AN ECONOMETRIC ANALYSIS OF THE U.S. HARDBOARD MARKET

by Albert T. Schuler

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370 REED ROAD, BROOMALL, PA. 19008

The Author

ALBERT T. SCHULER received his B.S. degree in forestry from Syracuse University and his Ph.D. degree in forest economics from Iowa State University. He began his career with the Forest Service in 1975 and is currently a research economist at the Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Princeton, West Virginia.

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Abstract

An econometric model of U.S. hardboard consumption was developed to identify the major variables affecting hardboard consumption and price. The variables identified were housing starts, residential improvement activity, disposable personal income, hardwood plywood price, productivity, pulpwood and residue price, hardboard tariff, and power cost. Disposable personal income was the most important of these variables, affecting both consumption and price. Annual projections show consumption increasing by 60 percent and price by 133 percent (over 1977 levels) by the year 1990.

INTRODUCTION

THE U.S. HARDBOARD MARKET is supplied by two sources. Since 1950, domestic producers have been providing approximately 90 percent of U.S. consumption, while imports made up the remainder. This study analyzes the aggregate market for hardboard (treated and untreated) consumed in the United States. Consumption is defined as domestic production plus imports minus exports.

The domestic hardboard industry set a production record in 1977 with an output estimated at 7.4 billion square feet (1/8-inch basis). United States consumption has increased 65 percent since 1970, and indications are that the increase will continue, but at a slower rate. Domestic wholesale hardboard prices have increased 53 percent since 1970, although the increase in 1977 was a modest 3.3 percent. The domestic hardboard industry must learn more about the structure of its markets to continue its rapid expansion. Price and consumption projections can facilitate long-range capital investment planning decisions which are particularly crucial to this capital-intensive, energy-dependent industry.

Hardboard has been described as having a thousand uses, ranging from wood panel products inside and outside the home to numerous uses in the furniture industries. However, the major market is exterior siding which consumes approximately 25 percent of domestic hardboard produced.

The domestic hardboard industry has 26 plants producing hardboard products and six plants producing both hardboard and insulation board. The 26 plants have an annual capacity of 7.8 billion square feet (1/8-inch basis).

Complete quantitative market information is lacking, which complicates annual and long-term planning in the domestic hardboard industry. What is needed is an adequate supply-demand prediction model for the industry. Although most firms have short- term intelligence in the form of order backlogs, marketing feedbacks, etc., annual planning would benefit from knowledge of the important factors that affect consumption and price of hardboard. For example, information that consumption of hardboard products varies with disposable personal income would justify monitoring projections of that variable and altering production levels accordingly. Quantification of the relationships between hardboard consumption or price levels and other demand-supply variables can provide the industry with "early warning" information which may help avoid major production errors.

Accurate long-term planning (10 to 15 years) is necessary to the survivial of individual firms and the industry itself. This type of planning requires estimates of future consumption and price levels to determine capital needs.

Reliable planning should result in adequate hardboard supplies to meet anticipated demand, and thus keep consumer prices from spiraling. Consumption projections are also needed by forest planners to evaluate current forest programs, establish timber growth goals, and aid in formulating forest policies and proposed programs.

Specific objectives of the study reported here were: (1) to identify variables that are good predictors of hardboard supply and demand by developing a supply-demand model; (2) to quantify the relationships between these variables and U.S. hardboard consumption and price by developing projection equations; and (3) to project annual equilibrium U.S. consumption and price levels to the year 1990.

FRAMEWORK OF ANALYSIS AND METHODOLOGY

An equilibrium model consisting of a demand and supply equation and an identity was developed to study the U.S. hardboard market. The identity is necessary for demand-supply equilibrium. The general form of the linear model is:

$$\text{Demand} = \alpha_d P + \beta_o + \beta_1 \chi_{d1} + \ldots + \beta_p \chi_{dp} + e_d$$

$$\text{Supply} = \alpha_s P + \gamma_o + \gamma_1 \chi_{s1} + \ldots + \gamma_q \chi_{sq} + e_s$$

$$\text{Demand} = \text{Supply} = \text{Consumption}$$

where:

Consumption = domestic production + imports − exports
P = hardboard price
$\chi_{d1} \ldots \chi_{dp}$ = demand variables
$\chi_{s1} \ldots \chi_{sq}$ = supply variables
α_d, α_s = regression coefficients for price
$\beta_1 \ldots \beta_p$ = regression coefficients for independent demand variables
$\gamma_1 \ldots \gamma_q$ = regression coefficients for independent supply variables
e_d = demand error term
e_s = supply error term
β_o, γ_o = intercept terms for demand and supply equations, respectively

The model depicted is an equilibrium model that accounts for the interaction between demand and supply and the interdependence of prices and consumption. The data base was annual observations of each variable over the sample period 1950 to 1977. The data sources used were, for housing starts, value of residential improvements, disposable personal income, and power costs, U.S. Bureau of Census (1950-1977); for productivity, U.S. Bureau of Census (1954-1972); for pulpwood and residue prices, hardwood plywood prices, hardboard consumption, and hardboard price, Phelps (1977).

The two-stage least squares (2SLS) procedure was used to estimate the parameters in the demand and supply equations. This procedure is specifically designed for over-identified simultaneous systems (Christ 1966). Two-stage least squares was selected over other simultaneous equation procedures because it reduces computation and computer algorithms such as the SYSREG routine in SAS-76 (Barr et al. 1976) are readily accessible and inexpensive to use.

SPECIFICATION OF HARDBOARD MARKET MODEL

The first step in developing a U.S. hardboard market model was to identify major factors that influence demand and supply. Economic theory provided a basic framework and discussions with knowledgeable industry sources provided additional information.

The second step was to select variables that could represent the factors identified in step one. Selected variables had to be measurable and projections of them had to be available. Projections are necessary because they are needed to project hardboard consumption and price.

The major factors assumed to affect hardboard demand and supply, initial candidate variables selected to represent these factors, the expected relationships between the variables and supply and demand, and their units of measurement are presented in Tables 1 and 2.

Table 1.—Major demand factors, variables, expected relationships between variables and demand, and units for the hardboard model. The designations in parentheses in the variable column represent the same variables in equations 1, 2, 3, and 4

Factor	Variable(s)	Expected relationship	
1. U.S. building construction	a. Housing starts (starts)	Positive	1,000 units
	b. Residential improvements & repairs (improvements)	Positive	$ Million, 1967
	c. Nonresidential building construction (NR construction)	Positive	$ Million, 1967
2. U.S. furniture manufacture	a. Furniture production index (furniture)	Positive	Index·(1967 = 100)
3. U.S. income	a. Disposable personal income (income)	Positive	$ Billion, 1967
4. Substitute materials	a. Weighted average of imported and domestic hardwood plywood price (hardwood plywood price)	Positive	Index (1967 = 100)
5. Hardboard price	a. Weighted average of treated and untreated domestic wholesale hardboard prices (price)	Negative	Index (1967 = 100)
	b. Imported wholesale hardboard price (import price)	Negative	Index (1967 = 100)

Table 2.—Major supply factors, variables, expected relationships between variables and supply, and units for the hardboard model. Designations in parentheses in the variable column represent the same variables in equations 1, 2, 3, and 4

Factor	Variable(s)	Expected relationship	Units
1. Production costs	a. Weighted average of pulpwood and plant residue prices (wood)	Negative	Index (1967 = 100)
	b. Average of electricity and natural gas prices (energy)	Negative	Index (1967 = 100)
	c. Productivity in hardboard industry (productivity)	Positive	Value of shipments in 1967 dollars per man-hour of production workers
2. Hardboard tariff	a. U.S. hardboard import tariff (tariff)	Negative	Percent ad valorem
3. Domestic hardboard price	a. Weighted average of treated and untreated wholesale domestic hardboard price (price)	Positive	Index (1967 = 100)

ESTIMATED DEMAND AND SUPPLY EQUATIONS

Parameters of a linear demand-supply equation model were estimated by the 2SLS estimating procedure presented by Theil (1975). The following information was used in judging whether or not candidate variables should be retained in the estimated model: (1) the size of the beta coefficient in relation to its standard error—the coefficient should be greater than or equal to the standard error (ordinarily the "t-statistic" is used, however, this statistic is only asymptotically valid for 2SLS); (2) the significance of the Dubin-Watson D statistic which was used to test for serial correlation in the residuals; (3) whether the estimated model met identification requirements; and (4) whether the parameters in the model had the expected sign.

Estimating the demand equation presented some difficulties in that some of the expected relationships were not substantiated. The furniture production variable had a negative sign when a positive sign was expected, and the beta coefficient was less than its standard error. One possible reason is that disposable personal income and the furniture production index are highly correlated ($r = .98$). Dropping disposable income from the demand equation resulted in the Durbin-Watson D Statistic approaching significance. Therefore, disposable income was retained and furniture production was deleted. I believe disposable income is a more appropriate variable because income levels are probably the major determinant of furniture consumption, hence the disposable income variable should partially account for variation in hardboard demand due to changes in furniture production.

The nonresidential building activity variable also had a negative sign when positive was expected, and the beta coefficient was less than its standard error. I believe the problem here is that this variable is not specific enough to account for variation in hardboard demand, hence the variable was deleted from the model.

The hardboard import price variable had a positive sign when negative was expected, and its beta coefficient was less than the standard error. I believe that the influence of imports is probably stronger on the supply side of the market and, therefore, deleted the variable from the demand side of the model.

Residential improvement activity had a beta coefficient less than its standard error. However, it had the expected sign, and I felt that because of the growing importance of this building market, the variable should be retained in the demand equation. The remainder of the expected demand relationships met the statistical and economical criteria for retaining variables.

Hardwood plywood price was treated as an independent variable for purposes of this study. Although plywood price probably affects demand for hardboard through product substitution, activity in the hardboard market does not affect plywood prices. The dominant factor influencing hardwood plywood price is the considerable import volume, which has averaged 49 percent of U.S. consumption over the past 10 years.

Estimating the supply equation presented fewer difficulties. All coefficients had the expected sign. The pulpwood and plant residue price variable had a standard error greater than its beta coefficient, but because of the importance of wood raw material costs in making supply decisions, I felt the variable should be retained in the model.

Serial correlation among residuals was not significant in either the demand or supply equations suggesting that the linear model was adequate, and that no major variables were missing from the model.

Estimated model

The final model estimated using the 2SLS procedure was:

(1) Demand = $-7238110.1 - 13749.9$ price + 1098.9 starts + 26.3 improvements + 29405.9 hardwood plywood price + 14197.2 income
$D = 2.09$
$R^2 = .994$ SE = 185,484 MFT^2 (1/8-inch basis)

(2) Supply = $4873536.7 + 31957.5$ price − 669956.6 tariff + 268860.9 productivity − 7387.3 energy − 78662.1 wood
$D = 1.79$
$R^2 = .979$ SE = 354,822 MFT^2 (1/8-inch basis)

HARDBOARD CONSUMPTION AND PRICE PROJECTIONS

The demand and supply equations (1 and 2) were solved simultaneously to yield reduced form equations for hardboard price and consumption.

(3) Consumption = − 3594632 + 768.32 starts + 18.39 improvements + 20559.9 hardwood plywood price + 9926.3 income − 201539 tariff + 80879.9 productivity − 2222.3 energy − 23663.5 wood

(4) Price = − 264.98 + .024 starts + .00057 improvements + .64335 hardwood plywood price + .3106 income + 14.657 tariff − 5.882 productivity + .1616 energy + 1.721 wood

Evaluation of residuals in the projection equations

The projection equations (3 and 4) were evaluated to determine how closely they fitted the sample data. The closeness of the fit will provide some measure of their potential predictive ability beyond the sample data base. Three measures of fit were calculated for the consumption and price projection equations (Table 3). Values near zero imply a good fit to the sample data. In each case, actual values for independent variables were used to calculate the predicted (P) values.

Results listed in Table 3 indicate that the projection equations fit the sample data extremely well. Although these three measures are ordinarily used to evaluate predictive ability beyond the data base, they are useful in evaluating the fit of projection equations over the sample period.

Elasticity measures

The relative importance of each variable in the model can be determined by its respective elasticity; that is, the percent change in price or consumption associated with a 1 percent change in one of the predetermined variables, holding everything else constant. For example, a 1 percent increase in real disposable personal income (with a consumption elasticity of 1.36) could increase hardboard consumption by 66,197,000 square feet (1/8-inch basis). However, elasticity is only a partial measure of impact because disposable income, for example, may affect other variables within and outside the hardboard system that could offset or amplify the resulting impact on consumption.

Table 3.—Theil's (1975) υ-coefficient, mean percentage error (MPE) and mean absolute percentage error (MAPE) for consumption and price projection equations over the sample period.

Projection equation	υ-coefficient[a]	MPE[b]	MAPE[c]
Consumption	.034	.0057	.114
Price	.076	.0059	.2100

[a] $$\upsilon = \left[\frac{\sum_{i=1}^{N} (P-A)^2}{\sum_{i=1}^{N} A^2} \right]^{1/2}$$

A = actual values
P = predicted values
N = sample size

[b] $$MPE = \frac{1}{N} \left[\frac{\Sigma\ P-A}{\Sigma\ A} \right] X\ 100$$

[c] $$MAPE = \frac{1}{N} \left[\frac{\Sigma\ |P-A|}{\Sigma\ A} \right] X\ 100$$

The following elasticities were calculated for consumption and price of hardboard and are based on average values for each variable over the sample period.

Consumption		*Domestic hardboard price*	
Income	1.36	Income	1.46
Hardwood plywood price . .	.64	Tariff	1.32
Tariff	−.53	Productivity . . .	−.82
Starts	.34	Hardwood plywood price . .	.69
Productivity . . .	.33	Starts	.36
Wood	−.12	Wood	.29
Energy	−.07	Energy	.18
Improvements .	.07	Improvements .	.07

Both price and quantity are most sensitive to disposable personal income and least sensitive to residential improvement activity. The hardboard tariff had a surprisingly strong impact on domestic hardboard price, whereas energy and wood costs were less important. As expected, productivity was more important in affecting price than consumption. Generally, quantity is most sensitive to demand variables, although price was not similarly dominated by supply variables as one would expect.

Projections for predetermined variables

Projections had to be obtained for the predetermined variables before projections beyond 1977 could be made for consumption and price of hardboard. Wherever possible, forecasts by other sources were used, e.g., Marcin's (1977) housing start projections. Many government (e.g., U.S. Bureau of Economic Analysis 1974) and private sources project real disposable personal income to grow at an annual rate of approximately 3 percent. Residential improvement and repair activity has picked up considerable momentum in the 1970's in response to rapidly escalating housing construction costs and new home mortgage rates. The real rate of increase between 1970 and 1977 has averaged 3 percent annually, and this rate was used for the projection period.

Electricity and natural gas prices have increased at an average annual rate of 37 percent since 1973. However, for projection purposes, I assumed that energy costs will be more in line with the average annual rate of increase (10 percent) established over the sample period (1950 to 1977). For the remaining independent variables in the model, I assumed that each would continue at the annual rates of increase established over the period 1970 to 1977: deflated pulpwood and residue prices, 2 percent; productivity, 4 percent; and hardwood plywood prices, 3.08 percent. I assumed that the hardboard tariff would continue at the average yearly rate established during the period 1970 to 1977 (8.4 percent).

For projecting consumption and price of hardboard, I used the above rates as the basis for the medium-level projections. However, to provide some flexibility, projections were also made under somewhat more optimistic (high-level) and pessimistic (low-level) economic conditions. The independent variables in the model can fluctuate considerably from their norms; values of plus or minus 15 percent are not unusual. Therefore, the high-level projections are based on my assumption that the independent variables will increase at a rate 15 percent greater than the medium-level rate. For example, I assumed that real disposable personal income would increase at a 3.45 percent rate, instead of the medium-level rate of 3 percent. The low-level projections are based on the assumption that the independent variables will increase, but at a rate 15 percent less than the medium level rate. The corresponding rate for income, for example, was 2.55 percent. Similar assumptions were made for the other independent variables in the model.

Projections for quantity and price

Hardboard consumption and price were projected to the year 1990 (Tables 4 and 5). Consumption is projected to increase 60 percent (over the 1977 level) while the price index is projected to increase 133 percent by 1990. These figures were translated into average annual rates of increase of 4.6 and 10 percent, respectively, for quantity and price. The projected trends are the same as those of the past 10 years, when consumption and price

Table 4.—U.S. consumption projections for hardboard in thousand of square feet, 1/8-inch basis

Year	High	Medium	Low
1980	9,024,045	8,902,891	8,784,005
1985	11,115,160	10,762,380	10,411,190
1990	13,201,710	12,527,010	11,875,460

U.S. Consumption = domestic production + imports − exports

Table 5.—Domestic hardboard price index projections. 1967 = 100 (average of treated and untreated)

Year	High	Medium	Low
1980	229.2	198.9	171.5
1985	310.3	267.9	226.3
1990	429.4	359.5	295.4

increased at annual rates of 8.2 and 5.7 percent, respectively; however, consumption is no longer increasing faster than price. One possible reason for the rate reversal is that hardboard is no longer the new product it once was, and its product life cycle may be approaching a more mature stage. With most consumer products, demand growth eventually slows after initial rapid expansion.

CONCLUSIONS

The hardboard market model developed in this study can be most useful for long-range (10 to 15 years) planning because projections for consumption and price can help provide industry planners with trend information they need for capital investment decisions. Current industry capacity is approximately 7.8 billion square feet (1/8-inch basis), and according to my analysis, will have to be increased 60 percent by 1990 if projected consumption is to be met from domestic production. If imports account for 11 percent of consumption (as they have for the past 10 years), domestic plant capacity will still have to be increased 43 percent. If price increases at the projected 10 percent annual rate, this could provide some incentive to expand plant capacity.

The market model also provides useful annual planning information in the form of consumption and price elasticities. Calculated elasticities show hardboard consumption and price to be most sensitive to disposable personal income. Income is monitored closely by government agencies and projections are developed frequently. These projections, in conjunction with the elasticity information from this model, could be used by the hardboard industry to detect early warning signs of changing market conditions.

A concern with the study is that the projection equations were not tested adequately for predictive ability. Unfortunately, sufficient observations could not be reserved from the available time series. However, an analysis of the residuals of the projection equations over the sample period indicated a good fit. Therefore, the accuracy of the projections beyond 1977 will depend on the accuracy of the independent variable projections and the degree of future structural changes in the hardboard industry. Nevertheless, results from this study suggest the potential of econometric models to provide forest planners with valuable information on future trends in the wood-using industries. These estimates are needed to determine future forest resource requirements and to evaluate current and proposed forest programs.

When using any econometric model, one must recognize that structural changes can occur. A variety of developments could significantly change the estimated relationships among the variables in the demand and supply equations. If changes occur, altered conditions will necessitate a new look at any conclusions drawn from the study. There may be a need to re-estimate the model and re-project consumption and price periodically.

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