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 étre 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 incorporate clans 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 influencent les décisions d'investir. Les résultats obtenus ici indiquent que la théorie s'applique bien clans les industries des panneaux gaufrés orientés, des contreplaqués de pin du sud et des panneaux de particules. Toutefois, les formules empiriques doiventêtre 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 premiéres 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[1] 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

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[1] Technical change, the ability to do more with less, is another source of capacily growth. This type of change is called "disembodied" technological change. In panel production, the development of faster curing or high moisture tolerant resins, for example, increased the capacity of presses and dryers. Mills did not necessarily need to incur capital expenses to take advantage of these enhancements if pressing and (or) drying were the mill bottlenecks.

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_t, *less* average variable cost, AC_t) in an industry.[2] The marginal cost of capital (RC_t, the denominator) is the current replacement cost of capacity, so from these, the approximation of marginal q is

$$[1] \quad q_t = \frac{p_t - AC_t}{RC_t}$$

and the working equation is

$$[2] \quad RCG_t = a + bq_t + u_t$$

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_t *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_t 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

[2] 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.

	Particleboard				Southern pine plywood				Oriented strandboard			
Year	RC	*C*	*P*	AC	RC	*C*	*P*	AC	RC	*C*	*P*	AC
1962	89	610	103	58	—	—	—	—	—	—	—	—
1963	89	650	104	59	—	—	—	—	—	—	—	—
1964	90	750	104	59	50	146	54	42	—	—	—	—
1965	90	1035	113	58	50	556	52	42	—	—	—	—
1966	90	1143	101	58	51	1 439	55	44	—	—	—	—
1967	91	1263	92	57	51	2 229	49	46	—	—	—	—
1968	94	1475	104	59	53	2 939	65	49	—	—	—	—
1969	98	1747	124	58	57	3 328	67	54	—	—	—	—
1970	103	2100	96	57	58	3 804	55	53	—	—	—	—
1971	103	2833	90	61	61	4 634	65	59	—	—	—	—
1972	109	3132	95	66	63	5 449	91	65	—	—	—	—
1973	117	3482	114	79	63	5 754	93	75	—	—	—	—
1974	125	3662	116	94	61	6 302	84	82	120	560	85	64
1975	134	4078	108	103	70	6 933	87	81	136	685	85	68
1976	150	4323	115	104	84	7 412	116	92	150	685	112	71
1977	172	4170	136	104	96	7 777	149	102	180	795	135	71
1978	195	4294	220	121	105	8 369	163	116	195	925	145	70
1979	208	4022	170	138	115	9 179	154	139	215	1 085	137	81
1980	223	3959	180	155	118	9 592	158	135	230	1 315	135	92
1981	240	3894	187	169	125	10 299	143	135	235	1 880	128	99
1982	254	3800	196	181	134	10 715	142	124	236	2 680	127	104
1983	261	3700	202	181	143	10 785	159	131	211	3 595	140	106
1984	267	3673	218	186	150	10 838	150	129	208	4 560	124	107
1985	273	3808	203	179	159	10 997	145	120	206	5 405	135	108
1986	278	3910	213	175	168	11 335	149	118	206	5 913	129	101
1987	283	4184	225	172	175	11 884	149	132	206	6 701	125	105
1988	290	4262	224	181	184	12 369	141	134	170	7 846	109	107
1989	301	4276	229	185	192	12 753	163	136	187	9 122	147	111
1990	311	4628	216	183	199	12 886	149	137	189	9 907	110	103
1991	321	4616	213	178	210	13 038	143	139	192	10 082	127	97
1992	328	4598	228	182	—	—	—	—	195	10 317	187	102
1993	—	—	—	—	—	—	—	—	215	10 497	192	107
1994	—	—	—	—	—	—	—	—	230	11 607	192	110

Note: RC is replacement cost of capacity (in US$ per 1000 ft^2,3/8-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.

usable results even when q was lagged by various periods. I ascribe this failure to the fact that the three industries were modeled from at or near their origins in time. That this was not a problem in modeling the paper industry, I attribute to the period chosen for study, which represented a mature phase of that industry where the effect of such nonlinearities are small.

This suggests the need for a more general formula that accounts for the different effects of q over the various phases of an industry's life cycle. I posited that the parameter b is a function of an industry size barometer. For this role, I selected the previous period's capacity, C_{t-1}:

$$[3] \quad b = c + \frac{d}{C_{t-1}}$$

that converts eq. 2 to

$$[4] \quad \mathrm{RCG}_t = a + cq_t + d\left(\frac{q_t}{C_{t-1}}\right)$$

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}:

$$[5] \quad \mathrm{RCG}_t = a + cq_t + eq_{t-1} + d\left(\frac{q_t}{C_{t-1}}\right) + f\left(\frac{q_{t-1}}{C_{t-2}}\right) + g(\mathrm{RCG}_{t-1})$$

An additional consideration is the lag between market signals and the response. For capital intensive enterprises

Fig. 1. Cost of new particleboard mills, per unit of capacity.

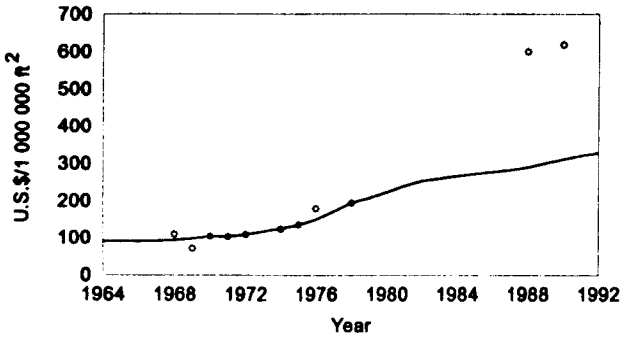


Fig. 2. Cost of new OSB mills, per unit of capacity.

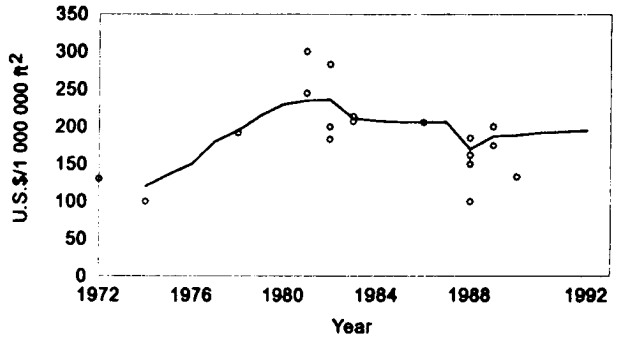
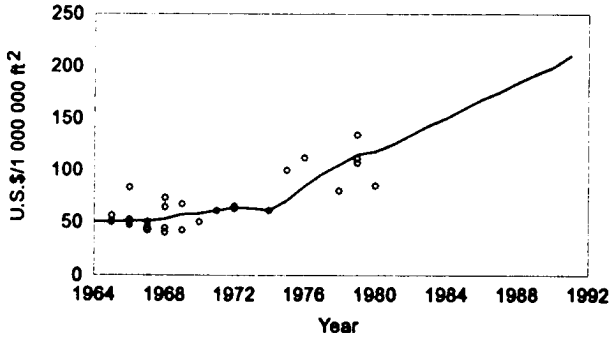


Fig. 3. Cost of new southern pine plywood mills, per unit of capacity.



such as southern pine plywood, 0SB, 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 0SB) 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 0SB 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 ft^2 = 0.0929 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

Table 2. Estimated model parameters.

	Particleboard	Southern pine plywood	Oriented strandboard
Independent variables			
Equation intercept	−0.057 (−2.3)	−0.013 (−1.0)	−0.046 (−1.1)
Long-run turnover	−0.057	−0.057	−0.090
q_t	−0.036 (−0.3)		
q_{t-1}	−0.300 (−1.7)	0.521 (4.8)	
q_{t-2}	0.900 (5.0)	−0.233 (−3.1)	0.206 (1.5)
q_{t-3}		−0.059 (−1.0)	0.416 (2.5)
q_{t-4}			0.098 (0.4)
q_t/C_{t-1}	521.3 (2.5)		
q_{t-1}/C_{t-2}	184.4 (0.7)	−3357.0 (−5.4)	
q_{t-2}/C_{t-3}	−572.5 (−2.7)	1855.0 (6.4)	−309.2 (−2.3)
q_{t-3}/C_{t-4}		422.0 (3.0)	
q_{t-4}/C_{t-5}			317.0 (1.5)
RCG_{t-1}		0.751 (5.9)	0.488 (3.7)
Summary statistics			
Years	1965–1990	1969–1991	1978–1994
No. of observations	26	23	17
Adjusted R^2	0.78	0.86	0.88

Note: Numbers in parentheses represent parameters divided by their standard errors.

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, 1 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_t 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

Fig. 4. Simulated and actual particleboard capacity.

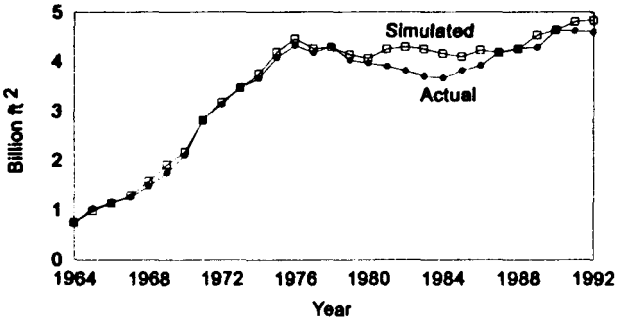


Fig. 5. Simulated and actual 0SB capacity.

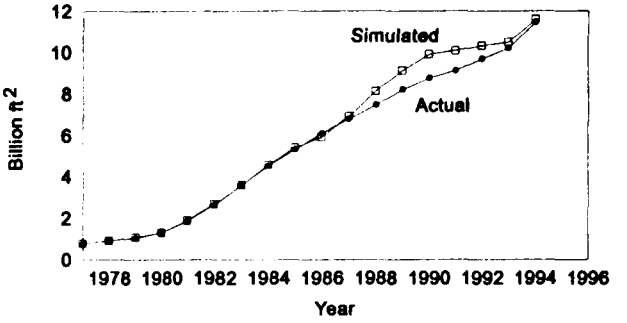
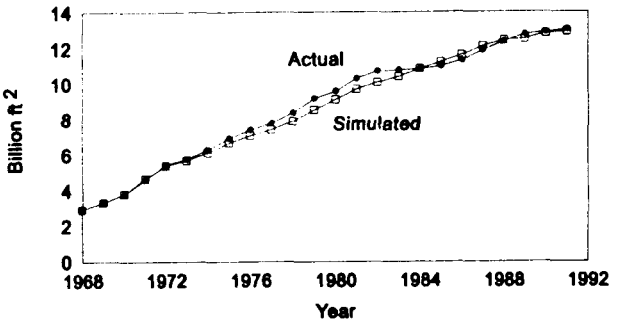


Fig. 6. Simulated and actual southern pine plywood capacity.



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 southern pine plywood and OSB, the loss rate adjusted gradually over time to higher levels calculated from the equation for an infinite series:

[6] long-run depreciation rate

$$= \frac{\text{constant}}{(1 - \text{coefficient}_{(\text{lagged depreciation})})}$$

These values appear below the constants in Table 2 and range from 5.7% for southern pine plywood to 970 for 0SB.

The model allows for the effects of q to change as industry 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 positive value for the cross-product term means that the influence 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 necessitated 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 declined 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 50×10^6 ft^2 (89 000 m^3) of annual capacity. Environmental 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 regulators. 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 southern 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 predicted inputs, a more formidable test consists of a dynamic simulation in which, instead of historical values, we substitute 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 framework 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

Abel, A.B. 1980. Empirical investment equations: an integrative framework. *In* On the state of macroeconomics. Vol. 12. *Edited by* K. Brunner. Carnegie-Rochester Conference on Public Policy, 1979, Rochester, N.Y. North Holland, Amsterdam.

Addams, D., and Haynes, R. 1980. The 1980 softwood timber assessment market model: structure projections and policy simulations. For. Sci. Monogr. 22.

Canadian Particleboard Association. 1993. Industry statistics. Canadian Particleboard Association, Ottawa, Ont.

Crow's Digest. 1989. OSB 1989: specialties and developments. C.C. Crow Publications, Portland, Oreg.

Dickerhoof, H.E., and McKeever, D.B. 1979. Particleboard, MDF and Mende process board plants in the United States, 1956–76. USDA For. Serv. For. Prod. Lab. FPL-RB-6.

Gilles, J.K., and Buongiorno, J. 1987. PAPYRUS: a model of the North American pulp and paper industry. For Sci. Monogr. 28.

Hayashi, F. 1982. Tobin's marginal q and average q: a neoclassical interpretation. Econometrica, **50**(1): 213–224.

McKeever, D.B., and Meyer, G. 1984. The softwood plywood industry in the United States, 1965–82. USDA For. Serv. For. Prod. Lab. FPL-RB-12.

Meyer, J., and Kuh, E. 1957. The investment decision. Harvard University Press, Cambridge, Mass.

National Particleboard Association. 1993*a*. 1992 U.S. annual shipments and production. National Particleboard Association, Gaithersburg, Md.

National Particleboard Association. 1993*b*. 1993 U.S. annual capacity survey. National Particleboard Association, Gaithersburg, Md.

Spelter, H. 1990. PLYMAP–a computer simulation model of the rotary peeled softwood plywood manufacturing process. USDA For. Serv. For. Prod. Lab. FPL-GTR-65.

Summers, L.H. 1981. Taxation and corporate investment: a q-theory approach. Brookings Pap. Econ. Activ. **1**: 67–140.

Tobin, J. 1969. A general equilibrium approach to monetary theory. J. Money Credit Banking, **1**: 15–29.

Veltkamp, J.J., Young, R., and Berg, R. 1983. The Data Resources Inc. approach to modeling demand in the softwood lumber, plywood and pulp and paper industries. *In* Forest sector models. *Edited by* R. Seppala. AB Academic Press, Berkhampstead, England.

von Furstenberg, G.M. 1977. Corporate investment: does market evaluation matter in the aggregate? Brookings Pap. Econ. Activ. **2**: 347–397.

Zhang, D., and Buongiorno, J. 1993. Capacity changes in the United States paper and paperboard industries: q theory and empirical model. Can. J. For. Res. **23**: 72–80.

Zhang, D., Buongiorno, J., and Ince, P. 1993. PELPS III. USDA For. Serv. For. Prod. Lab. FPL-RP-526.

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