Forecasting Prices, Production and New Orders in the Douglas Fir Plywood Industry

SPECIAL REPORT 165
OCTOBER 1963

Agricultural Experiment Station
Oregon State University
Corvallis

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This publication is a draft of a forthcoming Agricultural Experiment Station bulletin. The draft is being made available to the plywood industry so that pertinent results may be applied immediately. The reader is cautioned, however, to regard the conclusions as tentative.

Authors:

Robert S. Simpson is a former research assistant in Agricultural Economics and Dr. Albert N. Halter is Associate Professor of Agricultural Economics at Oregon State University.

The advice and assistance of Dr. Charles F. Sutherland of the School of Forestry, and R. M. Kallander of the Forest Research Laboratory are acknowledged. The advice, suggestions, and evaluations provided by Arthur Jones and other representatives of the Douglas fir plywood industry are appreciated.

The financial support provided by the Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service and the suggestions and encouragement provided by Dr. Carl Newport and his staff at that station, are also acknowledged and appreciated.

FORECASTING PRICES, PRODUCTION AND NEW ORDERS IN THE DOUGLAS FIR PLYWOOD INDUSTRY*

INTRODUCTION

Managerial decision makers in the Douglas fir plywood industry are concerned with forecasting the behavior of important economic variables. An intimate acquaintance with the price determining forces in the market provides a basis for such forecasting. Most managers are quite familar with these forces in a qualitative way. In recent years new methods have been developed to help managers put their qualitative knowledge into a more quantitative form. In fact, attempts have been made to describe what goes on in the market place with mathematical equations. To the extent that data are also available, statistical means have been devised which will provide numerical values of the coefficients in the equations. These equations with numerical coefficients can be used to obtain quantitative information about the future behavior of the variables under study. This procedure, which involves the application of statistics to the understanding of the operation of the market, has been called econometrics.

The objectives of this report are first to describe the sanded and unsanded fir plywood markets in mathematical equations and statistically derive coefficients from quarterly data relating to the plywood industry during the 1950-1960 sample period. Second, the predictive capabilities

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* This bulletin is based upon Robert S. Simpson's M.S. thesis, "An Econometric Analysis of Demand and Supply Relationships in the Douglas Fir Plywood Industry," Oregon State University, June, 1963.

of the equations (or as frequently called, models) are shown by comparing real and estimated plywood prices, production, and new orders during the sample period and by contrasting real and forecast values of these variables for the four quarters of 1961, the first year outside of the sample period. Finally, the implications of the analysis are discussed and means are suggested whereby price and quantity forecasts could be used by plywood firms to optimize production and market planning decisions and whereby the models themselves could be used both by the industry and government in evaluating and estimating the effects of policy decisions. A concluding paragraph considers the question of overproduction in the Douglas fir plywood industry.

The remainder of this section is devoted to a brief description of the fir plywood industry, identifying primary production costs, marketing channels, and types of consumers. The following sections present results of the analysis of the sanded and unsanded markets.

(1) The Douglas Fir Plywood Industry

Oregon leads all other states in the production of Douglas fir plywood, accounting for 65% of total production (8.4 bil. sq. ft.) in 1961. In 1960, plywood comprised approximately one-third of the value of all Oregon's forest products. Plywood manufacturing employed about 17% of Oregon's total manufacturing employment in 1962.

D.F.P.A.

Quantitative industry statistics concerning Douglas fir plywood production are maintained and published by the producers' trade organization, the Douglas Fir Plywood Association (DFPA), in Tacoma, Washington. In addition, the DFPA stamp appears on all plywood graded in accordance with the performance standards of the DFPA and the industry commercial standards. This amounts to virtually all Douglas fir plywood produced.

Sanded and Unsanded Types of Plywood

Since 1958, industry statistics have been published on the basis of sanded and unsanded types of plywood.[1] Some mills are engaged exclusively in the production of unsanded plywood, while mills which can produce sanded plywood have the added flexibility of producing either type, depending upon market conditions.

The Production of Plywood

Plywood mills may vary from small, independent firms to a few manufacturing branches of large, vertically-integrated corporations with captive wholesale and sales organizations. Sales, at the manufacturing level, however, are weighted more toward the latter group as many small firms sell their product to the larger firms by contract or informal agreements.

Production costs vary between mills on the basis of size and efficiency and by type of product produced. Sanding adds to production costs and exterior types require a more costly bonding agent. However,

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/1 Technically, "type" of plywood refers to the type of glue bond used between the plys; exterior types utilize waterproof glue and interior types use moisture resistant, but not waterproof, glue. However, reference will be made to type in this bulletin on the basis of the sanded or unsanded faces of plywood panels.

by far the most costly input in plywood production is the raw material, logs.

Historically, plywood mills have depended heavily upon peeler logs as a primary input./1 At the beginning of the sample period (1950-1960) it is estimated that log consumption in the industry was 80 percent peeler grades and 20 percent sawlogs (4, p. 50-59). At present, log consumption is estimated to be approximately 56 percent peeler grades and 44 percent sawlogs, and the average cost of logs about 42 percent of total production costs./2 The indicated shift toward utilization of sawlogs in plywood manufacturing is undoubtedly due to the decreasing supply of peeler logs (and their considerably higher costs) as well as technological improvements which have made possible more efficient utilization of sawlogs.

The second major cost in the production of plywood is that of labor. Technological improvement and the substitution of capital for labor reduced the number of factory man-hours required to produce 1,000 feet of plywood from 15.1 in 1935 to 11.8 man-hours in 1946 (23, p. 71). There is every reason to believe that this trend has continued since 1946, as per hour labor costs have risen as indicated in Figure 1.

Glue, sanding, patching and other costs, together with fixed costs, make up the remainder of total production costs for the various types

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/1 Peeler logs are old-growth Douglas fir logs whose large sizes permit relatively long, continuous lathe runs, which also result in a higher proportion of top quality veneer.

/2 Current cost information was made available by the Douglas Fir Plywood Association.

and grades of fir plywood. None of these appear to be major costs, and their effects will not be investigated in this analysis.

Figure 1. Quarterly index of average hourly earnings--sawmill employees in Douglas fir region of Western Oregon and Washington, 1950-1961 (1949 average = 100)

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Marketing of Douglas Fir Plywood

Although a complex system of market channels exists in the fir plywood industry, it is relatively easy to characterize the primary flow of plywood from mills to wholesalers (independent or captive jobbers with warehouses) to retail lumber dealers and final consumers.[/1]

/1 In 1959, nearly half of total mill sales went directly to wholesalers, while 56 percent of the latter's sales were directly to retail lumber dealers. (PMI Marketing Report)

The primary market for plywood is the building materials market. The DFPA estimates that only 32 percent of plywood sales were to industrial users in 1962.

Table 1 shows the estimated consumption of fir plywood by sanded and unsanded types in 1962.

Table 1. Consumption of Sanded and Unsanded Plywood - 1962[a]

	Final User (Percent of total consumed)				
	Non-Residential Construction	Residential Construction	Industrial	Agricultural	Other[b]
Sanded Types	17.1	36.6	27.4	2.1	16.8
Unsanded Types	14.5	60.4	16.1	2.3	6.7

[a] This information was made available by the Douglas Fir Plywood Association.

[b] Individuals for private use.

If the general relationships shown in the table held during the sample period used in this study, residential construction activity should show up as highly significant determinant of demand for unsanded plywood.

Competitive Products

The success of plywood in the construction materials market has come largely at the expense of lumber. In addition to its possession of certain desirable structural characteristics, a primary reason for the use of plywood by builders appears to be an economic one, it saves construction labor. This fact suggests that construction wage rates might be an important long-run factor in the demand for plywood.

The industrial market for plywood is extremely difficult to characterize because of the great diversity of uses to which the product is put. Hardboards and fiberboards appeared to offer stronger competition in this market, than in the construction market, but undoubtedly lumber remains the strongest competitor.

THE SANDED FIR PLYWOOD MARKET

This section gives the equations which were found after considerable analysis to describe the price determining forces of the sanded fir plywood market.[/1] Each equation is discussed under a separate heading as to the variables included and some explanation for their appearance. Then, a quantitative analysis of the various forces operating in the market is given and finally the predictions and forecasts of prices, new orders and production are presented. Graphic presentation of the predictions and forecasts in comparison with the actual behavior of the variables provides a clear picture of the magnitude of the errors involved.

The following equations were estimated to provide the description of the price determining forces operating in the sanded fir plywood market.[/2]

1. Demand

$$P_t = 10.57 - \underset{(4.15)}{.00003259}\, N_t - \underset{(3.06)}{.2759}\, {}^{s}I_{w_t} + \underset{(6.85)}{1.195}\, {}^{s}L_{t-1} + \underset{(5.33)}{1.363}\, {}^{s}(P_{w_{t-1}} - P_{w_{t-2}}),$$

2. Supply

$$P_t = 121.2 + \underset{(4.53)}{.00003808}\, Q_t - \underset{(6.47)}{.9387}\, B_{t-1} + \underset{(10.39)}{.7070}\, P_{t-1},$$

3. Warehouse Inventory

$$I_{w_t} = 54.39 - \underset{(2.01)}{2.200}\, {}^{s}P_{w_{t-4}} + \underset{(2.37)}{.007481}\, {}^{s}C^{tot.}_{t-1} + \underset{(4.47)}{.5482}\, I_{w_{t-1}} + \underset{(2.39)}{1.249}\, {}^{s}P^{sand.}_{t-4},$$

4. Unfilled Orders

$$U_t = 793{,}790 + \underset{(2.95)}{7176.0}\, P_{t-1} - \underset{(5.09)}{.7339}\, U_{t-1} - \underset{(2.84)}{13{,}713.0}\, P_{w_{t-1}},$$

/1 See Appendix 3 for procedures used in deriving these equations.

/2 Values of the statistic t are given in parentheses below the coefficients.

5. Accounting

$$Q_t = 48{,}976.3 + \underset{(56.14)}{1.0027\, N_t} - \underset{(16.15)}{1.148\, \Delta U_t}.$$

Demand Relation

The demand relation is formulated with price (P_t) as the dependent variable, a function of new orders (N_t), wholesale inventories (${}^{s}I_{w_t}$), the price of lumber in the preceding quarter (${}^{s}L_{t-1}$), and the lagged change in wholesale prices ${}^{s}(P_{w_{t-1}} - P_{w_{t-2}})$. /1 The opposite signs on the coefficients of price and new orders indicate a negatively-sloping demand curve.

Although either price or quantity (new orders) could theoretically appear as the dependent variable in a demand relation, special difficulties were encountered when the latter formulation was investigated. Plywood being a growth industry, the quantity variables, N_t and Q_t, show strong growth trends and, as a result, were highly correlated with any variable which also increased in magnitude over time ("time" itself would yield a high correlation). Thus, price appears as the dependent variable. /2

It is noted that the signs of the remaining coefficients in the relations are reasonable. Lumber is shown to be a competitive building material by the identical signs N_t and L_{t-1} when the relation is

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/1 The superscript s indicates the variable was seasonally adjusted. The subscript t indicates the current quarter, while t-1 and t-2 indicate the previous and two quarters ago, respectively.

/2 It is possible that using per capita new orders as the dependent variable would have corrected the problem of excessive trend influence. This procedure was not tried.

solved for N_t.[/1] In the same manner it is seen that, as wholesale inventories increase, new orders for plywood decrease. The relation shows that mill price generally moves in the same direction as preceding wholesale prices.

Finally, it is interesting that none of the indicators of construction activity appear in the demand relation. Since demand for building materials is first felt at the retail, rather than at the wholesale level of the market, it is not surprising that consumer demand makes itself felt at the mill through the actions of wholesalers.

As might be expected, lagged construction indicators do appear in the wholesale inventory relation. The effect of construction activity upon mill demand can be determined by subtituting the right-hand side of the inventory relation into the demand relation for I_{w_t}. Thus the elasticity of mill price with respect to total construction put-in-place (in previous quarter) may be estimated from the resulting equation.[/2]

Supply Relation

The supply relation was also formulated with price as the dependent variable because of the previously-mentioned problem of trend in the quantity variable (Q_t). Mill price is a function of total production (Q_t), sawmill workers' wages (B_{t-1}), and mill price last quarter (P_{t-1}).

/1 This does not, of course, imply that lumber competes in all uses with sanded plywood, but that for the bulk of sanded production, a competitive relationship exists.

/2 Elasticities are given in Table 3.

A positively-sloping supply curve is thus obtained with the variables B_{t-1} and P_{t-1} acting as shift variables in the supply curve./1

It is worth noting that sawmill workers' wages apparently enter the relationship as a productivity variable as opposed to a pure factor cost. The reasoning is that, as wages have risen, management has substituted capital for labor thereby raising the productivity of labor and lowering the total industry cost curves. Thus, wage increases are associated with a fall in plywood prices.

Wholesale Inventory Relation

The wholesale inventory relation shows the level of wholesale inventories to be determined by construction put-in-place (${}^{s}C_{t-1}^{tot.}$) and an adjustment of the level of inventories in the preceding quarter as well as the price expectation variables (${}^{s}P_{t-4}$ and $P_{w_{t-4}}$) measured in the same quarter of the preceding year.

The sign on the coefficient of ${}^{s}C_{t-1}^{tot.}$ is positive as expected. That is, when the right-hand side of the warehouse inventory equation is substituted into the demand equation for I_{w_t}, it can be seen that an increase in total construction put-in-place will increase the dependent variable, P_t. Little can be said on an a priori basis concerning the expectation variables and the signs on their coefficients.

/1 "Shift" variables are those that shift the supply (or demand) curve.

Accounting Relation

Data which are generated by existing market sources imply some equilibrating relation between supply and demand. It is customary to write, Supply = Demand = Sales, as an equilibrium condition. However, since it was possible to distinguish between new orders (N_t) and production (Q_t) in the specification of supply and demand relations, it became necessary to explain the relationship between the two variables.

The Douglas Fir Plywood Association indicates that the following relation should hold approximately: $Q_t = N_t + \Delta U_t$. /1 Because, however, of the (substantial) error involved, it was decided to estimate the relationship statistically.

The fact that the coefficients on the variables of the accounting relation are close to 1.0 indicates that there probably exists a relatively persistent error imposed from some source(s).

Unfilled Orders Relation

The level of unfilled orders in any quarter is determined both by the actions of producers (in setting production) and buyers (in placing new orders). Thus it is impossible to make any <u>a priori</u> judgment as to the variables that might appear in this relation.

/1 ΔU_t (read "delta U_t") is the change in unfilled orders from the preceding period; i.e., $\Delta U_t = U_{t-1} - U_t$. The exact relation intended to hold is shipments = new orders + change in unfilled orders. Mr. H. A. Peterson of DFPA indicated there is a 1½ - 2% fall-down between shipments and production on the average. Actually reporting errors, unaccounted for changes in mill inventories, and the estimation of nonassociated mills activity add an additional random element to the above error.

Because of the relatively large amount of unexplained variation in the dependent variables(s), much energy was expended in attempting to find a more meaningful relation. Short of solving the accounting relation for U_t and re-estimating that relation as the unfilled orders equation, no improvement was made. This relation remains one of the primary weak points in the present model. That is, there are probably formulations of the decision-making equation concerning the unfilled order file that would better describe the actual situation.

Quantitative Analysis of Price Determining Forces

One of the results of summarizing market statistics in the form of mathematical equations is that useful decision-making information can be derived in quantitative form. In regard to the demand relation, the responsiveness of new orders to changes in price is one such piece of useful information. The response of one variable to changes in another is generally expressed in percentage terms to avoid units of measurement. Hence, the figures given in Table 3 are percentage changes in the variable given in the numerator to a 1 percent change in the variable given in the denominator. Thus, it was estimated that on the average during the period 1950-1960 a 1 percent rise in the price of sanded plywood would be associated with a 4.58 percent decline in new orders. When the response of a quantity variable is considered in regard to a change in price, the response is called elasticity. Thus, columns two and three of Table 3 are supply and demand elasticities respectively.

Table 3. Estimated Response of P_t, N_t, and Q_t During Selected Periods - Sanded Douglas Fir Plywood

	Demand[a]	Supply	Demand	Supply[b]	Construction[c]
Assumed Values of Variables	$\frac{R \text{ of } P_t}{Q_t}$	$\frac{R \text{ of } Q_t}{P_t}$	$\frac{R \text{ of } N_t}{P_t}$	$\frac{R \text{ of } P_t}{N_t}$	$\frac{R \text{ of } N_t}{s_{C_{t-1}}^{tot.}}$
1950-1960 Av.	-.234	5.29	-4.58	.256	1.77
1961- Q1	-.398	3.11	-2.36	.497	1.40
1961- Q2	-.397	3.12	-2.88	.407	1.57
1961- Q3	-.392	3.16	-2.51	.466	1.40
1961- Q4	-.442	2.80	-2.28	.514	1.37

[a] To obtain these estimates, the accounting relation was solved for N_t and substituted into the demand relation, thus obtaining demand in terms of Q_t. R of P_t means the percentage change in P_t (price) in response to a 1 percent change in Q_t (quantity produced).

[b] Here the accounting relation was solved for Q_t and substituted into the supply relation, thus obtaining supply in terms of N_t.

[c] These are calculated from the reduced form (RF) coefficients of the 1950-1960 sample period (see Table 4).

A comparison of columns two and three shows that the estimated elasticity of supply consistently exceeded the estimated elasticity of demand for sanded plywood./1 This result would be expected from the fact that plywood constitutes only a portion of the total outlay of consumers' wood product budgets, whereas producers are engaged exclusively in plywood production, and hence are more sensitive to price movements.

When the response of a price variable is considered in regard to a change in a quantity variable, the response is called flexibility. Thus columns one and four of Table 3 are demand and supply flexibilities.

/1 For an explanation of the calculation of elasticity coefficients, see Leftwich, (18, pp. 34-41) 1st. ed.

Columns one and four indicate that price is slightly less flexible with respect to changes in new orders than to changes in production. Thus, for example, identical one percent increases (over predicted values) of N_t and Q_t would have been expected to result in a price slightly above (.072 percent above) its predicted value in 1961, quarter 4. That is, the expected percentage increase in price (.514 percent) resulting from a 1 percent increase in new orders, would exceed the expected decrease in price (-.442 percent) resulting from a 1 percent increase in production, by the stated amount. Thus, it appears that buyers have enjoyed slightly more leverage in the sanded plywood market than have sellers, at least for the periods given in Table 3.

The response of new orders with respect to lagged total construction put-in-place (column 5) is considerably smaller than with respect to price (column 3). These responses, as well as the elasticity of production with respect to price, were at lower levels in 1961 than were the same average elasticities over the entire sample period.

There are many other variables for which the response interrelationships can be calculated; the above are some of the important ones. Keeping this type of information current for the industry would provide an indication of some of the consequences of manager's decisions. Although the actions of one firm may seem inconsequential in relation to the industry, the same price determining forces are working on everyone. To the extent that past responses are indicative of future behavior, managers can formulate quantitative expectations of the consequences of their decisions and actions.

Prediction and Forecasts of Prices

There are a number of ways of obtaining predictions and forecasts from the equations given on Page 8. The results of only one will be presented here, although several were used in the original study. The way in which the predictions and forecasts were obtained is from the least squares reduced form equations. This formidable title names a method whereby new equations are formulated from those on Page 8 and new coefficients are estimated by ordinary least squares regression techniques. The new equations have one of the variables to be predicted on the left-hand side and all other variables (except the other variables which are predicted by the system of equations) on the right-hand side. Thus, for example, price (P_t) would be on the left-hand side of the regression equation to be estimated and all other variables in the five equations on Page 8 except N_t, Q_t, I_{w_t} and U_t would appear on the right-hand side.

The least squares reduced form coefficients for the sanded plywood model (equations) are given in Table 4. From these equations predictions of price, new orders and production were made. Figure 2 gives real and estimated (predicted) average prices for sanded plywood for the period 1950-1960 and forecasted prices for 1961.[/1]

It should be noted that the estimated (predicted) line lies generally to the left of the real price line. It appears that the reduced form

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/1 When reference is made to prediction, it means that estimates of the variables are being derived from the models for the sample period 1950-1960. When reference is made to forecasts, it means that estimates of the variables are being derived from the models outside of the sample period. The numerical values of the 1961 forecasts are given in Tables 5 and 8.

Table 4. Coefficients of Reduced Form Equations for Sanded Plywood a/

Forecast Variable	Predetermined Variables										
	${}^{s}L_{t-1}$	${}^{s}(P_{w_{t-1}} - P_{w_{t-2}})$	B_{t-1}	P_{t-1}	U_{t-1}	$P_{w_{t-1}}$	${}^{s}P_{w_{t-4}}$	${}^{s}P^{sand.}_{t-4}$	${}^{s}C^{tot.}_{t-1}$	$I_{w_{t-1}}$	Constant
P_t	.604	.361	-.435	.218	.000054	.483	.244	-.304	-.00195	-.0313	33.48
N_t	4,752.0	-2,166.4	584.2	899.4	-.609	-8,026.2	-7,010.9	240.1	161.6	-1,715.0	462,158
Q_t	7,329.4	-790.6	2,251.5	-3,998.7	.408	-601.3	-7,176.4	1,244.8	132.2	-1,264.8	-365.781

a/ These are simple linear equations.

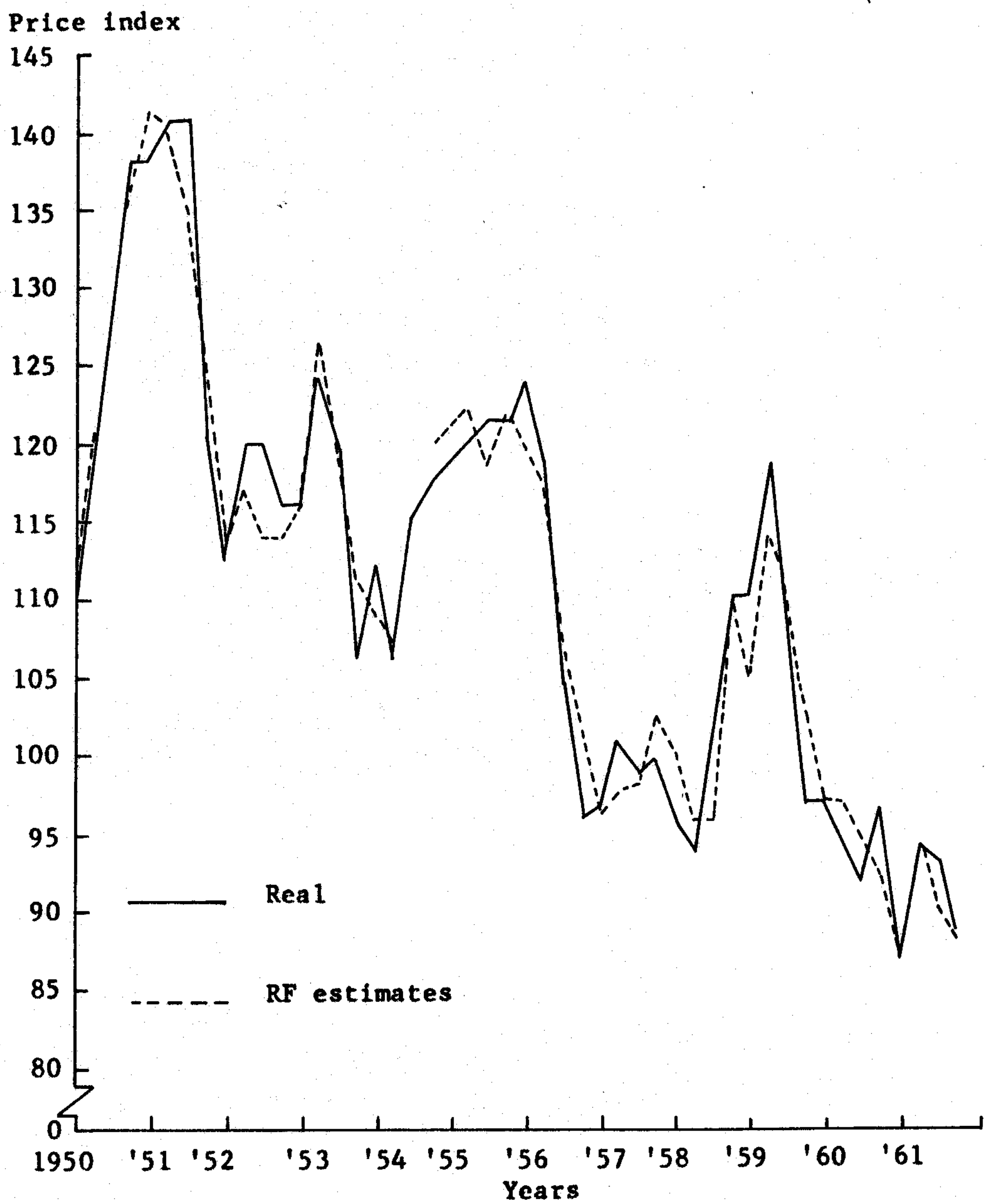

Figure 2. Quarterly index of average prices, real and RF estimates, Douglas fir plywood, sanded types, 1950-1961.

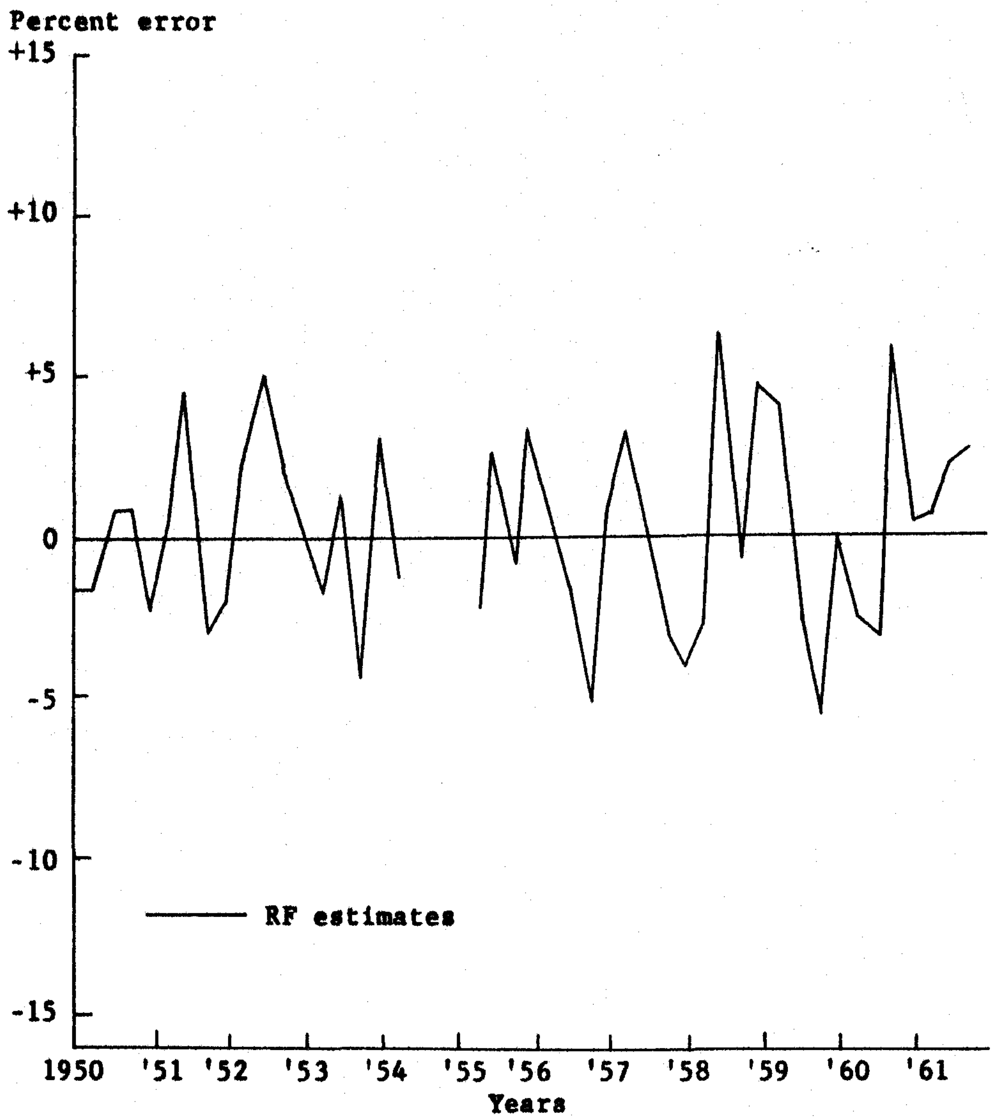

Figure 3. Reduced form estimation errors (as percent of real values) - Quarterly price index of Douglas fir plywood, sanded types, 1950-1961.

estimates frequently anticipated price downturns and upturns and "led" real price over most of the period.

Reduced form (RF) estimates indicated the <u>direction</u> real price would move (from the real value in the preceding quarter) 77 percent of the time during the entire 12 year period.

The magnitudes of price estimation errors as percentages of real values are shown in Figure 3.

Prediction and Forecasts of New Orders and Production

Figure 4 gives real and predicted quarterly industry totals of new orders for sanded plywood for the period 1950-1960 and forecasted values for 1961. The lack of fluctuation in the estimates, compared to that of real values during the period, indicates that some relevant shift variables have not been discovered in empirical investigation. It should be noted, however, that the variation is not due to simple seasonal movements. The peaks and troughs of the graph do not consistently appear in the same quarters.

For new orders, the reduced form estimates indicated the direction of change in the real variable 81 percent of the time.

Figure 5 shows percentage errors of estimation for the period.

Real and predicted quarterly industry totals of sanded plywood production are shown in Figure 6 for the period 1950-1960 and forecasted values for 1961. Immediately obvious in the real data is the effect of the industry-wide strike in the third quarter of 1954.[/1] Obvious too, is the heavy trend in the data that necessitated the rejection of Q_t as the dependent variable in the supply equation.

/1 The third quarter of 1954 was not used in the analysis.

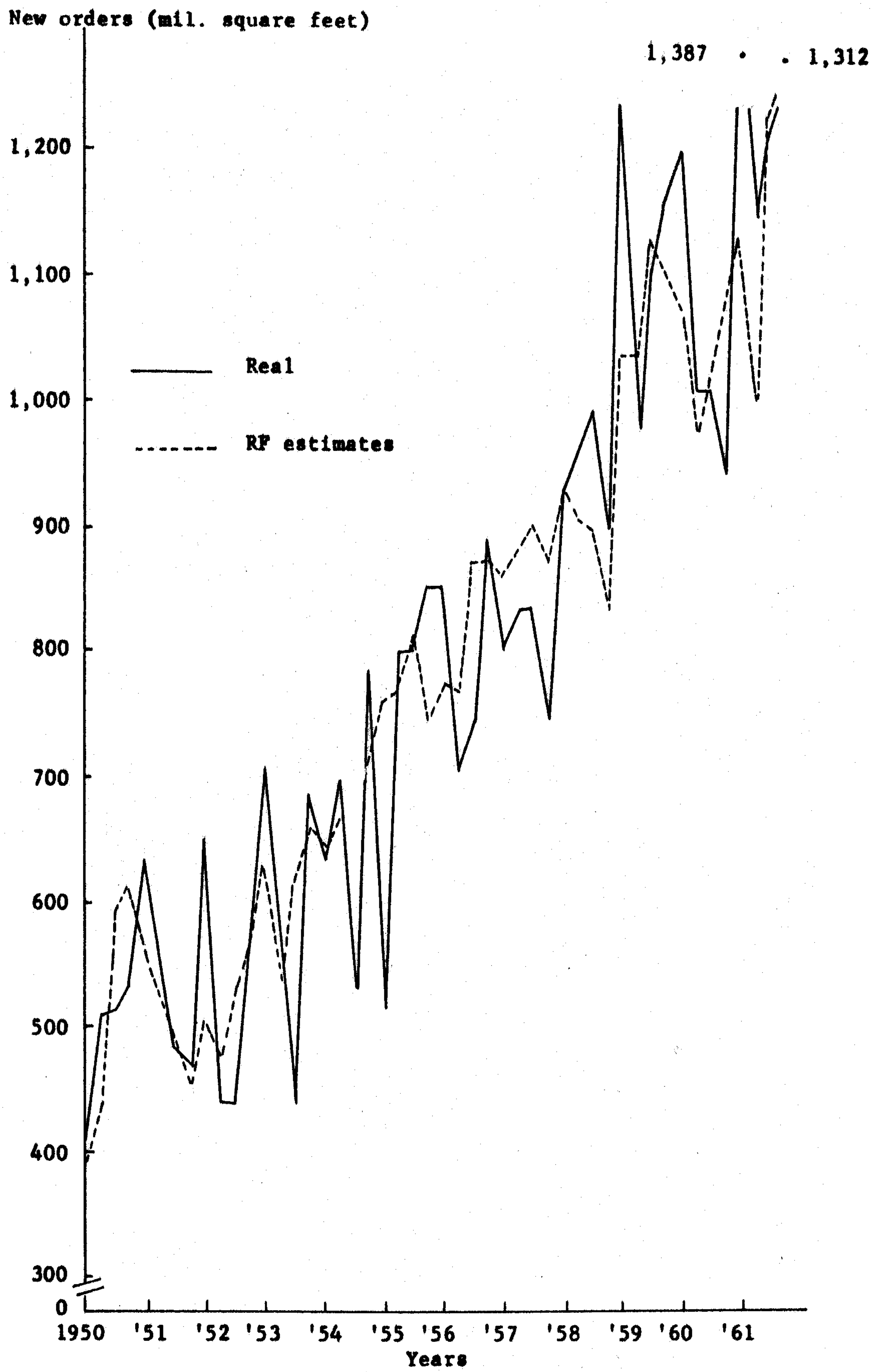

Figure 4. Quarterly totals of new orders, real and RF estimates, Douglas fir plywood, sanded types, 1950-1961.

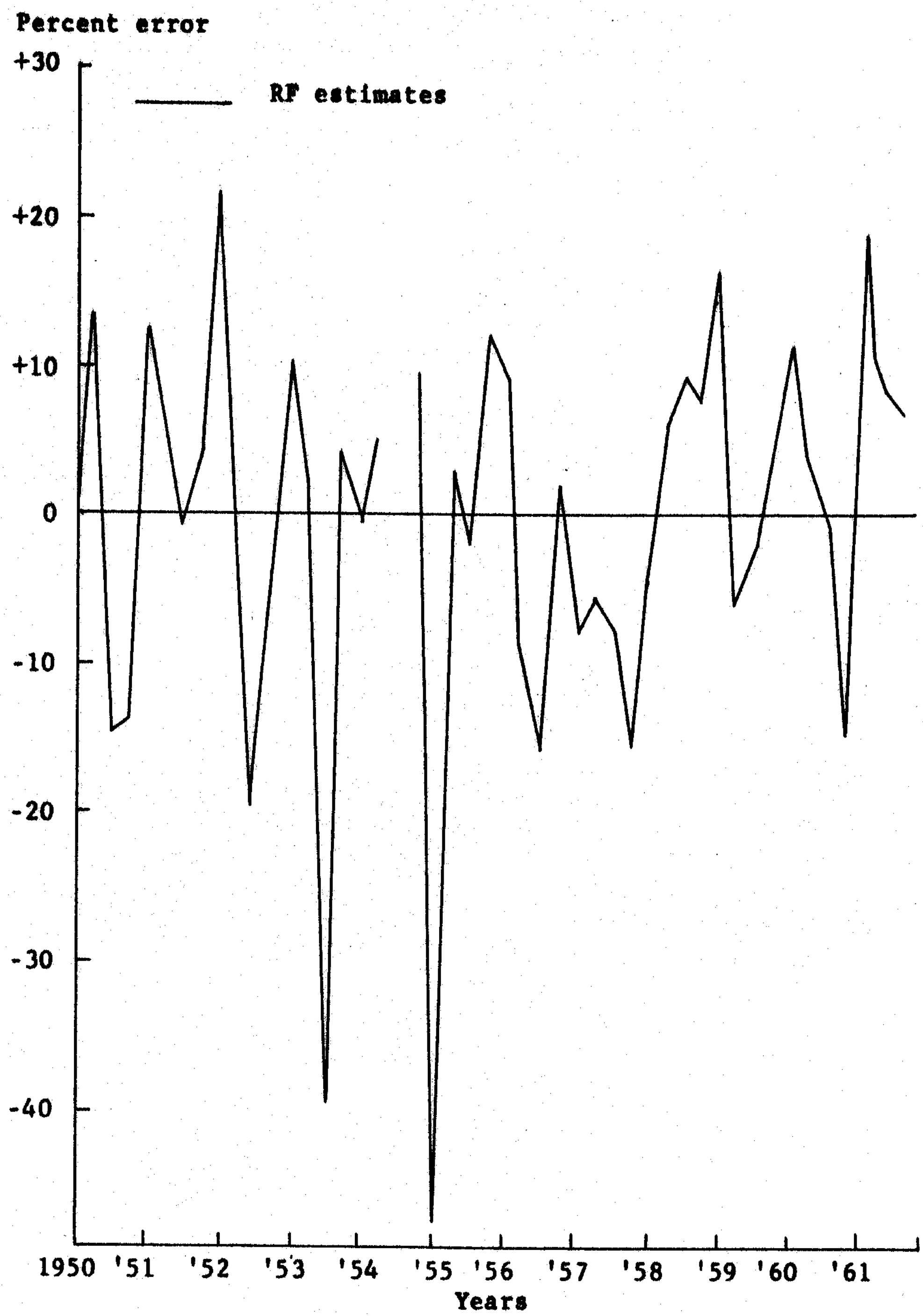

Figure 5. Reduced form estimation errors (as percent of real values) - Quarterly totals of new orders, Douglas fir plywood, sanded types, 1950-1961.

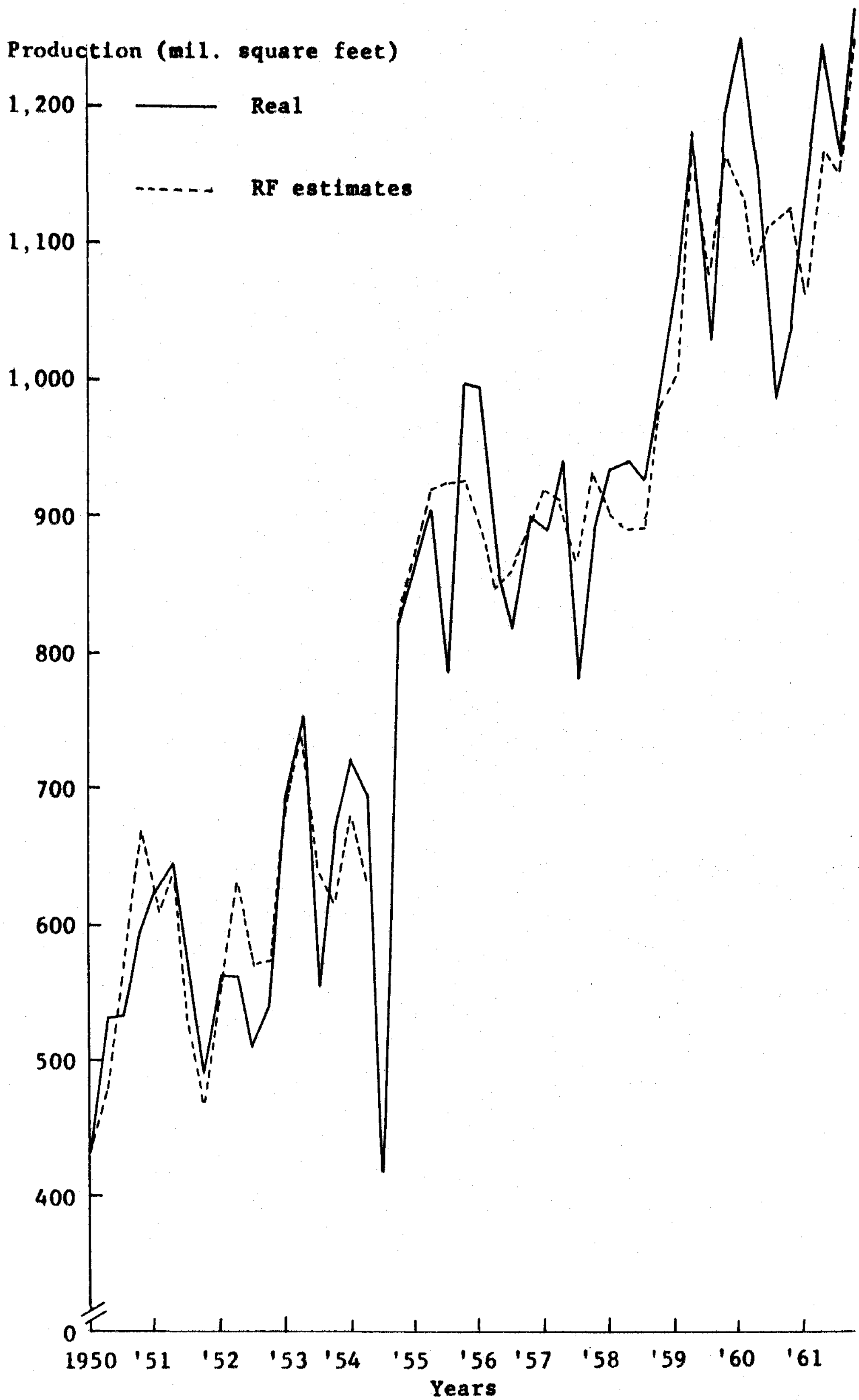

Figure 6. Total quarterly production, real and RF estimates, Douglas fir plywood, sanded types, 1950-61.

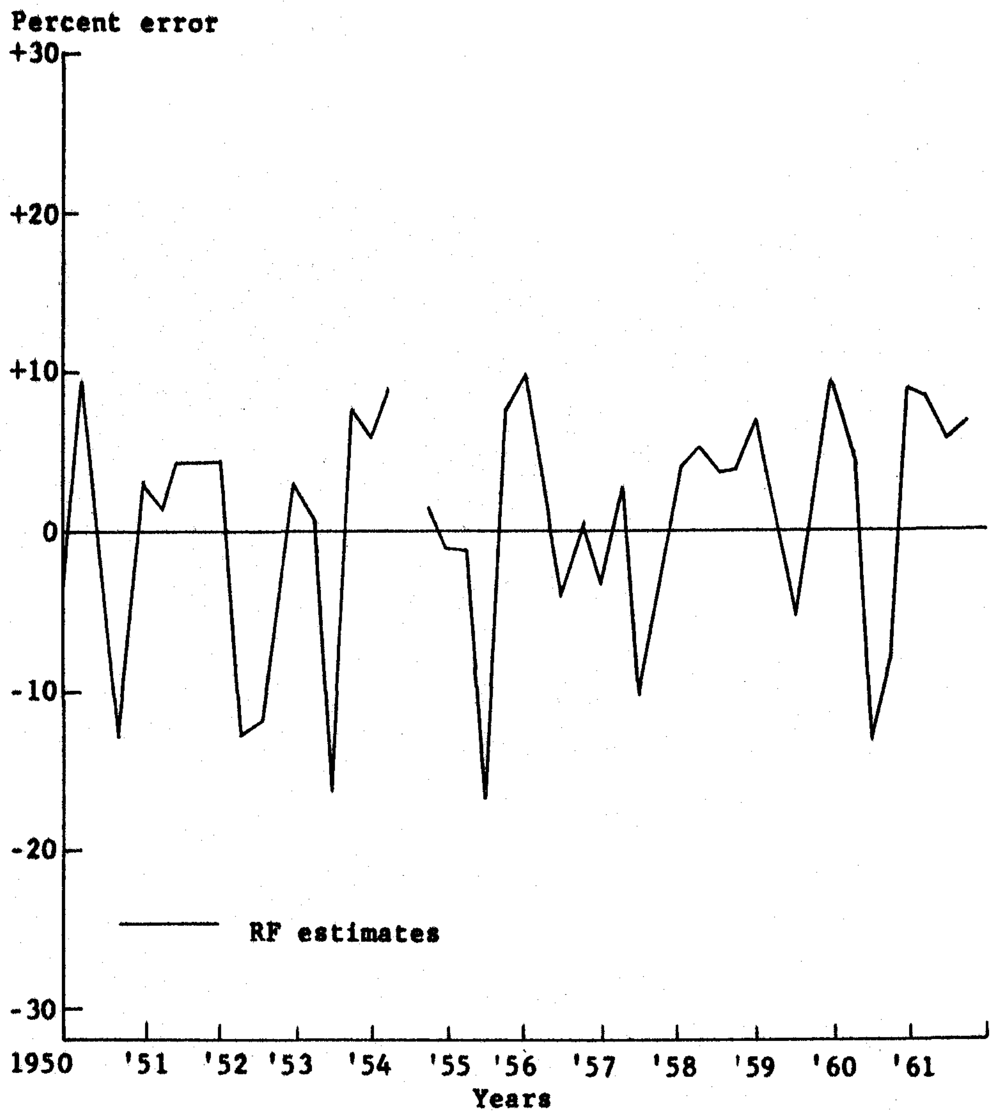

Figure 7. Reduced form estimation errors (as percent of real values) - Total quarterly production, Douglas fir plywood, sanded types, 1950-1961.

The RF estimates correctly indicated the direction of change in the real variable 85 percent of the time during the 1950-1961 period. Estimation errors are shown in Figure 7.

1961 Forecasts

A primary objective of this study was the development of mathematical models of the fir plywood markets that would be capable of generating meaningful price and quantity forecasts one quarter into the future. The results of forecasting 1961 market data for sanded plywood are given in detail in Table 5.[/1] These forecasts for the first year outside of the 1950-1960 sample period constitute a critical test of the model's predictive capabilities.

In general, 1961 forecasts for sanded plywood appear to be quite good. The direction of change (from the preceding quarter) of the real variables was correctly indicated in every case. The largest estimation error for price occurred in the third quarter when price was underestimated by $2.34 per thousand square feet.[/2] This represented a percentage error of 3.2%, well within the range of errors encountered during the sample period (Figure 5). The average fluctuation of the real price between quarters of 1961 was $4.51 per thousand square feet.

/1 See Appendix 2 for an explanation of how 1961 forecasts were obtained.

/2 The price data given in Table 5 are index numbers with base (100) = $78.25.

Table 5. 1961 Forecasts and Real Values for Sanded Plywood Data

1961	Variable[a]	Forecast	Dir. of Change[b]	Real Value	Dir. of Change[b]
Qtr. 1	P_t	86.8	↓	86.9	↓
	N_t	1,128	↑	1,387	↑
	Q_t	1,061	↑	1,166	↑
Qtr. 2	P_t	94.2	↑	94.6	↑
	N_t	1,051	↓	1,134	↓
	Q_t	1,170	↑	1,247	↑
Qtr. 3	P_t	90.3	↓	93.3	↓
	N_t	1,225	↑	1,216	↑
	Q_t	1,154	↓	1,165	↓
Qtr. 4	P_t	88.2	↓	89.5	↓
	N_t	1,312	↑	1,259	↑
	Q_t	1,253	↑	1,273	↑

[a] N_t and Q_t are given in millions of square feet (3/8" basis).

[b] Direction of change is the direction indicated by the estimate away from the real value of the variable in the preceding quarter.

It is interesting that, for each quarter of 1961, the RF estimates for P_t and Q_t are less than the real values. N_t is less than the real value two out of four times. This apparently persistent underestimation suggests that downward bias may be present in these estimates. However, in no case did percentage forecast errors fall outside the range of estimation errors during the sample period (Figures 3, 5, 7).

The 1961 forecasts are the only ones currently available. To bring the forecasts up to date and to keep them current would necessitate obtaining more data. The expense of doing this to test the model further from a research standpoint did not seem justified. However, from the standpoint of the decision makers in the industry, current forecasts could be highly desirable information and could be a way of obtaining expectations of industry prices, new orders and production.

THE UNSANDED FIR PLYWOOD MARKET

This section presents the equations which were found to describe the price determining forces of the unsanded (rough) fir plywood market.[/1] Each equation is discussed under a separate heading where the variables are defined and some explanation is provided for their appearance. Similar results of analysis to the section on sanded plywood are given. Forecasts and predictions are presented graphically and some comparisons are made with the sanded market.

The model statistically estimated for the unsanded plywood market is given below.[/2]

1. Demand

$$P_t = 61.34 \underset{(4.04)}{-.0000483} N_t \underset{(1.73)}{-.136}\, {}^{s}I_{w_t} \underset{(3.00)}{+.752} (P_{w_{t-1}} - P_{w_{t-2}}) \underset{(3.91)}{+.0122}\, {}^{s}C^{res.}_{t-1} \underset{(3.42)}{+.352}\, {}^{s}P_{t-1}$$

2. Supply

$$P_t = 96.8 \underset{(2.55)}{+.0000235} Q_t \underset{(9.44)}{+.841}\, {}^{s}P_{t-1} \underset{(3.40)}{+.0000967}\, {}^{s}\Delta U_{t-1} \underset{(4.01)}{-.700} B_{t-1}$$

3. Inventory

$$I_{w_t} = 129.3 \underset{(4.56)}{-.882} P_t \underset{(3.21)}{-.0000836} Q_t \underset{(3.15)}{+1.39}\, {}^{s}P^{sand.}_{t-4} \underset{(3.54)}{-2.98}\, {}^{s}P_{w_{t-4}} \underset{(5.73)}{+.0268}\, {}^{s}C^{tot.}_{t-1}$$

/1 See Appendix 3 for procedure used in deriving these equations.

/2 Values of the statistic t are given in parentheses below the coefficients. The superscript s indicates the variable was seasonally adjusted. The subscript t indicates the current quarter while t-1 and t-2 indicate the previous and two quarters ago, respectively.

4. Unfilled Orders

$$U_t = 56{,}136.3 + \underset{(5.38)}{157.3}\, C^{s\ misc.}_{t-1} + \underset{(5.30)}{.589}\, U^{s}_{t-1} - \underset{(2.37)}{1{,}549.3}\, P_{w_{t-1}}$$

$$- \underset{(4.81)}{.215}\, N_{t-1}$$

5. Accounting

$$Q_t = -31{,}855.9 + \underset{(45.3)}{1.07}\, N_t - \underset{(5.85)}{1.21}\, U_t + \underset{(6.76)}{1.08}\, U_{t-1}$$

Demand Relation

The demand relation was formulated with price (P_t) as the dependent variable and new orders (N_t), wholesale inventories ($I^{s}_{w_t}$), the lagged change in wholesale prices ($P_{w_{t-1}} - P_{w_{t-2}}$), residential construction put-in-place ($C^{s\ res.}_{t-1}$) and last quarter's price (P^{s}_{t-1}) as independent variables.

Unlike the demand relation for sanded plywood, the present demand relation includes a construction activity indicator (residential construction put-in-place). However, total construction put-in-place was also reflected through the wholesale inventory relation as with the sanded model.

This is true despite the fact that (in 1962) a relatively smaller proportion of unsanded plywood was sold directly to contractors and retail dealers, bypassing wholesalers, than was the case with sanded plywood./1 Whether or not this was the case during the sample period is not known. However, the explanation for the appearance of $C^{s\ res.}_{t-1}$ undoubtedly lies in the fact that such a large proportion of unsanded plywood production is used in residential construction (60.4% in 1962).

/1 According to data made available by the Douglas Fir Plywood Association, only nine percent of total unsanded plywood production was sold directly to retailers and final users in 1962, while the figure for sanded plywood production was approximately 12 percent.

The variable is such an important determinant of demand that it cannot be omitted from the primary relation.

The present demand relation further differs from the demand for sanded plywood in that the price of lumber does not appear as a significant variable, but the lagged mill plywood price (P_{t-1}) does so appear. No reason is immediately apparent that the price of lumber should be significant in the sanded plywood relation but not in the unsanded relation. Lagged mill price in the present relation is presumed to be a price expectation variable.

The sign on the coefficient of the change in wholesale prices, another expectation variable, is (reasonably) the same as in the previous model.

Supply Relation

The supply relation is identical to the relation developed for sanded plywood except that an additional variable, the change in unfilled orders (${}^{s}\Delta U_{t-1}$), is added and the lagged mill price (${}^{s}P_{t-1}$) is now seasonally adjusted.[/1] The equation shows a positively sloped supply curve and sawmill workers' wages (B_{t-1}) is again considered to reflect the productivity of labor.

Wholesale Inventory Relation

In adding (unsanded) mill price and production to the inventory relation, the lagged inventory variable ($I_{w_{t-1}}$) was eliminated. However, the price of sanded plywood the preceding year (${}^{s}P^{sand.}_{t-4}$) was retained. Again, total construction put-in-place was seen to influence

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/1 $\quad {}^{s}\Delta U_{t-1} = {}^{s}(U_{t-1} - U_{t-2})$

demand through the inventory equation and had the expected positive sign on its coefficient.

A reduced form equation for I_{w_t} can be formulated since the addition of P_t and Q_t in the relation made the system solvable for I_{w_t} in terms of all the other variables./1 The simultaneous determination of wholesale inventories along with P_t, N_t, and Q_t appears to make the present relation a more reasonable one than the sanded relation for wholesale inventories.

Unfilled Orders Relation

As is indicated by the relatively high R^2 value (.756) a good deal more success was had in explaining the level of unfilled orders for unsanded plywood than was had in the previous relation for sanded plywood (.438)./2 As previously stated, however, little can be said about the variables (or the signs on their coefficients) that appear in this mixed relation.

Accounting Relation

As in the sanded relation, the signs on the coefficients, being close to 1.0, indicate a true accounting relation. Here (although not in the previous model) the sign on the constant term lends support to the contention of a fall-down factor between shipments and production (see f.n. 1, Page 12)./3

/1 See Page 16 for discussion of reduced form equations.

/2 See Page 12.

/3 It is seen that by transposing the constant term to the left-hand side of the equation, production would have to have been increased to have eliminated the constant error in the relation.

Quantitative Analysis of Price Determining Forces

Table 6 shows the estimated responsiveness of certain variables to changes in other variables for selected time periods.

Columns two and three of Table 6 show that the estimated elasticities of supply were, as was true for the sanded model, of greater magnitude than the estimated elasticities of demand. In fact, the differences between the coefficients of elasticity are even greater in the present case. Despite the greater flexibility that producers of sanded plywood enjoy (i.e., they can switch production to unsanded types) it appears that industry production of unsanded plywood has been more sensitive to price changes than has been the case for sanded plywood.

Another difference between the sanded and unsanded plywood markets is indicated by the fact that, whereas in the previous model price was more inflexible with respect to production than with respect to new orders, in the present situation, price was found to be more inflexible with respect to new orders than with respect to production. This fact suggests that producers, not buyers, may have the greatest leverage in the unsanded plywood market.

Referring to the last column in Table 6, it appears that the response of new orders with respect to residential construction put-in-place was approximately the same as the elasticity of new orders with respect to total construction put-in-place in Table 3. Thus the influence of residential construction activity upon the demand for unsanded plywood was estimated to be approximately equal to the influence of total construction activity upon the demand for sanded plywood.

Table 6. Estimated Response of P_t, N_t, and Q_t During Selected Periods - Unsanded Douglas Fir Plywood

	Demand[a]	Supply	Demand	Supply[b]	Construction[c]
Assumed Values of Variables	R of P_t / Q_t	R of Q_t / P_t	R of N_t / P_t	R of P_t / N_t	R of N_t / $S_{C\,t-1}^{res.}$
1950-1960 Av.	-.159	12.00	-5.65	.093	1.99
1961 - Q1	-.441	4.32	-2.01	.261	1.13
1961 - Q2	-.447	4.26	-2.22	.236	1.08
1961 - Q3	-.390	4.48	-2.42	.217	1.28
1961 - Q4	-.451	4.22	-2.13	.247	1.25

[a] To obtain these estimates the accounting relation was solved for N_t and substituted into the demand relation, thus obtaining demand in terms of Q_t. R of P_t means the percentage change in P_t (price) in response to a one percent change in Q_t (quantity produced).

[b] In this case, the accounting relation was solved for Q_t and substituted into the supply relation, thus obtaining supply in terms of N_t.

[c] These are calculated from the RF coefficients of the 1950-1960 sample period (see Table 7).

Prediction and Forecasts of Prices

The least squares reduced form coefficients for the unsanded plywood model (equations) are given in Table 7.[/1] From these equations, forecasts of price, new orders and production were made.

Figure 8 gives real and estimated (predicted) average prices for unsanded plywood for the period, 1950-1960, and forecasted prices for 1961.

In the preceding section it was observed that the RF (reduced form) price line appeared to lead real prices in downturns and upturns during most of the period.[/2] In Figure 8 no leading is indicated; however, the RF estimates are extremely close to real values in almost all cases. These estimates correctly indicated the direction real price would move from time t-1 to time t, 83 percent of the time during the entire 12-year period.

Estimation errors for the period are given in Figure 9.

Prediction and Forecasts of New Orders

Real, predicted and forecasted quarterly industry totals of new orders for unsanded plywood are given in Figure 10. Compared to the same results for sanded plywood, a good deal more of the variability present in the real data was accounted for by the predetermined variables in the present model. Estimation errors are given in Figure 11. RF estimates correctly indicated the direction of change in the real levels of new orders 79 percent of the time.

Prediction and Forecasts of Production

Figure 12 gives real and estimated (predicted) quarterly industry production totals for unsanded plywood for the period 1950-1960 and

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/1 See Page 16 for explanation of least squares reduced form equations.

/2 See Page 16.

Table 7. Coefficients of Reduced Form Equations for Unsanded Plywood[a]

Forecast Variable	Predetermined Variables						
	$(P_{w_{t-1}} - P_{w_{t-2}})$	$^{s}C^{res.}_{t-1}$	$^{s}P_{t-1}$	$^{s}\Delta U_{t-1}$	B_{t-1}	$^{s}C^{misc.}_{t-1}$	$^{s}U_{t-1}$
P_t	.410	.00191	.320	.0000417	-.525	-.0225	.0000698
N_t	4,410.9	243.5	306.7	.370	12,345.6	687.3	.0368
Q_t	2,829.9	251.2	-2,500.5	-.0313	8,775.9	608.8	-.279

Forecast Variable	Predetermined Variables						
	$P_{w_{t-1}}$	N_{t-1}	$^{s}P^{sand.}_{t-4}$	$P_{w_{t-4}}$	$^{s}C^{tot.}_{t-1}$	U_{t-1}	Constant
P_t	.391	-.0000164	.0607	-.305	.00645	.0000333	97.54
N_t	-4,433.5	-.131	-2,252.3	3,757.9	-212.7	-.846	-830,517.0
Q_t	2,445.1	.228	-1,826.4	1,215.2	-245.4	.241	-433,987.2

[a] The equations are simple linear equations.

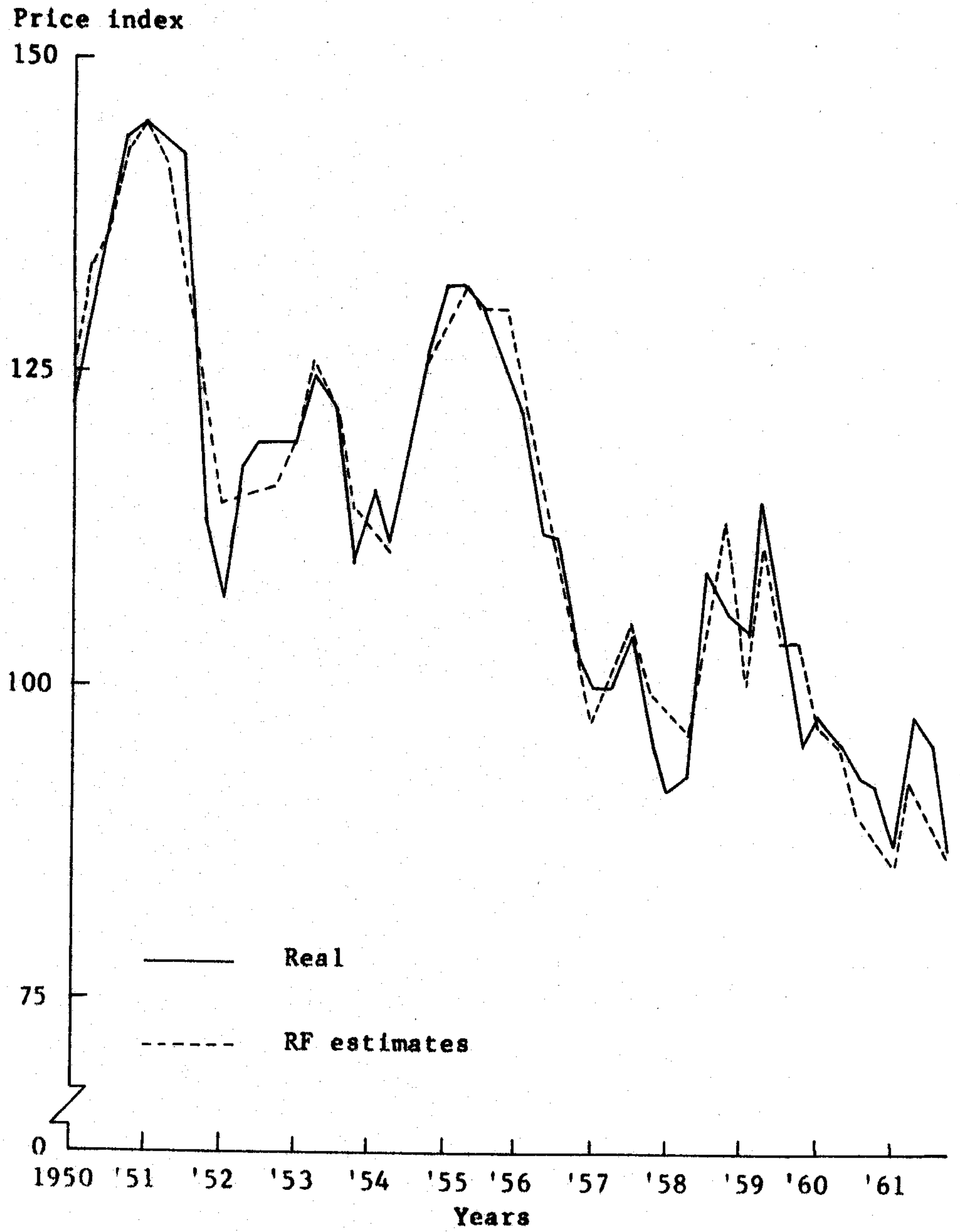

Figure 8. Quarterly index of average prices, real and RF estimates, Douglas fir plywood, unsanded types 1950-1961 (1949 average = 100).

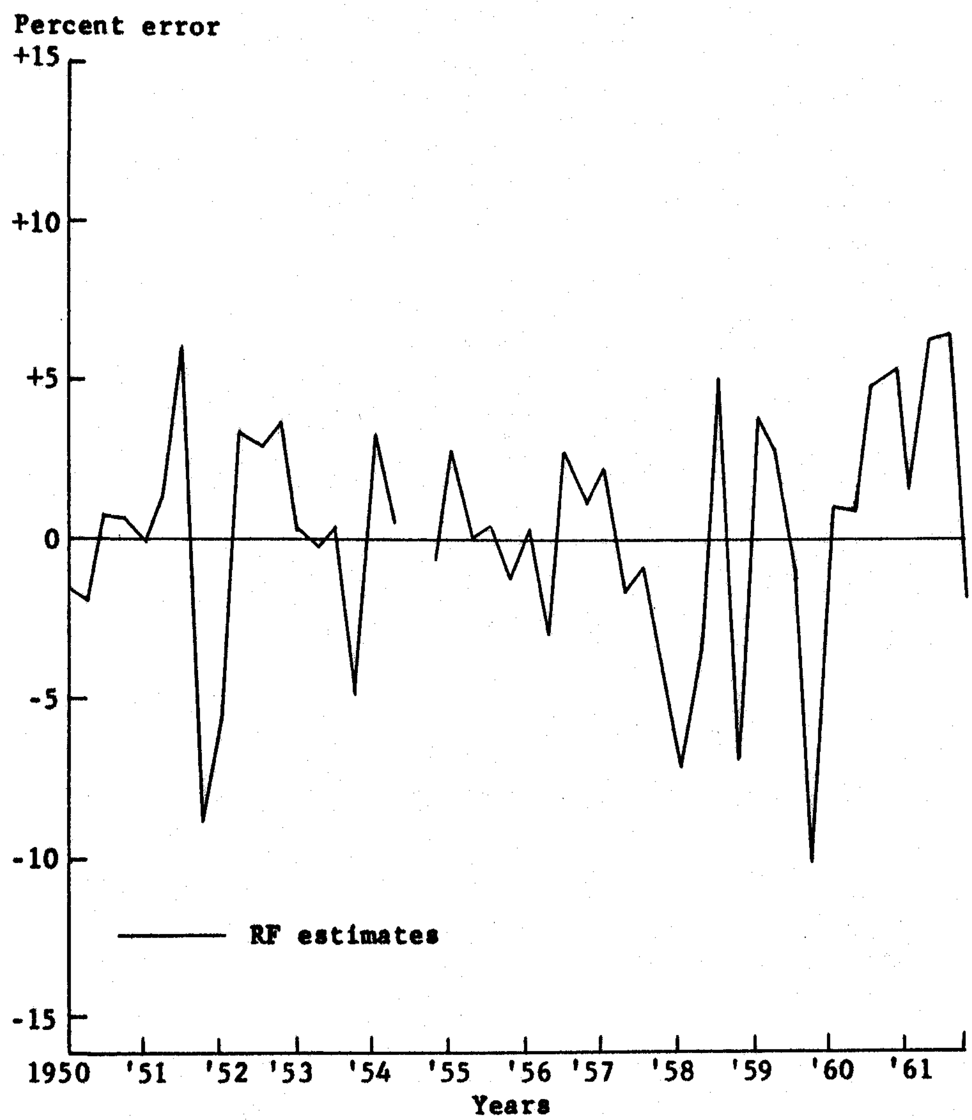

Figure 9. Reduced form estimation errors (as percent of real values) - Quarterly price index of Douglas fir plywood, unsanded types, 1950-1961.

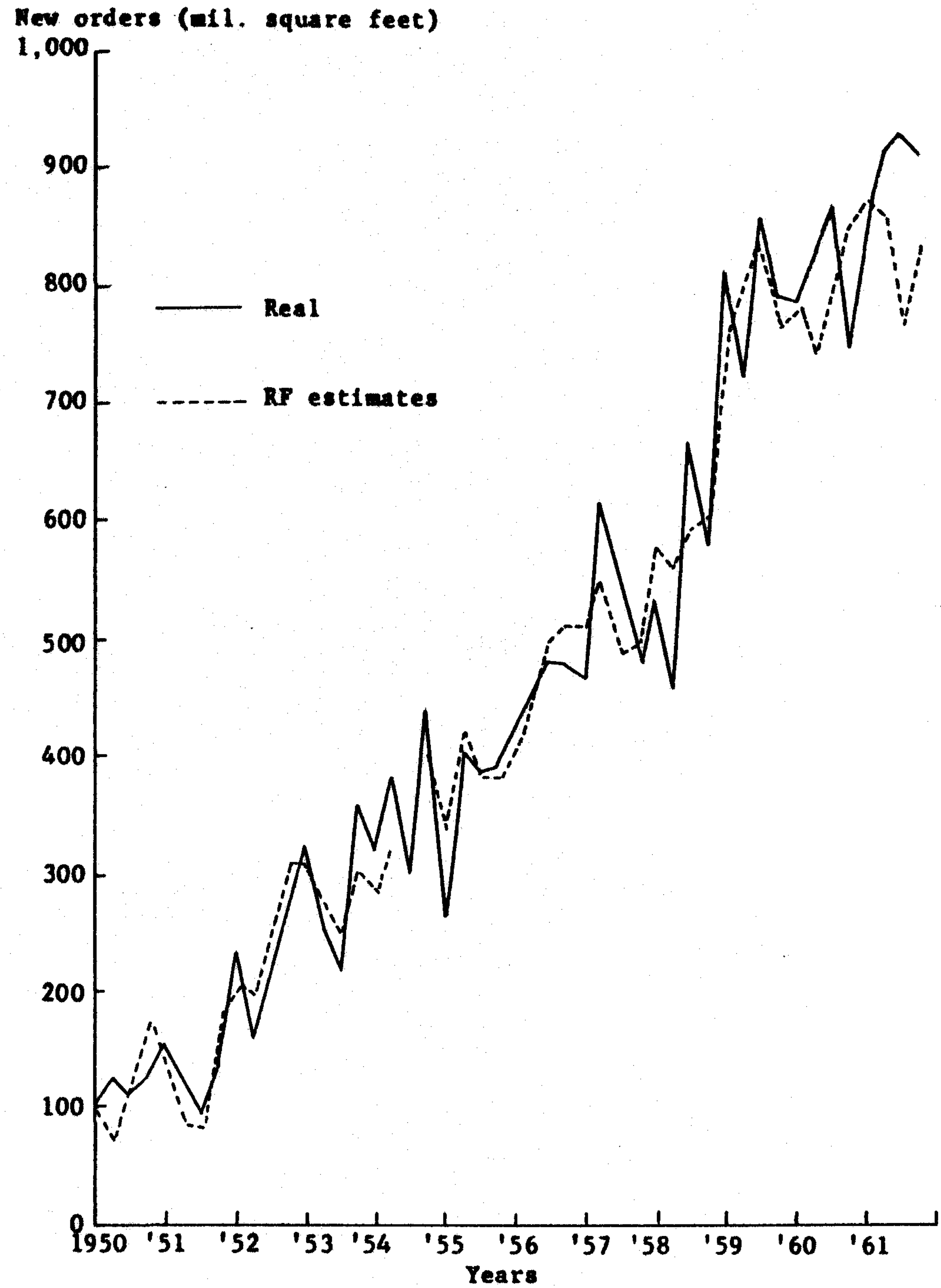

Figure 10. Quarterly totals of new orders, real and RF estimates, Douglas fir plywood, unsanded types, 1950-1961.

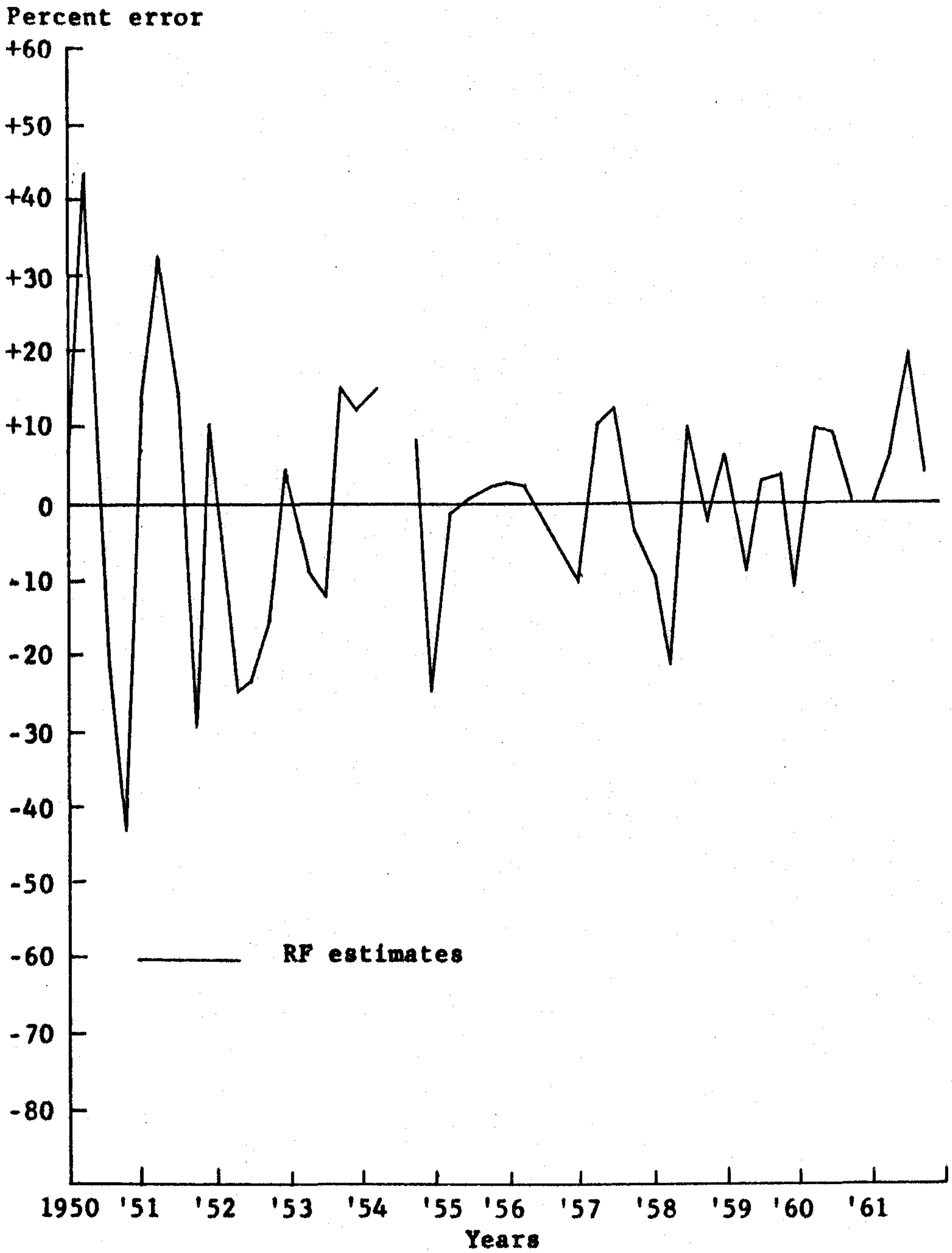

Figure 11. Reduced form estimation errors (as percent of real values) - Quarterly totals of new orders, Douglas fir plywood, unsanded types, 1950-1961.

forecasted values for 1961. Again the effect of the strike in the third quarter of 1954 is evident. The direction of change in the real data was accurately indicated by the RF estimates 70 percent of the time during the entire 12-year period.

Finally, estimation errors are indicated in Figure 13.

1961 Forecasts

Table 8 presents the numerical values of the unsanded plywood market forecasts and real values for the first year outside of the sample period./1

While, in general, reduced form estimation of prices, new orders, and production over the sample period was apparently more successful in the case of unsanded plywood, the above forecasts of the same variables for the year 1961 show little or no improvement over those for sanded plywood.

The possibility of downward bias in the RF forecasts was again suggested by the fact that nine of the 12 forecasts given underestimated the real data.

Forecasts correctly indicated the direction of change of real prices, new orders, and production eight out of 12 times. In the second and third quarters of 1961, forecasts underestimated real prices by approximately $3.78 per thousand square feet./2 Percentagewise, these forecasts

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/1 See Appendix 2 for an explanation of how 1961 forecasts were obtained.

/2 The price data given in Table 8 are index numbers with base (100) = $61.25.

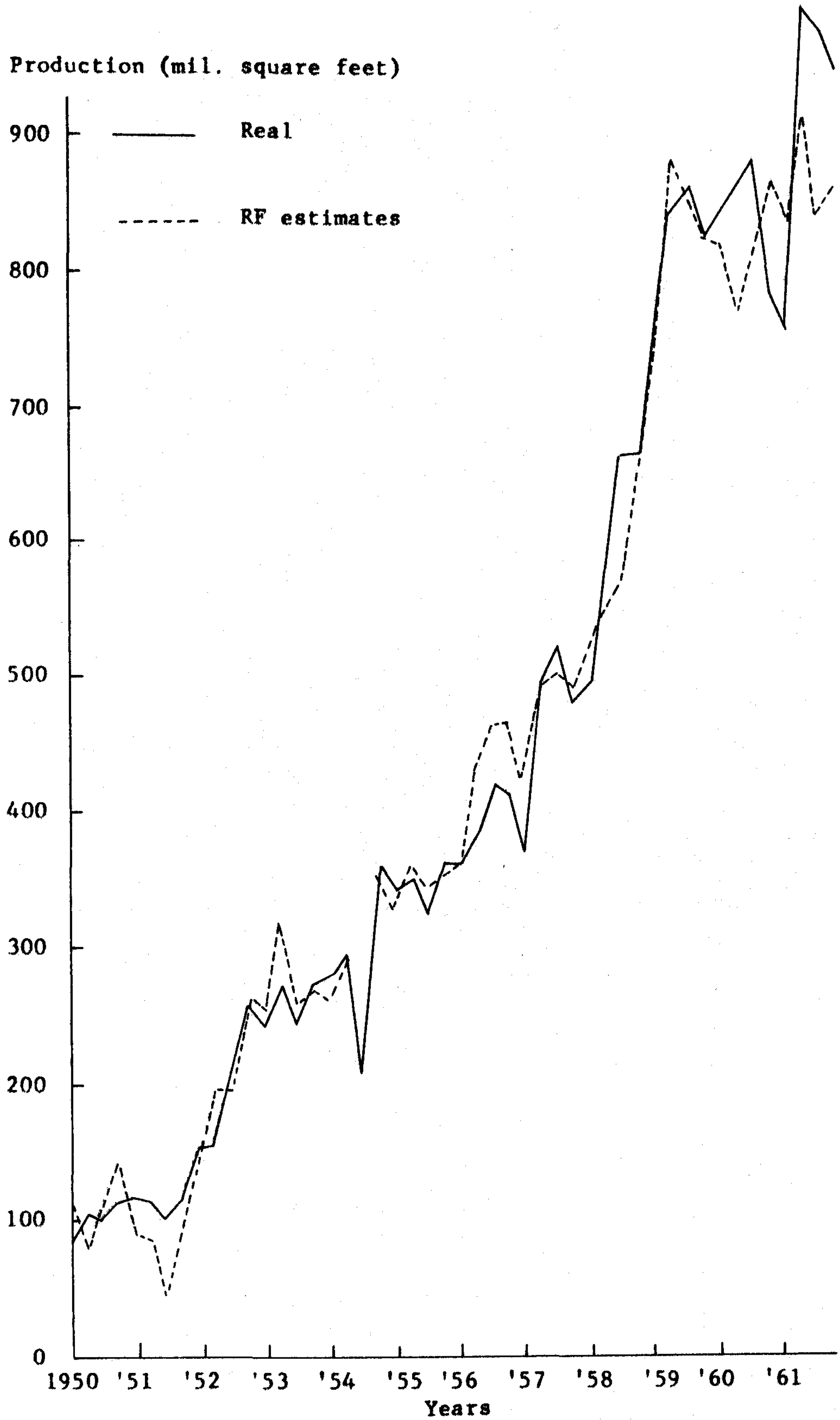

Figure 12. Total quarterly production, real and RF estimates, Douglas fir plywood, unsanded types, 1950-1961.

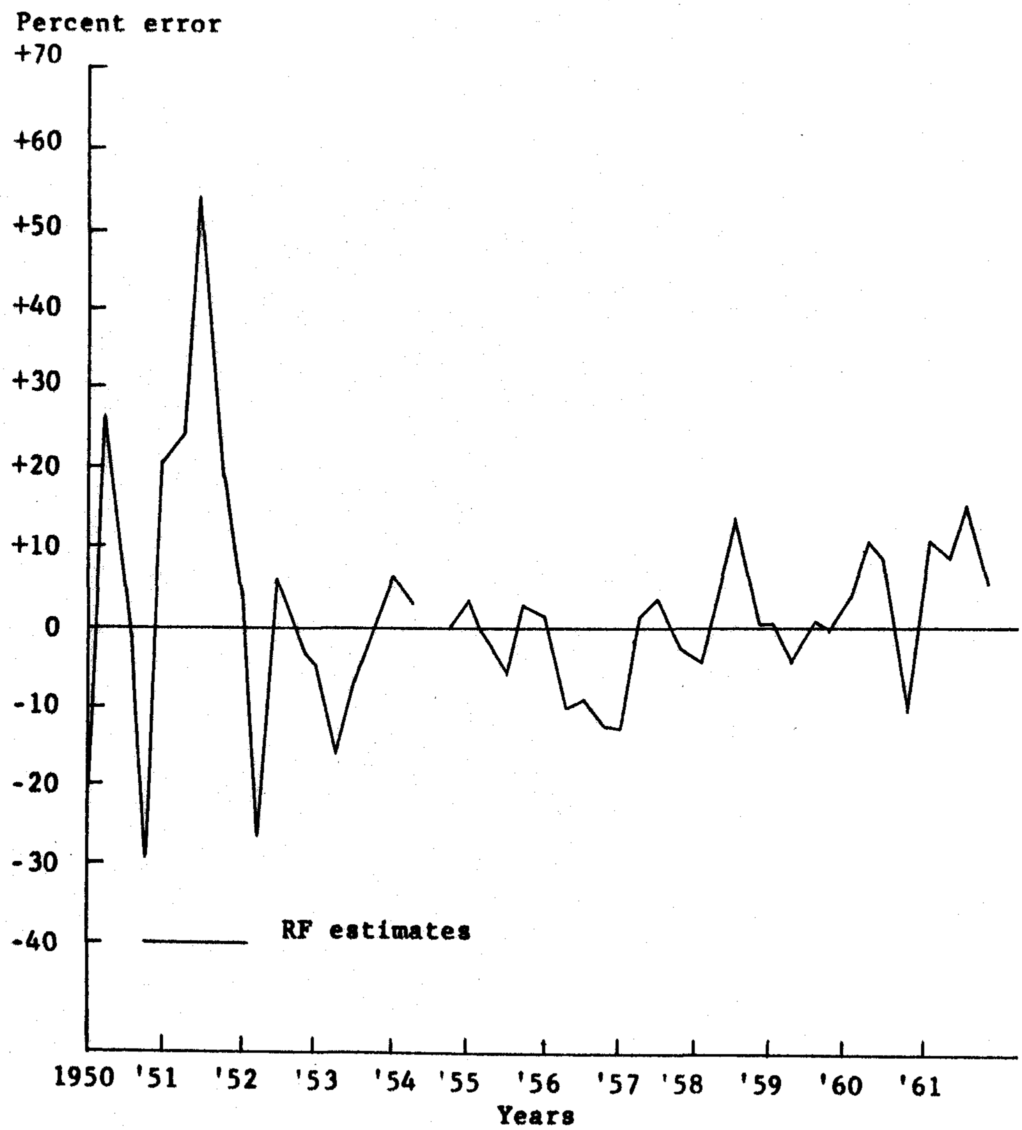

Figure 13. Reduced form estimation errors (as percent of real values) - Total quarterly production, Douglas fir plywood, unsanded types, 1950-1961.

Table 8. 1961 Forecasts and Real Values for Unsanded Plywood Data

1961	Variable[a]	Forecast	Dir. of Change[b]	Real Value	Dir. of Change[b]
Qtr. 1	P_t	85.0	↓	86.5	No change
	N_t	875.3	↑	868.8	↑
	Q_t	835.8	↑	754.3	↓
Qtr. 2	P_t	91.8	↑	98.0	↑
	N_t	855.3	↓	909.8	↑
	Q_t	909.7	↑	992.6	↑
Qtr. 3	P_t	88.5	↓	94.7	↓
	N_t	751.8	↓	927.0	↑
	Q_t	823.4	↓	974.7	↓
Qtr. 4	P_t	87.9	↓	86.5	↓
	N_t	880.3	↓	907.4	↓
	Q_t	891.5	↓	946.6	↓

[a] N_t and Q_t are given in millions of square feet (3/8" basis).

[b] Direction of change is the direction indicated by the estimate away from the real value of the variable in the preceding quarter.

underestimated real values by greater amounts than at any time during the sample period. However, greater absolute percentage errors occurred during the sample period (Figure 11). In the first and fourth quarters, forecast errors amounted to less than $1 per thousand square feet. The average fluctuation of the real price between quarters of 1961 was $4.27 per thousand square feet.

IMPLICATIONS OF THE ANALYSIS

Evaluation of the Statistical Models

In the two preceding sections, statistical models of the sanded and unsanded fir plywood markets were described. Although Student values for the various structural coefficients were reported, it should be emphasized that tests of significance concerning these coefficients were in no way meant to be tests of the models, _per se_. Because of the empirical approach used to discover the structural characteristics of the two markets, it is doubtful that many degrees of freedom remained for conducting such tests. Rather, the t values give some indication of the relative reliability (significance) of the various variables in each relation, assuming that descriptive equations have been obtained.

Thus, for testing any hypotheses set forth in this investigation, primary attention is directed to the results of the prediction of market variables over the sample period, and more importantly, to forecasts (for 1961) outside of the sample period. It is the degree of success with which a model explains actual market behavior that constitutes a critical test of the underlying hypothesis.

Unfortunately, no exact quantitative tests are available for testing predictability for the reduced form estimates presented here, and a degree of subjective judgment must be relied upon.[/1] In time, of course, as more forecasts are obtained, standard errors of forecasts could be calculated and tolerance intervals established. This is not to say, however, that no systematic evaluation procedures can be employed. Thus, throughout the preceding sections, the implications of the signs and magnitudes of the coefficients have been discussed in the light of previously indicated qualitative knowledge about the market. The success with which forecasts and estimates indicated the direction (as well as the magnitude) of change in the real variables was stated, and the characteristics of the percentage estimation errors were presented graphically. Also, the elasticities of various variables were discussed and rationalized when possible.

Out of this considerable amount of information and evaluation, a picture emerges which indicates the overall adequacy or inadequacy of the models in reflecting the true price determining forces or process of the markets. In the present analysis, not only did the strategic variables in each relationship appear in conformance with an *ex ante* knowledge of their fundamental influence in the various relations, but the critical forecasts of the dependent variables outside of the sample period were extremely successful.

/1 Hildreth and Jarett (14, pp. 119-126) discuss "tests of predictive usefulness" on the calculated residuals of the various structural relations. What relation these tests have to forecasts of market data utilizing all the relations in a structural model, is not clear. Hooper and Zellner (15, pp. 544-555) discuss the construction of probabilistic forecast regions applicable to reduced form estimates of certain simultaneous equations models but the analysis is not extended to establish the properties of forecasts from equations containing lagged endogenous variables in the set of predetermined variables and based on small samples of data.

The above implies that the various assumptions made concerning price determining forces cannot be rejected, viz., the assumptions of competitiveness, linear relationships, and simultaneity./1 It is contended that these conclusions and results presented compel tentative acceptance of the hypothesis that the economic models for sanded and unsanded plywood markets, are generally consistent with the true price determining forces in the industry and are useful for economic analysis and forecasting. This conclusion was generally supported by a number of industry spokesmen to whom the results were reported.

Applications of the Analysis

The discussion of elasticities indicated that a considerable amount of information is obtainable from mathematical equations describing the industry. Not only are forecasts of the values of the dependent variables available, but quantitative predictions concerning any of these variables may also be made (using coefficients of elasticity) when one (or more) of them is assumed to differ from its predicted value by a given amount./2

/1 These assumptions are implicit in the models. That is, the demand and supply equations are appropriate for a competitive market equilibrium, the equations are of linear form, and P_t, N_t, and Q_t are determined by solving the complete set of equations simultaneously.

/2 Quarterly forecasts could be made from the present models approximately 20 days after the beginning of the forecast period when construction activity, and wholesale plywood and lumber price data become available from the U.S. Department of Commerce. However, if earlier forecasts were desired, preliminary estimates of these data could be obtained (based on the first two months of the relevant quarter).

This additional information suggests the feasibility of a game theoretic approach to production management decision problems by any firm in the industry wishing to make assumptions concerning competitors' and buyers' behavior.[/1]

Of course, the most valuable use, from a microeconomic standpoint, to which the present type of analysis could be put, would be in the forecasting of market price, from which optimizing linear programming solutions to production and marketing decisions could be found. The potential in this approach for scheduling profit maximizing operations would be extremely large. However, with price and quantity forecasts available to the entire industry, the problem of the forecasts themselves influencing market behavior could be encountered. Speculation on this point by industry spokesmen ranged from "no effect" to "considerable effect" and indicated no concensus of opinion. If the forecasts should, in fact, significantly influence market behavior, no alternative would exist but to fall back on the game theoretic approach mentioned above. From a theoretical standpoint, if sufficient knowledge and rational behavior is attributed to plywood producers, the argument can be made that this latter development (production decisions based on game theoretic decision criteria) would lead to a more stabilized market situation in the

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/1 Payoffs could be calculated for various states of nature (for example, "best possible" and "worst possible" deviations of Q_t and N_t from predicted values) and either historical or subjective probabilities attached to the various events. For an introduction to game theory and decision problems, see Luce and Raiffa (19).

industry.[1] Thus, even if forecasts do affect market behavior, the present analysis could be used to contribute to a more stable situation in the industry. More importantly, this would be a spontaneous result, accomplished without collusion and without breach of federal restraint-of-trade legislation.

From a macroeconomic or policy point of view, the present type of analysis is again extremely useful. For example, the effect upon demand for unsanded plywood of a specified government expenditure for public construction could easily be estimated from the coefficient of response of new orders (or price) with respect to $C_{t-1}^{s\ mis.}$.[2] Similarly, the effect of specified production quotas (or increases) upon mill price could be estimated.

Finally, of course, the present analysis is useful in describing, quantitatively, historical changes in price determining forces.[3]

Forecasting Several Time Periods into the Future

Forecasts from the models presented in this publication are not just limited to one quarter into the future. If a suitable basis can be found for estimating future values for the predetermined variables (construction put-in-place, mill workers' wages, lumber prices, etc.)

/1 This would result, for example, if producers adopted strategies that would minimize their maximum loss or maximize their minimum gain. "Minimax" concepts are discussed in Luce and Raiffa (19).

/2 This elasticity would be estimated from the least squares reduced form equation for N_t (or P_t).

/3 For example, historical changes in demand and supply elasticities could be traced.

forecast values for P_t, N_t, Q_t, U_t, and I_{w_t} can be reused as variables for forecasting P_{t+1}, N_{t+1}, Q_{t+1}, U_{t+1}, and $I_{w_{t+1}}$. This process can be repeated indefinitely, as long as one is willing to assume future values for the predetermined variables and that the price determining forces have not changed in their relative influence.[/1]

The most serious difficulty here would undoubtedly be that of supplying future estimates of wholesale prices. Mill and wholesale prices undoubtedly move together and would probably be determined simultaneously in a more sophisticated market model than the general model hypothesized here.

Overproduction in the Plywood Industry

The contention has frequently been made that the basic ills of the Douglas fir plywood industry are due to overproduction, that "supply has exceeded demand" and that this has been the cause of unfavorable price movements during the period considered in this analysis. The economic models and the theory presented here should indicate that such statements must be made rather more carefully and explicitly if they are to be made meaningful.

It makes no economic sense to say merely that "supply has exceeded demand"; such a statement has meaning only when supply and demand at

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/1 This need not be done blindly. Maisel (20), for example, has developed an econometric model for forecasting residential construction activity. Where such forecasts were not already available, trend estimates could be derived from the time series data given in the Appendix.

a specific price is being considered, given a set of conditions concerning the relevant "shift" variables. Thus, for a given price in the first quarter of 1961, it is possible to indicate the volume of production that must be forthcoming to exactly satisfy demand at that price./1 In a purely competitive situation, it is presumed that the price level established will be that price which will equate supply and demand at the level of zero profits in the industry (in the long run)./2 Thus, it appears to be the volatility of price, not its downward trend, that requires explanation by economic theory and research.

The present analysis has isolated some of the factors, the combined influence of which account for much of the variation in plywood prices. However, in some instances, where estimation errors were exceptionally large, additional unidentified factors appear to have been at work.

The assumption of competitiveness in the fir plywood industry cannot be rejected on the basis of this analysis. The explanation for extreme price fluctuations could, perhaps, be found in rigidities that might exist at crucial points in the market structure. This is an empirical question to which the present analysis could be extended. Much fertile ground yet lies open for research in this important industry of the Pacific Northwest.

/1 This quantity is subject, of course, to the statistical properties of the stochastic model.

/2 Zero profits means no profits above the remuneration to entrepreneurship required to keep the resources employed. One would expect declining prices in a competitive industry that has realized productivity gains over time.

APPENDIX I

Definitions, Data, and Data Sources

APPENDICES

APPENDIX TABLE 1. Plywood and Related Data, by Quarter. 1949-1961.

Year	Quarter	t	Variable							
			P_t Sand.	P_t Unsand.	Q_t Sand.	Q_t Unsand.	N_t Sand.	N_t Unsand.	U_t Sand.	U_t Unsand.
1949	1	--								
	2	--								
	3	--								
	4		097.1	106.1	0467838.	114702.	0586939.	175320.	284829.	073447.
1950	1	1	108.6	122.5	0419515.	086534.	0388732.	100239.	303424.	071173.
	2	2	118.9	130.6	0530631.	105617.	0511445.	124680.	285417.	068698.
	3	3	126.5	137.2	0533071.	102294.	0515178.	109280.	298442.	059402.
	4	4	138.0	143.7	0592113.	113623.	0538864.	124762.	268885.	053906.
1951	1	5	138.0	145.3	0623215.	118708.	0636439	151233.	320405.	068909.
	2	6	140.6	143.7	0644031	117235.	0551363.	122675.	261444.	057390.
	3	7	140.6	142.1	0564612.	099637.	0483286.	094807.	229439.	041765.
	4	8	121.4	114.3	0489967.	117179.	0467224.	136424.	209046.	052589.
1952	1	9	112.5	107.8	0564346.	157324.	0651172.	231175.	323504.	103282.
	2	10	120.1	117.6	0561406.	158345.	0440874.	154902.	231774.	080170.
	3	11	120.1	119.2	0509924.	212348.	0440256.	207179	192449.	083661.
	4	12	116.3	119.2	0542474.	260364.	0567954.	272215.	246146.	099565.
1953	1	13	116.3	119.2	0696956.	243605.	0706593.	318941.	359961.	144893.
	2	14	124.0	125.7	0751453.	273721.	0550091.	252961.	214051.	097069.
	3	15	120.1	122.5	0551560.	243195.	0436297.	218803.	134575.	061885.
	4	16	106.1	109.4	0665478.	274463.	0686614.	356872.	220594.	096352.
1954	1	17	112.5	115.9	0724667.	280419.	0634938.	319856.	178065.	088499.
	2	18	106.1	111.0	0696969.	297280	0699017.	381380.	206506.	111196.
	3	19	115.0	119.2	0422372.	207094.	0533193.	298621.	331391.	169957.
	4	20	117.6	125.7	0824724.	360224.	0783747.	433251.	355105.	164054.

APPENDIX TABLE 1 (Cont'd). Plywood and Related Data, by Quarter. 1949-1961.

Year	Quarter	t	Variable							
			P_t Sand.	P_t Unsand.	Q_t Sand.	Q_t Unsand.	N_t Sand.	N_t Unsand.	U_t Sand.	U_t Unsand.
1955	1	21	118.9	132.3	0870287.	343503.	0515678.	265653.	390173.	178593.
	2	22	120.1	132.3	0906422.	357765.	0799858.	401130.	336704.	166591.
	3	23	121.4	130.6	0787457.	328668.	0798566.	384494.	394134.	170528.
	4	24	121.4	127.4	0998210.	367331.	0851145.	391403.	323999.	125999.
1956	1	25	124.0	122.4	0994871.	367462.	0849589.	417755.	268698.	120720.
	2	26	117.6	112.7	0861778.	388989.	0702546.	455455.	182839.	118876.
	3	27	104.8	111.0	0819248.	423920.	0745641.	478647.	181760.	099168.
	4	28	095.9	102.9	0901474.	416471.	0887614.	476892.	223305.	082173.
1957	1	29	097.1	099.6	0890146.	376065.	0794495.	461006.	195557.	118843.
	2	30	101.1	099.6	0942252.	502920.	0833287.	613366.	158668.	152186.
	3	31	098.4	104.5	0781643.	527642.	0834470.	553358.	267142.	120020.
	4	32	099.7	096.3	0893649.	481196.	0747149.	478543.	179050.	088189.
1958	1	33	095.9	091.4	0937020.	498149.	0926289.	526357.	197528.	121066.
	2	34	093.3	093.1	0940298.	581694.	0963768.	458245.	193642.	155329.
	3	35	102.2	109.4	0927859.	663528.	0989497.	665189		
	4	36	109.9	106.1	1017967.	663677.	0896137.	581939.		
1959	1	37	109.9	104.5	1078518.	751748.	1237074.	806616.	CONFIDENTIAL	CONFIDENTIAL
	2	38	118.9	114.3	1181394.	840678.	0974259.	719977.		
	3	39	108.6	104.5	1021687.	861588.	1101460.	856881.		
	4	40	097.1	094.7	1192350.	824385.	1162878.	789279.		
1960	1	41	097.1	098.0	1251859.	841406.	1197068.	779867.		
	2	42	094.6	098.0	1130937.	859968.	1005460.	812328.		
	3	43	092.0	093.1	0981782.	880427.	1008755.	965595.		
	4	44	097.1	091.4	1038433.	785997.	0941290.	746824.		

APPENDIX TABLE 1 (Cont'd). Plywood and Related Data, by Quarter. 1949-1961.

Year	Quarter	t	Variable							
			P_t Sand.	P_t Unsand.	Q_t Sand.	Q_t Unsand.	N_t Sand.	N_t Unsand.	U_t Sand.	U_t Unsand.
1961	1	45	086.9	086.5	1165960.	754283.	1387326.	868794.	CONFIDENTIAL	
	2	46	094.6	098.0	1246691.	992562.	1134228.	909751.		
	3	47	093.3	094.7	1165177.	974658.	1215804.	927046.		
	4	48	089.5	086.5	1272686.	946616.	1259056.	907379.		
	Quarter		Seasonal Index Numbers							
	1		.98	.98						1.13
	2		1.01	1.01						.99
	3		1.00	1.01						.97
	4		.98	.98						.89

Time			Variable							
Year	Quarter	t	B_t	Pw_t	Iw_t	L_t	s tot. C_t	s ind. C_t	s res. C_t	s mis. C_t
1949	1	--								
	2	--								
	3	--								
	4	--	100.1	094.0		097.1	06127.	2045	2721.	0951.
1950	1	1	099.7	099.7		102.3	06440.	2099.	2909.	0954.
	2	2	103.6	101.1		110.3	06882.	2189.	3262.	0986.
	3	3	108.3	109.4		121.5	07297.	2264.	3629.	0987.
	4	4	109.1	115.7		123.8	07234.	2434.	3321.	1039.
1951	1	5	109.6	117.6		126.4	07203.	2587.	3160.	1098.
	2	6	112.9	117.7		125.6	07119.	2783.	2699.	1146.
	3	7	118.5	116.2		121.9	07025.	2806.	2680.	1154.
	4	8	118.3	108.8		120.8	07030.	2717.	2746.	1173.
1952	1	9	117.5	104.9	CONFIDENTIAL	120.6	07226.	2758.	2798.	1248.
	2	10	118.8	105.6		120.6	07257.	2745.	2807.	1281.
	3	11	123.0	105.9		120.5	07205.	2811.	2803.	1257.
	4	12	123.6	103.6		120.0	07387.	2828.	2908.	1267.
1953	1	13	123.2	110.5		120.5	07562.	2904.	2973.	1335.
	2	14	123.7	112.3		120.9	07611.	2963.	3012.	1291.
	3	15	124.2	110.6		119.3	07518.	2946.	2925.	1323.
	4	16	123.0	103.9		116.6	07616.	3009.	2915.	1327.
1954	1	17	123.3	103.8		115.6	07744.	3024.	2957.	1400.
	2	18	124.5	100.6		115.2	07946.	2998.	3148.	1417.
	3	19	126.4	103.9		118.8	08174.	3021.	3328.	1469.
	4	20	125.0	104.3		119.6	08381.	3003.	3557.	1469.
1955	1	21	127.8	104.8		120.8	08611.	3095.	3877.	1483.
	2	22	128.8	105.3		123.9	08946.	3126.	3921.	1528.
	3	23	128.8	105.8		126.2	08853.	3130	3830.	1546.
	4	24	129.6	105.9		126.5	08696.	3135.	3676.	1554.

(cont'd)

		Time	Variable							
Year	Quarter	t	B_t	Pw_t	Iw_t	L_t	s tot. C_t	s ind. C_t	s res. C_t	s mis. C_t
1956	1	25	132.6	107.5		128.6	08633.	3166.	3551.	1582.
	2	26	133.7	103.5		130.1	08764.	3212.	3525.	1677.
	3	27	134.1	100.6		126.9	08663.	3256.	3429.	1667.
	4	28	133.2	095.2		123.1	08649.	3268.	3392.	1647.
1957	1	29	133.5	196.6		121.9	08781.	3338.	3348.	1753.
	2	30	134.0	097.1		120.9	08768.	3408.	3302.	1693.
	3	31	134.4	095.6		119.2	08646.	3361.	3300.	1657.
	4	32	133.3	096.3		117.0	08800.	3364.	3342.	1762.
1958	1	33	131.6	094.0		116.1	08756.	3271.	3376.	1784.
	2	34	132.9	093.8		116.5	08565.	3150.	3347.	1753.
	3	35	135.4	100.2	CONFIDENTIAL	118.9	08770.	3078.	3536.	1813.
	4	36	137.3	100.6		120.3	09297.	3064.	3882.	2045.
1959	1	37	137.9	102.4		123.2	10003.	2994.	4600.	2120.
	2	38	138.7	106.1		128.7	10267.	3024.	4826.	2135.
	3	39	143.1	100.0		129.8	10138.	3044.	4804.	1994.
	4	40	145.2	096.1		126.5	09748.	2965.	4577.	1884.
1960	1	41	145.6	097.1		126.0	09642.	3172.	4297.	1853.
	2	42	146.5	095.8		124.6	09620.	3229.	4173.	1926.
	3	43	149.4	095.5		119.6	09692.	3298.	4140.	1969.
	4	44	149.3	096.1		115.5	09759.	3399.	4066.	2018.
1961	1	45	148.6	096.4		113.9	09712.	3461.	3798.	2171.
	2	46	150.2	097.2		117.0	09657.	3371.	3990.	1930.
	3	47	152.2	093.3		115.8	09968.	3316.	4306.	1980
	4	48	151.8	092.8		114.3	10312.	3293.	4495.	2128

Quarter	Seasonal Index Numbers		
1	1.00	1.04	.99
2	1.00	1.08	1.00
3	1.00	.97	1.00
4	.99	.89	.99

Year	Quarter	Time t	D_t	W_t	A_t	S_t
1949	1	--				
	2	--				
	3	--				
	4	--			101.	
1950	1	1		50.22	103.	0627848.
	2	2		53.75	103.	0638716.
	3	3		60.24	105.	0667836.
	4	4		62.32	108.	0694551.
1951	1	5	21.03	59.97	111.	0717119.
	2	6	22.82	61.70	112.	0735410.
	3	7	17.04	62.27	114.	0747357.
	4	8	23.87	63.31	115.	0776515.
1952	1	9	27.15	61.72	117.	0808288.
	2	10	23.52	66.90	116.	0845494.
	3	11	26.61	65.95	119.	0865566.
	4	12	22.68	64.29	123.	0896506.
1953	1	13	16.84	61.45	125.	0926575.
	2	14	21.32	63.98	126.	0948077.
	3	15	19.38	62.57	128.	0960141.
	4	16	17.96	61.54	131.	0966628.
1954	1	17	13.19	63.12	133.	1036347.
	2	18	15.32	62.58	132.	1075711.
	3	19	15.92	65.92	134.	1077765.
	4	20	16.10	63.62	136.	1133262.
1955	1	21	17.15	68.35	136.	1177969.
	2	22	27.15	70.77	136.	1243411.
	3	23	30.23	72.17	138.	1276639.
	4	24	37.14	68.82	140.	1345825.
1956	1	25	37.52	68.80	142.	1421056.
	2	26	43.56	70.16	142.	1460901.
	3	27	45.00	71.35	145.	1506557.
	4	28	39.12	68.05	148.	1597492.
1957	1	29	37.18	72.31	150.	1634360.
	2	30	32.72	71.04	151.	1613846.
	3	31	33.36	66.99	154.	1641367.
	4	32	27.94	53.40	156.	1731028.

(Cont'd)

Year	Quarter	Time	Variable			
			D_t	W_t	A_t	S_t
1958	1	33	24.77	63.72	158.	1786875.
	2	34	22.52	65.57	158.	1869820.
	3	35	20.95	72.22	160.	1962463.
	4	36	19.89	68.92	162.	1979233.
1959	1	37	21.55	64.09	164.	1885444.
	2	38	23.53	70.52	164.	2000244.
	3	39	34.69	73.61	166.	2103464.
	4	40	37.70	76.89	169.	2169484.
1960	1	41	34.52	67.76	172.	2200684.
	2	42	35.44	64.94	172.	2245760.
	3	43	37.06	70.97	174.	3217740.
	4	44	32.32	67.73	177.	2399284.
1961	1	45	33.79	67.56		2471252.
	2	46	26.76	74.04		2492992.
	3	47	26.60	68.47		2560588.
	4	48	28.60	73.67		2580729.

Quarter	Seasonal Index Numbers
1	
2	
3	
4	

Definitions of Variables and Data Sources/1

P_t Index of quarterly (average) realized plywood mill prices, by sanded and unsanded types of plywood. Components of indexes are given in Table 2, Page 64. Sanded plywood, 1949 base = $78.25 per thous. feet. Unsanded plywood, 1949 base = $61.25 per thous. feet. Source: Sales data 1949-1961, from a sample of plywood firms.

Q_t Total quarterly industry production of Douglas fir plywood, by all sanded and unsanded types, in thousands of feet. Source: Plywood Quarterly Statistical Reports. Douglas Fir Plywood Association. Tacoma, Washington.

N_t Quarterly totals of new orders for Douglas fir plywood, by all sanded and unsanded types, in thousands of feet. Source: (same as Q_t).

U_t Average level of unfilled orders for Douglas fir plywood during last reported period of the quarter, by all sanded and unsanded types, in thousands of feet. Source: Data was provided privately by the Douglas Fir Plywood Association.

B_t Index of the average hourly earnings of sawmill employees in the Douglas fir region of Western Oregon and Western Washington. Includes shift differential and overtime pay. Source: West Coast Lumbermen's Association, Portland, Oregon.

P_{w_t} Index of wholesale plywood prices. Source: Housing Statistics, U.S. Housing and Home Finance Agency (see Bibliography).

I_{w_t} Average value of Douglas fir plywood inventory per warehouse (all types), by quarter, in constant (1947-49) dollars. Source: Confidential.

L_t Index of wholesale lumber prices (1947-1949 = 100) Source: Housing Statistics, U.S. Housing and Home Finance Agency. (see Bibliography)

/1 Only the current sources of data are listed. Value data is measured in current dollars unless otherwise indicated.

$^{s}C_t^{tot.}$ Total quarterly value of all new construction put-in-place in the U.S., seasonally adjusted, in constant (1947-49) dollars. Data is measured in millions of dollars. Source: Construction Reports (series C30), U.S. Bureau of the Census. (see Bibliography)

$^{s}C_t^{ind.}$ Total quarterly value of new industrial and commercial construction put-in-place in the U.S., seasonally adjusted, in constant (1947-49) dollars. Includes: Private sector - industrial, commercial, other nonresidential, public utilities (excludes agricultural); Public sector - nonresidential buildings. Source: (same as $^{s}C_t^{tot.}$).

$^{s}C_t^{res.}$ Total quarterly value of new residential construction put-in-place (both public and private) in the U.S., seasonally adjusted, in constant (1947-49) dollars. Source: (same as $^{s}C_t^{tot.}$).

$^{s}C_t^{misc.}$ Total quarterly value, public miscellaneous construction put-in-place in the U.S., seasonally adjusted, in constant (1947-49) dollars. Includes: military, highways, sewer and water, public service, and conservation and development. Source: (same as $^{s}C_t^{tot.}$).

D_t Average quarterly stumpage prices of Douglas fir (west side) in the Pacific Northwest. Source: U.S. Forest Service, Washington, D.C.

W_t Average quarterly price, weighted by volume, of No. 2 and No. 3 peeler logs and No. 2 sawlogs for Columbia River, Gray's Harbor and Puget Sound logging companies. Source: Pacific Northwest Loggers Association, Seattle, Washington.

A_t Index of average hourly earnings in contract building construction (1949 = 100). Housing Statistics, U.S. Housing and Home Finance Agency. (see Bibliography).

S_t Total industry quarterly capacity for production of Douglas fir Plywood (all types). Source: (same as Q_t).

APPENDIX 2

Explanation of 1961 Forecasts

Because of the ease with which RF estimates could be obtained, it was decided to keep the model up to date, so to speak, in estimating outside of the sample period (for 1961). This was accomplished by dropping off early observations from the sample and adding later observations (in computing new reduced form coefficients) as estimation progressed into 1961. Thus, for 1961, quarter 1, estimates were made from coefficients based on the regular sample period (1950-1960). For 1961, quarter 2, however, reduced form coefficients were computed from a new sample period obtained by dropping out observations for 1950, quarter 1, and adding observations for 1961, quarter 1. For 1961, quarter 3, the procedure was repeated (dropping out 1950, quarter 2, and adding 1961, quarter 2). Thus, estimates for each quarter of 1961 were based on a sample period of the immediately preceding 11 years. In this manner, the model was kept up to date so that the effects of structural change in the industry could be incorporated, through time, into the model via the changing values of the coefficients. The RF forecasts of P_t, N_t, and Q_t in Tables 5 and 8 were obtained by this procedure. All are forecasts for the first quarter outside of their respective sample periods.

APPENDIX 3

Investigation Procedures

Data and the sample period: The 11-year period, 1950-1960, was selected as the sample period for this analysis and data were gathered and summarized on a quarterly basis for that period. Elimination of the third quarter of 1954 from the analysis (because of an industry-wide strike during that period) reduced the total number of quarterly observations from the sample from 44 to 43 observations.

In addition, data were obtained for 1961 so that four quarterly forecasts could be made and compared with the actual values for data outside the sample period. This test of the models was considered to be the most meaningful and powerful one available.

The two price indexes (for sanded and unsanded types) were obtained from a sample of plywood firms and contain the weighted (by volume) realized prices of the grades and types given in Appendix Table 2. As can be seen from the table, these grades together represent the bulk of all plywood produced by the industry, and hence, individually, the bulk of their respective categories. Other data were obtained from the sources indicated in Appendix 1.

Specification of General Model

A general model or system of equations was hypothesized to represent the basic price determining forces of both the sanded and unsanded fir plywood markets. This system of equations consisted of a demand, supply, wholesale inventory, unfilled orders and accounting relations. Each

Appendix Table 2. Components of Price Indexes, Sanded and Unsanded Types of Douglas Fir Plywood - 1960

	Grade	Total shipments of all plywood[a] (Percent)	Proportion in price index (Percent)
Sanded Types Plywood			
Interior	AB	3.66	6.03
Interior	AD	21.87	42.78
Exterior	AC	13.70	48.90
Exterior	BB	5.68	2.29
		44.91	100.00
Unsanded Types Plywood			
Interior	CD	27.05	93.52
Exterior	CC	1.37	6.48
		28.42	100.00

[a] Douglas Fir Plywood Association, Geographical Analysis, Shipments Douglas Fir Plywood, 4th Quarter, 1960.

[b] Weighted by quantity of plywood sold.

equation was assumed to be of linear form. Variables were included in the relation provided the variables were considered to be relevant to the relation based upon the researcher's qualitative knowledge of the industry./1 The following general equations were specified:

Demand relation

New orders⟵Current mill price; Current wholesale warehouse inventories; Wholesale warehouse price; Construction put-in-place; Lumber price; Construction worker's wage; Expectations of mill and wholesale warehouse prices./2

/1 The exact definitions of the variables and the sources of data are given in Appendix 1.

/2 The ⟵ is read "is influenced by."

Supply relation

Quantity of production ⟵ Current mill price; Current industry capacity; Sawmill worker's wages; Price of logs and stumpage; Price of competing products in production; Expectations of mill price; Unfilled orders.

Wholesale inventory relation

Wholesale inventories ⟵ Current mill price; Current quantity of production; Wholesale warehouse price; Construction put-in-place; Expectations of mill and wholesale prices and warehouse inventories.

Unfilled orders relation

Unfilled orders ⟵ Mill price; Wholesale warehouse inventories; Expectation of mill and wholesale prices.

Accounting relation

Quantity of production = New orders + Change in unfilled orders.

Estimation of Coefficients

It would be very unlikely that all of the suggested variables could be statistically significant in the above relations, hence a procedure was used to determine approximately the "best" combinations of variables to keep in the two models. This was to obtain multiple regression equations for all combinations of the variables specified for each relation.[/1] The combination was designated "best" which explained the greatest amount of variation in the dependent variable (measured by the multiple correlation coefficient squared, R^2) and made sense from an economic point of view in the equation being evaluated. Thus, out of 15 variables evaluated in

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/1 The amount of computation involved in obtaining these regressions was staggering and it could only be accomplished by utilizing electronic computing equipment. For example, to obtain R^2 values for all combinations of variables in the demand relation (assuming six price expectation variables are tried) 2^{13} or 8,192 multiple correlation problems must be solved.

the supply equation for unsanded plywood, variables numbered 1, 3, 9, 10, and 11, might be selected as the best combination (with $R^2 = .892$), while variables numbered 1, 3, 6, 7, and 13, might be chosen as the second best combination (with $R^2 = .847$).

Once the best combination(s) of variables was found for each equation of a model, structural coefficients were estimated for these variables by methods appropriate to systems of equations./1 These coefficients quantitatively describe the price determining forces in the sanded and unsanded plywood markets.

Finally, coefficients of the reduced form equations for P_t, N_t, and Q_t, were estimated so that these variables could be forecast one quarter into the future, given the values of the predetermined variables./2

/1 Specifically, the Theil-Basmann method for estimating equations in a simultaneous system was employed. For an introduction to maximum-likelihood estimation, see Tintner (28). For a discussion of Basmann's method, see Basmann (2), Wallace and Judge (40), and Foote (10).

/2 See Page 16.

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