Computer Simulation of the Economics of the United States Softwood Plywood Industry

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In recent years computer simulation or "simulation," as it is perhaps better known, has become an important tool to assist management in making the important business decisions that influence profits at the firm level and market behavior at the industry level. During the past year, a team at Oregon State University has been constructing a computer simulation model of the United States softwood plywood industry. The purpose of this report is to briefly summarize the work done to date, to present and describe typical computer runs made with the model as constructed, and to describe possible future applications of the simulation model to specific problems in the plywood industry.

Before going into details of the plywood industry simulation model, a brief explanation will be given about computer simulation in order to give the reader some idea of what this new tool is and what its capabilities are. Basically, a simulation of a business or an economic system is a program that instructs a computer to behave through time like the firm or industry that is of interest. An essential feature of a computer simulation is that the management decisions and the physical structure of the system (production capacities, inventory capacities, time delays, costs, etc.) that determine profits, prices, and other important variables
are included in the computer program. A computer simulation is therefore not limited to representing a firm or an industry as it is at the present time; it also has the capability of being able to say something about how the firm or industry would react—if certain management decision rules were changed in a specific way—if the structure of the system were changed in a particular aspect. If a realistic computer simulation of the firm or industry is available, then management has a tool which can be used to seek changes in decision rules and structure which can result in improved system performance.

Reference (1)—at the end of this report—is an excellent source of additional information relating to computer simulation applied to business and economic systems.

The construction of a realistic simulation model of a complex business or economic system is no small undertaking. The Oregon State University team of researchers has spent the equivalent of one and one-half man years on the plywood industry simulation to date. Even with this expenditure of effort, the results presented in what follows must be considered as preliminary. It is estimated that a like amount of additional effort would be necessary to apply the work to specific industry problem areas. A general description of the plywood industry simulation model will be presented.

**General Industry Model**

The purpose of this section is to define industry subdivisions or sectors into which firms were placed for purposes of aggregation. Some form of aggregation is necessary because of the prohibitive complexity
involved in simulating, individually, hundreds of firms. A fundamental principle applied in the aggregation of firms was to group together those which have common input variables, common output variables, and similar rules of behavior relating outputs to inputs. The "general system model" consists of a number of interacting sectors which, when simulated, approximately represent the hundreds of interacting firms. It should be stressed that no one general model can correctly aggregate every firm in the industry. Due to the wide diversity of organizational patterns that were found to exist, some firms, of necessity, did not fall into the sectors defined. Since aggregation, for the present at least, is essential from the practical standpoint, the problem is one of defining the sectors of the general model so that as many firms as possible are correctly aggregated and, at the same time, the general model is tractable.

The general model of Figure 1 was arrived at on the basis of published information relating to the industry (References 2, 5, 6, and 7) and interviews with industry personnel. Included in the general model are two producing sectors, three wholesaling sectors, and two sectors at the retail level. It should be pointed out that two of these models, illustrated in Figure 1, are required to represent the entire industry--one each for the sanded and unsanded markets. Descriptions of the individual sectors that make up the general model follow.

Producing Sectors

The two producing sectors are designated as the "M" and "P" sectors in Figure 1. Firms included in the "M" sector are "independent producers" in the sense that they are not tied organizationally to wholesaling
Figure 1. General system model

Notes
1. Arrows denote direction of plywood flow
2. LCL = Less than Car Load
3. CL = Car Load
4. Percentages shown are percent of 1962 softwood plywood production
organizations—they are in business primarily to produce plywood. On the other hand, the producers of "P" sector are tied organizationally to the plywood distributors of "C-D" sector and are hence termed "integrated producers." The integrated producers are typically the giants of the industry—Georgia Pacific, U.S. Plywood, Weyerhaeuser, Evans Products, and small independent producers bound to these larger firms by contractual agreements. In 1962, independent mills were responsible for 60% of industry production, with the remainder produced by integrated mills.

This sectoral breakdown of plywood producers was based upon two considerations. Firstly, as seen in Figure 1, the output of the independent producers of "M" sector is offered for sale on a competitive market designated the "mill market," while that of the integrated producers of "P" sector, for the most part, bypasses the mill market and is transferred intra-firm to the distribution outlets of "C-D" sector. Secondly, due to the organizational difference cited, the independent and integrated producers have markedly different price and production policies. Independent mills are subject to the direct competitive forces of the market which strongly influence their price and production decisions. Integrated mills on the other hand are buffered from these market forces by the large distribution warehouses to which they are organizationally tied.

Retailer-User Sectors

The retail-user sectors are designated "L" and "K" in Figure 1. These sectors include not only plywood retailers but also users of plywood
who buy from the same sources as do the retailers. Included among such
users are building contractors and industrial users who, due to the volume
of their utilization, can purchase from wholesale outlets.

In Figure 1 the "L" sector represents the aggregation of retailers
and users who buy plywood in less than boxcar load lots from distribution
warehouses. They are called "LCL Retailers and Users" where "LCL" stands
for Less-than-Car-Load. On the other hand, "K" sector represents users
and retailers who buy plywood in boxcar load lots. They are hence called
"CL Retailers and Users" where "CL" is a mnemonic representation for
"carload."

The distinction between the two types of retailers and users is a
significant one. While less-than-carload purchases usually are made out
of distribution warehouses, boxcar-sized lots are normally shipped directly
from the mill to save unloading, warehousing, and reloading costs at the
wholesale level. There are therefore the two distinct wholesale markets
for plywood shown in Figure 1. Prices in the LCL market are higher than
the prices that prevail in the CL market because of increased costs in
selling out of warehouse. In 1962 it was estimated that 50% of production
was sold through the LCL market, 40% through the CL market, and that 10%
bypassed wholesale markets.

Wholesale Sectors

As shown in Figure 1, three sectors have been defined at the wholesale
level. The three sectors represent firms that are distinctly different in
terms of policies and behavior. The "C-D" sector, has been mentioned in
connection with the integrated producers of "P" sector. The "C-D" sector
is an aggregation of jobbers 1/ and office wholesalers 2/ who are organizationally integrated with firms in "P" sector. As seen in Figure 1, this sector obtains the major portion of its plywood on intra-firm transfer from integrated producers. In the aggregate, however, the "C-D" sector is able to sell more plywood than "P" sector can produce. The "C-D" sector is, therefore, a net buyer in the mill market and, in 1962, obtained about 10% of its input by buying from independent mills in the mill market. On the selling side, the "C-D" sector sells out of warehouse into the LCL wholesale market and arranges for direct shipments from mills to customers through the CL wholesale market. The sector, therefore, represents the aggregation of firms which perform both jobbing and office wholesaling functions. This dual role is the reason for the dual nomenclature in the sector designation "C-D." Large integrated firms spanning the "P" - "C-D" sectors, make profit by producing as well as by selling plywood and overall profit is of primary importance. Production as well as selling policies are therefore influenced by the integrated nature of firm organization.

In Figure 1, the "O" sector represents an aggregation of distributors who act as independent office wholesalers. The firms of "O" sector buy plywood in carload lots from mills (mainly independent ones) and sell with a markup of approximately 3% to the retailers and users of "K" sector. Though these firms legally own the plywood for a time, the physical flow of plywood is from mill to customer. Some firms of this sector take advantage of the seasonal variation in plywood price and sell short, and

1/ The term "jobber" here will be taken to mean a middleman who physically stocks plywood and sells out of his inventory.

2/ An "office wholesaler" will be defined as a middleman who buys and sells plywood without taking physical possession of the product.
engage in position buying to increase their normal 3% markup. In 1962 it was estimated that 15% of industry production was handled through independent office wholesalers.

The last of the three sectors at the wholesale level is "W" sector, an aggregation of independent jobbers. These firms are not integrated with producers and make their profit by selling plywood and other building materials out of inventory. As shown in Figure 1 these firms buy from independent mills and sell out of inventory in less-than-carload-lots to retailers and users of "L" sector. Independent jobbers also perform an office wholesaling function but since this part of their operation is essentially the same as that of the office wholesalers of "O" sector, it has been lumped together with the firms of "O" sector. Independent jobbers also take advantage of seasonal plywood price variation. They tend, as a group, to increase buying when prices are low and decrease buying when prices are high and are largely responsible for the negatively sloped demand curve which has been measured by econometric methods (Reference 7). Independent jobbers handled 30% of 1962 production.

Results of Model Tests

The model described above has been programmed for the IBM 7090. The program consists of 150 equations which when processed by a computer will generate the behavior of prices, production, inventories, unfilled orders, and sales. Thus, a deck of 200 IBM cards, a magnetic tape containing the DYNAMO program, and a computer can "act" out the interrelationships among decisions, production and sales delays, and market forces to produce the characteristic behavior of the plywood industry. The myriad of technical
details underlying the actual simulation will not be discussed here but is presented in Reference 8. In what follows, the results of typical computer runs will be presented.

**Two-Sector Model with Seasonal Fluctuations in Jobber Sales**

In testing the simulation model, it became apparent that by far the most important sectors in determining the behavior of the mill market were the independent jobbers of the "W" sector and the independent mills of "M" sector. Extensive computer runs were, therefore, made with a two-sector model that includes only the behavior of independent jobbers and independent mills. Figure 2 represents data taken from a particular run of this two-sector model. In this particular run, it was assumed that jobber sales (demand) varied seasonally over the year with sales approximately 30% below average at the beginning of the year, rising to 30% above average at the middle of the year, and falling again to 30% below average at the end of the year. The object here was not to represent a particular year, but rather to represent the typical seasonal behavior of demand for plywood. Given this demand, the two-sector simulation model generated the industry data shown in the figure—price, production rate, mill unfilled orders, and jobbers inventories.

The number 416 at the bottom of Figure 2 represents the beginning of the year; each dot represents two weeks and the dot corresponding to 468 weeks represents the beginning of the following year. The curve formed by connecting the D's in the figure represents independent jobber sales (demand) of sanded plywood. As indicated, aggregate sales of independent jobbers were assumed to have a low of 43 million square feet per week in January and rise to a high of 75 million square feet per week at midyear.
Figure 2. Computer Simulation of Two-Sector Model with Seasonal Fluctuations in Jobber Sales
and fall again to the same low at the end of the year. The mill price was
generated by the simulation model and is shown by the curve with the P's in
the figure. The price, based on 1/4" AD, had a low of $60 per thousand
rising to a high of $68 per thousand. The curve represented by the Q's
represents independent mill production of sanded plywood in millions of
square feet per week. Production, as generated by the simulation model,
is low at the beginning of the year, rises and then falls due to summer
vacation shutdowns, rises again and then falls toward the end of the
year. The simulation model decrease in production due to summer shutdowns
is based on conservative estimates of industry shutdowns and is probably
not as great as that actually experienced in the industry. Independent
mill unfilled orders, designated by U's in the figure, rise to a maximum
of two and one-half weeks (at the average production rate of 60 million
square feet per week) approximately eight weeks before the maximum market
price and then fall to minimum of one week toward the end of the year.

The main variable of interest in connection with the independent
jobber sector, inventory level, is given by the curve labeled "S" in
Figure 2. As generated by the simulation model, independent jobber in-
ventories reached a maximum of 8.3 weeks (again at the average sales rate
of 60 million square feet per week). This maximum occurred about 12 weeks
before the maximum market price. The minimum jobber inventory level of
4 weeks occurred about 12 weeks ahead of the price minimum. This behavior
of jobber inventories is a direct result of the policy of many wholesalers
to buy low and sell high.

Figures 3 and 4 indicate actual past behavior of price, production,
jobber sales, and jobber inventories. Figure 3 illustrates the seasonal
Figure 3. Months of relative jobber inventory and sales maxima

Source: Based on responses of 273 jobbers to questionnaires of the Plywood Manufacturers Institute 1960 market study.
Figure 4. Average seasonal production and prices for plywood.
pattern of jobber sales and inventories of all softwood plywood. As shown, the peak value of jobber inventories precedes the peak in sales by about three months—essentially the same as the figure generated by the simulation model. Figure 4 depicts monthly averages of production (of all softwood plywood) and price based on 5/8" CD.

Two-Sector Model with Independent Mill Production Control

In conversations with industry officials and managers, a basic industry problem became apparent—that of overproduction during times of low end user demand for plywood. For this reason, a policy of production control on the part of independent mills was introduced into the simulation model. The results of these tests must, however, be considered tentative as, due to time limitations, data and decision rules incorporated in the model at key points were first approximations. The results of introducing production control into the behavior of independent mills are summarized in Table I.

TABLE I

<table>
<thead>
<tr>
<th>Production change</th>
<th>Price maximum</th>
<th>Price minimum</th>
<th>Profit MM</th>
<th>Profit increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>$</td>
<td>$</td>
<td>$/Yr.</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>68.8</td>
<td>62.4</td>
<td>25.56</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>68.6</td>
<td>63.0</td>
<td>26.75</td>
<td>4.7</td>
</tr>
<tr>
<td>5</td>
<td>68.5</td>
<td>63.4</td>
<td>27.37</td>
<td>6.3</td>
</tr>
<tr>
<td>10</td>
<td>67.9</td>
<td>63.7</td>
<td>27.92</td>
<td>9.2</td>
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The first column in the table represents the percent by which production was changed. It was assumed that production was cut by the indicated percentage during times of low seasonal demand and increased during times of high market price to keep average production over the year unchanged. (The same net result could be obtained without production change, of course, by utilizing large mill site warehouses.) The second and third columns represent, respectively, the maximum and minimum seasonal market prices under the indicated production change. Column four indicates the aggregate profit of independent mills per year and the fifth column indicates the percent profit increase due to introduction of production control.

Two effects are indicated by the computer runs. Seasonal price fluctuations in the computer simulation are reduced by the introduction of production control, and profits are seen to increase. As mentioned above, these results should be taken as tentative. They do, however, indicate that production control is an area worthy of future investigation. The results also provide an example of how a computer simulation model can be used as a tool for investigating means of improving industry performance.

Possible Areas of Future Work

During the course of this study and the many associated interviews with industry personnel, a number of possible future applications of the simulation model presented themselves. These are discussed below, recognizing that there may well be other applications not specifically noted.

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3/ The maximum and minimum prices are somewhat different from those in Figure 2 because a slightly different simulation model was being tested.
The first possible application of the simulation model has been alluded to above in connection with the use of the simulation model to study the effects of production control. In interviews with industry managers, the subject of mill site inventories came up numerous times. A possible application of the model, then, would be to investigate the profitability of increased independent mill storage capacity for the individual mill and the effects of such increases upon the market in general.

A second problem area to which the simulation model might be applied is an assessment of the impact of various United States Forest Service log policies upon the plywood market. Log prices are a vital factor in the economic life of the nontimber-holding mill. The question arises as to whether alternate government timber policies would better serve the general welfare.

A third possible application for the simulation model pertains to a problem area peculiar to the integrated producer who is organizationally tied to a wholesale distribution system. A major decision such a firm must make is that of whether to be sales or production oriented. That is, it must be decided whether sales are to be geared to production or vice versa. A simulation model might well shed light on the desirability of one policy over the other.
In Conclusion

The work done to date in constructing a simulation model of the plywood industry has been discussed as well as some possible applications to problem areas in the plywood industry. While simulation models, as discussed here, appear to have some important applications, they should not be considered a panacea for solving all industrial problems. Much thought and planning must precede the choice of computer simulation as the tool for handling a particular problem.