Capacity changes in U.S. particleboard, southern pine plywood, and oriented strandboard industries

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Abstract: An industry’s supply response can be decomposed into tactical (short-run) and strategic (long-run) components. The strategic component, dealing with investments in new capacity, determines the evolution of an industry and its ability to meet changing market demands. A decisive factor affecting capacity investment is the profitability of the commodity produced in relation to the cost of the equipment needed to make it. This concept is related to a theory of investment embodied in the concept of “q” developed by J. Tobin, which suggests that the ratio between the market value of an industry and the replacement cost of capital influences decisions to invest. The results developed here suggest that the theory works well for oriented strandboard, southern pine plywood, and particleboard industries. However, adjustments must be made to the empirical formula to take into account lags between the price stimulus and investment response and the difference in growth rates during the early phases of an industry’s life compared with the more mature phases.

Résumé : La réponse de l’offre d’une industrie peut être subdivisée en des composantes tactiques (de court terme) et des composantes stratégiques (de long terme). La composante stratégique, portant sur les investissements en capacité nouvelle, détermine l’évolution d’une industrie et son habileté à répondre aux changements de la demande du marché. La rentabilité du bien fabriqué, en relation avec le coût de l’équipement requis pour le produire, constitue un facteur décisif influençant l’investissement de capacité. Cette idée est reliée à la théorie de l’investissement incorporée dans le concept de “q” développé par J. Tobin, lequel propose que le rapport entre la valeur au marché d’une industrie et le coût de remplacement du capital influence ces décisions d’investir. Les résultats obtenus ici indiquent que la théorie s’applique bien dans les industries des panneaux gaufrés orientés, des contreplaqués de pin du sud et des panneaux de particules. Toutefois, les formules empiriques doivent être ajustées pour tenir compte des décalages entre l’incitation du prix, la réponse de l’investissement et la différence dans les taux de croissance durant les premières phases du démarrage d’une industrie comparativement aux phases plus matures. 

[Traduit par la Rédaction]

Introduction

When we think of an industry’s supply, we often have an image of the upward sloping relationship depicted in textbooks and found in many empirical studies. In the short run, however, the amount of plant and equipment physically in place constrains the supply of a commodity. Although managers may manipulate tactical inputs such as product mix, overtime, downtime, and inventory, their efforts can only go so far as the available capacity allows. In the long run, it is primarily investments in new capacity that broaden the scope of their discretionary powers by altering production boundaries. In contrast with those decisions that I call tactical, investment in added capacity can be termed strategic.

The separation of supply-affecting inputs into tactical (short-run) and strategic (long-run) components suggests that different forces are at work in the determination of each, and the two concepts should be treated separately to better characterize overall supply. Both sets of actions are behavioral responses to market stimuli. However, while tactical decisions involve responses to profitability subject to a capacity constraint, strategic decisions involve responses to profitability subject to a capital constraint. In an economy
that is market driven, such decisions flow from economic signals that point to the profitability of an activity. As such, the modeling of the behavior, based upon accepted economic principles and theory, should be possible.

The purpose of this paper is to focus on the capacity change component of supply. Specifically, I present empirical results for three sectors of the forest products industry: particleboard, oriented strandboard (OSB), and southern pine plywood. First, I review previous work and experiences with capacity change models. Second, I develop the empirical model. Third, I describe the industries and the data used. Finally, I present and discuss the results.

Previous work

The separation of supply into short- and long-run components in forest products modeling was first evident in the work of Veltkamp et al. (1983). The short-run supply response was related to current profit margin and available capacity; in turn, capacity was related to a weighted average of previous outputs.

Addams and Haynes (1980) also modeled supply and capacity separately but did not include capacity as an explicit shifter in the supply relationship. Rather, capacities were used to set upper bounds on the amount of output the supply equations could specify. Capacity adjustment was modeled with the expectation that investment depends on the amount of realized profits in relation to historical “target” profit margins.

Submodels of capacity change are a crucial part of economic models used to represent the paper industry in the price endogenous linear programming system (PELPS III) (Gilles and Buongiorno 1987; Zhang et al. 1993). In previous versions, capacity growth equations were based on accelerator-type functions similar to those used by Veltkamp et al. (1983). To better predict capacity changes, Zhang and Buongiorno (1993) revisited the capacity functions and attempted to improve them by employing the “q” model of investment suggested by Tobin (1969). Zhang and Buongiorno’s model relating the rate of change of capacity in the paper and paperboard industries to q ratios gave good explanations of long-term capacity change. However, a dynamic version of the model was needed to explain short-term change.

In previous empirical tests of the q theory in other sectors, the results were not always as successful (von Furstenberg 1977; Abel 1980; Summers 1981; Hayashi 1982). However, this approach lends itself well to linear program based models that yield shadow prices of capacity if the capacity constraint is binding. In economic models using a linear programming (LP) approach, demand is allocated to the least costly sector first, up to its limit. However, this is a static solution for a single period. To allow the system to dynamically solve for multiple periods, a method is needed to use information on shadow prices (profitability of an added unit of a constraint) generated for one period to update the next period’s capacities, so that the next LP solution reflects the changes in profitability of technologies. The development of such equations thus is a necessary part of developing dynamic LP-based economic models. Because this study is a part of a project to construct a linear program based model of solid-wood products, I wanted to test whether the q approach would also work for wood-based industries other than paper.

The model

The theory of investment embodied by q is based upon the notion that the rate of investment is a function of the ratio between two evaluations of the same assets: the financial market value of company stock and bond obligations (the numerator) and the replacement cost of their assets (the denominator). The replacement cost of assets is similar in concept to book value, except that book value is expressed in terms of original cost and replacement is valued at current cost. When the ratio is unity, financial markets are simply reflecting the current value of the assets to which the holders of the stocks and bonds are entitled. The greater the ratio, the greater is the market value of the company’s assets relative to their acquisition costs. This decreases the cost of raising funds and provides an incentive, similar to a reduction in interest rates on corporate bonds, for companies to acquire additional assets similar to the ones the markets are evaluating.

The translation of this theory into empirically testable models has been problematic because the only observable q is the average q, while Tobin’s (1969) concept implies a marginal q. At best, the marginal value of capital (the numerator) can be approximated by observing the current unit profitability (price, P, less average variable cost, AC,) in an industry. The marginal cost of capital (RC,, the denominator) is the current replacement cost of capacity, so from these, the approximation of marginal q is

\[ q = \frac{P - AC}{RC} \]

and the working equation is

\[ RCG = a + bq + u, \]

where RCG is the ratio of the change in capacity to the previous period’s capacity or the observed rate of capacity growth; a and b are parameters to be estimated, and u is the error term with the usual assumptions.

The observed rate of capacity growth consists of three components: (1) construction of new capacity; (2) replacement of worn-out capacity; and (3) retirement of uneconomic capacity. When capacity is not binding; that is, there is excess capacity and q, equals zero, there should be no new construction of capacity. Thus, the constant a equals the sum of the replacement and retirement rates or the loss rate of capacity when price just equals variable costs.

Returning to eq. 2, the left-hand term, because it is a ratio, is intrinsically nonlinear with respect to the previous period’s capacity. When an industry is new, the addition of a plant will appear to yield a much larger rate of capacity growth than when the same industry is more mature and has a larger existing stock of capacity. When applied to the industries that I studied, the formula failed to yield

\[ q = \frac{P - AC}{RC} \]

This is an exact representation only when average and marginal costs are equal, a very restrictive assumption (Zhang and Buongiorno 1993).
Table 1. Data used to estimate capacity models for panels.

<table>
<thead>
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Note: RC is replacement cost of capacity (in US$ per 1000 ft$^3$/3/8-in. basis, except for particleboard, which is on a 3/4-in. basis); C is capacity (in 10$^6$ ft$^2$, 3/8-in. basis, except for particleboard, which is on a 3/4-in. basis); P is price (in US$ per 1000 ft$^2$, 3/8-in. basis, except for particleboard, which is on a 3/4-in. basis); AC is average variable costs (in US$ per 1000 ft$^2$, 3/8-in. basis, except for particleboard, which is on a 3/4-in. basis) (1 ft$^2$=0.0929 m$^2$; 1 in, =0.025 m). —data not available.

**Note:** (4) RCG$_t$ = $a + c q_t + d \left( \frac{q_t}{C_{t-1}} \right)$

As capacity grows, the effect of the parameter $d$ declines, so that over time, the effect of $q$ on RCG, declines asymptotically to the value of the parameter. To account for possible misspecification as a result of omission of inputs, eq. 4 can be further transformed to a dynamic adjustment version containing the lagged dependent variable RCG$_{t-1}$:

**Equation 5:**

\[ RCG_t = a + cq_t + eq_{t-1} + d \left( \frac{q_t}{C_{t-1}} \right) + f \left( \frac{q_{t-1}}{C_{t-2}} \right) + g(RCG_{t-1}) \]

An additional consideration is the lag between market signals and the response. For capital intensive enterprises...
such as southern pine plywood, OSB, and particleboard, the time between the inception of an investment idea and its implementation is necessarily lengthy. Furthermore, the lag has increased in recent times because of the large size of most projects and the increasingly stringent permitting process. To reflect such delays, the $q$ variable in eq. 5 should be lagged by a number of periods. For each industry, a lag structure was determined empirically within the overall framework of eq. 5.

The data

All three industry sectors are relatively new. (The southern pine branch of the plywood industry was chosen for study over the entire industry in order to study capacity growth from its beginnings.) The first particleboard plant based on modern techniques went into operation in 1947. The technology came of age and most growth occurred in the late 1950s to mid-1970s. Similarly, the first commercially viable structural particleboard plant (later OSB) was built in 1964. The main growth spurt, however, was delayed until the late 1970s. In contrast, the southern pine plywood industry, which began in 1964, experienced rapid growth from the start and continued through the early 1980s. With the advent of the OSB sector, southern pine plywood growth continued, but its character changed from growth caused primarily by the construction of new plants to that caused by retrofitting and debottlenecking existing plants.

To implement the $q$ approach for these industries, data on the following items were needed: cost of capacity; industry capacity; product prices; and costs of production (Table 1).

Capacity replacement costs were obtained from mill announcements obtained from past years in the trade press. Not every mill's cost was disclosed, but a sufficient number were reported to provide a reasonable database for all three sectors. The various plant costs were converted to costs per square foot ($1 \text{ ft}^2 = 0.0929 \text{ m}^2$) of annual capacity and are shown in Figs. 1-3. Except for major mill overhauls, costs did not include smaller retrofit and modernization projects. Based on the few announcements of such projects, it appeared that they may yield greater capacity changes per dollar of expenditure than new mills. To the extent this was true, the series for capital costs derived was biased upward, although the bias was consistent.

Capacity costs also varied by mill size. Initially, I attempted to adjust each mill’s reported cost to a standard size, but abandoned the attempt because I could not distinguish between the effect that occurred for reasons of economies of scale from those that occurred because of disembodied technological change referred to previously.

Figure 1 depicts the estimated trend line for particleboard capacity costs along with the observations from which the trend was derived. It shows that the costs for two mills built or planned for the late 1980s were much greater than the trend line. However, the two mills in question were significantly different from the ones previously built. The latter were, for the most part, located in the West or South and designed to make unfinished boards from mill residues. In contrast, the two outlying mills were designed to use roundwood, and their equipment included board-laminating capabilities to add value to raw boards. These items boost plant and equipment costs in a number of ways over what would be required for a straightboard production facility. For these reasons, I felt the capital costs were not comparable with the type of mills previously built and did not use those values to establish recent costs. Instead, I used a general plant and machinery price index to extrapolate values from costs reported for previous years.

Mill capacities were derived in the same manner from news releases published in the trade press. Trade association reports and other sources were examined to determine changes in mill capacities over time as a result of expansions, modernizations, and technological change (McKeever and Meyer 1984; Dickerhoof and McKeever 1979; National
Particleboard Association 1993b; Canadian Particleboard Association 1993; Crows Digest 1989). The data represented U.S. plants, except for North American OSB, which included Canadian mills.

To obtain industry prices, I used two approaches. For particleboard, I employed the value of industrial shipments, because these represent the best estimate of the value of all items sold (National Particleboard Association 1993a). Such data were not available for southern pine plywood and OSB, and mill selling prices obtained from price-reporting publications, such as Random Lengths and Crows, were used as proxies. Unfortunately, the use of a single price to represent overall industry realization renders the $q$ ratios for different industries not comparable. For OSB, this is a small problem because the bulk of the industry’s shipments are composed of standard grade, commodity-type items. In a typical southern pine plywood mill, however, several grades of products are made over and above the basic commodity type. To reflect this higher value mix, I increased the commodity grade price by 2%, a value chosen so as to always place the price above the cost series; that is, $q$, was never less than zero.

Industry costs were determined in a two-step procedure. In the first step, up to three historical industry processes were identified, labelled as old, modern, and advanced. For each process, input-output coefficients were estimated based upon the normal requirements for inputs associated with each technology. Basic data were obtained from a general review of individual mill reports contained in the trade press. In the case of southern pine plywood, these coefficients were derived using a process simulation model developed by Spelter (1990). Historical unit costs for each input were collected and multiplied by the input-output coefficients to derive an average cost series for each process type.

In the second step, the shares of each process type were estimated based on size and plant technology descriptions of individual mills contained in trade reports. These shares were used as weighting factors to derive average industry costs. The results were cross checked against aggregate Census of Manufactures cost data to determine whether the two were reasonably close. If not, then the data, usually the process shares, were modified to bring the two into closer proximity. (This procedure was employed to estimate the changing share of technologies as this industry evolved.)

**Results and discussion**

Table 2 contains the parameters and statistics estimated for the three models industries using the format of eq. 5.

The first thing to note is that the left-hand variable, the rate of capacity growth, is based on observed capacity changes that incorporate the replacement and retirement rates of existing equipment as well as the addition of new equipment. Accordingly, as noted, when capacity is not binding and the shadow price of capacity is zero ($q$, equals zero), then no new investment should occur, and the constant equals the sum of the replacement and retirement rates, that is, the net rate of loss. In the short run (within a year), this ranges from 1.3% for southern pine plywood to 5.7% for particleboard. The long-run rate of loss differs...
according to the value of the coefficient associated with
the lagged dependent variable. Because the particleboard
lagged rate of capacity growth was not significant, the
long-run loss rate was the same as the short run. For south-
ern pine plywood and OSB, the loss rate adjusted gradually
over time to higher levels calculated from the equation
for an infinite series:

\[
[6] \text{long-run depreciation rate} = \frac{\text{constant}}{1 - \text{coefficient} \cdot \text{lagged depreciation}}
\]

These values appear below the constants in Table 2 and
range from 5.7% for southern pine plywood to 970 for
OSB.

The model allows for the effects of \( q \) to change as indus-
try size changes. When the value of the coefficient for the
term \( q \) divided by lagged capacity is negative, then the
effect of \( q \) increases as capacity grows. Conversely, a posi-
tive value for the cross-product term means that the influ-
ence of \( q \) declines with increasing capacity. Historically,
OSB technology has changed the most in relation to other
panels in terms of press times, adhesive application rates,
and handling of the wood furnish. These changes neces-
sitated plant modifications and equipment replacements at
a faster rate than for more stable processes in order to stay
competitive with new, more modern installations.

For particleboard, both the current and lagged \( q \) had
positive effects when industry capacity was small but
decreased as industry grew. In contrast, \( q \) with a lag of 2 years
showed an increasing effect over time. An explanation for
this is that initially, particleboard plants were small, about
50 x 10^6 ft^2 (89 000 m^2) of annual capacity. Environmen-
tal regulations were also less strict. Both factors aided faster
implementation of projects, hence the ability to respond
to profit signals quicker. In recent times, projects have
become bigger, involve greater financial investment and
risk, and are subject to more stringent scrutiny from regu-
lators. These factors tend to prolong the implementation
of projects.

For southern pine plywood, the reverse pattern emerged,
with the \( q \) lagging 2 years being the dominant influence
in the early part of the industry, and then \( q \) lagging 1 year
becoming dominant in the current, mature period. This
meshes with the changing nature of growth, namely the
switch from growth caused by the building of new plants
to growth caused mainly by modernization of existing
plants. Because the latter involves incremental changes to
existing facilities and costs less, the response time should
be shorter than for new plant construction.

For OSB, the timing effect was more stable, with a
small bias toward faster response times. Similar to south-
ern pine plywood, a large amount of capacity growth
resulted from improvements to existing plants that are
faster to implement, and hence may account for the trend.

The ability of these equations to simulate the past is
indicated by the standard statistical measure of goodness of
fit. Because these equations involve lagged values of pre-
dicted inputs, a more formidable test consists of a dynamic
simulation in which, instead of historical values, we sub-
stitute model-generated values of capacity. The results of
these experiments are depicted in Figs. 4–6. By and large,
errors are small but are carried forward and tend to build on
each other, persisting for lengthy periods. In the frame-
work of a linear program, however, low capacity would
stimulate higher shadow prices that would tend to act as a
corrective mechanism for such errors.

**Conclusions**

The results of capacity change presented here for three wood
panel industries were based on a model of investment
derived from a theory in which the driving variable is the
ratio of the financial market valuation of assets to their
replacement costs. Note that the actual working model
boils down to a formulation in which the driving variable
is simply an inflation-adjusted profit. As such, the model
harks back to previous econometric studies that were based
on the hypothesis that investment rates were profit driven
(Meyer and Kuh 1957). Whatever its genealogy, the results
achieved with the \( q \) theory for wood panels appear at least
as satisfactory as previous results on paper and paperboard, suggesting that this method may be applicable to a wide range of forest products.

In terms of the mechanics, this approach, using industry specific capacity replacement costs to deflate profits, offers an advantage over the use of aggregate inflation indexes that may not truly reflect industry conditions. Care should be taken in the calculation of replacement costs, however. Using aggregate investment data and dividing it by capacity changes to get current replacement costs may cause severe bias unless that portion of investment spent for noncapacity-producing purposes (e.g., pollution abatement or energy conversion) is filtered out.

A further advantage of the general formulation is that it allows for the possibility of structural change. By permitting the effect of \( q \) to vary, the equation is able to accommodate underlying changes in the conditions of an industry. Evidence of structural change was found in this study, attributed to the changing size and environmental hurdles that have occurred as these industries evolved. Evidence of structural change was also found in studies by Hayashi (1982), who detected shifts in the response to \( q \) following the increase in energy prices after 1975.

References


