IMPACT OF LOG SMALL-END DIAMETER ON THE COST OF SAWN TIMBER: CASE STUDY OF A SMALL BANDMILL

R. K. GRANT*

ABSTRACT

A case study of a small bandmill showed that increasing log small-end diameter from 250 mm to 800 mm caused a 14 to 18% reduction in the mean cost of sawn-timber production. Nearly all of this reduction was due to the effect of log small-end diameter on conversion rather than on the rate of production.

However, log small-end diameter was found to be a poor indicator of the cost of the sawn timber produced from a log; 82% of the variation in percentage conversion and over 99% of the variation in the cost of the sawing process were due to factors other than log small-end diameter.

INTRODUCTION

For some years now the concept of a price/size relationship for logs has been advocated as a way of compensating forest growers for the increased costs involved in producing larger logs. While many countries recognise that log size is a major determinant of stumpage values, it is rarely incorporated into sales of standing timber in New Zealand (Sutton, 1973). However, it is commonly accepted that both the cost of producing sawn timber and the returns from it are influenced by log size.

The cost of sawing is an important component of the cost of production; it ranges from 17 to 50% (depending on the interest rate used) of the total cost (including growing and sawing costs) (Fenton, 1972). Sawing cost/small-end diameter (s.e.d.) relationships have been used in forest profitability studies for a number of years (Fenton and Brown, 1963; Fenton, 1972) and they are essential if the profitabilities of silvicultural regimes producing different log size distributions are to be compared.

This paper describes an attempt to provide some insight into the nature of cost of sawing/log size relationship for pine sawlogs in New Zealand from the study of a simple but fairly efficient band headrig mill.

*Scientist, Forest Research Institute, Rotorua.

THE STUDY

At the time of the study, the mill had a weekly sawn-timber production of roughly 100 m^3 from a medium-duty band headrig,[1] two breast benches, and three docking saws. In practice one of the breast benches was primarily devoted to sawing slabs and the other, with setworks, was used to recut cants. Only rarely was the second breast bench required to resaw slabs. The headrig undertook sawing both for boards and for structural grades greater than 100 × 50 mm (4 in. × 2 in.). Because the cants sent to the second breast bench had to be small enough to be manhandled, they could be cut from most log sizes. For this reason the decision to put cants and slabs to the breast benches for further sawing was dependent at least as much on the state of their infeed decks as on the size of the log. Thus the breast benches were not dependent on any particular size of log as a source of wood for sawing, nor was their rate of production influenced by the size of the log. Accordingly, for the mix of logs supplied to mill, and the mix of products required, the breast benches had a daily production which was independent of log size.

For this reason the only sawing time recorded for each log was the headrig sawing time (the total time taken to load a log on to the headrig plus the time taken to saw the log). No attempt was made to associate the time taken to saw the log on the breast benches with the time taken on the headrig. Log volume (end diameters and length) and total sawn output (after docking) were also recorded for each log.

In ensuring that the data collected were representative of normal operating conditions, it was found necessary to disregard data collected on the first 3 days of the study because production was both higher than normal and unsettled. This was so even though the members of the study team had been at the mill for intervals over the previous month.

The study resulted in a complete set of consistent data for a total of 815 pine logs, mainly from clearfellings. The logs were widely distributed within the diameter range 180 to 700 mm[2] and ranged in length from 3 to 7 metres (a full joint diameter/length distribution is given in Appendix 2). Samples from the log input had a mean basic specific gravity of 43.4 kg/m^3 (standard error 2.0) and the percentage saturation of the sampled logs was 63.2 (standard error 2.95).

---

[1] See Appendix 1 for a full description of the headrig and carriage.

[2] Actual diameter range was extended to 150 mm and 800 mm by a few outliers.

THE CONVERSION FACTORS

Figure 1 shows both the mean percentage conversion for each 30 mm diameter class and the least squares regression. Percentage conversion = 58.54 − 537.15/(s.e.d.). The regression explained only 18% of the total variation in percentage conversion. However, the manner in which the means for the 30 mm diameter classes closely follow the regression line shows that the regression provides a good indication of the impact of small-end diameter on conversion The unexplained variation in conversion is due to factors other than log s.e.d. The extent of this unexplained variation is illustrated by the distance between the 95% confidence limits of the regression given in Fig. 1.

Further, the means of the diameter classes graphed in Fig. 1 illustrate the stepwise nature of change in conversion, presumably because each cutting pattern is used over a range of diameters before a new cutting pattern becomes more efficient.

In spite of the poor explanation the regression offers it does indicate that, everything else being equal, small-end

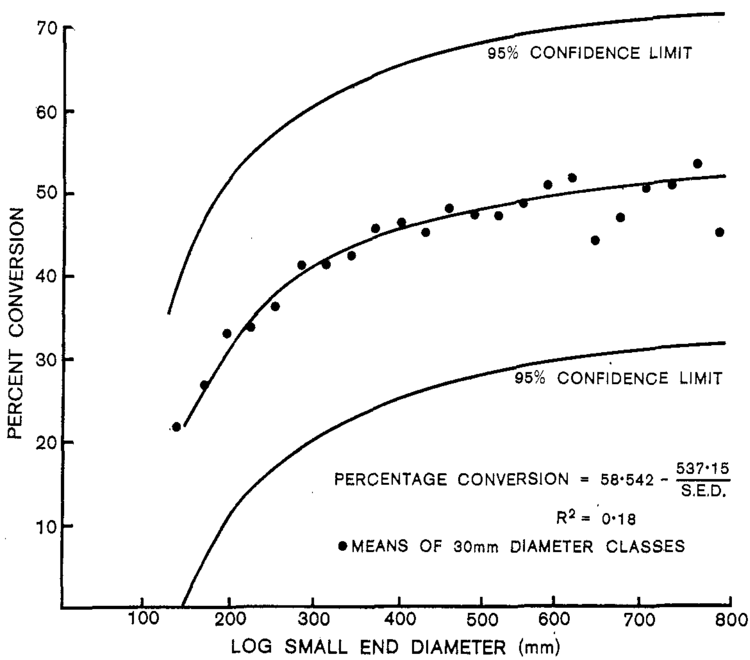

FIG. 1: *The effect of log small-end diameter on the percentage conversion.*

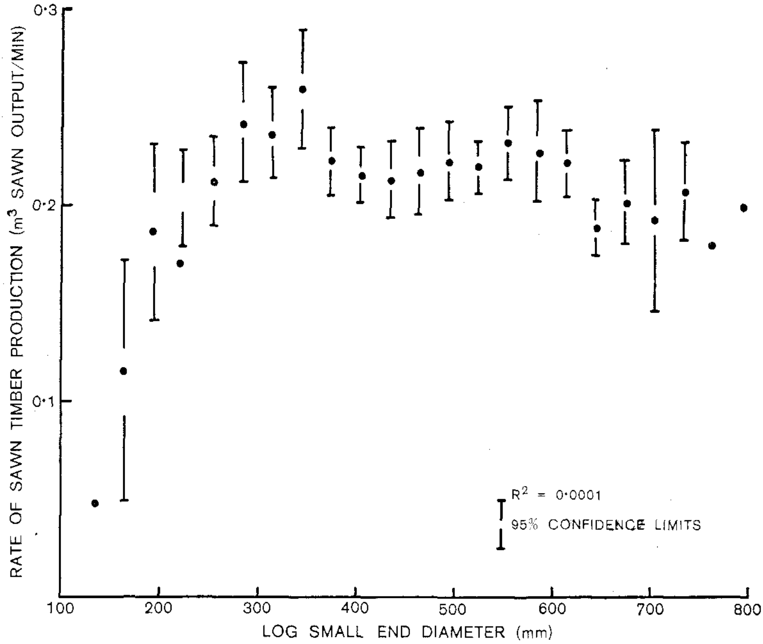

FIG. 2: *The effect of log small-end diameter on the rate of production.*

diameter has a pronounced impact on the percentage conversion obtained, particularly within the diameter range 150 mm to 300 mm.

THE RATE OF PRODUCTION

In Fig. 2 the mean output/min for each of the 30 mm diameter classes is graphed, together with their 95% confidence limits. While the figure shows some fall in the rate of production for logs with s.e.d. less than 200 mm, the rate of sawn-timber production in this mill was not related to log s.e.d. In fact, the linear correlation between rate of production and s.e.d. was not significantly different from zero.[3]

[3] While Fig. 2 suggests that a non-linear correlation may be more appropriate, this ignores the distribution of the data. In fact only 5 of the 815 data points are for diameters less than 180 mm. (See Appendix 2.) There is the further problem that the data on rate of production are correlated with each other in a complex manner. This precludes fitting a non-linear relationship using least squares analysis.

Consequently the mean rate of production for all logs with s.e.d. greater than 200 mm (0.22 m^3/min) can be used for distributing the costs of sawing. For logs less than 200 mm, the rate of production has arbitrarily been set at half this rate.

THE COST STRUCTURE

Because the final analysis was to be published, no survey of the mill's costs was conducted. Instead an "average New Zealand sawmill" cost structure (Table 1) was synthesised from an analysis of the detailed costings of the Waipa and Conical Hill State sawmills (both bandmills and framemills) and from a study of the cost structure of the industry as a whole (Department of Statistics, 1972). The most important feature of the table is the division of the cost of producing sawn timber into the cost of logs (40 to 50% of the total cost) and the cost of the sawing process (50 to 60% of the total cost). The percentage conversion of log volume into sawn timber is obviously relevant to the 40 to 50% of the costs that is the cost of logs because a higher conversion will lower the log cost component of sawn timber.

In his costings, Grainger (1970, 1971) suggested that the cost of the sawing process may be fairly approximated as a constant cost per minute irrespective of the momentary rate of production. This is because, given the distribution of logs

TABLE 1: APPROXIMATE DISTRIBUTION OF THE COSTS OF PRODUCING GREEN-SAWN TIMBER

Item	*Percentage*	
Direct cost of sawing:		
Wages and salaries	15-16	
Power and steam	1-2	
Saw maintenance	2	
Transport (yard and waste)	4	
Repairs and maintenance	6-9	
Miscellaneous	1-2	
Total direct costs		30-40
Indirect costs of sawing:		
Depreciation of assets	2-3	
Supervision salaries	1-2	
Mill overheads	4-5	
Total indirect costs		7-10
Marketing (wages and salaries 2-4)		7-10
Manufacturer's surplus		9-11
Total cost of sawing process		50-60
Cost of logs		40-50

Sources: Department of Statistics (1972); Grainger (1970, 1971).

going into the mill, the hourly labour, depreciation, and overhead components of sawmill costs will remain the same for all logs. The only detectable cost changes likely to occur with differences in log size are in power, marketing charges, and manufacturing surplus. Jointly these items comprise only 17 to 24% of the total cost of sawn timber. Since variations in log size are likely to cause less than a 10% change in labour, depreciation, and overhead charges, the variation in total sawing costs is likely to be limited to around 2% — an inconsequential amount in view of the inaccuracies of the costing system and it may be safely ignored.

Accordingly, variations in the rate of production with log s.e.d. (sawn output per unit time) are an appropriate vehicle for distributing between logs the 50 to 60% of the costs which are the costs of the sawing process.

COST OF SAWN TIMBER — LOG SMALL-END DIAMETER DIFFERENTIAL

Assuming an average cost of sawn timber for all logs (say, $50/m^3$), it is then possible to incorporate the conversion factor and rate of production effects into a cost-of-sawn-timber/s.e.d. relationship by using the cost structure given in Table 1.

With the average cost of production set at $50/m^3$ of sawn output, Table 1 shows the cost of the sawing process will be $25 to $30/m^3$ of sawn output. Since the average rate of production for all logs was 0.223 m^3/min$ (standard error 0.003) the cost of sawing per minute of sawing time will range between $5.58 and $6.69. These can be converted to a cost of the sawing process for the two log sizes (s.e.d. $<$ 200 mm and s.e.d. $>$ 200 mm) by dividing by the appropriate rate of production. The results of these calculations are given in Table 2.

With an average cost of production of $50/m^3$ of sawn output, the average cost of logs will be $20 to $25/m^3$ of sawn output. Since the mean conversion factor for all the logs is 43.3%, the average cost of logs delivered to the mill will be between $8.66 and $10.83 per cubic metre of log.

TABLE 2: THE COST OF THE SAWING PROCESS

($/m³ sawn output)	*Logs with s.e.d. < 200 mm*	*Logs with s.e.d. > 200 mm*
Cost of sawing at 50% of total cost	50.72	25.36
Cost of sawing at 60% of total cost	60.81	30.40

Given that these per-cubic-metre costs of log to the sawmill are constant for all logs, then the log component of the cost of sawn timber can be determined for each log size by dividing the average stumpage by the conversion factor. Figure 3 shows the results of applying the conversion factors derived from the regression of Fig. 1 to the average cost of logs delivered to the mill. Curves A1 and A2 of the figure confirm that the rapid increase in conversion factor with increasing s.e.d. in the diameter range 100 to 300 mm results in an equally rapid decline in log costs per cubic metre of sawn output.

Figure 3 also contains a curve (B) showing the variation with log s.e.d. in the total cost of sawn-timber production; this variation is due to the combined impact of changes in both the rate of production and the percentage conversion. Little emphasis should be placed on the discontinuity in the graph at s.e.d. of 200 mm: it is most probably caused by the arbitrary division of logs into two groups for rate of sawn timber production (see "The Rate of Production" above). The broken line sketched in this graph is a more likely indication of the impact of log s.e.d. on the cost of sawn-timber production. However, the mill study included only 25 logs with s.e.d. less than 210 mm (see Appendix 2) and the entire relationship revealed by the graph should be treated as tentative for such log diameters.

Unexpectedly, when the percentage conversion and the rate of production effects were combined, it was found that differences in the allocation of costs (between logs and the sawing process) made little difference to the total cost of production for log diameters greater than 200 mm. In fact, for logs in this diameter range the difference in the cost of production in the two situations tested (logs 40% of total cost and logs 50% of total cost) was equivalent to less than 2% of the total cost.

DISCUSSION

Although the graphs of Fig. 3 show a pronounced relationship between log s.e.d. and the cost of producing sawn timber, it is essential to remember that log s.e.d. explains only a small proportion of the between-logs variation in the cost of timber production. Thus the results given in Fig. 3 depend on the assumption that everything except log diameter is held constant. Figures 1 and 2 illustrate that the variation in both percentage conversion and the rate of production is such that equivalent changes in the cost of production can be caused by other log characteristics or by log-characteristic/sawing-pattern interactions. Consequently there is no guarantee that,

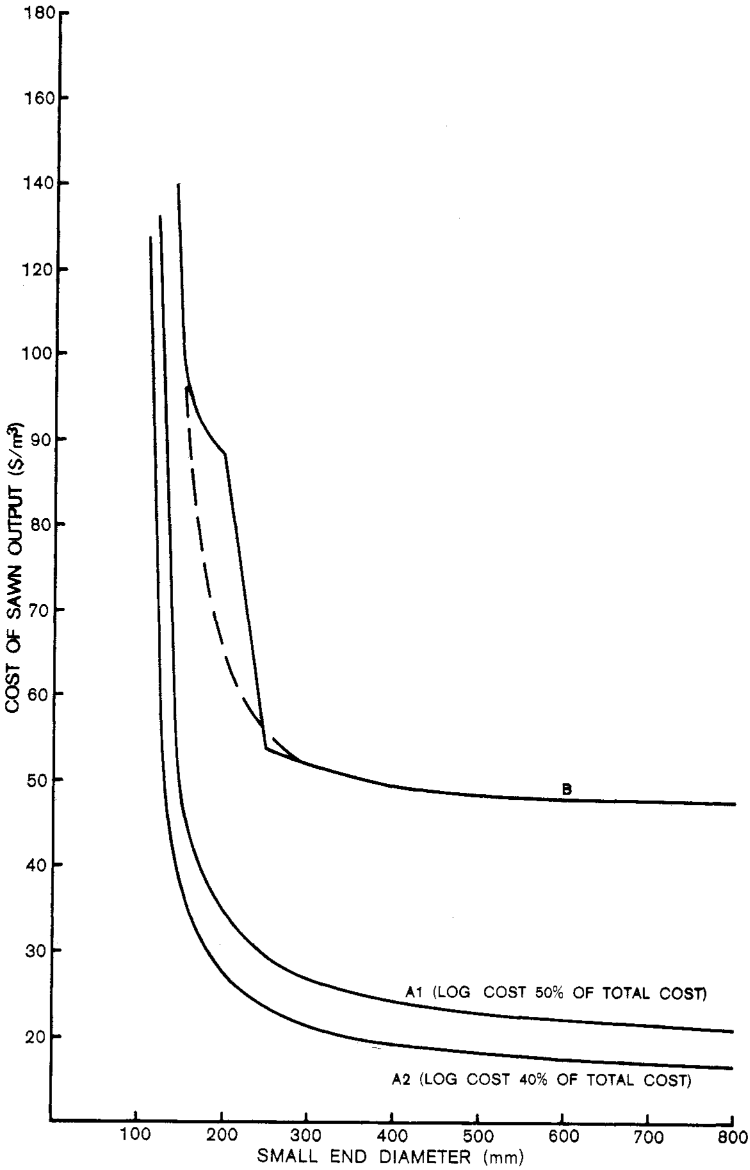

FIG. 3: *The effect of log small-end diameter on the sawn-timber production costs: A. Log cost per unit output. B. Total cost per unit output.*

for any mill, small-end diameter is the single most appropriate characteristic to use in grading logs.

Further, for logs of s.e.d. greater than 200 mm (that is, based on 807 of the 815 study logs) there is little variation caused by log s.e.d. in the cost of producing sawn timber. The drop in production costs in moving from a 250 mm s.e.d. log to an 800 mm s.e.d. log is only 14 to 18% of the total cost of production, depending on the breakdown of costs used. By far the most important factor in this decline in costs is the increase in percentage conversion accounting for more than 90% of the change.

Nevertheless it appears that, given the cost distribution shown and the assumptions involved in distributing these costs, it may be possible to lower the average cost of sawn-timber production at this mill merely by increasing the average log size. This does not mean that all small logs are sawn at high cost. In fact, it is apparent that timber produced from some small logs will cost less than timber produced from many larger logs.

Thus while it is possible, as a matter of expediency, to introduce a system which charges more for larger logs because of the variation in the cost of sawn-timber production with log size, it may be more appropriate to consider some other criterion (or combination of criteria) to indicate the cost of sawn-timber production.

REFERENCES

Department of Statistics, 1972. *Industrial Production Statistics.* Government Printer, Wellington. 288 pp.

Fenton, R., 1972. Economics of radiata pine for sawlog production. *N.Z. Jl For. Sci., 2* (3): 313-47.

Fenton, R.; Brown, C. H., 1963. An economic analysis of tending *Pinus radiata* in Southland. *N.Z. Jl For., 8* (5): 793-813.

Grainger, M. B., 1970. The comparative cost of frame sawing and band sawing at Conical Hill Sawmill. *N.Z. For. Serv., For. Res. Inst., Econ. of Silv. Rep. No. 16* (unpubl.).

——— 1971. The comparative cost of frame sawing and band sawing at Waipa Sawmill in 1970. *N.Z. For. Serv., For. Res. Inst., Econ. of Silv. Rep. No. 43* (unpubl.).

Sutton, W. R. J., 1973. Price size gradients for sawlogs: a review. *N.Z. Jl For., 18* (2): 298-300.

APPENDIX 1

DESCRIPTION OF THE BAND HEADRIG

The bandsaw was a Sumner right-hand medium-duty bandmill with 2.134 m diameter band wheels and a 0.305 m wheel face. It was powered by a 150 hp motor giving 960 rpm and providing a saw speed of 2743.2 m/min in exotic timbers. The bandsaw, which had a maximum length of 12.88 m and a minimum length of 12.42 m, was a 0.330 m wide 14-gauge saw with teeth swaged to give a kerf of 0.00419 m and 0.102 m wide sliver teeth on the back of the saw. It proved best with 0.051 m tooth spacing, tensioned to a 10.668 m diameter circle with a 0.04 cm in 1.524 m back in the saw under a 4953 kg flexible strain.

An Edwards carriage was powered by a Salem winch type feedworks giving a feed speed of up to 121.9 m/min in exotic timber and a back speed of approximately 228.6 m/min.

It had electrically operated Jaymor setworks with three knees with 0.762 m high back plates with 2.438 m between front and middle knees and 1.829 m between middle and back knees. Each knee had upper and lower air-operated dogs with a "hold-back" system. There was a maximum distance of 0.914 m from the front of the knee to the back plate and the front of the carriage was set back 8.9 cm from the saw.

The log infeed to the saw was designed to take logs up to 6.706 m in length.

APPENDIX 2
THE JOINT LOG-LENGTH/LOG-SMALL-END-DIAMETER DISTRIBUTION
(Log s.e.d. (mm))

Length (m)	< 150	150-179	180-209	210-239	240-269	270-299	300-329	330-359	360-389	390-419	420-449	450-479	480-509	510-539	540-569	570-599	600-629	630-659	660-689	690-719	720	Total
3.0										1	1											2
3.1-3.5					4	3	6	5	6	8	6	4	5	4	2	1	4	1	3	1		63
3.6-4.0			3	5	4	4	4	7	7	11	9	6	5	2		2	3	1	1			74
4.1-4.5		1	4	2	8	11	13	9	13	26	14	15	7	10	7	4	2	2	2	1	1	152
4.6-5.0		2	2	5	9	8	9	10	7	5	5	8	9	5	4		2	2	2	1	2	97
5.1-5.5		1	3	9	8	8	9	13	13	9	5	6	6	4	3	4	4	2		4	3	114
5.6-6.0			3	8	10	16	12	11	14	7	6	4	9	5	7	3	5	1	1			122
6.1-6.5	1		3	9	19	18	17	19	11	13	4	7	4	3	3		2	1				134
6.6-7.0			2	8	10	5	6	7	4	4	3	2	4	2								57
Total	1	4	20	46	72	73	76	81	75	84	53	52	49	35	26	14	22	10	9	7	6	815