of a random nature, suggesting that there is little room for improvement in either approach. Some inefficiency was apparent in the plywood futures market.

"Forecasts are essential for the modern business enterprise: they must be made, they must be refined, and they must be revised" (17). In order to ensure that production and inventories are kept at an economical level, an enterprise requires forecasts to establish goals and determine how these goals are to be reached. During the seventies and the beginning of the eighties, having been confronted with continual recessions and severe inflation, enterprises not only needed the ability to manage well but also to predict the future accurately.

To meet the demand for forecasts, a variety of commercial services have sprung up, often based upon large econometric models. Among these services, the FORSIM model of Data Resources, Inc. (DRI), is one that focuses on the forest products sector, chiefly softwood lumber and plywood. With over one decade of experience with the FORSIM model, the question arises: how successful has it been in forecasting softwood lumber and plywood prices?

Another source of price forecasts is the futures market. Price formation on futures markets at any point is the result of the participants' appraisal of past and current information, and expectations of future supply and demand (6, 8). Recent studies of the futures markets have shifted attention from their use in hedging inventories to their potential in forecasting prices (7, 10). Much of the conceptual and empirical work on futures markets suggests that futures prices can be considered as unbiased predictions of the subsequent cash price (2, 4, 8, 15). Therefore, futures prices can be compared meaningfully with the price forecasts obtained from the FORSIM model.

A third forecasting method uses the actual cash price of the previous period as a predictor of future

The authors are, respectively, Professor and Project Assistant, Dept. of Forestry, Univ. of Wisconsin, 1630 Linden Dr., Madison, WI 53706; and Forest Economist, USDA Forest Serv., Forest Prod. Lab., Madison, Wis. They wish to acknowledge the generous assistance of Data Resources Inc., especially of J. Veltkamp in providing past price forecasts. They also thank two anonymous reviewers for very helpful comments. Research was supported by McIntire-Stennis Grant 2257, the School of Natural Resources, Univ. of Wisconsin, Madison, and the USDA Forest Serv. This paper was received for publication in December 1983.

Forest Prod. J. 34(7/8):13-18.

prices. This is one of the simplest methods of forecasting.[1]

The purpose of this paper is to compare and evaluate the price-forecasting performances of the FORSIM model, futures market, and last price for softwood lumber and plywood. The following questions are addressed: What is the comparative and absolute accuracy of the three methods? Are the observed differences in forecasting accuracy statistically significant? Does the accuracy depend upon the forecast horizon and the commodity? And, what types of errors tend to be made by each method and what are the implications behind these errors' tendencies?

The products examined here are inland hem-fir 2 by 4 (referred to as lumber) and 1/2-inch four- to five-ply C-D exterior Douglas-fir plywood (referred to as plywood). These commodities are traded on futures markets and forecasts of their prices are published by DRI in the FORSIM review (3). DRI forecasts prices up to 12 quarters ahead, but futures contracts expire within the same quarter or up to three quarters ahead. Therefore, only current-quarter forecasts through three-quarters-ahead forecasts could be compared. Accuracy was evaluated by analyzing mean square errors and turning point errors. Significance tests were done by regression.

FORSIM price forecasts

The structure of the FORSIM model can be summarized in the familiar demand and supply analysis. Two key assumptions underlie the model. First, demand is elastic to price in the long run, through end-use factors that respond to price changes. Demand shifters are various indicators of market activity, for example, housing starts (16). Second, industry supply is limited by capacity and "industry minimum average variable cost."[2] The prices of products are expressed as functions of costs, the ratio of demand to capacity, and other attendant variables, including unfilled orders in relation to mill stocks.

The model requires extensive inputs concerning the future evolution of the economy and the industry. In addition, each equation in the system includes an "add factor" that permits forecasters to modify the model by their judgment. Accordingly, the errors of the forecasts arise from erroneous exogenous variables, add factors, and the model itself (such as inappropriate functional forms, omitted variables, aggregation, etc.).

FORSIM forecasts are published every quarter. Sometimes, due to changes in the economy, forecasts are updated several times. In this study, 34 projections were evaluated for lumber from the first quarter of 1974 (1974-I) through the first quarter of 1980 (1980-I) and 20 projections for plywood from the fourth quarter of 1974 (1974-IV) through the first quarter of 1981 (1981-I).[3] All forecasts were paired with an actual price and were categorized depending on how far ahead into the future they projected. Only 30 observations for lumber and 16 observations for plywood were used to evaluate current-quarter forecasts. Six projections of lumber (four of plywood), made at the end of the quarter, corresponded almost exactly with their cash prices and had little meaning as forecasts.

Futures market prices

Lumber and plywood futures are traded at the Chicago Mercantile Exchange and the Chicago Board of Trade, respectively. End-of-the-week futures closing prices are summarized in the *Random Lengths Annual Yearbook* (13).

In order to make the comparison with FORSIM forecasts fair, the futures market prices were selected at about the same time of the month when the FORSIM forecasts were made. For example, the contracts' prices on October 14 were compared with the FORSIM forecasts made on October 16.

Due to the quarterly dimension of the FORSIM forecasts, a further issue arose as to which contract month for a futures market should be used to represent the forecast horizon. Contracts for both futures markets expire in alternate months, starting with January. It was decided to use the average price of contracts for January and March as the first quarter futures price, and that for July and September for the third quarter. The prices of contracts for May and November represented the respective second and fourth quarter futures prices.

Criteria of comparison

The root mean square error (RMSE), the mean square error (MSE) and its components, and the number of turning point errors were used to evaluate the price-forecasting performances of the different methods.

Let $F^{(D)}_{t,i}$, $F^{(F)}_{t,i}$, and $F^{(L)}_{t,i}$, respectively, represent the i-quarter-ahead forecast prices at time t of the FORSIM model, futures market, and the last cash price, for lumber or plywood. $A^{(D)}_{t+i}$, $A^{(F)}_{t+i}$, and $A^{(L)}_{t+i}$ are the subsequent actual prices.[4] Then the forecast errors are the differences between the forecast price and cash price. In order to make the comparison independent of the base of measurement, the relative forecast errors were used:

$$e^{(D)}_{t,i} = \frac{F^{(D)}_{t,i}}{A^{(D)}_{t-1}} - \frac{A^{(D)}_{t+i}}{A^{(D)}_{t-1}} = f^{(D)}_{t,i} - a^{(D)}_{t+i}$$

---

[1]The "naive" or lagged cash price forecast is:

$$F_{t,i} = A_{t-1} \qquad i = 0, 1, 2, 3$$

where $F_{t,i}$ = i-period-ahead price, predicted at time t.
A_{t-1} = one-period-lagged cash price

[2]Capacity is derived by interpolating between peak production periods. The "industry minimum average variable cost" measures changes in production costs and is derived by interpolating between the cyclical lows on price.

[3]After June 1980, the lumber contract traded on the futures market changed from hem-fir to spruce-pine-fir. Data Resources Inc. did not publish forecasts of plywood prices before 1974-IV.

[4]Lumber and plywood forecast (and actual) prices in the FORSIM publication are f.o.b. mill. However, the lumber futures price is a net price (i.e., f.o.b. mill less 2%), and the plywood futures price is a net, net price (i.e., f.o.b. mill less discounts of 5%, 3%, and 2% (13)). Therefore, different cash prices are denoted. Cash prices compared with futures prices and lagged cash prices all originated from *Random Lengths*. Cash prices compared with FORSIM forecasts came from the FORSIM review.

$$e^{(F)}_{t,i} = \frac{F^{(F)}_{t,i}}{A^{(F)}_{t-1}} - \frac{A^{(F)}_{t+i}}{A^{(F)}_{t-1}} = f^{(F)}_{t,i} - a^{(F)}_{t+i}$$

$$e^{(L)}_{t,i} = \frac{F^{(L)}_{t,i}}{A^{(L)}_{t-1}} - \frac{A^{(L)}_{t+i}}{A^{(L)}_{t-1}} = f^{(L)}_{t,i} - a^{(L)}_{t+i}$$

where $e_{t,i}$ is the relative error of a forecast made at time t, i quarters in advance, f and a are the relative forecast and actual prices obtained as ratios of their respective observed cash prices.

The method leading to the smallest mean square forecast error was considered best. This assumes that the cost of an error is proportional to the square of its magnitude, and that the forecaster's objective is to maximize cost (5, p. 157). Here,

$$\min_j MSE^{(j)} = \min_j \frac{1}{n} \sum_{t=1}^{n} (f^{(j)}_{t,i} - a^{(j)}_{t+i})^2$$

where $j = D$, F, and L. The square root of the mean square error (RMSE) measures the average relative error.

In addition to ranking the forecasts according to their MSE, it is desirable to know whether one forecast is significantly better than another by that criterion. The significance test used was that suggested by Granger (5, p. 157). It takes into account the correlation between errors arising in different methods.

Define $\quad Q^{(j,k)}_{t,i} = e^{(j)}_{t,i} - e^{(k)}_{t,i}$

and $\quad P^{(j,k)}_{t,i} = e^{(j)}_{t,i} + e^{(k)}_{t,i}$

where j and k refer to two different forecasting methods. Granger's procedure consists in testing the significance of the coefficient of P in the regression of Q on P.[5]

Some additional information can be obtained from a decomposition of the loss function (MSE), along the lines suggested by Theil (See Appendix).

MSE = [*Bias component*] + [*Regression component*] + [*Disturbance component*]

where the bias component indicates the extent to which the magnitude of the MSE is the consequence of a tendency to estimate too great or too small a change of the forecast price. The regression component measures that part of the error arising from a lack of correlation between actual and forecast price change. Thus, the sum of bias and regression components measures the systematic errors. The remainder of the MSE, the disturbance component, is unpredictable. Therefore, the best that forecasting methods can do is to minimize the bias component and the regression components.

[5]Suppose that the forecasts produce unbiased errors, so that the means of $e^{(D)}_{t,i}$, $e^{(F)}_{t,i}$, and $e^{(L)}_{t,i}$ are not significantly different from zero (an assumption that can be readily tested). Then, the hypotheses being tested are:

$$H_0: \sum_{t=1}^{n} (e^{(j)}_{t,i})^2 = \sum_{t=1}^{n} (e^{(k)}_{t,i})^2$$

against $$H_1: \sum_{t=1}^{n} (e^{(j)}_{t,i})^2 \neq \sum_{t=1}^{n} (e^{(k)}_{t,i})^2$$

Testing $\sum_{t=1}^{n} (e^{(j)}_{t,i})^2 = \sum_{t=1}^{n} (e^{(k)}_{t,i})^2$ is the same as testing

$$\sum_{t=1}^{n} (e^{(j)}_{t,i})^2 - \sum_{t=1}^{n} (e^{(k)}_{t,i})^2 = 0, \text{ that is}$$

$$\sum_{t=1}^{n} (e^{(j)}_{t,i} - e^{(k)}_{t,i})(e^{(j)}_{t,i} + e^{(k)}_{t,i}) = 0 = R_{Q,P},$$

the correlation between Q and P because the mean of e is zero. Finally, testing $R_{P,Q} = 0$ is equivalent to testing the coefficient $b_{Q,P}$ in the regression of Q on P (11, p. 404).

Economic time series show strong systematic movements — trends and cycles. It should then be relatively easy to predict the continuation of a rise or fall. Consequently, to predict the turning points, that is to predict when a change in direction occurs, appears to be a more crucial goal. Theil has suggested the following procedure to analyze turning point errors. It recognizes that there are four possibilities with respect to the prediction of turning points.

i) A turning point is correctly predicted; i.e., a turning point is predicted, and afterwards occurs in that time period.
ii) A turning point is incorrectly predicted; i.e., a turning point is predicted but does not occur in that period.
iii) A turning point is incorrectly not predicted; i.e., a turning point is not predicted for a given period but one does occur.
iv) A turning point is correctly not predicted; i.e., a turning point is not predicted and does not occur in a given period.

Theil calls cases (ii) and (iii) turning point errors of the first and second kind, respectively. Clearly, perfect turning point forecasting requires (ii) = (iii) = 0. Define

$$T_1 = \frac{\text{(ii)}}{\text{(i)} + \text{(ii)}}; T_2 = \frac{\text{(iii)}}{\text{(i)} + \text{(iii)}}$$

where T_1 and T_2 lie between 0 and 1.

The smaller T is, the more successful turning point forecasting is indicated. If none of the predicted turning points coincides with any of the actual turning points, i.e., if (i) = 0 then $T_1 = T_2 = 1$.

Results

The root mean square errors (RMSEs) for the lumber price forecasts appear in Table 1. The data are reported for four forecast horizons, from the current quarter to three quarters ahead, and by forecasting method: FORSIM, futures market, and lagged price. The table also shows the results of the tests that determine whether the mean square errors of two different methods are significantly different. Based on the data for the period 1974-I to 1980-I, there was no significant difference between the FORSIM forecasts and the futures market prices, for current-quarter and one-quarter-ahead forecasts. However, for forecasts made two or three quarters ahead, the FORSIM model did significantly better than the futures market. For these forecasts the average error for the futures market (RMSE) was 13 percent, against 9 percent for the FORSIM model. FORSIM and futures market gave forecasts that were significantly better than the last price for all forecast horizons.

The data in Table 2 show the components of the mean square error for lumber price forecasts, by method and forecast horizon. In all cases, the bias component is very small relative to the total error, especially for the FORSIM model and the futures market. The systematic error of the FORSIM model for forecasts made one to three quarters ahead varies between 1 and 6 percent of the total error. This suggests that there is little room for improving those forecasts. On the other hand, the systematic error represents 27 percent of the total error made by FORSIM for the current quarter forecasts. This is about the same for the futures market and may be due simply to the difficulty of measuring the current-period forecast errors, as noted earlier.

TABLE 1. — *Comparison of forecast errors for lumber prices predicted by three methods and for four horizons (1974-I to 1980-I).*

Forecast horizon	Method: FORSIM	Futures market	Last price
Current quarter (N = 30)			
RMSE	0.06	0.06	0.11
		b_{ij}	
FORSIM		0.04	−0.53***
Futures market			−0.61***
One quarter ahead (N = 34)			
RMSE	0.10	0.10	0.15
		b_{ij}	
FORSIM		0.00	−0.25**
Futures market			−0.24**
Two quarters ahead (N = 34)			
RMSE	0.09	0.13	0.18
		b_{ij}	
FORSIM		−0.24**	−0.45***
Futures market			−0.20**
Three quarters ahead (N = 34)			
RMSE	0.09	0.13	0.22
		b_{ij}	
FORSIM		−0.27***	−0.53***
Futures market			−0.27***

Notes: RMSE is the root mean square error, b_{ij} is the test statistic for differences between errors by methods i (row) and j (column). *, **, and *** indicate significant differences at the 0.90, 0.95, and 0.99 confidence level, respectively. N is the number of observations.

Similar results for plywood prices are reported in Tables 3 and 4. Table 3 shows that the FORSIM model and the futures market provided forecasts that did not differ significantly, except for forecasts made two quarters ahead, in which case the futures market did significantly better than the FORSIM model, reducing the average forecast error by 2 percent. For one-quarter- and two-quarters-ahead forecasts, the FORSIM model was not significantly more accurate than the last plywood price.

The results on the components of the mean square error for plywood price forecasts (Table 4) show that, as for lumber, the systematic error of the FORSIM model is a small component of the total error. For the FORSIM model, the systematic error varies between 0.3 and 5 percent of the total error for forecasts made one to three quarters ahead. The systematic error is higher for the current quarter (10% of total error) but this may again be due to difficulties of definition. Therefore, as for lumber, there seems to be only limited room for improvement in the FORSIM forecasting methodology. Systematic errors are generally larger for the futures market. This indicates some inefficiency in the plywood futures market, perhaps due to insufficient trading activity.

The results of the analysis of turning point errors are summarized in Table 5. This analysis was done only for forecasts made one quarter ahead. The results are in agreement with those of the mean-square error analysis. For lumber, the FORSIM model made less turning point errors, of both kinds, than the futures market. The reverse was true for plywood where the futures market was better at forecasting turning points than the FORSIM model. During the period 1974-I to 1980-I, setting the price next quarter equal to last quarter's would have been a good way of predicting turning points.

Summary and conclusions

The object of this paper was to evaluate the absolute and comparative accuracy of three methods of fore-

TABLE 2. — *Comparison of MSE and its components for lumber price by horizon and method of forecast (1974-I to 1980-I).*

Horizon method	No. of obser.	MSE = 1 + 2 + 3	Bias component 1	Regression component 2	Disturbance component 3	Systematic error = 1 + 2
Current-quarter forecast:						
FORSIM model	30	0.00369	0.00028	0.00070	0.00271	0.00098 (0.26)[b]
Futures market	30	0.00309	0.00009	0.00072	0.00227	0.00081 (0.26)
Last price	30	0.01197	0.00042	0.01152[a]		
One-quarter-ahead forecast:						
FORSIM model	34	0.01088	0.00001	0.00011	0.01065	0.00012 (0.01)
Futures market	34	0.01086	0.00000	0.00001	0.01075	0.00002 (0.00)
Last price	34	0.02269	0.00124	0.02139[a]		
Two-quarters-ahead forecast:						
FORSIM model	34	0.00793	0.00000	0.00045	0.00739	0.00045 (0.06)
Futures market	34	0.01634	0.00001	0.00009	0.01618	0.00010 (0.01)
Last price	34	0.03323	0.00190	0.02928[a]		
Three-quarters-ahead forecast:						
FORSIM model	34	0.00742	0.00002	0.00039	0.00672	0.00041 (0.01)
Futures market	34	0.01763	0.00017	0.00032	0.01685	0.00048 (0.03)
Last price	34	0.04802	0.00223	0.03908[a]		

[a]The $S_{\hat{f}l}$ of the lagged price being zero, the MSE couldn't be decomposed into these three components.
[b]Fraction of MSE that is systematic. Components may not add up to MSE due to round off errors.

TABLE 3. — *Comparison of forecast errors for plywood prices predicted by three methods and for four horizons (1974-I to 1981-I).*

Forecast horizon	Method: FORSIM	Futures market	Last price
Current quarter (N = 16)			
RMSE	0.04	0.05	0.07
		b_{ij}	
FORSIM		−0.33	−0.44**
Futures market			−0.48
One quarter ahead (N = 20)			
RMSE	0.08	0.06	0.10
		b_{ij}	
FORSIM		0.15	−0.12
Futures market			−0.30*
Two quarters ahead (N = 20)			
RMSE	0.11	0.09	0.15
		b_{ij}	
FORSIM		0.17**	−0.05
Futures market			−0.25**
Three quarters ahead (N = 20)			
RMSE	0.11	0.10	0.18
		b_{ij}	
FORSIM		0.11	−0.18**
Futures market			−0.27***

Notes: RMSE is the root mean square error, b_{ij} is the test statistic for differences between errors by methods i (row) and j (column). *, **, and *** indicate significant differences at the 0.90, 0.95, and 0.99 confidence level, respectively. N is the number of observations.

casting the price of lumber and plywood. The first method, used by Data Resources Inc., is based on a large econometric model (FORSIM) supplemented by judgment. The second is based on prices of contracts traded on the futures market. The third method is a naive forecast equating the price in the future to the last known cash price.

Due to the data available, quarterly forecasts were compared, with horizons ranging from the current quarter to three quarters ahead. For lumber the FORSIM model, during the period 1974-I to 1980-I, produced forecasts that were significantly more accurate than the futures markets when forecasts were made two to three quarters ahead. But there was no significant difference for current-quarter forecasts and those made one quarter ahead. The root mean square errors of the FORSIM forecasts ranged between 6 and 10 percent. Those of the futures market ranged between 6 and 13 percent. Both futures market and FORSIM were significantly more accurate than the naive forecasts.

For plywood, the futures market was significantly more accurate than the FORSIM model for forecasts made two quarters ahead. But there was no significant difference between these two methods for the other forecast horizons. Forecast errors ranged between 4 and 11 percent for both methods, increasing with the length of the forecast. For one-quarter- and two-quarters-

TABLE 4. — *Comparison of MSE and its decomposition for plywood price by horizon and method of forecast (1974-I to 1981-I).*

Horizon method	No. of obser.	MSE = 1 + 2 + 3	Bias component 1	Regression component 2	Disturbance component 3	Systematic error = 1 + 2
Current-quarter forecast:						
FORSIM model	16	0.00155	0.00010	0.00005	0.00140	0.00015 (0.10)[b]
Futures market	16	0.00302	0.00033	0.00162	0.00107	0.00195 (0.65)
Last price	16	0.00517	0.00020	0.00497[a]		
One-quarter-ahead forecast:						
FORSIM model	20	0.00608	0.00001	0.00002	0.00606	0.00002 (0.00)
Futures market	20	0.00407	0.00000	0.00002	0.00404	0.00002 (0.00)
Last price	20	0.01045	0.00174	0.00850[a]		
Two-quarters-ahead forecast:						
FORSIM model	20	0.01260	0.00032	0.00036	0.01220	0.00068 (0.05)
Futures market	20	0.00747	0.00078	0.00024	0.00673	0.00102 (0.14)
Last price	20	0.02139	0.00648	0.01473[a]		
Three-quarters-ahead forecast:						
FORSIM model	20	0.01313	0.00004	0.00007	0.01306	0.00012 (0.01)
Futures market	20	0.01018	0.00128	0.00039	0.00871	0.00167 (0.16)
Last price	20	0.03417	0.01022	0.02353[a]		

[a]The S_{fi} of the naive model at current period forecast is zero; the MSE couldn't be decomposed into these three components.
[b]Fraction of MSE that is systematic. Components may not add up to MSE due to round off errors.

TABLE 5. — *Frequencies of turning points of lumber and plywood prices, predicted over one quarter by three methods.*

Method	Turning points: Predicted	Actual	Correctly predicted	Errors: 1st kind	2nd kind	T_1	T_2
(Lumber)							
FORSIM	12	14	10	2	4	0.17	0.29
Futures market	10	14	7	3	7	0.30	0.50
Last price	23	14	14	9	0	0.39	0.00
(Plywood)							
FORSIM	12	10	7	5	3	0.42	0.30
Futures market	12	10	8	3	2	0.27	0.20
Last price	17	10	9	8	1	0.47	0.10

ahead forecasts, FORSIM did not improve upon the naive model. The same was true for the futures market for current-quarter forecasts.

Analysis of the mean square errors showed that FORSIM and the futures market do give unbiased forecasts. In addition, most of the error of FORSIM price forecasts appeared to be of a random nature, leaving limited room for improvements in methodology. Turning points of lumber and plywood price were predicted best by the lagged cash price.

In comparing the various methods one must keep in mind that the FORSIM model forecasts many variables besides prices, including production, demand, inventories, etc. It is possible to conceive a model that would provide better price forecasts only. The time-series methodology seems attractive in that respect (1, 12), but a time-series model would not provide as much information. Still, as econometric models become more widespread, it will be useful to continue monitoring their forecasting performance, and to compare econometric models with alternative methods, including the futures market. This study stopped in 1980-I, due to the change in the definition of the lumber contract from hem-fir to spruce-pine-fir. The forecasting potential of the lumber futures market under the current contract should be investigated as soon as enough data are available. Unfortunately, the futures market for plywood may close soon due to insufficient trading activity.

Literature cited

1. Buongiorno, J., and J. Balsiger. 1977. Quantitative analysis and forecasting of monthly prices of lumber and flooring products. Ag. Systems 2:165-181.
2. Danthine, J. 1978. Information, futures prices, and stabilizing speculation. J. Econ. Theory 17:79-98.
3. Data Resources, Inc. 1974-1981. FORSIM review. Data Resources, Inc., Lexington, Mass.
4. Gardner, B.L. 1976. Futures prices in supply analysis. Am. J. Agr. Econ. 58:81-84.
5. Granger, C.W.J. 1980. Forecasting in Business and Economics. Academic Press, Inc., New York, 226 pp.
6. Green, J. 1981. Value of information with sequential futures market. Econometrica 49:335-358.
7. Just, R.E., and G.C. Rausser. 1981. Commodity price forecasting with large-scale econometric models and the futures markets. Am. J. Agr. Econ. 63(2):197-208.
8. Kofi, T.A. 1973. A framework for comparing the efficiency of futures markets. Am. J. Agr. Econ. 55:584-594.
9. Maddala, G.S. 1977. Econometrics. McGraw-Hill, New York.
10. Martin, L., and P. Garcia. 1981. The price-forecasting performance of futures market for live cattle and hogs: a disaggregated analysis. Am. J. Agr. Econ. 63(2):209-215.
11. Neter, J., and W. Wasserman. 1974. Applied linear statistical models-regression, analysis of variance and experimental designs. Richard D. Irwin, Inc.
12. Oliveira, R.A., J. Buongiorno, and A.M. Kmiotek. 1977. Time-series forecasting models of lumber, cash, futures and basis prices. Forest Sci. 23(2):268-280.
13. Random Lengths. 1973-1981. Random Lengths Annual Yearbook, Eugene, Oreg.
14. Theil, H. 1970. Economic Forecasts and Policy. North-Holland Publishing Company, Amsterdam.
15. Tomek, W.G., and R.W. Gray. 1970. Temporal relationship among prices on commodity futures markets: their allocative and stabilizing roles. Am. J. Agr. Econ. 52:372-380.
16. Veltkamp, J.J., R. Young, and R. Berg. 1983. The Data Resources Inc., approach to modeling demand in the softwood lumber and plywood and pulp and paper industries. *In* Forest Sector Models. R. Seppala, C. Row, A. Morgan, Eds. AB Academic Press, Berkhamsted, England.
17. Whiteman, I.R. 1966. Improved forecasting through feedback. J. of Marketing 30(2):45.

Appendix

The decomposition of the MSE is done in the following manner. Let r denote the correlation between relative forecast price $f_{t,i}$ and relative actual price $a_{t,i}$

$$r = \frac{\sum_{t=1}^{n} (f_{t,i} - \bar{f}_i)(a_{t,i} - \bar{a}_i)}{\left(\sum_{t=1}^{n} (f_{t,i} - \bar{f}_i)^2 \sum^{n} (a_{t,i} - \bar{a}_i)^2\right)^{1/2}} = 1/n \sum_{t=1}^{n} (f_{t,i} - \bar{f}_i)(a_{t,i} - \bar{a}_i)/S_{F_i} S_{a_i}$$

Thus

$$\begin{aligned} MSE &= 1/n \sum_{t=1}^{n} (f_{t,i} - a_{t,i})^2 \\ &= (\bar{f}_i - \bar{a}_i)^2 + (S_{fi} - rS_{ai})^2 + (1 - r^2)S_{ai}^2 \text{ (14, p. 38)} \\ &= (\bar{f}_i - \bar{a}_i)^2 + S_{fi}^2 (1 - r\, S_{ai}/S_{fi})^2 + (S_{ai}^2 - r^2 S_{ai}^2) \\ &= (\bar{f}_i - \bar{a}_i)^2 + S_{fi}^2 (1 - \beta)^2 + (S_{ai}^2 - \beta^2 S_{fi}^2) \\ &= (\bar{f}_i - \bar{a}_i)^2 + S_{fi}^2 (1 - \beta)^2 + 1/n \sum_{t=1}^{n} (\epsilon_{t,i} - \bar{\epsilon}_i)^2 \end{aligned}$$

where $\bar{f}_i$ and $\bar{a}_i$ are the sample means of the forecast and actual relative prices for the ith forecast horizon; S_{fi}^2 represents the sample variance of $f_{t,i}$; β and $\epsilon_{t,i}$ are the estimated coefficient and the residual obtained by regressing the actual relative price $a_{t,i}$ on the forecast relative price $f_{t,i}$. The first term in the MSE equation, called the bias component, indicates the extent to which the magnitude of the MSE is the consequence of a tendency to estimate too great or too small a change of the forecast price. The second and third terms are called the regression and disturbance components of the MSE, respectively, for the following reason (9, p. 345). The actual relative prices $a_{1,i}, \ldots a_{n,i}$ can be viewed as consisting each of a random $(\epsilon_{t,i})$ and nonrandom $(\alpha + \beta f_{t,i})$ part, i.e.,

$$a_{t,i} = \alpha + \beta f_{t,i} + \epsilon_{t,i} \qquad i = 0, 1, 2, 3 \quad t = 1, \ldots, n \; .$$

assuming that the random part has zero mean. If the prediction is perfect on the nonrandom part, then, $\alpha = 0$, $\beta = 1$ and $a_{t,i} = f_{t,i} + \epsilon_{t,i}$. In that case, both the bias and regression components are equal to zero, and the MSE is equal to the variance of the residual $(\epsilon_{t,i})$. This residual, or random part is unpredictable, therefore, the best that forecasting methods can do is to minimize the bias and the regression components, i.e., the "systematic" errors.