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Evolution of Sawmill Productivity in East Coast Eucalypt Forests

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Introduction

Why is the increased productivity of thirteen small hardwood mills in south-eastern Queensland that occurred sixty years ago of interest? They no longer operate, their structures no longer exist and most of the people employed are now dead. What survives after six decades?

This question arises from examination of an economic study of thirteen sawmills in 1953 (Littler and Adkins 1954) and repeated in 1960 (Hinson and Horton 1961). The studies showed that, in 1960, 28 percent fewer men produced 43.5 percent more timber and recovered 12.5 percent more wood from logs when compared to the1953 results. Significantly, the improvement followed the Pareto distribution with the best mill increasing productivity by 240 percent above the 1953 average.[1]

This transformation occurred within the context of technological developments, improved operational management, evolving social mores and changes to forest silviculture. The techniques that enabled increased productivity were outlined by Littler and Adkins in the conclusion of their 1953 study. It is an outstanding example of research being published and then adapted to individual circumstances by industry. However, this evolution did not occur in all sawmills studied; by 1960 five sawmills had not markedly responded to the productivity challenge, five had partially responded and only three had strongly responded. The improvement of the most productive sawmill was outstanding. The most significant variable enabling this increase was the scale of the mill's log input, but this was not acknowledged in the studies because of confidentiality protocols - the identity of the mills was withheld by the authors.

It is reasonable to postulate that the most productive mill was owned by Hyne- a sawmill of long standing.[2] Sixty years later, by replacing mixed hardwood with logs from conifer plantations, Hyne Timber now operate two of Australia's largest sawmills.

Achievements evolve from ideas that create knowledge (Deutsch 2011). Ideas that endure challenge are the basis of human development and evolution. It is illustrated by the Pareto type distribution which shows skewed distributions that are recursive. As poor performers are displaced, those that remain form new populations that develop a more rigorous hierarchy and a renewed positively skewed distribution. The enduring ideas arising from the productivity studies are underpinned by the symbiosis of sawmill and forest management.

Summary of Results of Studies

The basis of the productivity gains by the hardwood sawmills in the 1950s arose from the replacement of steam by electricity as the dominant energy source which facilitated a number of outcomes as listed below.

1. Head saws were converted from frame saws to twin Canadian and band saws. Thus cutting patterns were developed whereby defect in logs could be removed at the head saw rather than the bench saw. This provided the production benches with billets that were free of defect. Logs containing higher defect became economic and by 1960 defect in logs increased by 36.5 percent which increased the sustainable yield of logs by at least 29 percent (Table 1).

Table 1: Sawmill Productivity in East Coast Eucalypt Forests

Variable	***1953***	***1960***	***Period Difference***	***Annual difference***
Number of sawmills	13	13		
Average sawn price: shillings/100 super feet	87.2	133	55%	7.8%
CPI 1953 to 1960	100	118	18%	2.6%
CPI 1950 to 1953	1950=100	1953=148	48%	16%
CPI 1960 to 1962	1960=100	1962=102	2%	1%
Number of logs	522	734	40.6%	5.8%
Gross log volume: super feet hoppus	273,743	396,960	45%	6.4%
Nett log volume: super feet true	210,657	272,415	29%	4.2%
Volume of Defect in log: super feet true	63,085	124,551	97%	13.9%
Log Defect: %	23%	31.4%	36.5%	5.2%
Sawn volume: super feet	136,674	202,312	48%	6.9%
Sawn recovery from gross log volume: %	50%	50.7%	0.7%	0.1%
Sawn recovery from nett volume: %	65%	73.9%	12.5%	1.8%
Mean log centre girth: inches	67	73.5	9.7%	1.4%
Log length: feet	22.4’	19.2’	-14.3%	-2.2%
Average Pipe: square inches	64	100	56%	8%
Average log volume: super feet hoppus	524.4	540.8	3.13%	0.45%
Number of species	15	15		
Employment total	160	125	-28%	- 4%
Average employment / mill	12.3	9.6	-28%	- 4%
Average mill size: super feet sawn	10,513	15,562	48%	6.9%
Average productivity: super feet/man-hour	43.4	62.3 @ 67”dia 63.3	43.5%	6.2%
4.5. Average productivity: man minutes/100 super feet	138	96	30.4%	4.3%

2. Without exception, productivity correlated positively with the size of the mill. The range was 37 super feet per man-hour for the smallest mill, 104 for the largest, with an average of 52. The Pareto distribution arose from the vastly superior performance of the three largest mills. Recovery of timber from logs also correlated with size of the mill, ranging from 51 to 83 percent (see Table 1). Thus the importance of scale became firmly enshrined in the production ethos of successful Australian sawmilling.

3. The silvicultural systems employed in coastal hardwood forests changed from being dominantly 'Australian group selection' towards 'clear falling' with retention of advanced regrowth.

4. The productivity gains not only enabled economic processing of poorer quality logs but logs in geographically remote forests also become economic. This conformed to government policy objectives of supplying timber for housing, a crucial element of resolving Australia's post war housing crisis. Timber supply from all Australian forests increased between 1945 and 1960 from 136 to 265 million super feet.3

5. These studies reveal that the conversion from steam to electric power facilitated the upgrading of sawmill performance by a vast increase in the energy to work ratio of electricity compared to steam. Further, the delivery of energy to saws via electric cabling, rather than mechanical fly wheels, shafts and belts enabled the innovative redesign of sawmills. This encouraged the design and application of sawing patterns that dramatically increased the productivity and recovery of sawn timber.

6. Concomitantly, it increased the economic utility of defective trees, thus increasing the quantity of logs available to sawmills and therefore the sustainable scale of their operation. Consequently, the silviculture of east coast hardwood forests changed.

7. Finally, it contributed to the transfer of the concentration of sawmilling in Australia from hardwood forests to conifer plantations.

Economic and Social Context

The economic situation in the period of the two studies needs to be understood within the broader context of the mid-20th century. Relevant factors were the increased demand for hardwood timber, fluctuations in economic cycles and increases in real sawn timber prices (Table 2).

Table 2: National annual production of sawn hardwood timber 1929-1960. *Source:* Australian Year Book, 1988)

Year	**Sawn super feet**	**Determinant of period**
1929	140,000,000	End of prosperous 1920s
1932	70,000,000	The Great Depression
1936	125,000,000	Economic recovery
1939	130,000,000	Start of World War 2
1945	136,000,000	End of World War 2
1953	240,000,000	Post-war recovery
1960	265,000,000	Steady prosperity

Between 1953 and 1960 the price of sawn timber rose 55 percent from 87 to 133 shillings per hundred super feet.[4] At the same time Consumer Price Index rose 18 percent, resulting in a 37 percent real price rise (Australian Bureau of Statistics calculator). However, the rate of increase in annual log cut reduced by a factor of five in the seven year period due to the need for sustainability of the log yield from the forests at a national scale. Further, competition from imports was constrained by import tariffs which were over 50 percent for sawn timber.

In the comfort of these competitive advantages, sawmillers could either confidently invest in capital improvements or take the opportunity to relax and enjoy the short term prosperity that unearned advantage so often brings. The mill studies reveal that both options were taken to various degrees by the individual sawmills. Thus, numerically, productivity gains for the group of mills as a unit were strongly skewed (Figure 1).

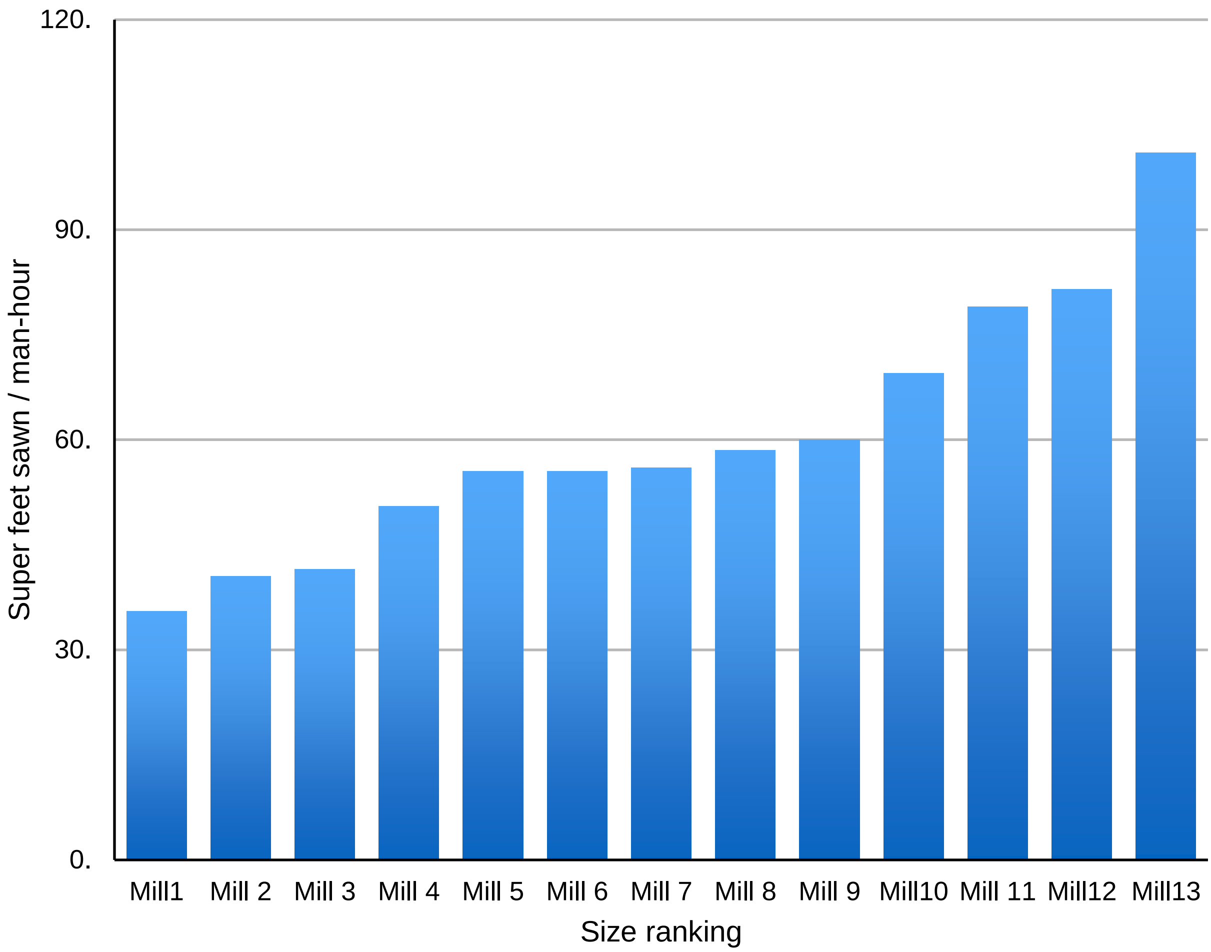

Figure 1: Sawmill Productivity in East Coast Eucalypt Forests

Productivity is the relationship between economic inputs and outputs. In manufacturing enterprises, the momentum generated by improved productivity in one sector changes all who are associated. The relationship between sawmills and forests is unquestionably one of mutual dependence - indeed it is a marriage.

Further, the replacement of steam by electricity as the primary energy for sawmills enabled flexibility in mill design by the placement of engines adjacent to saws, thus simplifying the transmission of power. This gave opportunities to improve mill layout, especially in the disposal of waste. Head saws presented timber flitches to the bench saw in a manner that enabled sawyers to be free of the task of waste disposal and consequently to concentrate on cutting saleable product - a clear example of productivity gains achieved by the division of labour.

Silvicultural Systems

In the 1950s issues of forest use were not entirely undebated. Who doesn't recoil from a world lacking the spontaneous generation of nature – but rejoice in a world where humanity's wants arise from the management of nature's generation (Roy 1997).

However, in Australia's post-war society, 'the spontaneous generation of nature' was dominated by 'the management of nature's generation'.

The increases in productivity and sawn recovery achieved by sawmills contributed to changes to the silviculture of the eucalypt forests. This was postulated by Max Jacobs in 1955 in *Growth Habits of the Eucalypts* (Jacobs 1986). He discussed the choice of silvicultural systems focusing on the size of canopy opening arising from single tree removal versus removing groups of trees, or clear falling. He asked, 'would future management of coastal hardwood forests adapt towards greater or lesser irregularity in size classes and species?'

The answer arises from the synergy that each specific relationship of technology, society and forest brings to the affinity of forests with their utility. Historically, Australian east coast forests have seven phases where social needs generated the application of the most appropriate technology. This technology in turn must accommodate the silvicultural attributes of the forest.

The pre-Anthropocene eucalypt forests that were of high light demanding species, regenerated following fire ignited by lightning (Goleman 2012). The ensuing canopy openings would have been wide-ranging depending on the weather events. Subsequent Aboriginal burning resulted in an open canopy from mosaic burning of the understory. During the last 200 years forests have sequentially experienced a series of technologies technologies which have significantly influenced the size of canopy openings (Table 3).

Table 3: Changes in technology and silviculture over last 200 years

Sawmilling Technology	**Era**	**Silviculture**
Manual pit saw	Convict era to late Victorian	Single tree selection by sawyer
Large steam sawmills	Late Victoria to WWI	Clear fall plus sawmill selection
Small steam sawmills	Late Victorian to post WWII	Group selection based on sawmill's immediate market needs
Electric sawmills	Post WWII	Clear fall with retention of regrowth
Enlarged sawmills	Late 20th to early 21st century	Group selection in regrowth forests
Sawmill closures (for conservation purposes)	Late 20th to early 21st century	Increased canopy density in both production and conservation forests

Categories shown in Table 3 brought differing demands to the management of the forests. The production studies that are the subject of this paper address the transition from steam to electric sawmills in the 1950s. Concurrently, it was a period of technological change in forest harvesting, such as the introduction of chain saws, crawler tractors, improved forest roads and heavier truck transport.

Until the 1950s, the uneven age of cut-over coastal forests arose from selective harvesting of individual large old growth trees containing logs of the high quality demanded by the economic imperatives of the late 19th and first half of the 20th centuries. The selective felling of large trees with low defect resulted in gaps in the forest canopy ranging in area from 400 to 1,500 m^2, occasionally exceeding 5,000 m^2 (Jacobs 1986:194). Often they regenerated well with a mixture of species and professional foresters referred to the result as the Australian group selection system – a term devised by Jolly in 1920 (Jacobs 1986:101-104) because it resembled well-established group selection silviculture systems in continental Europe (Jacobs 1986: 112). However, many foresters were less impressed and referred to it as 'sawmiller's selection'. They questioned the sustainability of a forest resource confined to falling only high quality mature trees acceptable to the immediate needs of sawmillers. Jacobs acknowledged both attitudes and postulated the evolution towards either uneven or even-aged stands.

The selection of these alternatives was determined by foresters adapting to the best interaction of silviculture with economics and society. In the post-war decades, when re-cutting forests that had been previously harvested old growth trees that had previously been considered uneconomic, were harvested. Simultaneously foresters retained the faster growing regrowth resulting from the canopy openings from the pre-war harvesting. Jacobs recognised the easier management of even-aged forests but also acknowledged that 'many foresters consider a very irregular forest a better biological unit'. In the regrowth forest, Jacobs favoured smaller gaps, 'a releasing rather than a clearing' (Jacobs 1986:104, 190-192). The direction taken from this debate was significantly influenced by the increased productivity of sawmills resulting from their transfer from steam to electricity. This enabled many trees that were previously uneconomic to be profitably sawn.

Social Economics of the 1950s

The social ambience of post-war Australia was a major influence on sawmill and forest economics. Post-war recovery required an increased emphasis on house construction which arose, not only from its cessation during six years of war, but also from its curtailment during ten years of economic depression from 1929. Post-war immigration added further pressure on housing. This is reflected in hardwood timber production in Australia which increased by 204 percent from 1939 to 1953.

The exigencies of the depression severely diminished faith in capitalism resulting in increased control of the economy by governments. Further, the war demanded strict control of the economy and employment, both civil and military. In the earlier post-war decades the supply of finance for both public and private housing was regulated by the Commonwealth Government to control development, inflation and employment.

During the war the supply of timber was directed exclusively via the Timber Control Board, a Commonwealth Government organisation that determined who supplied timber to whom and the prices that would be paid. Thus, by necessity, the government bureaucratised the 'market place' (Megalogenis 2012).

After the war State forest services assumed responsibility for timber supply to meet the demands of post-war reconstruction by determining the 'price to get supply'. By manipulating the price of sawn timber, forestry bureaucrats not only enabled economic access to remote forests, but also made it possible to utilise poorer quality logs. In order to meet the need for housing in the post-war period they applied much of the ethos of government control that prevailed during the war. This was accepted by sawmillers because it enabled them to influence government decisions. The affinity of the sawmill industry with the housing industry was reflected in the appointment of Lindsay Chapman, the Managing Director of Allan Taylor Ltd, the largest sawmilling company in NSW, to the Board of the NSW Housing Commission, which was the timber industry's largest customer.

In the period covered by this study, sawmills were protected from international competition by the tariff on imports which often exceeded 50 percent.

Controls operating during the immediate post-war period restricted inflation and ensured full employment, especially that of returned soldiers. However, the unintended consequences of regulation led to political change and thus a less regulated economy. But the 'unintended consequence' of deregulation was inflation which was exacerbated by the record high price of wool – the 'Korean War wool boom'. However, in the seven prosperous years between the two studies, annual inflation was constrained to an average of 2.6 percent (Australian Bureau of Statistics).

Rural electrification in the post-war period encouraged the development of rural industries, including sawmilling (CIGRE 1996). Between 1952 and 1960 electricity generation rose from 200,000 to 350,000 terajoules nationally and manufacturing contributed a record 29 percent to Australia's GDP (Australian Bureau of Statistics 1988). Sawmilling participated in this ethos. Analysis of the two economic studies shows that, whilst some sawmillers danced more elegantly than others, they all danced to the same principles of manufacturing. Those that acquired skills and productivity danced into the future – the tangled-footed collapsed.

Review of the two hardwood milling studies; Littler and Adkins (1954) and Hinson and Horton (1961).

Purpose

The studies were motivated by the need for the forest services to determine the relative value of the logs they sold, an essential basis for the implementation of a log pricing structure that directed an adequate wood supply for a vigorous housing industry. The forest services' responsibilities included providing revenue to the State from public forests and fair competition between sawmills, sourcing wood from public forests in regard to distance from market, logs of various species, diameter and with varying defect.

It was essentially a case of government orientation of the market that today would be denigrated as 'intervention'.

The two productivity studies were carried out co-operatively by the Queensland Forest Service and the Queensland Timber Stabilisation Board in 1953 and 1960.[5]

Methodology

The methodology of the studies was to measure each log at its mid-point circumference ('centre girth') and its length; identify, estimate and measure the defect of each log; colour code both ends of each log with crayon; record the time to saw each log on the breast bench and to record the production of sawn timber as it emerged from the docking saw where the length and quality grade of sawn timber was determined.

The data collection required a crew of three. A fourth person allowed for contingencies as well as managing the data as it was collected. Analysis was by the crew members in head office.

Data was collected in the same thirteen sawmills, each for one week. The analysis was reduced from 32 weeks in 1953, to 4 weeks in 1960 by the use of Powers-Samas 65 column cards to sort and tabulate data.[6]

Analysis of the studies

Meaningful comparisons of the two studies are possible because of several similarities: they were confined to the same thirteen sawmills; the market for sawn timber for all thirteen mills was dominated by Brisbane's housing needs; the number of species was the same although their proportion differed; the mean volume of individual logs was very similar and the period of data collection in the thirteen mills was very similar - 196,193 minutes in 1953 and 194,774 minutes in 1960.

To varying degrees, changes occurred at all the mills. Inputs included the energy source of sawmills, size of sawmills' output, type of head saw, sawing patterns, breast bench lay-out, docking saw lay-out, waste disposal, log circumference, gross log volume, log defect and sawn price. Outputs included recovery of sawn timber from logs and productivity per man-hour.

These factors are reviewed seriatim.

Characteristics of the Thirteen Mills

The mills included in the 1960 study were selected by the Department of Forestry because they were considered to be the 'same' as those in 1953. However, they differed in many respects from their 1953 counterparts. Characteristics discernible from the studies show a group of thirteen mills that had been powered predominantly by steam change to a group that was predominantly powered by electricity; the sawing pattern of the head saws changed from that determined by the discretion of each individual sawyer towards patterns that were predetermined and the sawing pattern dominating in 1953 was for the head saw to 'break-down' the log into flitches sufficiently small to be man-handled by the bench saw (Littler and Adkins 1954). There had been no amalgamations from within the group of thirteen mills. Nonetheless, to varying degrees, the scale of all thirteen sawmills increased. The source of this increased log supply was by the purchase of small mills outside the group of thirteen (Hyne Timber 2015). Commercial-in-confidence was respected in both studies in that productivity was not identified by naming of mill. Productivity increases were positively skewed to larger mills - the greatest was by a mill, perhaps owned by Hyne Timber and located in Maryborough, which used a band saw to precisely break down logs in a manner not commonly used in hardwood sawmilling in eastern Australia. The band saw technology was transferred by Hyne from their Hoop pine sawmill when the native forest pine resource ran out.

Economic Environment of the study period

The 1953 data was collected towards the end of a period of very high inflation - the CPI for the previous three years averaged 16 percent per annum. Whilst it was perhaps a period conducive to capital investment because of depreciation of money values, inflation creates uncertainties that debilitate capital investment. Thus, by 1953, the sawmillers had not made the changes they possibly had in mind but, from 1953 until 1960, CPI reduced to an average of 2.6 percent per annum, seven years that were conducive to investment. Productivity gains were made by all mills, but three were dominant.

The authors of the 1953 study stated that, in order to constrain the rate of harvesting forests, productivity gains should be achieved by more effective utilisation of logs rather than obtaining more logs from the forests. However, the source of the additional log volumes was not revealed in the Research Notes in 1960.

Concomitantly, other factors contributed to improved utilisation of native hardwood forests such as the gradual adoption of improved timber seasoning, more realistic timber grading, timber preservation, composite timber products and improved pulping technologies (Boas 1947). These technologies contributed to the industrial sawmilling ethos which was very strong in Australia's post-war era.

Log Quality Differences 1953 – 1960

The productivity gains postulated by the authors in 1953 included replacing frame saws with Canadian twin saws, as well as developing sawing patterns that would increase the productivity of the breast bench by 62 percent (Littler and Adkins 1954). These insights were revealed by the 1960 study which showed four mills exceeding this benchmark and the average for the group increasing by 43.5 percent.

However log quality also varied between the studies with regard to the percentage of defect in logs as well as their centre girth. If the average centre girth of logs in 1953 prevailed in 1960, production of sawn timber would have increased by 5.3 percent. If applied to the percentage of defect in the logs, productivity would have decreased by 3.4 percent. Thus log quality differences would have reduced average productivity for the thirteen mills from 43.5 to 41.6 percent (Hinson and Horton 1961). This difference appears insignificant but it does partly explain why sawmillers were able to recut previously cut-over forest.

Coinciding with electrification of sawmills was the replacement of manual felling with chainsaws and snigging by crawler tractors. Chainsaws enabled trees of doubtful utility to be economically felled. These were often large trees that axmen considered too uncertain to fall because of the risk of uneconomic quality. Thus the negative impact of increase in defect from 23 to 31.5 percent in logs from old-growth trees in 1960 was significantly offset by the positive gain in productivity by greater centre girth (67 to 73 inches).

Recovery of Sawn timber from Logs

A crucial factor determining the economics of sawmilling is the ratio of log that is converted to saleable timber - the 'recovery percent'. After subtracting defect from the gross volume of the logs, the recovery rose from 64.9 percent in 1953 to 74.3 percent in 1960 (Hinson and Horton 1961). This represents both a revenue gain and a log cost saving for the sawmillers.

Effect of Sawmill Size on Efficiency

Scale is an optimisation process determined by a combination of factors relevant to the activity. Big is not necessarily better. In the early years of the 20th century several large sawmills were developed in east coast eucalypt forests based on log inputs in the order of 300,000 cubic metres annually[7] (McNeil 2015). They were unsuccessful because their scale exceeded the energy, transport and markets of that era.

When optimised, larger sawmills expand the options available for their management. In the sawmill economic studies this is shown by the correlation of the size of sawn output with productivity and sawn recovery.

With regard to productivity, the following observations are apposite. Figure 1 shows that productivity increased with the size of sawmills, without exception. The average mill size rose by 48 percent. In 1953 the largest mill was less than twice that of the smallest, but by 1960 the largest mill was more than five times greater.

In 1953 the range of productivity between sawmills was 35 to 58 super feet sawn per man-hour (66 percent); in 1960 productivity ranged from 37.5 to 103 super feet per man-hour (172 percent). The increase was exponential. This is a precursor to the increase in sawmill size that has continued over the last 60 years.[8]

The trend shows four distinct populations within the thirteen sawmills - the most productive mill, the next three, the middle four and the bottom five. This conforms to a Pareto distribution with only three of the thirteen mills having productivity exceeding the mean. The most efficient mill was completely rebuilt between the studies whereas the other sawmills relied on modifications.

In their 1953 study, Littler and Adkins anticipated potential increases in productivity of 62.5 percent arising from more efficient cutting patterns in the head (breaking down) saw from an average of 43.5 to 70 super feet per man-hour. Within seven years this postulation was exceeded by four mills.

Sawn recovery in 1960, expressed as a percentage of net log volume, showed that the most productive mill also had the highest recovery. Recovery of the next four most productive mills also correlates positively with mill size.

It is interesting to observe that in the 1953 study the recovery rate of the five least productive mills was higher than their immediately larger more productive competitors. This reflects the not uncommon view held in 1950s that high sawmill production came at a cost to sawn recovery. This arose from the head saw not separating defect from flitches presented to the bench. Thus individual sawyers would devote different diligence to removing defect at the cost of production time.

Other factors also influenced recovery statistics. Firstly, the unit of measurement of the gross volume of logs differed from that of defect. Gross volume of logs was in super feet hoppus, but defect was in super feet true. The relationship between hoppus and true super feet is 1:1.2727. Thus defect in logs negatively distorts the true calculation of net log volume and consequently overstates recovery. This was a worldwide practice in countries that used hoppus log volume - the anomaly existed in Australia until metrification (Bradshaw 2011).

Secondly, defect in the central axis (heart) of old-growth logs tends to a parabolic configuration as does the external taper of trees. This gives rise to two variations. Firstly, in Queensland the measurement of 'pipe' was recorded as the largest diameter at either end of the log rather than the average of both ends.[9] Secondly, when cross-cutting logs from the full length of the fallen tree, experienced log fallers could use the parabolic taper of logs and defect, to either maximise or minimise the gross volume of logs, as well as the measurement of defect. Thus, by manipulation, log cutters could achieve a more favourable outcome for either the sawmiller or the forest department.

Thirdly, the small mills often produced a disproportionate volume of large dimension 'heart' centred sawn timber from small sound logs of durable species. These were called girders and were specified by engineers for structures such as bridges. The central pith (heart) of eucalypt logs was regarded as useless and an obligatory allowance was applied as 4 x 4 inches of defect. Thus by sawing girders rather than smaller dimension timber, the recovery from 60 inch centre girth logs increased by 5.6 percent. Additional increases also arose from fewer saw cuts.

The performance of the best sawmill in the1960 study is all the more outstanding, given that in 1953 it ranked third in production and sixth in recovery. However, this also reflects the larger size of logs it bought. In the 1960 study the most productive mill used logs that were three times the size of the average of the thirteen mills. Further they had the highest defect percent and thus their actual net true volume was understated relative to other mills.

In the 1960 study, Figure 1 shows the large logs supplied to the most productive mill account for about 18 percent of its performance above the average of all thirteen mills. (1604 versus 541 super feet hoppus).

Scale of operation often determines the ability of an enterprise to adopt new manufacturing technologies. However, aspects of the processes employed by the new technologies may sometimes be partially applied to those mills approaching redundancy. Thus the cutting patterns applicable to twin Canadian circular saws opened ideas for marginally better cutting patterns to be applied to frame saws (Littler and Adkins 1954).

Factors leading to improved productivity

The following improvements to productivity were made by the thirteen mills between 1953 and 1960 to varying degrees.

The head saw's function was changed from breaking down (carving-up) of logs to using sawing patterns that isolated defect in logs at the head saw. This was achieved by replacing frame saws with twin-Canadian or band saws. The log carriage was strengthened and redesigned to allow frequent turning of logs before the carriage re-presents logs to the saw, return speeds of the log carriage were increased and logs confined to a length ranging from 15 to 20 feet (market permitting).

Formal cutting patterns were varied depending on log diameter, defect and spring.
Seven cutting patterns were presented in the 1960 report.

The number 1 bench became strictly a production unit designed around the sawyer.
The most productive unit was a four man crew of the sawyer, one tailor-out of sawn timber, one to return flitches to the sawyer, plus a roller-man to optimise the feed speed of the flitch into the saw and its return to the sawyer. Replacement of peg fences with notched-bar to guide the forward direction of the flitch being sawn also increased productivity.

A number 2 bench was installed only where through-put was sufficient. It was strictly for production of sawn timber by repetitive cutting of standard sized flitches from the number 1 bench.

The docking sawyer was trained to better appreciate timber quality standards and a conveyor belt was provided under the docking saw with an automatic waste saw for cross-cutting fire wood.

Conclusion

Increased sawmill productivity in southeast Queensland in the 1950s was primarily enhanced by completing the conversion of energy from steam to electricity, head saws being changed from frame to twin Canadian or band saws and adoption of formal cutting patterns that separated defect from useable wood at the head saw.

Increased scale enhanced these changes. The study of thirteen mills show that greater scale correlated with increased productivity and higher recovery of timber from logs. Further, it encouraged Australian sawmilling to exponentially improve productivity by applying new technologies over the following six decades.

The pattern of this transformation followed the Pareto distribution. It is reasonable to assume that the most productive sawmill in 1960 was Hyne who have since applied the principle of scale to become the operators of very large sawmills based on plantation conifers. These plantations have the capacity to match the scale required by modern 'industrial' sawmilling. However, sawmills dependent on native forests need a significant market for specialty timber, which requires a smaller optimal scale.

Historically, the studies give understanding to three relevant issues for native forests.
Firstly, logs with greater defect became economic, leading to a significant increase in sustainable yields of sawlogs. Secondly, silvicultural systems in native forests moved away from the smaller canopy openings of the Australian Group Selection System towards larger canopy openings with retention of regrowth. Thirdly, the studies illustrate the role forestry played in post-war reconstruction. In all phases of the Anthropocene where humans have consciously managed forests, they have developed an affinity between their current technology and the prevailing social and economic reality, in an endeavour to manage nature's bounty.

To return to the question posed in the opening paragraph - what is the historical relevance of these studies? The studies illustrate three major points. Firstly, it is the ideas they advocated leading to increased productivity that live on and continue to grow through optimising scale (Deutsch 2011). Importantly these ideas are links in the chain of evolution not only of sawmills, but conform with industrial development generally. Secondly, in relation to native forest silviculture, they explain the increased size of canopy opening in east coast native forests. Thirdly, by demonstrating the evolution of scale, the two studies of sawmill economics in Queensland have contributed to the marriage of large industrial sawmills with conifer plantations.

Glossary

Mill layout: There were three sequences to the production-line of sawmills. Firstly, a saw to breakdown logs into flitches suitable for processing; secondly, a saw to cut timber to required end dimensions; and thirdly, a saw to cut timber to the required lengths.

Breaking down: The initial sawing of logs into billets suitable for further processing by the breast bench.

Frame saw: Saws attached vertically to a rectangular steel frame that reciprocated vertically to break down large logs.

Canadian twin saw: Two circular saws vertically aligned to enable breaking down large logs more rapidly than frame saws.

Band saw: A long continuous strip of saw powered by rotating around two vertically aligned wheels to break down large logs with very high speed and precision.

Breast bench: A circular saw located at the end of a bench, which is table height to enable billets to be manually fed (pushed) by the sawyer through the saw. The men who received the sawn wood were called 'tailor-outs'.

Docking saw: A circular saw to cut timber from the breast bench to the required lengths.

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Notes

[1] Pareto distribution applies where a small number of performers achieve disproportionally high outcomes.
[2] An Australian sawmill company operating since 1882 that continues to be a major and expanding company.
[3] One super foot hoppus = 1.2727 super feet and 0.036039 cubic metres.
[4] Both the 1953 and the 1960 studies list sawn prices applicable at the time.
[5]Publication was in Research Notes by authority of the Director General of the Queensland Department of Forestry in 1954 (Project Q.U.19) and in 1961 (Research Note No. 14), (Littler and Adkins 1954; Hinson and Horton 1961).
[6] For future studies Hinson and Hanson advocated the use of computers.
[7] 27.74 super feet hoppus = 1 cubic metre.
[8] The largest sawmill in Australia, owned by Hyne Timber and located at Tumbarumba in NSW, is one of the sawmills in these studies.
[9] In senile trees the vertical hollow created in the 'heart' by termites is called a 'pipe'.