ECONOMIES OF PLANT AND FIRM SIZE IN THE UNITED STATES PULP AND PAPER INDUSTRIES[1]

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ABSTRACT

Statistics from the United States Bureau of the Census, census of manufacturers of 1972 for the pulp and paper industries, were analyzed with respect to labor productivity and profitability for evidence of economies of scale. In the pulp industry, profitability and productivity appeared to decrease sharply for mills with more than 500 employees. For paper and paperboard, productivity and profitability tended to level off or decline only slightly in mills with more than 500 employees. Only in the small building paper and paperboard industry did the largest mills exhibit the highest productivity. Integrated paper mills appeared more profitable than nonintegrated mills, but even the former revealed a limit to productivity gains resulting from increases in size. Employees in large mills received significantly higher wages and worked fewer overtime hours. Survivor data for pulp mills indicated a strong increase in the relative frequency of plants with 250 to 500 employees, and a large decrease in plants with 100 to 250 employees. For paper mills, a small increase in the relative number of plants with more than 250 employees was apparent. Survivor data for other industries were inconclusive. For the three largest industries, there was no evidence of economies of scale at the firm level offsetting the stagnation or decline of productivity in large plants. Size of plants appeared to explain most of the variation in productivity among firms.

Keywords: Labor productivity, profitability, wages, survivor analysis.

INTRODUCTION

The view that there are considerable economies of scale in the manufacture of pulp and paper has a long history. Entrican (1950) argued that to achieve low average costs, production should be concentrated in as large plants as practicable. Sandwell (1960) asserted that except in extraordinary circumstances "small" mills cannot be as economic as "large" mills. More recently Sutton (1973) stated that plants are constantly being expanded to capture economies of scale. This general conclusion appears to be based on the belief that both capital and production costs per unit of output decline as the productive capacity of plants increases (FAO 1973; Gregory 1972; Guthrie 1972). Yet, a few dissenting opinions have also been expressed. Worrell (1959) contended that the most efficient plant size had already been reached. More recently, King (1977) has pleaded convincingly for the installation of small- to medium-size mills in developing countries. And Grant (1978) has, using Eklund and Kirjasniemi's (1969) data, reasoned that small mills can be economically viable even in industrialized countries.

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The extent of economies of scale in the pulp and paper industries is an important consideration in the formulation of public policy. These industries are generally quite concentrated, and have occasionally been characterized by noncompetitive behavior (Michaels 1979). Barriers to entry, which stem largely from the enormous capital required for new mills and the woodlands to supply them, while formidable at present, are predicted to increase in the future (Little 1977). Yet, if there exist large economies of scale, there may be significant social benefit from having only a few firms operate very large mills.

The objective of this paper is to examine the effect of plant and firm size on the economic efficiency of the pulp and paper industries. We plan to show that for the three major industries—pulp, paper, paperboard except building—although efficiency increases rapidly from small- to intermediate-size mills, it then levels off or even declines for very large mills. The same is true for integrated and nonintegrated paper mills, although integrated mills appear somewhat more efficient. Workers appear to fare better in large mills; they tend to work fewer hours and receive better wages. Nevertheless, there is no clear evidence that the relative number of small mills is declining. Analyses of profitability and productivity in firms of various size indicate that there are no economies of scale for firms that cannot be explained by the size of mills used.

METHODS AND DATA

The paucity of quantitative studies of economies of scale in the pulp and paper industry may be due to the difficulty of using econometric or engineering analysis in this context. Econometric estimation of economies of scale from cost functions requires data which, while available for some public utilities or railroads (Borts 1968; Christensen and Greene 1976), are not readily available for other industries. On the other hand, engineering studies are costly and often limited in scope.

In this study we have instead used simple comparisons of labor productivity and profitability, along the lines suggested by Miller (1978a, b). In addition we have sought additional evidence from survivor data (Saving 1961; Gorecki 1978).

All data were taken from the 1972 census of manufactures, except for the survivor analysis, which uses information gathered during the last six censuses. For the census of manufactures, the data are reported for each establishment (esentially a plant) on value of output, employment, payroll, and cost of materials used. These data are tabulated by size of plant, defined by number of employees; and by size of firm, defined by value of shipments. For the pulp and paper industries, data are available at the four digit Standard Industrial Classification level, comprising: Pulpmills (SIC 2611), Papermills except Building Paper (SIC 2621), Paperboard Mills (SIC 2631) and Building Paper and Board Mills (SIC 2661).

INFLUENCE OF PLANT SIZE ON LABOR PRODUCTIVITY

Labor productivity will be used here as an indicator of the efficiency of pulp and paper plants of various sizes. Although this may be challenged on theoretical grounds (Kaiser 1971; Dempsey 1973), no practical alternative is available. In particular, over-all productivity cannot be computed because of the absence of data on capital input. However, several measures of labor input are available. These include total number of employees, total payroll, number of production

TABLE 1. *Labor productivity in pulp and paper plants of various size, based on value added per man-hour of production worker in 1972.*

Plant size					
Class	Number of employees	Pulp mills	Paper mills	Paperboard mills	Building paper and board mills
			(Dollars/hr)		
I	20–49	10.4	11.4	10.6	7.6
		(7)	(31)	(24)	(29)
II	50–99	12.6	11.6	11.0	8.2
		(6)	(33)	(66)	(19)
III	100–249	21.5*	12.6	11.7	12.0
		(5)	(80)	(80)	(16)
IV	250–499	19.7	13.3*	19.7*	10.7
		(10)	(56)	(43)	(5)
V	500–999	15.9[b]	12.9	18.8	13.3[b]*
		(7)	(68)	(20)	(5)
VI	1,000+		12.9	17.5	
			(27)	(15)	

Notes: Numbers in parentheses refer to the number of mills in that size class. * indicates the maximum labor productivity. The superscript b indicates that some larger mills were included.

workers, number of production worker man-hours, and total wages of production workers. We have chosen man-hours of production workers as the measure of physical labor input mainly because it is a relatively homogeneous and well-defined quantity.

The simplest measure of output is the value of shipments. However, Census Bureau data also provide an estimate of value added by manufacture. Value added is derived by subtracting the total cost of materials from the value of shipments, and adjusting the resulting amount by the net change in finished products and work-in-process inventories between the beginning and end of the year. Thus defined, value added is widely accepted as a measure of output. Value added, in conjunction with the number of man-hours of production workers, forms the basis of the labor productivity index used here.

Value added per man-hour has been computed for the four industries of interest, for each size class of plant as defined by the total number of employees, for which census data are reported. According to this size classification, number of employees doubles between each successive class. Roman numerals have been used to identify these size classes in Tables 1 to 6. They will be used throughout the text for brevity in referring to a given size class. It should be noted that there is a much larger absolute difference in number of employees between size classes V and VI than between size classes I and II (Table 1).

As indicated in Table 1, labor productivity in pulp mills increases rapidly with size of plant up to plants with 100 to 250 employees. Value added per man-hour in pulp mills of size class III was double that of size class I. However, labor productivity measured in this manner was slightly lower for the next largest size class, and considerably lower (by about $5 per man-hour) for the seven mills with more than 500 employees.

For paper mills, value added per hour also increased with size of plant up to

a point. The increase in productivity is much smaller than for pulp mills; the difference is only about $2 per man-hour between mills employing fewer than 50 persons and mills ten times larger. Labor productivity peaks in mills with 250 to 500 employees and declines slightly in larger mills.

For paperboard mills there appears to be little increase in labor productivity between size classes I and III. But, in contrast with paper mills, value added per hour is much higher for plants in size class IV, i.e., 250 to 500 employees. Productivity tends to decline for larger mills.

The pattern is less systematic for building paper and board mills. Value added per man-hour of production worker increases steadily from size class I to III, declines for size class IV but reaches its maximum in size class V. This is the only industry in which the largest mills exhibit the highest labor productivity. However, the productivity difference between size classes III and V is not very large. Furthermore, it must be kept in mind that value added originating from building paper and board mills represented only some 5% of the value added for the entire pulp and paper industry, in 1972. The situation in this small sector therefore cannot be considered typical of what occurs in all pulp and paper industries.

In summary, the evidence provided by value added and employment data tends to indicate that although there is generally a substantial increase in labor productivity as size of plant increases, there is a limit to this phenomenon. For paper and paperboard, giant mills are no more productive than mills with 250 to 500 employees, whereas pulp mills with 100 to 250 employees appear much more productive than mills that are two to four times as large.

EFFECT OF PLANT SIZE ON PROFITABILITY

To get some indication of how profitability may vary according to mill size, we used the profitability index adopted by Miller (1978a). Total profit or, more accurately, "gross rent" is defined as value added minus payroll—that is, value of shipments, minus value of materials, minus payroll. Gross rent is not comparable across mills, however, because of large differences in mill size. Miller adjusted for mill size by dividing gross rent by number of employees. We chose instead to use number of man-hours for production workers as our standard in order to obtain a measure of profitability similar to the productivity measure used above. The resulting profitability index (gross rent per man-hour of production worker) is in effect a combination of economic profit, return to capital, depreciation, nonplant costs, purchased services, and payment for proprietor's labor (Miller 1978a). Since the pulp and paper industries are capital-intensive, one might expect return to capital and depreciation to be of major importance.

The results are reported in Table 2. The pattern observed for labor productivity is repeated by the profitability index—rising profitability up to medium-size mills, then stagnant or declining profitability over a wide range of sizes, with the exception of the building paper and paperboard industry, in which the largest mills appear most profitable.

EFFECT OF VERTICAL INTEGRATION AND SIZE ON PRODUCTIVITY AND PROFITABILITY OF PAPER MILLS

There appears to be an increasing tendency for pulp and paper firms to integrate vertically, for example for pulp mills to acquire a paper mill or vice-versa. There-

TABLE 2. *Profitability of pulp and paper plants of various sizes, based on gross rent per man-hour of production worker in 1972.*

Plant size					
Class	Number of employees	Pulp mills	Paper mills	Paperboard mills	Building paper and board mills
			(Dollars/hr)		
I	20–49	6.2	6.5	5.3	3.4
		(7)	(31)	(24)	(29)
II	50–99	6.3	6.1	5.6	3.1
		(6)	(33)	(66)	(19)
III	100–249	14.9*	6.4	6.1	6.8
		(5)	(80)	(80)	(16)
IV	250–499	12.2	6.9*	12.9*	4.9
		(10)	(56)	(43)	(5)
V	500–999	8.7[b]	6.6	12.2	8.0[b]*
		(7)	(68)	(20)	(5)
VI	1,000+		6.3	10.5	
			(27)	(15)	

Notes: Numbers in parentheses refer to the number of mills in that size class. * indicates the maximum profitability. The superscript b indicates that some larger mills were included.

fore, it is of interest to know the effect of such integration on plant performance. The Bureau of the Census collects data by size classes for both integrated and nonintegrated paper mills, paperboard mills and building paper and board mills. However, disclosure rules prevent the publication of many data. A notable exception, however, is paper mills, except building paper (SIC 2621) for which fairly complete data are available. For this class of mills, we have computed the profitability and productivity indices described above, for both integrated and nonintegrated mills (Table 3).

It appears that at equal size, paper mills integrated with a pulp mill are generally

TABLE 3. *Value added and gross rent per hour of production worker for integrated and nonintegrated paper mills.*

Plant size		Integrated with a pulp mill		Not integrated with a pulp mill	
Class	Number of employees	VA/H ($/hr)	P ($/hr)	VA/H ($/hr)	P ($/hr)
I	20–49	11.0	6.2	11.5	6.5*
		(7)		(24)	
II	50–99	11.2	5.6	11.8	6.3
		(8)		(25)	
III	100–249	13.1	6.7	12.3*	6.3
		(27)		(53)	
IV	250–499	14.3*	7.9*	12.0	5.7
		(31)		(25)	
V+	500+	13.2	6.7	11.2	4.8
		(79)		(16)	

Notes: Numbers in parentheses refer to the number of mills in that size class. P is the profitability index (gross rent per hour of production worker). VA is value added in millions of dollars. H is thousand man-hours. * indicates maximum labor productivity and profitability.

both more labor productive and more profitable than nonintegrated mills, except for mills with less than 100 employees. For integrated mills, labor productivity and profitability tend to increase with size, up to 250 to 500 employees. Both productivity and profitability appear to decrease beyond that size. Nonintegrated mills, on the other hand, seem to reach maximum labor productivity at smaller sizes (100 to 250 employees), while profitability is greatest in very small mills (fewer than 50 employees). In summary, paper mills integrated with a pulp mill appear to be both more productive and more profitable. However, even for integrated mills there is a limit to the gains resulting from increases in size. These gains are much smaller for nonintegrated mills.

LABOR PRODUCTIVITY AND WAGES IN PULP AND PAPER PLANTS OF VARIOUS SIZES

The profitability index used above gave some indication of the advantages (disadvantages) of various pulp and paper plant sizes from the point of view of the owners of capital. In a similar manner it is of interest to determine whether, and by how much, returns to labor vary in mills of different size.

According to economic theory, under competitive conditions any input into a production process is paid the value of its marginal product. For labor this should lead to a close relationship between the wage rate and labor productivity. Guthrie (1972) argues that in the pulp and paper industries wage rates are a direct function of productivity. While the industries are strongly unionized (97% for papermakers and 100% for pulp mill workers), contracts are normally negotiated independently at each mill. Hence, wage rates largely reflect productivity (Guthrie 1972). According to Guthrie (1972), unions have modified their wage demands in low productivity mills in the past. In this section we examine whether variations in wages by size of plant follow the pattern of variations in labor productivity reported in Table 1.

Average wage rates for production workers have been computed for all mills in each size class for pulp mills, paper mills, paperboard mills, and building paper and board mills (Table 4). These wage rates are based on census data for total wages and total number of production worker man-hours.

The results indicate that wage rates do follow the general trend of labor productivity, both within and across industries. Within each industry, as the size of plants increases, wages and labor productivity tend initially to rise rapidly but then to rise only slowly as labor productivity reaches a plateau.

As Table 4 indicates, the difference between wage rates in the smallest and largest mills may be considerable, ranging from 20% for paperboard mills to 69% for pulp mills. Furthermore, these differences in average wage rates underestimate the differences in actual wage rates because the average wage rates in Table 4 are computed by aggregating normal and overtime work hours. An overtime index computed from census data and assuming a regular working year of 2,000 hours indicates that workers in small mills do considerably more overtime work than those in large mills. For example, in 1972 the average worker in pulp mills with fewer than 50 employees worked 24% more overtime hours than his counterpart in mills with more than 500 employees. Nevertheless, his average hourly wage was $3.20 versus $5.40 for workers in the largest plants, and his total annual earnings were 36% lower. Only in the paperboard industry did pay of workers in

TABLE 4. *Labor productivity and wages in pulp and paper plants of various sizes.*

Plant size		Labor productivity ($/hr)	Average wage rate ($/hr)	Overtime index[1]
Class	Number of employees			
		Pulp mills, except building		
I	20–49	10.4	3.2	1.25*
II	50–99	12.6	4.7	1.16
III	100–249	21.5*	5.2	1.07
IV	250–499	19.7	5.7*	1.09
V	500+	15.9	5.4	1.01
		Paper mills, except building		
I	20–49	11.4	3.9	1.25*
II	50–99	11.6	4.0	1.18
III	100–249	12.6	4.4	1.12
IV	250–499	13.3*	4.9	1.06
V	500–999	12.9	4.8	1.11
VI	1,000+	12.9	5.0*	1.08
		Paperboard mills		
I	20–49	10.6	4.1	1.26*
II	50–99	11.0	4.2	1.19
III	100–249	11.7	4.5	1.17
IV	250–499	19.7*	5.2*	1.13
V	500–999	18.8	5.1	1.10
VI	1,000+	17.5	4.9	1.04
		Building paper and board mills		
I	20–49	7.6	3.5	1.12*
II	50–99	8.2	4.3	1.09
III	100–249	12.0	4.3	1.20
IV	250–499	10.7	4.4	1.04
V	500+	13.3*	4.5*	1.05

[1] Computed as total number of man-hours per year divided by 2,000. * indicates maximum productivity, wages, or overtime.

the smaller mills match the yearly pay of workers in the largest mills, but they achieved this by working 21% more hours.

To summarize, there appears to be a clear advantage to working in large mills; e.g., less work for better wages. These differences may arise in part from differences in labor productivity and related differences in labor skills. For example, differences in wage rates between the largest and smallest paperboard and building paper and board mills are more than compensated for by differences in productivity. But this is not the case in pulp mills and paper mills. It may well be that there are some economies of scale in labor organization itself (Masters 1969). Larger plants are likely to face stronger unions capable of obtaining better contracts for their members.

EFFECT OF PLANT SIZE ON SURVIVAL

Because of the measurement and definition problems attached to the productivity and profitability indices used above, additional evidence was sought regarding the effects of plant size on economic performance. A good indicator of the economic efficiency of a plant of a particular size is its ability to survive over