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Technological Change in the New Zealand Sawmilling Industry

A thesis presented in partial fulfilment of the
requirements

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Abstract

This thesis addresses the role of technological change in the New Zealand sawmilling industry.

It consists of an examination of the importance of technological change on economic and industrial growth. The mechanisms by which technological change occurs in industries are examined, particularly the technological push model of Schumpeter, the demand pull model of Schmookler, and the technological paradigm/trajectory model of Dosi.

The technological paradigm/trajectory model is expanded upon and operationalised to examine the New Zealand sawmilling industry in terms of that model's parameters.

Two empirical studies were conducted to ascertain the historical effect of technological change in the development of sawmilling in New Zealand.

The first study examined various input and output variables in an econometric framework, with an emphasis on a production function approach. The second study utilised a factor analytic approach to reduce various technology related variables to a lesser number of variables. This was in order to describe a pathway of technological change in as simple terms as possible. The factor analytic approach facilitated the use of the technological

paradigm/trajectory model.

Generally, results showed that the economic and technological development of New Zealand sawmilling was characterised as having an emphasis on throughput of timber, possibly because economies of scale are difficult to achieve in sawmilling.

Specific findings were that the production of sawn timber in New Zealand has been increasing in an exponential manner, that there has been a slow but steady increase in the number of persons engaged in the industry, that the number of kilowatts in the industry has been increasing rapidly, that value added to timber, while being erratic, has been rising, that the level of value added per person has been rising, whilst the level of value added per kilowatt has been static. It was concluded that capital was substituted for labour in the production of sawn timber, and that the skill levels of labour in sawmilling increased. It was estimated that through time, the effects of technological change were such that an additional 2,402 cubic metres of sawn timber were added to the national output every year.

It was concluded that, given the globalisation of manufacturing, and process value adding in general, New Zealand sawyers need to saw to particular customer standards, in smaller order lots, and with greater degree

of manufacturing flexibility than has hither to been the case. This implies that sawmilling technology might well be on the point of a paradigm shift.

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CHAPTER 1. INTRODUCTION.

1.1. Introduction.

The forestry and forest products industry is the most important in New Zealand¹, both as a potential large foreign exchange earner and for its potential for lost opportunities². There is a large resource of raw wood coming on stream from the exotic plantation forests throughout the country, and this stream is expected to more than double in the next couple of decades. However, there is a relatively small wood processing infrastructure. The investment needed to expand this processing capacity over the next 20 years is estimated to be in the order of \$NZ 10 to \$NZ 11 billion.³

In response to these issues, Governmental and official focus on investment in forestry has been levelled at the growing of more wood. For instance, the tax regime pertaining to the growing of timber trees has been altered to allow growers to claim tax deductibility on all growing and tending expenses in the year in which they are incurred. Previously, such costs had to be accumulated throughout the life of the stand of trees, and could only be made net of tax at harvest time. Additionally, there has been much exhortation directed at land owners which highlights the advantages of growing wood, either as a supplement to, or in place of traditional New Zealand

farming.⁴

This may be a misplaced response. Given an expansion in the processing infrastructure, it is not unreasonable to suggest that a concomitant expansion in the forest estate might follow as the demand for wood increases. The contention therefore is that the nation's focus in the forest industries should be towards the processing of wood, with recognition given to the importance of innovation and technological change as a means to opening a new competitive advantage in wood processing. This would complement the already existing and substantial competitive advantage found in wood growing.

Probably the pivotal sector of the wood processing industries in New Zealand is sawmilling.⁵ In 1992, sawmilling provided one third of all wood input into the pulp, paper and panel sectors of the wood processing industries in New Zealand, as well as using around 40 percent of the total New Zealand log harvest in the same year. Edgar, Lee and Quinn⁶ further argued that the greatest impediment to the collective wood processing industries growth was the lack of a strong, vibrant, innovative, internationally focused sawmilling sector. There were a number of reasons for this, but two of the most significant ones were that a strong sawmilling sector would strengthen the position of New Zealand's log and chip exporters, and it would provide a source of residue wood

fibre for expansion of the pulp, paper and panel sectors.

Edgar, Lee and Quinn⁷ have suggested that the sawmilling sector holds the greatest potential for non capital intensive expansion due to its current (1992) low level of capacity utilisation. Additionally, part of the process of revamping New Zealand's sawmilling sector would be to assess the strength and direction of the industry's technological change and innovation pathways with a view to building on existing strengths and in developing growth strategies for the future.

It is a consequence of all the above that this research, initially discusses the importance of developing a better processing infrastructure. The study then goes on to discuss the importance of innovation and technological change and their relationships with respect to sawmilling. Thereafter, the rate of innovation and technological change in the sawmilling industry will be investigated with the aim of identifying where possible strengths and weaknesses might exist, as a platform for building up a successful expansion of the sector.

Firstly, however, an examination of the economic status of the whole exotic forestry industry in New Zealand is necessary both to understand the over all importance of the industry in New Zealand, and to gain an understanding of the pivotal role of sawmilling within the industry.

1.2. The Economic Status of Exotic Forestry in New Zealand.

Forests cover about 27 percent or 7.4 million hectares of the country's land area. Of this, about 6.2 million hectares are in indigenous forest and 1.2 million hectares are in exotic plantations. Of the total plantation forest estate, about 89 percent is radiata pine (Pinus radiata), and 5 percent is Douglas fir (Psuedotsuga menziesii). Hardwoods comprise only 2 percent of New Zealand's plantation forests.⁸

The available wood resource from plantations is expected to rise rapidly over the next two decades (Figure 1.1). Because domestic demand for timber is not expected to change significantly, the volume of wood available for export is expected to increase even more dramatically. Major increases in supply begin in the mid 1990s.

The forest industry's direct production represents more than 6% of the country's Gross Domestic Product. Subsequent product use is additional to this. The industry, including packaging, directly employs more than 28,000 people, and its direct foreign exchange earnings are significant at \$NZ 1.4 billion for the year ended June 1990. This puts forestry in third place behind Dairy and Meat products on the export earning stakes. (Figure 1.2)

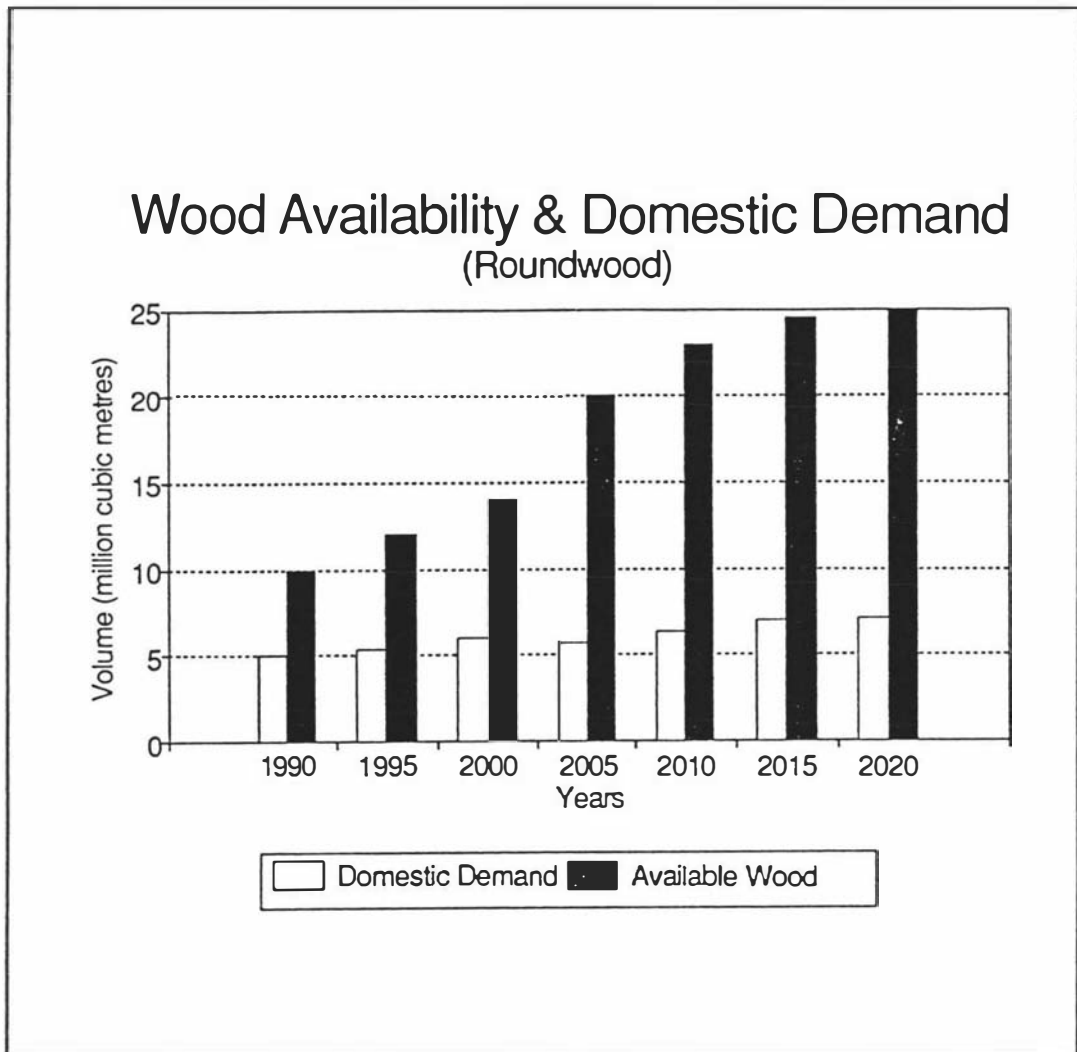


Figure 1.1 Roundwood Removals and Projected Domestic Consumption. (Source: Ministry of Forestry)

The composition of the forestry export mix shows by far that the largest product group was logs and chips. (Figure 1.3) This is important to one the main streams of this thesis; namely that a large amount of the nation's forest products are in a relatively unprocessed form. By not adding value, the opportunity to increase the wealth of New Zealand is foregone. In fact, examination of figure 1.3 reveals that the items Sawn Timber and Paper & Paperboard

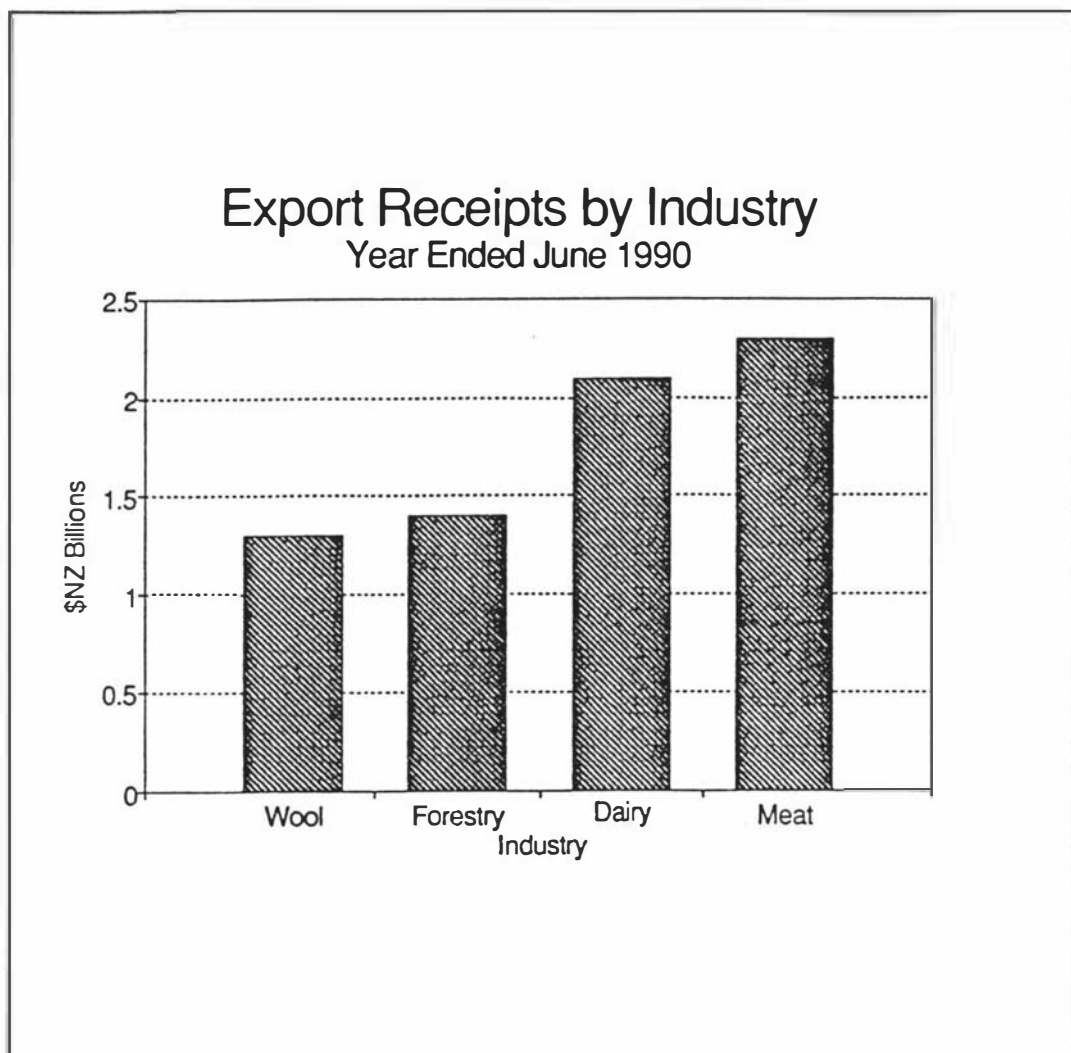


Figure 1.2 Export Receipts by Industry Group. (Source: Dept. of Statistics)

constitute relatively low and static export volume groups, but are the most processed form of wood shown.

1.2.1. Industry Product Types.

Log Exports

New Zealand's log exports have increased dramatically over the past five to six years. Since June 1986, New Zealand's log exports have increased by 732 percent to more than

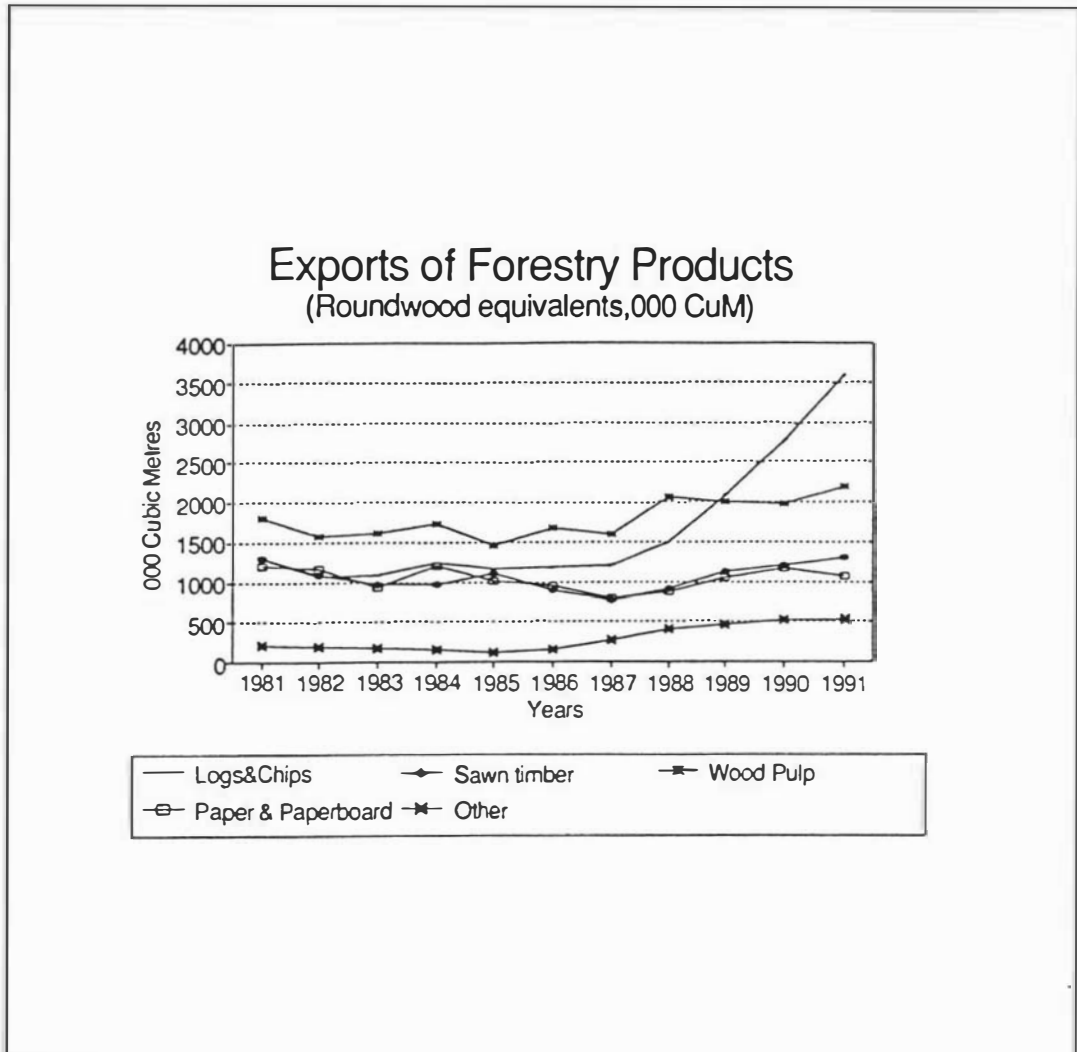


Figure 1.3 Forest Products Export Mix. (Source: Ministry of Forestry)

3,500,000 cubic metres per annum. New Zealand presently holds a 7 percent share of the Pacific Rim log market, with major markets being Japan, Korea and China.

Sawn Timber

Strategically, sawmilling is an important segment of the wood processing industry. Not only is it a significant employer and foreign exchange earner, but it also provides a critical link between forest growing and the

reconstituted board industries. For the year ended March 1991, over 34 percent of roundwood removals from New Zealand forests were sawlogs. Sawn timber exports presently exceed 700,000 cubic metres per annum, with the major overseas markets being Australia and Japan.⁹

Pulp and Paper

The two largest wood processing plants in New Zealand are the complexes of NZFP Pulp and Paper (a subsidiary of Carter Holt Harvey Ltd) at Kinlieth and Tasman Pulp and Paper (subsidiary of Fletcher Challenge Ltd) at Kawerau. Both produce chemical pulp which utilises the strength properties of radiata pine. The Tasman Pulp and Paper plant also produces mechanical groundwood pulp which, in combination with chemical pulp, is manufactured into newsprint.

The New Zealand pulp and paper industry supports the bulk of the country's domestic needs as well as providing a large volume of exports which were worth \$NZ 695 million for the year ended June 1991. In the march 1991 year, total wood pulp production was 1.35 million tonnes while paper and paperboard was 821,000 tonnes.

Panel Products

Fibreboard and plywood production began in New Zealand in

the 1940s and particleboard production began in the 1950s. Since that time, the production of panel products has increased steadily, with total production of panel products for the year ending June 1991 exceeding 750,000 cubic metres. Fibreboard production has increased most markedly over the 1980s, as new plants have been developed. Of particular note is the Nelson Pine Industries fibreboard plant which is the largest single site producer of fibreboard in the world. Total panel product exports exceeded 370,000 cubic metres to June 1991, and were valued at \$NZ 168 million.

Figures 1.1, 1.2 and 1.3, shown above lead to a number of salient features about the New Zealand forestry industry. New Zealand currently exports about two thirds of its wood harvest, in various forms, but many forests are not yet in full production. When plantations are fully productive they can sustain the following levels of overseas exchange earnings each year, (table 1.1) assuming all the production is exported.

Clearly, up to four and a half times as much income per hectare is generated by New Zealand if nearly all processing is carried out before export. However, the adding of value may only be the adding of costs, and adding value is only a valid option if it is profitable. Moreover, investment in plant and machinery will only be done in the expectation of future profits.

	Bayliss 2015 (1.3m ha)	Sutton 2020 (4.3m ha)	Earnings
Log Export scenario	\$2.6B	\$6.5B	\$1,400/ha
Sawn Timber mix	\$4.0B	\$17B	\$4,000/ha
Added value potential	?	\$30B	\$7,000/ha
(NZ's total merchandise exports 1990 = \$15B)			
[Source: Sutton, W.R.J., New Zealand Institute of Forestry. April 1991.]			

Table 1.1 Earnings per Hectare

1.2.2. Comparative Costs.

Competition in forest products is driven by cost. Most forest products are commodities, for which suppliers with lower costs obtain higher margins. As the price of most forest products is set in the international market place, cost minimisation is therefore critical.

The major components of cost for forest products are wood fibre, energy, transport, labour and capital. These will be examined in more detail below.

Fibre

The cost of fibre depends upon a number of factors, including whether the fibre was sourced from plantation forests (since the cost of planting and tending is included

in the price) or virgin forests (as these costs are not included), growth rates, logging, haulage and administration. These factors have resulted in considerable cost variations among nations. New Zealand is no longer cutting from its virgin forests and is therefore, in one regard, placed at a cost disadvantage. However, New Zealand's fast growing trees are a countering source for cost advantage. As figure 1.4 illustrates, New Zealand's softwood fibre cost is near the middle of the range when compared with other softwood producing countries.

Energy

Energy costs can also vary widely from country to country. The choice of energy type exercises an important influence over total energy costs. The most intensively used form of energy by the wood processing industry, particularly by pulp and paper mills, is electricity. A recent survey by energy cost analysts at NUS international found that of 16 countries surveyed, New Zealand's electricity costs were the least expensive. Comparative electricity prices are shown in table 1.2 below.

Comparative Electricity Prices (April 1991)		
Rank	Country	Average Cents/kwh
1	Germany	20.87
2	Italy	20.26
3	Japan	17.80
4	Belgium	15.80
5	Ireland	15.21
6	USA	14.45
7	UK	14.37
8	France	13.49
9	Finland	13.06
10	Netherlands	12.63
11	Norway	12.14
12	Hong Kong	11.37
13	Sweden	11.30
14	Australia	10.87
15	Canada	9.89
16	New Zealand	8.06

Source: NUS International, 1991.

Table 1.2 Comparative Electricity Costs

Transport

Transport expenses are the most important variable for export sales. Transport costs for large bulky and heavy raw materials and outputs are generally high everywhere.

Variations between exporting countries tend to be distance dependent. Because New Zealand is located close to its major forest product markets in Australia and East Asia, she enjoys lower costs than potential competitors. Figure 1.5 shows the extent of this advantage.

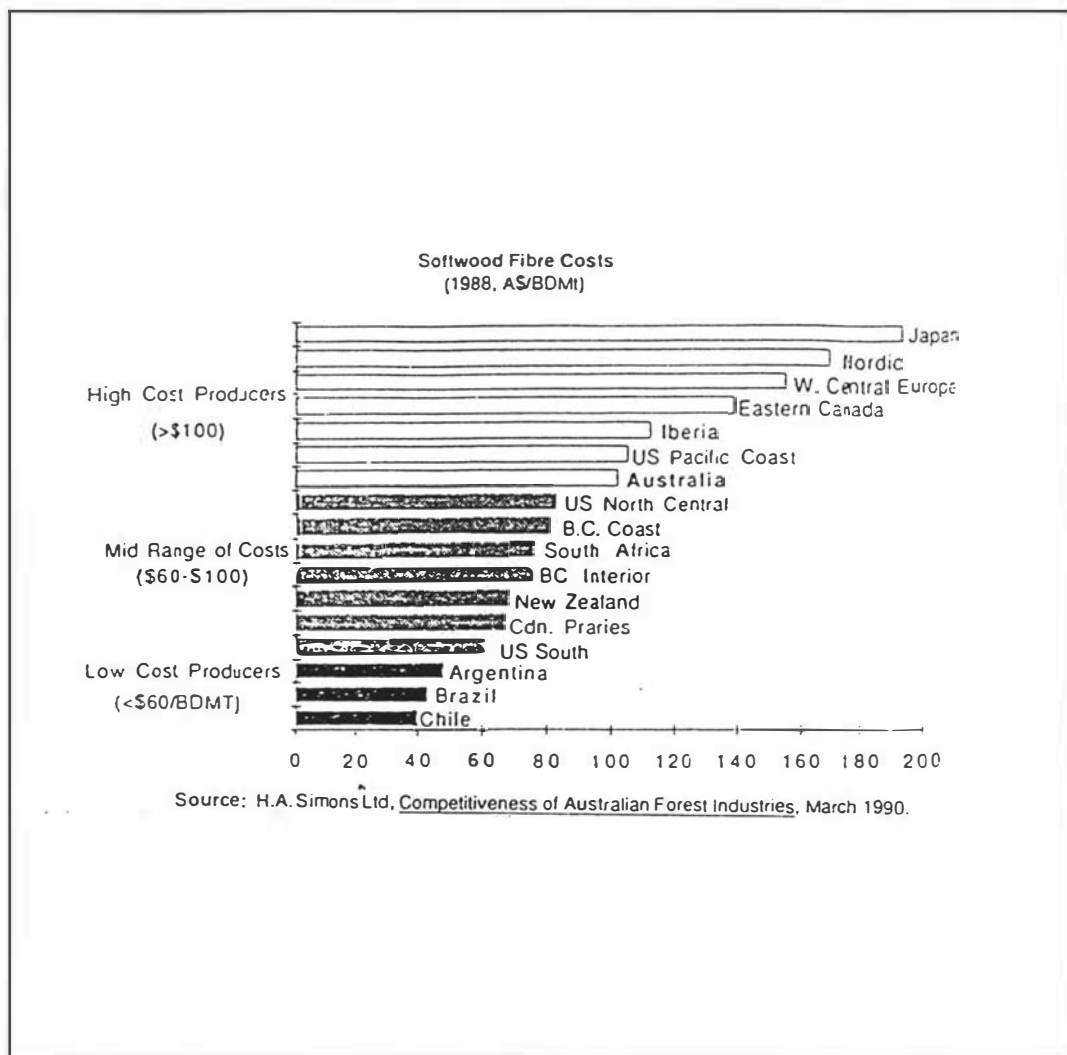


Figure 1.4 Softwood Fibre Costs.

Labour

New Zealand labour costs are low and make up only a small percentage of total product costs under current technology. Figure 1.6 compares New Zealand labour costs with that of other nations with forestry interests.

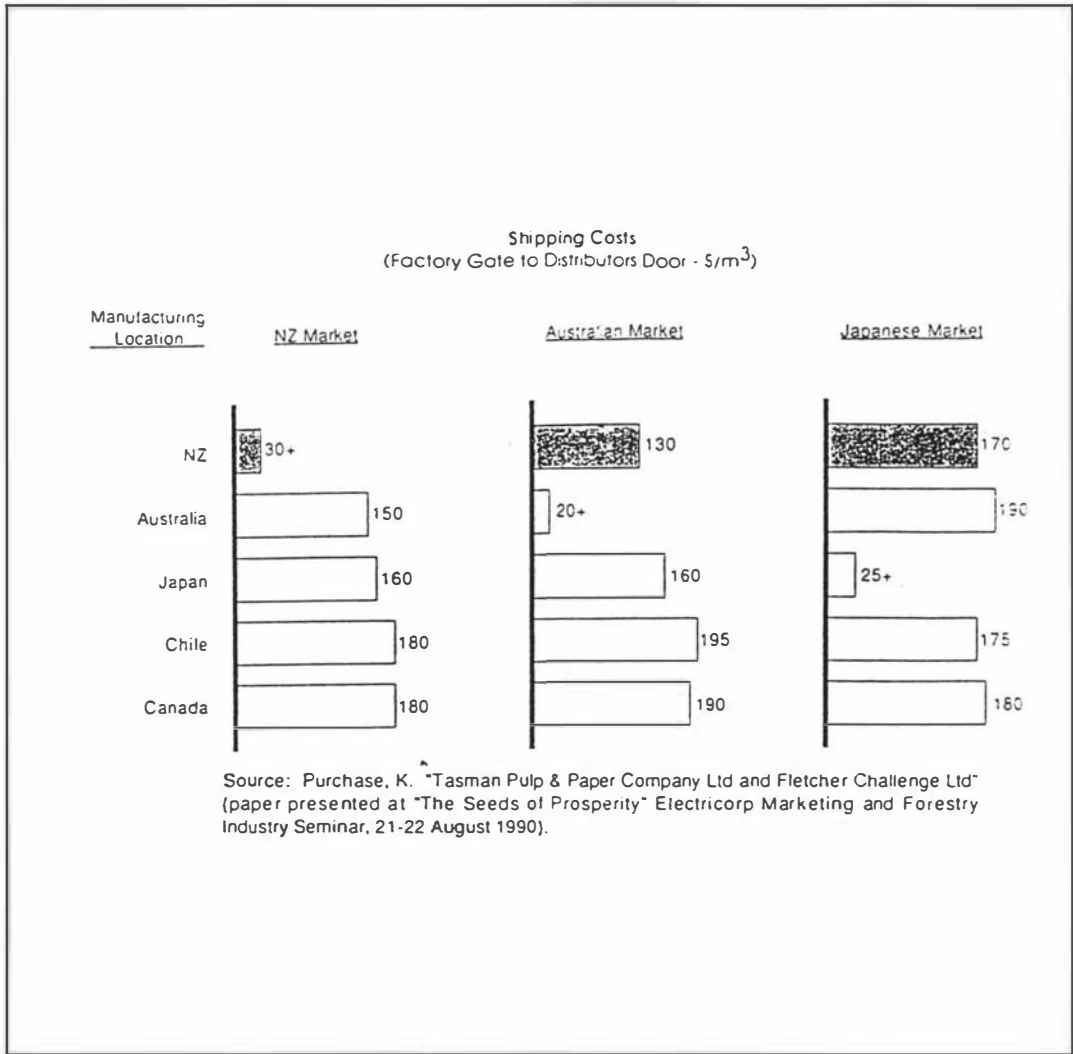


Figure 1.5 Shipping Costs.

Capital

The wood processing industries are capital intensive. Capital costs vary widely between product types. Figures 1.7 to 1.10 below compare the capital charges (and operating costs) of softwood producing countries for various product types.

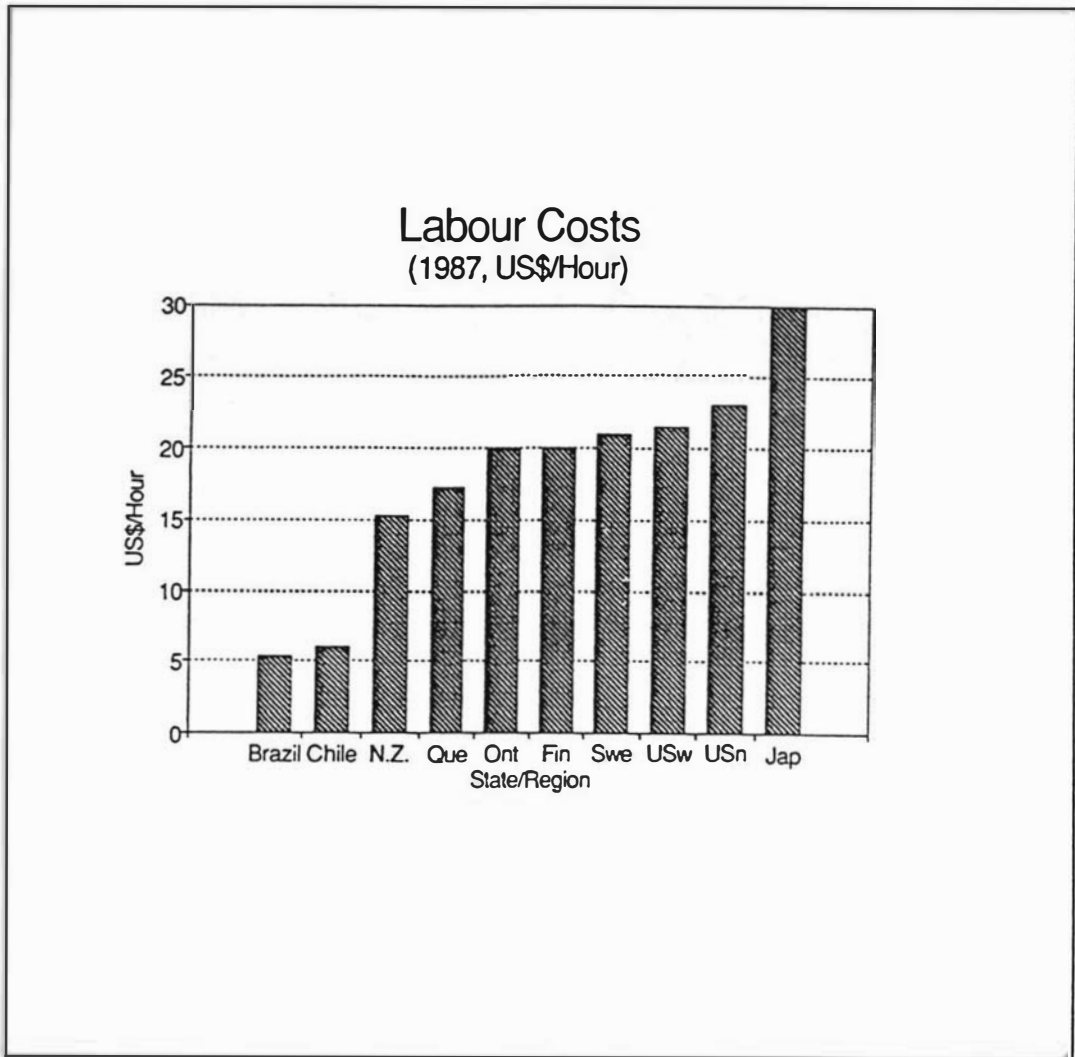


Figure 1.6 Labour Costs. (Source: H.A. Simons Ltd.)

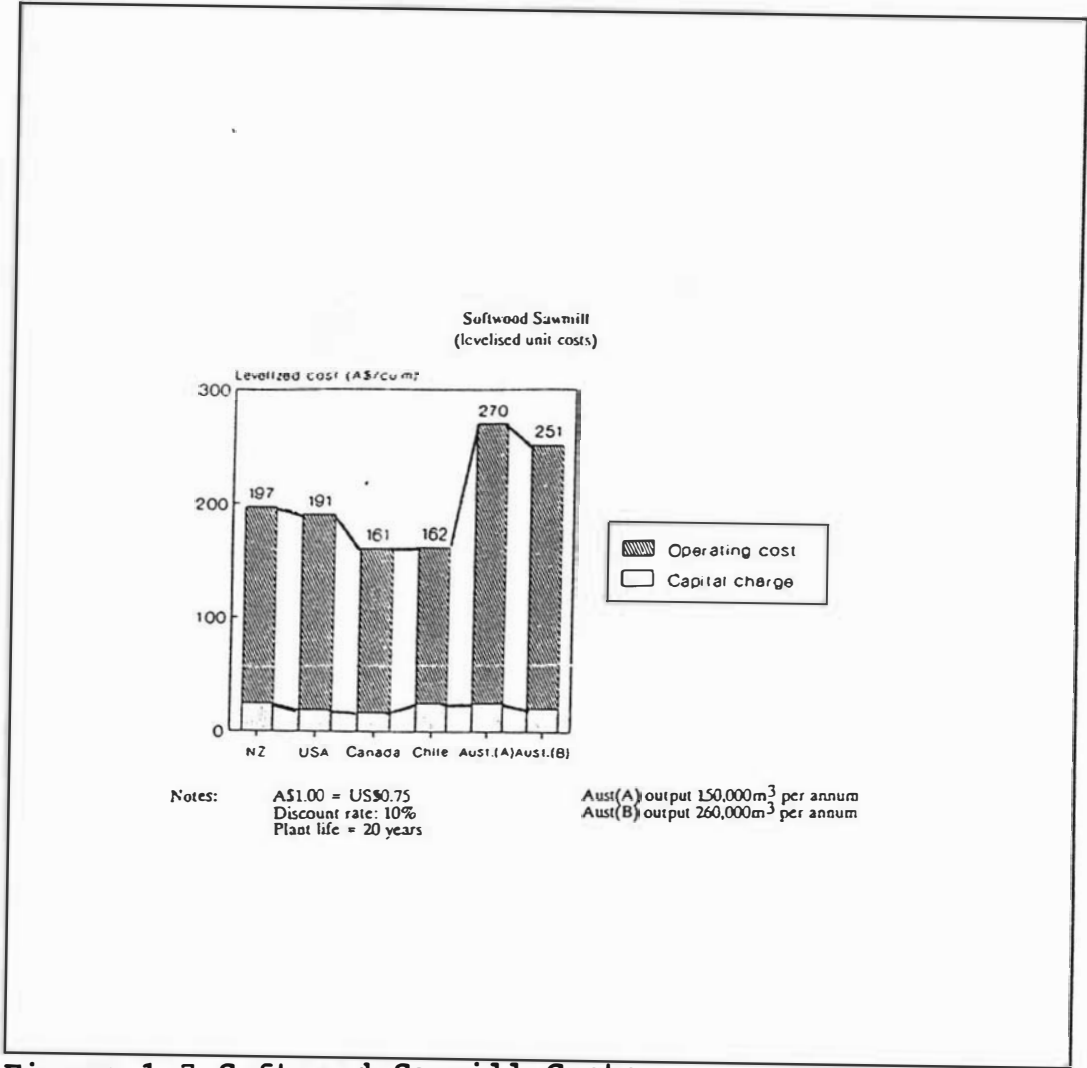


Figure 1.7 Softwood Sawmill Costs.

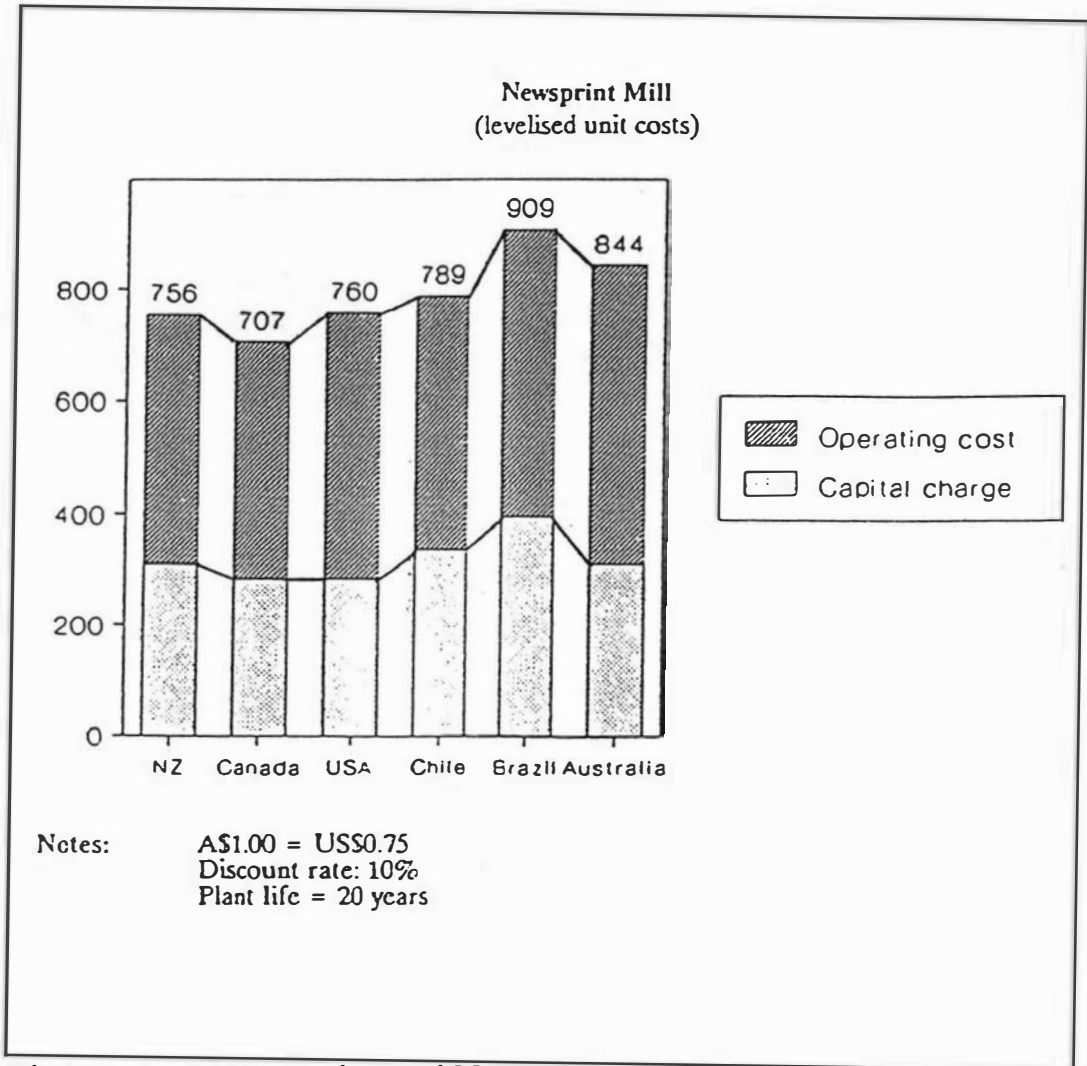


Figure 1.8 Newsprint Mill Costs.

The operating costs of the various forms of wood processing are broken down into their components (fibre, energy, transport etc.) and compared with other softwood producing countries in figures 1.11 to 1.14 below.

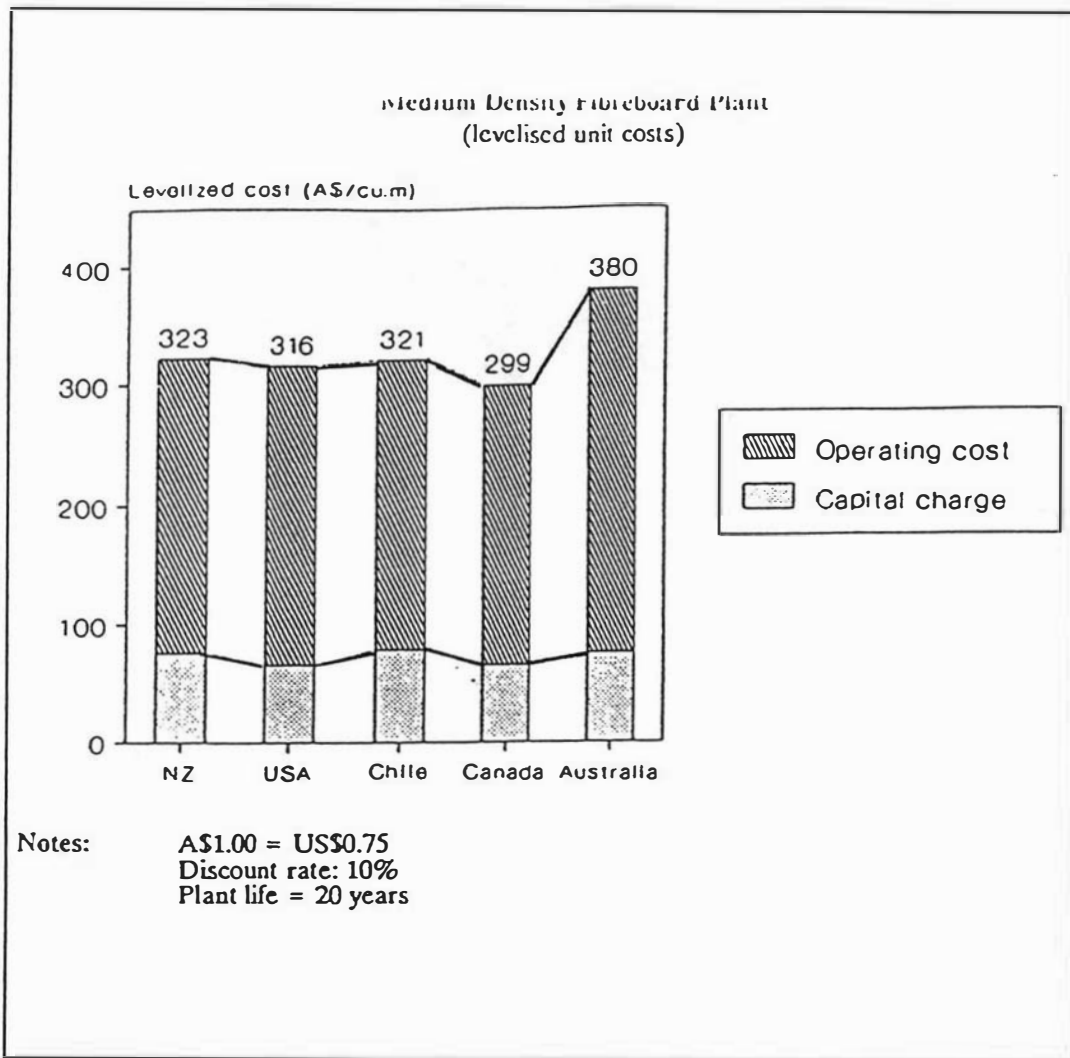


Figure 1.9 M.D.F. Plant; Operating vs Capital Costs.

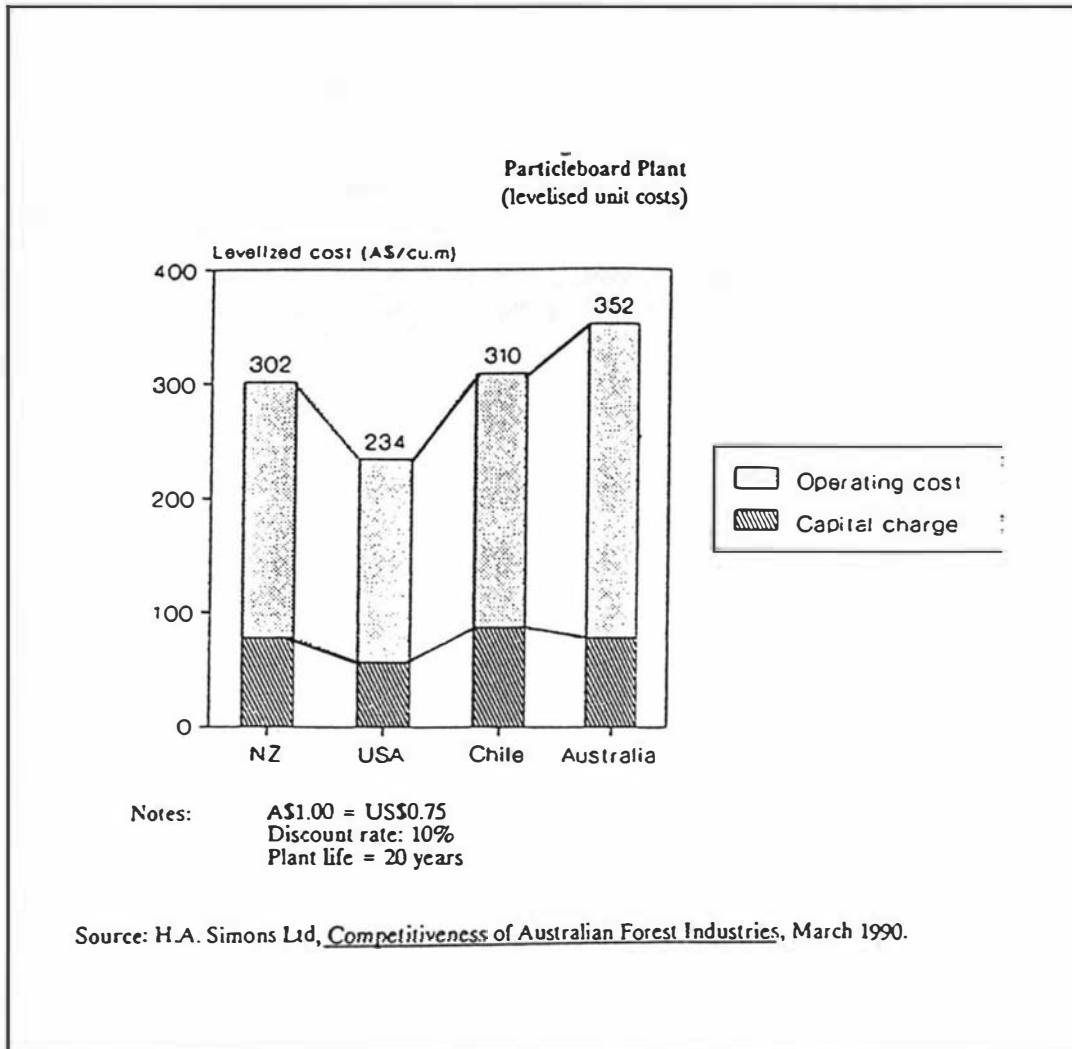


Figure 1.10 Particle Board Plant; Operating vs Capital Costs.

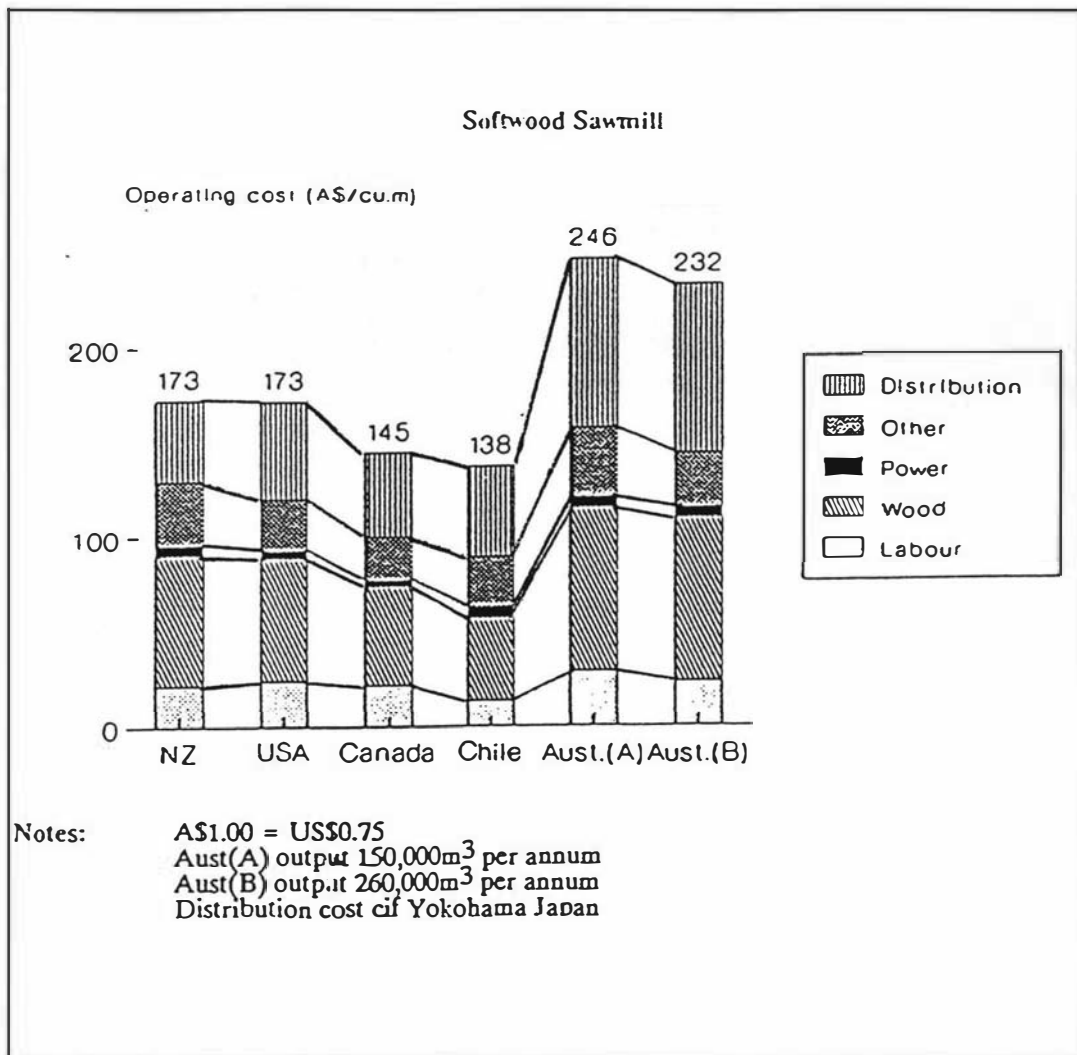


Figure 1.11 Softwood Sawmill Costs.

In most of the figures shown, New Zealand appears to do reasonably well vis a vis other countries. Yet input and infrastructural costs are only part of the explanation for developing competitive advantage. According to Porter,¹⁰ the purely cost advantage view of the world considers only a limited type of factor - based advantage and is therefore limited in explaining industrial success. There is a need

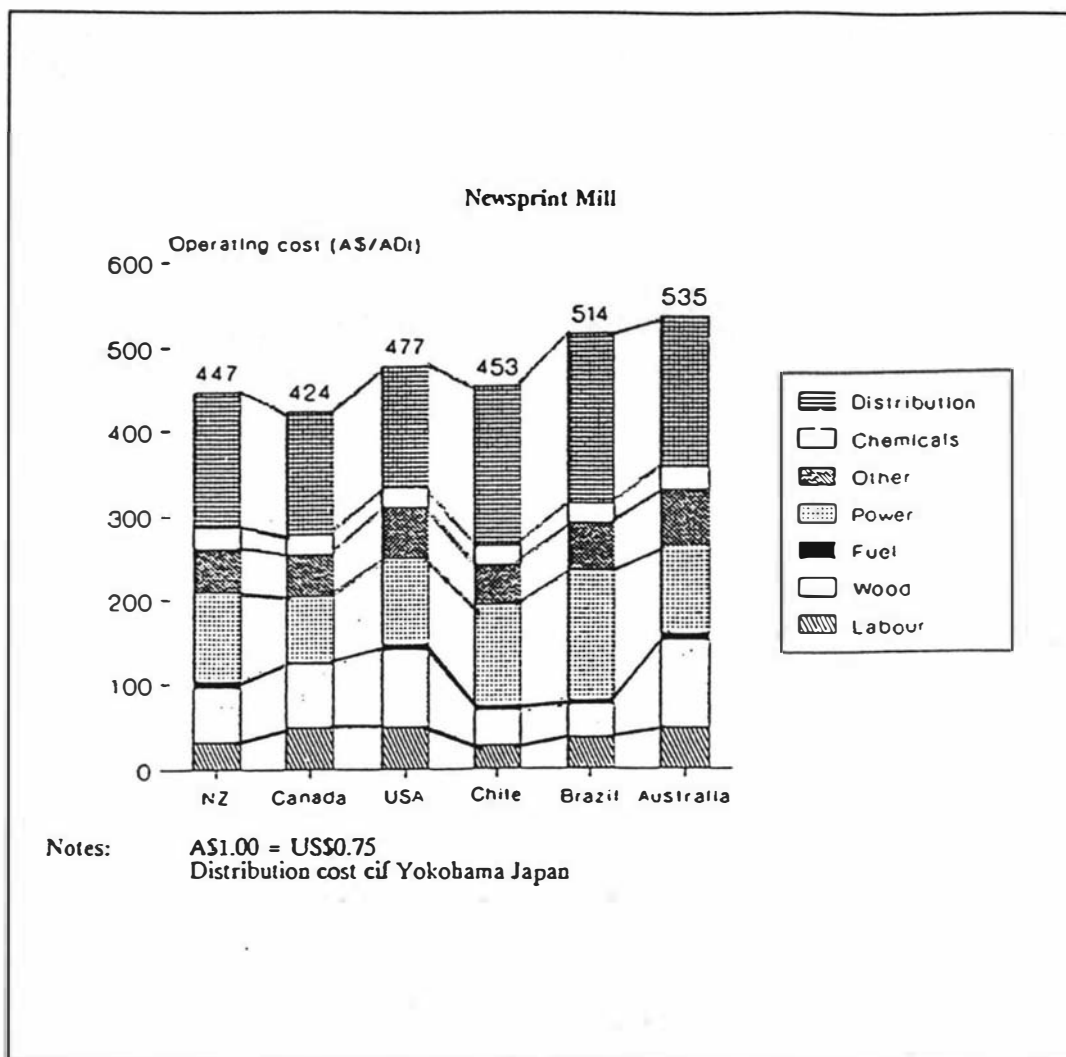


Figure 1.12 Newsprint Mill Operating Costs.

to consider such aspects as segmented markets, differentiated products, technology differences, economies of scale and so on. Moreover, quality features and new product and process innovations are central in advanced industries and segments. Innovation is thus crucial to economic development.

1.2.2. Investment Parameters.

A survey of views of foreign industry investors, together

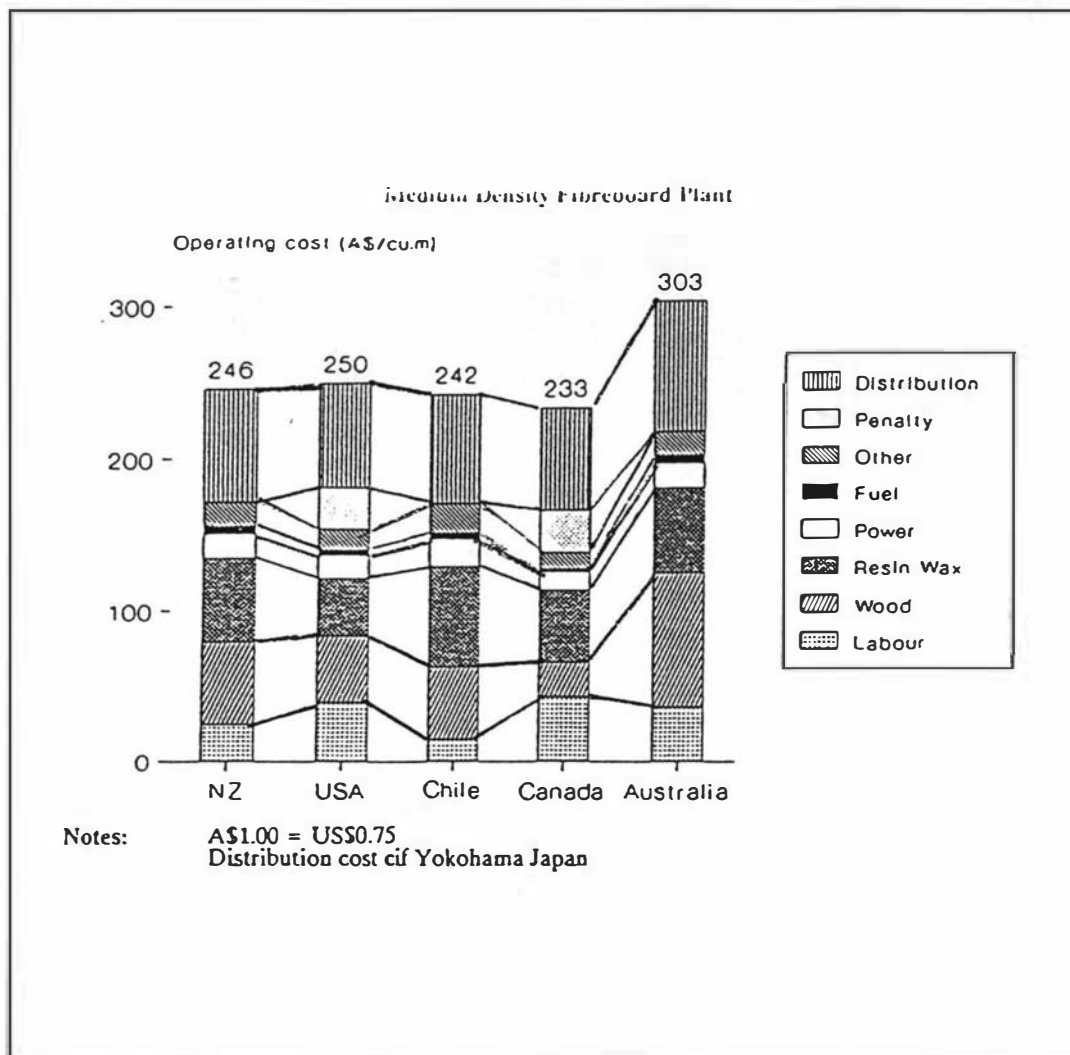


Figure 1.13 M.D.F. Plant Operating Costs.

with an extensive evaluation of comparative industry and tax policies, and after tax investment returns, in New Zealand versus other countries with a similar surplus of softwood fibre in the coming 15 years, provided a basis on which to start assessing New Zealand's wood processing prospects.¹¹ A comparison with the industry policies of Chile, in particular, together with a number of other growing economies, further enabled identification of the inadequacies of New Zealand's policy settings. It was concluded that the current policy will not attract the

scale of investment necessary to realise the social economic enhancement required, despite the progress made since the mid 1980s. The study specifically concluded that the most probable outcome is that the future level of new processing investment will be substantially below that required to ensure a reasonable amount of added value wood products leave New Zealand in the future. This is because:

Firstly, when risk relativity is included in comparisons of financial return for greenfields site investments, New Zealand's returns are mediocre compared with returns from greenfields opportunities in other countries with softwood surpluses.

Secondly, New Zealand's opportunities primarily require a greenfields site, but these will be competing with principally brownfields expansion and corporate acquisition opportunities offshore. They have superior risk/return profiles to greenfields opportunities in New Zealand.

Thirdly, overall, foreign industry investors views of New Zealand are at best neutral. We are too small and remote, with a perceived history of poor labour market conditions, and a lack of any form of explicit welcome mat or invitation card in respect of foreign investment. While overseas policy advisors/analysts and bank executives may applaud New Zealand's economic policy changes and the resulting lower inflation rate and more open economy, these

are not the investors in processing - rather, they are the purchasers of New Zealand debt. Industry investors require more from New Zealand than low inflation and so - called orthodoxy in Governmental fiscal and monetary policy.

Lastly, the scale of new investment possible in New Zealand is substantial for the industry's existing companies, particularly when they also have to account for regional investment portfolio factors. Participation by these New Zealand corporates is more likely to involve well structured joint ventures, provided the foreign partner finds New Zealand investment attractive.

In the development of any industry, the creation of suitable human capital is crucial, as is some degree of innovation to the skilful combination of capital and labour in the production and marketing processes. So in addition to the above considerations, one important element is the rate and status of innovation in the New Zealand wood processing industries, particularly in the pivotal sawmilling sector.

It is contended in this work that, given a suitable level of product, and especially process innovation, all the disadvantages currently accruing to the New Zealand wood processing industries would be reduced as added value processing increased. Moreover, the comparative advantage enjoyed by New Zealand in wood growing would be

complemented and enhanced by the competitive advantage bestowed by innovation in processing in the forestry industries.

1.3. Aims of the Research.

This chapter examined the size and importance of New Zealand's forest and forest products industries. In particular, the pivotal role of the sawmilling sector was examined. The New Zealand industries costs were compared with those of competitors, and generally New Zealand came out at around the mid point of the range of cost structures. So far as investment was concerned, New Zealand fared as a mediocre place to invest, in the eyes of foreigners. Throughout, the importance of innovation in developing competitive advantage was emphasized.

The success or otherwise of an industry or economy is conventionally judged as to how well that industry or economy grows. This growth is, in turn, very dependent upon the rate of technological advance within the industry. The forest products industry is important to New Zealand because of its potential to become the largest earner of foreign exchange in the economy. Such potential must be realised through the achievement of as much domestic added value production as possible. The major means of bringing this about is through innovative management and production techniques, which implies a high level of technology

change.

Previously, it was stated that sawmilling provides a critical link between forest growing and the reconstituted board industries. Sawmilling, therefore is the focus of this work, and the aims of the work are fourfold:

- (1) To examine the nature and components of economic growth, with a particular emphasis on the role of innovation and technological change in economic growth.
- (2) To examine in detail, the nature and dynamics of innovation and technological change. In particular, both market states and the importance of a given social milieu will be examined to ascertain their importance and inter relatedness in innovation and technological change.
- (3) To examine the development of the New Zealand sawmilling industry in economic and physical terms using an econometric framework, through the timespan 1880 to 1990. Thus, the effects of innovation and technological change on the output of sawn timber and relative efficiencies of resource in producing sawn timber will be considered.

- (4) To consider the nature and direction of the development of sawmilling technology in and of itself, and thereby gain some understanding of the rate of innovation and technological change in New Zealand sawmilling. The years 1880 to 1990 will be used once again.

The following chapter examines the definitions and meanings of innovation and technological change, and their interrelatedness with economic growth.

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CHAPTER 2. TECHNOLOGICAL CHANGE AND ECONOMIC GROWTH.

2.1. Introduction.

It was stated in the previous chapter that the success or otherwise of an industry is conventionally judged by its economic growth rate, and this in turn is dependent upon the rate of technological advance within the industry. In this chapter the meanings, importance and inter relatedness of technological change, innovation and economic growth will be examined.

It is almost a truism that technical advance is pervasive in modern societies. It is looked to so that, *inter alia*, the worst effects of depleting natural resources are ameliorated, inflation is moderated by productivity increases, balance of payments deficits are improved, economic growth might be speeded up, famine is eliminated by bio engineering, cancer might be cured, heart disease lessened and so on. Faith in technological change is bolstered by such achievements as computers, the landing of man on the moon, heart transplants and telecommunications. It is achievements such as these that mark human beings out from other life forms on earth.

At root, technical advance is dependent upon the ability of human beings to learn and understand basic principles about the world and to consolidate these principles into the act of production and economic gain. The act of bringing

consolidated principles (in whatever form) into production, implies that they are brought into a marketing system, in order that they may be traded. This may be broadly termed "innovation". The breadth of this view belies deeper and interwoven aspects of innovation and ignores the inter relationships between innovation, technological change and economic growth.

2.2. Economic Growth.

Economic growth has been one of the dominant forces in industrial nations over the past two or three centuries, and it relates to society's growing (or declining) capacity to provide the material basis for human and social existence. It has been the source of some of industrialization's greatest triumphs: it has raised living standards to levels where leisure, travel and luxury goods are within the reach of ordinary people for the first time in history. Economic growth has also been the source of spectacular failures - including pollution of the air, water and land by chemicals, heat and noise.

Economic growth is defined as "a long - term rise in capacity to supply increasingly diverse economic goods to a national populace, this growing capacity based on advancing technology and the institutional and ideological adjustments that it demands."¹ Therefore, it relates to the rate of change of the rate of production of a community

over a given time period (usually a calendar year) and may be measured in terms of the rate of increase (or decrease) of some measure of national product, for example, gross domestic product (G.D.P.).

2.2.1. Components of Economic Growth.

Todaro² has suggested that the major factors in or components of economic growth in any society are:

1. **Capital accumulation**, including all new investments in land, physical equipment and human resources. Capital accumulation results when some proportion of present income is saved and invested in order to augment future output and income. By foregoing consumption of product in the present, higher levels of consumption are facilitated in the future. This process can take many forms, from the building of new productive capacity through to less obvious and more indirect ways such as increasing the educational and technical expertise of an economy's population.

Thus, at the core of the growth process, two great structural shifts must take place. Firstly, a shift of effort within the capital sector to increase its own productive capacity and secondly, a shift of effort from the consumption sector to the capital sector, and a need to utilize the growing volume of equipment which emerges from the enlarged capital sector.

2. **Growth in population**, and therefore, although delayed, growth in the labour force. Population growth and the associated, although delayed, increase in the labour force has traditionally been considered a positive factor in stimulating economic growth. A larger labour force means more productive manpower, while a larger overall population increases the size of domestic markets, and therefore demand. Given appropriate training and education, that is, by increasing the level of human capital, productivity or output per head of labour force will also increase.

3. **Technological progress**. To many writers, for example, Marx, Schumpeter and Mansfield, technological progress or technological change is the most important source of economic growth, and it is central to this exposition. Accordingly, it is dealt with separately below.

2.3. Technological Change.

In the first instance it is necessary to define what is meant by technology before the process of technological change can be examined. Traditionally, technology has been defined variously as "The sum of knowledge of the means and methods of producing goods and services"³, or as a "pool of the social arts or knowledge of the industrial arts."⁴ A more focused and therefore useful definition is, "a set of pieces of knowledge, both directly practical (related to concrete problems and devices) and theoretical (but

practically applicable) knowhow, methods, procedures, experience of success and failures, and also physical devices and equipment."⁵ This definition points to some important aspects of technology.

Firstly, the definition admits the idea of methods of organisation as well as of physical technique. A famous example of this is the introduction and use of the assembly line by Henry Ford. Secondly, technology is not merely applied science because technology can run ahead of science. For example, things can often be done without a precise knowledge as to how and why they work, except that they are effective. Moreover, the definition points to the importance of "disembodied" technology. A machine operator may find a more effective way of using a given machine as he gains experience with it. Therefore, a new procedure evolves which, while pertaining to the machine, is not part of it. It is disembodied.

In general however, modern technology is increasingly science based and rather than relying on an acquired skill, is easily communicable by demonstration and printed material to those qualified to receive it. Clearly, the development of appropriate human capital is essential if an economy is to experience any degree of technologically based growth.

Technological change is the corollary of technology;

typically it implies productivity raising improvements. Thus technological change results from new and improved ways of accomplishing traditional tasks, or the replacement of an existing technology with a newer one. There are three basic classifications of technological change: neutral, labour saving and capital saving.

Neutral technological change refers to the instance where higher output levels are achieved with the same quantities and combinations of inputs. Put differently, productivity (the ratio of outputs to inputs) has increased.

A labour saving technological change is achieved when there are higher levels of output with lower levels of labour inputs. Against this, capital saving technological change occurs when there are higher levels of output, but with fewer capital inputs. Capital saving technological change is a relatively rare phenomenon because almost all of the world's scientific and technological research is conducted in countries where relative labour scarcity is usual.

2.3.1. Early Observations on Technological Change.

Traditionally, technological change was treated as exogenous to economic systems, implying that it was treated as a given characteristic of the environment that is determined outside economic systems. Even now many economics texts treat technology in this fashion. Yet

recognition of the role of economic gain in the achievement of technical advance can be traced back at least to the "father" of modern philosophy, Rene Descartes:

"As for myself, I am persuaded that if I had been taught in my youth all the truths of which I have since sought demonstrations, and if I could have learned them without difficulty, I might never have learned any others, or at least, I would never have acquired the habit and ability that I believe I possess, always to *find truths in proportion to the efforts I made to find them...*

It is true that as far as the related experiments are concerned, one man is not enough to do them all, but he could not usefully employ other hands than his own, unless those of workers or other persons whom he could pay. *Such people would do, in the hope of gain, which is a very effective motive, precisely what they are told.* As for those volunteers who might offer to do it out of curiosity or the desire to learn, besides that ordinarily they are stronger in promises than in performance and they make nothing but beautiful proposals of which none ever succeeds, they would infallibly expect to be paid by the explanations of some difficulties, or at least in compliments and useless conversation, which would necessarily

consume so much time needed for investigation that the assistance would be a net loss.⁶

One hundred and fifty years after these words were written, Adam Smith recognized the importance of technological change in economic activity by identifying the two ingredients that make technological advance an economic activity itself.⁷ Firstly, it is done to gain an advantage, such as easing one's work, and secondly, it requires the investment of money. Yet he still failed to combine them into a theory of technical advance as a deliberate economic process. Malthus and Ricardo were also concerned with the impact of technical advance, especially in the form of improved machinery on the displacement of labour but regarded it as exogenous to the economic system.⁸ The work of Karl Marx⁹ combined an interest in the fundamental mechanisms of capitalist society with an analysis of how technological change itself was taking place.

For around 100 years after these economists had written, technology was assumed as a kind of static datum in analysis, effectively assumed away via, *inter alia*, the *ceteris paribus* assumption. Theorists were concerned with questions about resource allocation in the short run, when the capital stock was assumed to be fixed, and in the long run, when it was allowed to vary in certain ways. This type of analysis, along with the comparative statics technique,

was (and is) not particularly useful in shedding light on the process of growth, largely because it can only deal with a small number of variables at discrete time intervals and under restricted conditions. Technical conditions were treated as exogenous, that is, as variables not determined by the system under study. Generally, investment was assumed to be the cause of growth.

In a remarkable study carried out in 1956, Robert Solow¹⁰ attempted to provide a statistical explanation for the causes of United States manufacturing growth over the period 1911 to 1956. His major conclusions were that 12.5 percent of the observed growth of labour productivity could be explained by increments to the capital stock, while the remaining 87.5 percent was a statistical residual which could be explained by something like "an improvement to productivity" or an "unexplained technological change". The study showed that the rate of investment was (is) not important as an explanation of growth, but rather the productivity of investment is.

In essence, the concern is to make technological change an endogenous variable within the economic system, so that it is affected by and in turn affects changes within that system. The development of this form of analysis is taken up in the following chapter.

2.4. Innovation.

In order to successfully deal with innovation in this work, it is necessary to arrive at a working definition.

Previously, at the beginning of this chapter, innovation had been briefly referred to as, "The act of bringing consolidated principles (in whatever form) into production, implying that they are brought into a marketing system, in order that they may be traded." It is necessary to expand on these notions. The following sections, (2.4.to 2.4.5.) will examine the dimensions, meanings and implications of innovation, before bringing all the aspects together as a definition towards the end.

Innovation can be simply defined as the introduction of new products or production processes.¹¹ However, this outward simplicity hides a number of important aspects of innovation.

Firstly, innovation is a process. Therefore, there is a time dimension to it, and the significance of this is that 'new' products or processes do not just suddenly appear at a given instant in time. The history of a given new product or process may stretch back many years to a number of important antecedents which could have been unrelated discoveries in various disciplines of pure research. For example, the process of the introduction of nuclear reactors in the generation of electricity could be traced back to the recognition by Einstein of the equivalence of matter and energy in the year 1905.

Secondly, innovation can mean the introduction of a new way of producing an existing product or service, as well as the introduction of a new product (either consumer or capital) or service in a given market. Put slightly differently, product innovations involve development of new or improved products or services, whereas process innovations are technical advances that reduce the cost of producing existing products or services. Thus, product innovations reduce the cost of satisfying existing needs or the creation of new production functions. Process innovations represent upward shifts in the production function.

Often, the classification of innovations depends upon one's perspective. For example, a new computer is a product innovation from the standpoint of the manufacturers but is a cost reducing innovation from the point of view of say, banks and accountants. In this sense, there is probably little point in distinguishing between process and product innovations, so unless such a dichotomy is germane to the discussion, it will not be made.

Thirdly, organisational innovations are possible, particularly in the sphere of production. Capital equipment can remain unaltered, but the organisation of the equipment and personnel, and the relationship between capital and labour can be altered. Henry Ford innovated the organisation of the production line, using existing capital equipment, and the advent of fast food chains, particularly

McDonalds, demonstrated what was organisationally possible in that industry. Food is still cooked and prepared as previously, but through standardisation and organisational innovation, the time between receipt of an order and the delivery of that order to customer, is drastically reduced. Moreover, the McDonalds hamburger produced in Moscow is supposedly identical to the one produced in Auckland.

Fourthly, innovation can be subdivided into four processes: invention, entrepreneurship, investment and development.¹² This arrangement would seem to be the logical order of innovation processes, although they do overlap. For example, investment decisions could be made by entrepreneurs about each of invention and development. For ease of convenience, these processes will be dealt with in the following order, invention, entrepreneurship, investment and development.

2.4.1. Invention.

Invention can be said to be the bringing into being of new techniques or pieces of equipment for the performance of tasks. It does not consider the introduction of new techniques or products into the production and marketing system. Thus a new product can be invented, but it is not necessarily put on the market. Similarly, a new production method or process can be invented, but it is not necessarily used as an item of productive capital.

Generally, there are three theories of invention: the transcendentalist, the mechanistic and the cumulative process.¹³ Each is discussed below.

The transcendentalist¹⁴ view is that which emphasizes the lone or individual genius. Through one creative thought, or flash of insight, the reclusive eccentric makes a great technological impact. Accordingly, the lives of millions of people are forever altered.

The mechanistic¹⁵ view posits the notion that invention proceeds under the stress of necessity, with need dictating and technology complying. In this formulation, invention is placed in the economic milieu and is seen as entirely endogenous to any given economic system. The role of the individual genius is minimised or rejected outright.

The third view, the cumulative process,¹⁶ has invention arising from a cumulative synthesis from what has gone before. In this view, an act of insight is required, and an individual may play an important role in the solution of technical problems. However, such individuals are not reclusive geniuses working alone, nor are they pushed aside nor insignificant in the onrush of an inevitable historical process. By a synthesis of previous knowledge and an act of insight, a discontinuity may be overcome. Thus, invention is neither divorced from a social and economic milieu, nor is it absolutely a deterministic phenomenon. Inventions

occur 'in their own good time', responding more or less to the demands of society, yet not fully pre-ordained by historical and technological progress.

Cumulative synthesis is probably the most realistic theory of invention, because it places invention in a relatively prosaic light, while suggesting that it arises out of past technological activity.

2.4.2. Entrepreneurship.

Within a firm, the entrepreneurial function is concerned with the financing of the supply of capital of the firm, organising production by buying and organising inputs, deciding on the rate of output in the light of estimates of demand and bearing the risks involved in such activities.¹⁷

So far as innovation is concerned, entrepreneurship involves deciding to go forward with the innovational effort, organising that effort and obtaining financial support. In some respects, the firm entrepreneur is identifiable with a kind of 'product champion' who sees an idea from its early stages through to the product launch or the introduction of a new production method and beyond.

In many instances, decisions to innovate within a firm are subject to much political debate and manoeuvre. The

persuasive skills of the entrepreneur are paramount in gaining support for the development and introduction of a product or idea.

2.4.3. Development.

Typically, development tends to be a much more expensive activity than invention. The following table shows the division of costs incurred in bringing an invention to market.¹⁸

Stage	Average % of total cost arising at each stage.
1 Applied research	9.5
2 Specifications	7.6
3 Prototype or pilot plant	29.1
4 Tooling and manufacturing facilities	36.9
5 Manufacturing start up	9.1
6 Marketing start up	7.7

Figure 2.1 Division of Costs Incurred in Bringing an Invention to the Market

Clearly, the applied research and specifications account for only 5 percent to 10 percent of the costs, while the remainder, which could be termed the 'commercialisation' or 'development' phases, are at least ten times the cost of the invention phase. The time taken to complete the stages also varies considerably.¹⁹ The prototype or pilot plant stage usually takes up to 50 percent of the time taken to achieve the whole innovation process. Stages 1 and 4 also

take up a considerable amount of time, together accounting for about 30 percent of the total.

2.4.4. Investment.

In developing an invention, firms commit funds in the hope of future benefits. The risks involved can be broadly categorised as two types; technical risk and market risk. Technical risk refers to the possibility of being thwarted, in that no saleable output will result from the invention and development process. Market risk, on the other hand, refers to the likelihood (or otherwise) of commercial success of a given technological development.

2.4.4.1. Technical Risk.

The larger the magnitude of the size and complexity of a technological advance envisioned by a firm, so correspondingly, will be the magnitude of the technical risk. The likelihood of bringing a radical new concept to market fruition is more uncertain than bringing a relatively 'mundane' change to the market.

Firms can control for the degree of technical risk by initiating a range of projects and selecting from those showing promising progress. This means that risk is spread over a range of options, and the larger the firm, the more able it is to spread risks across a wider range of options.

A United States study,²⁰ involving a larger company sponsoring 70 projects, showed that the expected probability of technical success in about three quarters of the cases exceeded .80. Seven projects had expected probabilities of success less than .60. When these expectations were compared with actual results, 44 percent of the projects were successful. 16 percent failed because of unforeseen difficulties and a large number failed because of deliberate company policy. In 9 percent of cases, the objectives of a project were changed and in 18 percent, manpower was diverted to other uses. The same study showed that the firm concentrated on short run projects.

2.4.4.2 Market Risk.

There are a great many factors that will influence the commercial outcome of a given innovation. Whereas technical risk is largely determined by the technical competence of research and development teams, market risk is more susceptible to extra - firm influences. An American study²¹ showed that 45 percent of failures could be attributed to inadequate market analysis and weak marketing effort. It cannot be overemphasized that assessment of market potential is a crucial function in the innovation process.

2.4.5. The Definition of Innovation.

Whilst it has been suggested that innovation can be defined as "the introduction of new products and production processes", this ignores the component processes of invention, entrepreneurship, investment and development. Each is an important part of the innovation process, and without any of them, innovation would not occur. There is a considerable degree of overlap between each of the component processes, for example, invention and development imply investment in time and resources, on the part of entrepreneurs. It is exceedingly difficult, and probably pointless, to try to disentangle one process from the other. Broadly, they serve a useful taxonomic arrangement facilitating a conceptualisation of all the aspects of innovation. However, this conceptualisation may not be particularly useful in empirical work as current measurement techniques do not allow such fine distinctions.²² Accordingly, innovation shall be defined as "all those activities, from basic research to invention, entrepreneurship, investment and development that give rise to a new product, service or organisational form in an existing or new market, or new means of production of an existing product or service, in a productive system."

By adopting this definition, all the aspects and fine distinctions of innovation are acknowledged, while allowing that the disentangling of them in empirical work is "probably impossible, if not pointless. The wording "or new

means of production is deliberate, because it allows for new organisational forms in production, even if the capital equipment remains unaltered. The method by which it is intended to capture the process of innovation in empirical work is left until a later chapter.

2.5. Summary

In this chapter it was suggested that one of the salient characteristics of human beings is that they are inveterate users of technology, and suggested that the use of technology, by increasing the productivity of human beings, is an important component of economic growth. It was argued that the major components of economic growth are capital accumulation, population growth and technological change.

So far as economic growth is concerned, the classical and neo classical economic paradigm tended to ignore technological change as an important element by assuming that it was exogenous to the economic system. Apart from such writers as Marx and Smith, it has only since Solow published his pioneering work in 1957 that attention has once again focused on the importance of technological change and innovation.

The act of bringing new technologies into the productive or market milieu is innovation, and this was examined. A definition of innovation was developed to facilitate

discussion and investigation throughout the remainder of this work.

The next chapter will focus on recent treatments of technological change and innovation, and then move on to consider why innovation might happen. Questions will be examined as to the market states that might encourage innovation, technological paradigms, evolutionary theories in economics, the importance of technological change in Kondratieff cycles, and so on. There will be some discussion as to the usefulness of current theory in capturing the full richness of technological change in capitalist and mixed economies.

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CHAPTER 3. MODELS OF INNOVATION AND TECHNOLOGICAL CHANGE.

3.1. Introduction.

This chapter will examine various treatments of innovation and technological change, with a view to capturing some of the relationships that might exist between market states, innovation and technological change. The nature and importance of a given social system will be examined to understand why technologies take the forms and functions they do.

The previous chapter considered the phenomenon of economic growth and briefly looked at the role of technological change and innovation in economic growth. It was argued that the neo classical economic paradigm tended to treat both technological change and innovation as exogenous to the economic system, thereby forestalling any examination of real world economic systems. It was argued that there was a need to make technological change endogenous to the economic system, both to be the explanation for technological change within the system itself, and to show how technological change both influences, and is influenced by, economic growth. Thus, technology and technological change could no longer be "givens" for an economic system, but integral to it. Put simply, economic behaviour itself could help give rise to technological change.

The work of Joseph Schumpeter¹ in the first half of the twentieth century pointed the way to embedding technological change into economic systems by arguing that the lure of profits acted on entrepreneurs to bring new or improved products and services to markets. He argued that most competition was not of the "price" variety, as was suggested by the neo classical model of perfect competition, but of the "non - price" variety, typically found in markets showing some degree of monopoly; that is in nearly all markets.

Schumpeter has been viewed as a technology push advocate in the debate, whereas, the work of Jacob Schmookler², argues the case that the allocation of resources to inventive activities can be substantially explained in terms of individuals acting in response to future profit, as these expectations are shaped and influenced by the complex of socio - economic changes. Far from being the product of autonomous forces, therefore, technological progress can be studied and explained as the outcome of society's demand, as expressed in the market place, for specific categories of invention. Put simply, this is a demand pull view point.

Giovanni Dosi³, on the other hand, has suggested that technologies typically display a unique opportunity set of potential development and change, and argued that development occurs along a technological trajectory.

Having established a model by which technological change is placed within an economic system, it is reasonable to ask whether or not technological change moves along trajectories determined by technology supply, market demand, or whether there is an inexorable and deterministic logic to change as offered by the nature of the technology itself. The issue becomes one of whether or not there is a "demand - pull" or a "technology - push" phenomenon which influences the trajectory of technological change and development.

In each instance, general conclusions relating to the theories and research of the models of Schumpeter, Schmookler and Dosi are offered, along with an attempted synthesis of the models. This will act as a prelude to moving into the next chapter which develops a research framework and associated methods.

3.2. The Schumpeterian Breakthrough.

Joseph Schumpeter was one the few economists in the first half of the twentieth century who both questioned the static underpinning of neo classical economics and simultaneously suggested an alternative approach.⁴

Schumpeter set out to identify an endogenous explanation of economic and productivity growth, and a mechanism that

would generate long term continuity, along with persistent fluctuations in the growth of total output. In short, he wanted to describe a system closer to reality than hitherto had been the case.

His starting point was the role of profits in the evolution of the capitalist system, which he saw as providing an important motivating function to entrepreneurs. With profits acting as a lure to entrepreneurs to innovate, either production costs were lowered or new products were brought into markets. This energising role of profits ensured that economic growth would ensue in the first place, and without profits, the system would not function. By assuming that entrepreneurs, attracted by the lure of profits, innovate new products, processes and organisational systems, technological change was brought about and economic growth was the result.

Innovation, for Schumpeter, could take five major forms;⁵

- 1 The introduction of a new good or a new quality of good.

- 2 The introduction of a new production process (not necessarily one based upon scientific discovery).

- 3 The opening up of a new market.

- 4 The development of a new source of input supply.
- 5 Changes in industrial organisation.

Broadly speaking, anything that increased efficiency in resource use was regarded by Schumpeter as an innovation.

In Schumpeter's formulation, invention and entrepreneurship were separate; an inventor might not necessarily be an entrepreneur and vice versa. The important thing was the act of entrepreneurship that brought an invention to market.

Given that a successful new product or new method of production called forth extra or higher or supernormal profits, then that same act of innovation would call forth imitation by competitors, thereby eventually eroding the supernormal profits of the innovator. The sooner imitation occurred, the sooner the profits were eroded, and the less likely a firm would engage in innovative activity.

For Schumpeter, it was in markets that were characterised by monopoly conditions that innovation occurred. The next section examines some of this reasoning.

3.2.1. Market States in the Schumpeterian Schema.

Schumpeter argued that monopoly was an inefficient form of

market organisation only if competition occurred purely in terms of price.⁶ Clearly, much competition is of the non price variety, with many firms developing new products, services, processes, and so on. Accordingly, for Schumpeter, the resources required to develop these new products and services could only come from supernormal profits made available in markets and industries with some degree of monopoly. A highly competitive market could lead to the highest efficiency only in a static world, with a constant set of products or services made available to customers at ever decreasing costs. Firms maximising static efficiency preclude the development of new products, whereas monopolies and oligopolies, while statically inefficient, allow for the introduction of new products, leading to greater dynamic efficiency.

A monopolist has a number of advantages over a perfect competitor, which makes it easier to develop innovations. For example, the monopolist could prevent or slow down imitation of its new product or service by imitating firms. The use of such devices as patents, copyright, trade marks and distribution channel control are examples of this. Further ploys might be to maintain secrecy by the use of internal funding and the attracting of creative people by offering high inducements to join and by the establishment of a good research and development reputation. These ploys represent the raising of entry barriers to other firms if and when they contemplate joining the industry or breaking

into the new market.⁷

The amount of monopoly existing in a market or industry will both influence the rate of innovation and the rate of imitation by other firms in that industry or market. For example, the longer an innovator holds a monopoly position in a product or service, the higher the imitation costs will be to other firms and the slower the rate of diffusion of the innovation.

Monopolies are large firms, relative to the size of a market, so there are reasons to argue that large firms, *ipso facto*, might well behave in similar ways to monopolies, so far as innovation is concerned. The next section examines firm size.

3.2.2. Firm Size and Innovation.

There are several reasons why firm size can be expected to influence innovative activity, and they are similar to the reasons explained by market structure or state.

Galbraith,⁸ in pointing to the rising costs of innovation, argued that larger firms were in an increasingly advantageous position as costs continued their upward movement.

Economies of scale⁹ accrue to larger organisations, and

these economies aid in lowering the unit costs of innovation as well as other aspects of an organisation's operations.

There may well be disadvantages accruing as well, for example, unexpected research findings could be wasted as a result of a managerial "mind set".¹⁰ Furthermore, researchers' motivation to perform may be lower in a larger firm than in a smaller one because their compensation may be less directly related to performance in a larger firm.

In general, Schumpeter, in coining the term "creative destruction"¹¹ pointed to the possibility that non price competition in markets showing varying degrees of monopoly, might actually be the spur to technological change and growth in capitalist economies. By creative destruction, he meant that the process of innovation, while being creative, also destroyed older and established products, services and technologies as a result of non price competition.

As a summary of Schumpeter's thinking, three central questions or ideas can be posed about the origin of innovation.

- (i) Whether the central character is the entrepreneur or the large firm, it is only by introducing radically new ideas into economic life that whole new industries can be created. Technology,

whether generated outside the economic system or in large scale R&D laboratories of a monopolistic competitor, is for Schumpeter, the leading engine of growth. Therefore, the "technology-push" hypothesis of the origin of innovation finds a natural home in Schumpeter's ideas.

- (ii) Will more and better innovations be produced by many entrepreneurs or by a few large oligopolists? In other words, "What is the ideal market structure to stimulate innovation?"

- (iii) What is the best firm size to stimulate innovation? (This question has also been addressed by Galbraith in many of his writings)

The above statements show that the Schumpeterian view can be classified generally as a technology-push notion, wherein new technologies are innovated into the economic system as they become available. Essentially, these new products and processes create their own new markets. However, the role of demand, while not ignored, is down played in this view, and the importance of demand in bringing about innovation will now be examined. The technology-push versus demand-pull hypotheses were effectively contrasted by Jacob Schmookler in his studies of patenting and investment.

3.3. The Demand Pull Hypothesis.

Jacob Schmookler¹² looked at investment, shares, employment and inventive activity in the railway, petroleum refining, agriculture and paper making industries in the United States of America from the first half of the nineteenth century to the 1950s. His time series for inventive activity were composed of patents and investments in capital goods, and these two variables showed a high degree of synchronicity, with investment leading patent series significantly more often than the reverse.

Schmookler's particular findings were that investment usually led patenting in the upswing from the troughs of economic depressions, and he argued that fluctuations in investment could be better explained by external events than by the course of invention. Upswings in inventive activity therefore responded to upswings in demand. Schematically, the following picture was postulated:

DEMAND -> INVESTMENT -> INNOVATION

Schmookler did not argue that demand forces were the only determinants of inventive and innovative activity, but was trying to correct the opposite imbalance according to which it was only the exogenous flow of inventions which could create new innovations and new economic activities. Indeed, he suggested that demand and invention were the opposite

blades of a pair of scissors, equally important as cutting edges in technological advance.

The relative importance of the push versus pull views has been investigated in a wide range of studies¹³, and most of them ostensibly come down in favour of the demand pull hypothesis. However, a number of writers¹⁴ have reviewed much of this work and conclude, that because of such things as methodological difficulties, loosely defined concepts of needs instead of the narrower economic definition of demand as the independent variable, and the fact that technology push factors were often rendered impossible to find in the studies by being conceived in a caricatured way as entirely *scientific* events free of any economic component whatsoever, the studies do not show conclusively the prime importance of the demand-pull hypothesis.

It is worthwhile summarising the demand pull/technology push debate here. Patterns of investment, scientific papers, patents, innovations and output have been analysed in many studies and in many industries. Neither technology push nor demand pull are found to predominate systematically, but each one of them can lead the other at different stages in the development of an industry. Coombs, Saviotti and Walsh¹⁵ state, "If any generalisation can be made, technology push tends to be relatively more important in the early stages of development of the industry while

demand pull tends to increase in relative importance in the mature stages of the product cycle." Therefore, neither the ideas of Schmookler nor of Schumpeter are adequate alone. A combination appears to be a better explanation for the development of industries.

The questions in respect of firm size and market concentration posed as a result of an examination of Schumpeter's work above, are now examined in respect of the empirical evidence. The following section deals with some of the flavour of empirical research findings that might support or refute the Schumpeterian view.

3.4. Empirical Research on Innovation, Firm Size and Market Structure.

Typically, much of this research centres around the question of market structure and how it might be related to R&D inputs and outputs. The sheer volume of the work prevents a comprehensive discussion of the research findings, so some of the more typical efforts are briefly considered below. Also, see the reference for a good review of the literature.¹⁶

Scott¹⁷ looked at the possibility that a "competitive oligopoly" was most conducive to technological advance. He tested the hypothesis that the relationship between market concentration and research and development is a "U" shape,

with R&D at first falling with market concentration and then rising as concentration increases. He found that this was the case, but when demand conditions were controlled for, the relationship disappeared. This finding highlights the importance of demand conditions and technological opportunities as determinants of technological advance.

Lunn and Martin¹⁸ hypothesized that in both high and low technological opportunity industries, high profit operations spend less on R&D, *cet.par.* This was held to indicate the importance of competition as a stimulus to innovation. Their findings were in the affirmative, and the authors held that firms in competitive markets invest in R&D in search of profit.

However, in the same article, support was still given to the Schumpeterian notion that the organisation of production in large firms favours technological advance. The reasoning was that in low technological opportunity industries, operations with larger market shares and operations in concentrated industries spend more on R&D per dollar of sales, *cet.par.* The authors argued that a fair interpretation of their evidence is that market power encouraged investment in innovation in low technological opportunity industries, but that it was also possible that larger operations with greater assets, in low technological opportunity industries, spend more on R&D even after differences in market share and market concentration are

accounted for.

There were different findings for high technological opportunity industries, Neither market share nor market concentration had a statistically significant impact on research spending. On the other hand, large firms in high technological opportunity industries spent more per dollar of sales on R&D, *cet.par.*

Lunn¹⁹ found that process patents were positively related to market concentration, and suggested that this was consistent with Schumpeter's ideas. Also, there were more process patents in industries with high technological opportunities. Lunn further found that new product patents were not affected by market concentration or technological opportunities, but there was less patenting of new products in industries in which average spending on advertising per dollar of sales was high. He argued therefore, that the findings confirmed the importance of product differentiation as an incentive for new product innovation.

The literature on the relationship between market structure, firm size and innovation is voluminous, but has not come to a firm conclusion. Both on theoretical grounds and on the grounds of casual observation, it is easy to propose disadvantages in innovation for monopolies and competitive structures, and for large and small firms.

Kamien and Schwartz²⁰, in reviewing a large number of studies on these relationships, found little consensus, but remarked that there appear to be strong industry effects and that the degree of technological opportunity at industry level may be a major influence on the rate of innovation and technological change. The following section examines this proposition further.

3.5. Technological Paradigms.

The modern philosophy of science suggests the existence of scientific paradigms, or research programmes, which determine the direction and nature of scientific enquiry. In a similar vein, Dosi²¹ has argued for the existence of technological paradigms, which he defines as, "... pattern of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies."²² He argues further, that a technological paradigm defines contextually the needs that are meant to be fulfilled, the scientific principles utilised for the task, and the material technology itself. Thus, a technological paradigm may be seen as a focusing device for a cluster of technologies whose joint function is to contribute to a set of common processes or products. In other words, technological paradigms define the technological opportunities for further innovations and some basic procedures on how to exploit them.

The above notions do not mean that a determinism is being dealt with, in which the actual pathway for development is predetermined in the nature of the technology itself. Rather, the paradigm helps define the set of possible pathways that may be followed, and it is through the interaction of social forces (economic, political, etc) that the actual pathway or trajectory is determined. Once a new technology is innovated, it begins an evolutionary track that is in part determined by the social milieu in which it rests.

3.5.1. Technological Trajectories.

Implied in the development of a technological paradigm is the idea of a technological trajectory, which has been defined as, "...the activity of technological progress along the economic and technological trade-offs defined by the technological paradigm."²³ Thus, a technological trajectory can be seen as a problem solving activity (ies) which comprises routine changes to existing technologies within a paradigm. In summary and contrast, a technological paradigm reflects what is scientifically possible, whereas the path of the technological trajectory reflects what is socially possible.

Inevitably, the actual path of innovation and improvement pursued by any given firm is dependent upon, *inter alia*, the specific competencies that reside within that firm.

Given a set of competencies (knowledge, experience, attitudes, marketing ability, research capacity, etc), then the particular form of the (any) innovation is highly specific to that firm. This means that innovative activities are highly selective and finalised in rather precise directions, and are often cumulative activities.²⁴ The importance of this is that the idea runs counter to the view²⁵ that technology as information is generally applicable and easy to reproduce and reuse; where firms can produce and use innovations mainly by dipping freely into a pool of technology and knowledge. Instead, firms produce things, and use processes, in technically differentiated ways from one another, largely on the basis of in house technology, but along with some contributions from other firms and publicly available knowledge.

Given the cumulative and firm specific nature of technology, then development over time becomes less and less random, as social forces determine the "desirable" market state or form of the technology. Firms' products and processes tend to converge as a product or process nears or enters a mature phase. In a sense, uncertainty diminishes as the market becomes known. However, a shake out occurs as less successful market forms of the technology are rejected by the market.

3.5.2. Market and Technological Opportunities.

Gort and Keppler²⁶ have offered a five stage model of the patterns of entry during the evolution of a particular market for a technology, as follows;

- (i) Rapid growth of entry following the first innovation, conditioned by ease of entry and the number of potential entrants.
- (ii) Increase in the number of producers.
- (iii) Entrants and exits cancelling each other out with net entry at zero.
- (iv) Negative entry (or shake out)
- (v) Zero entry as the industry becomes mature.

This model is highlighted to emphasize that firms are initially attracted to a new market by the opportunities offered therein. Each firm runs along a given idiosyncratic technological trajectory, and the market gradually selects out the perceived "undesirable" manifestations of a technology that some firms may be producing. Eventually, a stable form of the technology is settled upon at some mature stage. This model could apply as much to process innovations as to product and service innovations.

Opportunities perceived by firms are market opportunities and technological opportunities. Given some incremental development and innovation, a firm sees the chance to gain a profitable position within a market. Early in the product or process life cycle, opportunities are high, whereas

later in the cycle, they are low.

3.5.3. Paradigm Shifts.

New markets are typically created by the introduction of new products and processes, which implies the innovation of new or radically different technology. So called radical innovations bring with them new paradigms and paradigm shifts, and a new set of technological opportunities and trajectories that are worked through.

Dosi²⁷ has suggested that the source of entirely new paradigms is increasingly coming from fundamental advances in science and in related "general" technologies. (e.g. in electricity and information processing, etc.) Thus, for example, traditional process type technologies are becoming increasingly controlled and operated by the newer silicon chip related technologies. In general, the linkages between scientific advances and technological opportunities are likely to be much more direct at the early stage of emergence of new technological paradigms.²⁸

3.5.4. Relative Factor Prices.

Innovation yields new techniques which are likely to be superior to the old ones, irrespective of relative prices.²⁹ If the new techniques had existed before they would have also been adopted at the old relative prices. In

the microelectronics industries, electronics based production technologies are,

- (i) labour saving,
- (ii) fixed capital saving (i.e., they induce a fall in the capital/output ratio),
- (iii) circulating-capital saving (i.e., the optimisation of production flows allows a fall in the stocks of intermediate inputs per unit of output),
- (iv) quality improving (i.e., they increase the accuracy of production processes, allow quality testing, etc.),
- (v) energy saving (in so far as the energy use is also a function of mechanical movements of the various machineries, the substitution of information processing equipment for electromechanical parts reduces the use of energy).³⁰

Thus, taking all these characteristics together, the electronics based production techniques are generally superior to electro mechanical ones, irrespective of relative prices. In other words, the new wage/profit frontiers associated with the new techniques do not intersect for any positive value for the old one. This finding may be generalisable to other market sectors, given the possibility of rapid technological development arising

from wide technological opportunities.

3.5.5. Industrial Taxonomy for Innovative Potential.

Clearly, there will be differences between sectors in terms of technological opportunities, because of *inter alia*, varying stages of development of technologies, markets and more particularly, the nature of the products and processes themselves. Pavitt³¹, in attempting to answer the question as to why sectors might differ in their rates and modes of innovation, set up the following taxonomy sectors.

- (i) **Supplier Dominated Sectors**, (which include textile, clothing, leather, printing and publishing, wood products.) Innovations are mainly process innovation: innovative opportunities are generally embodied in new varieties of capital equipment and intermediate inputs, originated by firms whose principal activity is outside these sectors themselves. Thus the process of innovation is primarily a process of diffusion of best practice capital goods and of innovative intermediate inputs (such as synthetic fibres, etc.) The knowledge base of innovation in these sectors mainly relates to incremental improvements in the equipment produced elsewhere, to its efficient use and to organisational innovations.

- (ii) **Scale Intensive Sectors.** Innovation relates to both processes and products; production activities generally involve mastering complex systems (and often manufacturing complex products); economies of scale of various sorts (in production, design, R&D, etc.) are significant; firms tend to be big, produce a relatively high proportion of their own process technology, devote a relatively high proportion of their resources to innovation, and tend to integrate vertically into the manufacturing of some of their own equipment. This group includes transport equipment, some electric consumer durables, metal manufacturing, food products, parts of the chemical industry, glass and cement. Moreover, within this group, a finer taxonomic distinction can be made, according to the nature of the production process, between (a) assembly based industries of the Taylorist/Fordist type and (b) continuous process industries.
- (iii) **Specialised Suppliers.** Innovative activities relate primarily to product innovations which enter sectors as capital inputs. Firms tend to be relatively small, operate in close contact with their users and embody a specialised knowledge in design and equipment building. Typically, this group includes mechanical and instruments

engineering. Opportunities are generally high and are often exploited through informal activities of design improvements, introductions of new components, etc.

- (iv) **Science Based Sectors.** This group includes the electronics industries and most of the chemical industries. Innovation is often directly linked to new technological paradigms made possible by scientific advances; technological opportunity is very high; innovative activities are formalised in R&D laboratories; a high proportion of their product innovation enters a wide number of sectors as capital or intermediate inputs; firms tend to be big (with the exception of some highly entrepreneurial and specialised producers).

3.6. Theoretical Framework.

It is possible to draw the theoretical threads of this chapter together to propose a model of technological change and innovation which incorporates the theories discussed.

Nelson and Winter³² have suggested an evolutionary theory of economic change in which organisations are the counterparts of species in biology. Building on the analogy, they argue that an organisation's rules of

operation, or policies, are the equivalent of genes in evolutionary theory.

Successful species are those which are able to adjust to their changing environments, generally through genetic mutation and natural selection. Thus, in similar fashion, organisations that are able to change their policies in response to environmental changes are most likely to survive. Accordingly, innovation and technological change can be seen as part of the adaptive and survival mechanism of organisations, and the rate of genetic mutation has its parallel in the rate of innovation and technological change.

The pathway of change in the biological case and in the organisational case will follow a distinctive course or trajectory, since specific problems have to be solved and given environmental changes dealt with.

Any organisation's environment can be assessed as to the degree of monopoly which might exist, which is to say the nature of the niche of the organisation can be ascertained. Additionally, it is possible to argue that the rate of technological change is reflected in the ability of the organisation to adjust to changing environmental conditions, and to employ the possibilities presented by genetic mutation (i.e policy changes) as survival and growth mechanisms.

In this schema, Schumpeter's³³ view of the role of monopoly conditions can be seen as the environmental context which offers opportunities for Schmookler's³⁴ demand pull model to operate. In other words, the demand pull model can be seen as the genetic and adaptive response to environmental change.

The evolutionary pathway that a species exhibits is a history of its responses to a changing environment. At any time there will be a collection of survival problems to be addressed by the species and a collection of genes that may change (randomly) and perhaps help ameliorate the problems. Thus, the actual changes that occur can be seen in the evolutionary pathway.

Dosi's³⁵ notion of a technological paradigm is analogous to the set of environmental problems and potential genetic responses, whereas the technological trajectory is the counterpart to the evolutionary pathway actual taken by a species.

The empirical content of this work is concerned with two aspects of the model outlined above.

Firstly, it is possible to understand how well an organism or species fits into its environment at any given time by examining *inter alia*, how and how well it uses resources in its interaction with the environment during the process of

living. For example, a given mode of energy capture and use may or may not be better than another mode, when judged against the efficiency of energy capture and use. Such a view looks at the output of evolutionary change, particularly when changes in resource use, "life" production and so on are examined through time. Similarly, it is possible to look at the outputs of technological change through time. For instance, the rate of production, the levels and efficiency of resource use, relative factor efficiencies and so on can be examined through time. Thus, changes in the organisation's adaptive production ability can be traced and understood.

Secondly, it is possible to examine the organisation's technology directly to ascertain how it is specifically changing to environmental conditions. In this case, the direction and velocity of technological change could be understood and described in and of itself. The biological parallel of this is the changing morphology of a species as it evolves. The history of the changes is the evolutionary pathway for the species and the technological trajectory for the organisation.

Chapters 4 and 5 examine New Zealand sawmilling technology in similar terms to the two explained above.

3.7. Summary.

This chapter examined the black box of innovation.

Prior to the writings of Schumpeter, technological change had been treated as exogenous to economic systems.

Schumpeter proposed a technology push view of innovation, whereby entrepreneurs introduce new technologies into the economic milieu in search of profits. Most competition was (and is) of the non price type, and the most useful market states to bring about this gale of "creative destruction" carried some degree of monopoly.

Schumpeter's view tended to ignore the role of demand, and Schmookler corrected this imbalance by showing that an upsurge in demand lead firms to invest in R&D and thereby raise the level of innovation.

The technology itself has a role to play in determining its actual mature market form. Dosi has shown the importance of technological paradigms as pointing to the range of possibilities of technological development, and to technological trajectories as the actual roads taken by technological change.

Thus technology push, demand pull, the technology itself and the surrounding social milieu determine a particular market or productive form of a piece of technology.

Some industries display differing potentials for technological opportunities because of a raft of factors, and it is possible to place a given industry into an appropriately set out taxonomy. The rest of this work will look at technological change in the New Zealand sawmilling industry. For these purposes, it is necessary to state that this industry is best characterised as being supplier dominated. This is because nearly all sawmill equipment is supplied on international markets by a few specialist sawmilling suppliers. However, given the rise of the electronics based production technologies, there is some degree of idiosyncratic technological development within individual firms.

The following chapter looks at the development of the New Zealand sawmilling industry in economic and physical terms using an econometric framework, and by considering the years 1880 to 1990. The aim will be to examine the effects of technological change on the output of sawn timber and the relative efficiencies of resource use in producing sawn timber.

Appendix I comprises a brief historical examination of the technological development of the sawmilling industry of New Zealand.

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CHAPTER 4. ECONOMIC AND PHYSICAL DEVELOPMENT.

4.1. Introduction.

This chapter will consider economic and physical production effects of technological change in the saw milling industry for the period 1880 to 1990. This is necessary since firstly, the given trajectory of a technology is determined by what is socially (e.g. economically and politically) possible, and secondly because a process technology such as sawmilling is better understood in terms of its physical output and economic effects, than in terms of its engineering specifications and arrangements alone. Thus, technological change can be seen in its evolving economic system and is not left exogenous to it. Following this, the next chapter will examine the direction of technological change itself.

4.2. Method.

Data concerning the production of sawn timber in sawmills by five yearly intervals were collected for the years 1880 to 1990, inclusive. The data sources consulted were, "The Blue Books of New Munster and New Ulster.", held in the National Archives, Wellington; "The Statistics of New Zealand.", New Zealand Department of Statistics, for five yearly intervals from 1880 to 1920; "The New Zealand Year Book.", New Zealand Department of Statistics, for five

yearly intervals from 1925 to 1990; various issues of the "Census of Manufacturing.", New Zealand Department of Statistics; "New Zealand Forestry Statistics 1991.", Ministry of Forestry; and perusal of old New Zealand Forest Service files now held by the Ministry of Forestry, Wellington, and by the National Archives in both Wellington and Auckland.

The collected data were sawn timber production (volume measure), full time equivalent persons engaged in sawmilling, kilowatt ratings of sawmills, value of sawn timber production (money measure), value added, and value of capital plant and equipment. Other statistics were available and were collected, but they were not used in this exercise.

The treatment and analysis of the data will be detailed below under separate headings for each type.

4.3.1. Estimation of Sawn Timber Production, 5 Year Intervals.

For each of the five yearly intervals, data were available showing, by geographical area, full time equivalent persons engaged, power ratings of sawmills and sawn timber production. Up until the year 1975, the power ratings were given in horsepower, and thereafter in kilowatts. In some instances, particularly in the years 1980, 1985 and 1990,

the data were either not available at all, or were given as a national total. In these cases, the numbers of sawmills were given and the kilowatt ratings were estimated on the basis of an ordinary least squares regression between sawmills and kilowatt ratings, using earlier data. High correlation coefficient values were obtained, and on this basis, the estimated regression equation was considered suitable. Furthermore, up until 1975, the production figures for rough sawn timber were given in either board feet or super feet (being identical measures) and after 1975, the figures were given in cubic metres. All the data were converted to, and used in, cubic metre measure.

It was hypothesized that a relationship existed between these variables, which could be described according to the following general form;

$$Y_i = B_1 + B_2X_{2i} + B_3X_{3i} + u_i$$

Where	Y	=	sawn timber volume
	B_1	=	"Y" intercept term
	B_2	=	sawn timber attributable to the action of labour
	X_2	=	persons engaged in sawing (full time equivalents)
	B_3	=	sawn timber attributable to the use of non human power
	X_3	=	power rating of sawmills (kilowatts)
	u_i	=	error term

Equation 4.1

For each of the years, 1880, 1885, and so on, by five yearly intervals to 1990, equations were estimated using

multiple regression¹ analysis, which conformed to the generalised form, equation 4.1, above. The dependent variable was sawn timber production (M^3), while the independent variables were full time equivalent (F.T.E.) persons engaged and kilowatts, respectively.

4.3.2. Results.

Details of the equations estimated using multiple regression techniques are presented in the appendix at the end of this chapter.

4.3.3. Discussion.

A. The Coefficients' Signs.

The theoretical equation did not allow for negative signs in the coefficients of L (full time equivalent persons engaged) and K (kilowatt ratings in sawmills). However, the years 1885, 1930, 1965 showed negative coefficients for K, whilst the years 1895, 1905, 1970, 1975 showed negative coefficients for L. The literal meaning for a negative coefficient in such cases was that the factor (variable) concerned was responsible for a reduction of sawn timber in the year concerned, all else being equal. Obviously this does not make sense. Explanations for such results are;

(1) There might have been an over abundance of the factor

so affected, implying a case of diminishing or negative returns in the relevant year. It was significant that, by and large, the presence of negative signs in the coefficients coincides with years marked by economic recession. Thus, there would have been surplus capacity in the sawmilling industry.

- (2) The phrase, "all else being equal" is relevant here because taken in tandem with the other (and counterpart) factor, on average, it would probably have contributed positively towards the production of sawn timber. It was clear that sawn timber couldn't be produced in the presence of one of the factors alone.

B. The "t" Values Pertaining to the Coefficients.

Most of the years were characterised by t and P values which could not reject the null hypothesis that "the levels of sawn timber production were NOT influenced by the numbers of persons engaged (F.T.E.) or by the numbers of kilowatts available to saw timber." This poses a problem from a statistical point of view, but in the wider sense of attempting to see the changing nature of the relationships between the variables, it is not of great importance. Clearly there are changing relationships, if only because the coefficients changed, and in the next section, when an "overarching" equation is estimated, this change will be discussed.

C. The ANOVAs.

In every case, the null hypothesis that the means of the regressors were the same was rejected. This is to say that all three variables were distinctly and significantly different from one another. To an extent, it was argued that the ANOVA results could help compensate for the "poor" t test results discussed above.

D. The Coefficients of Determination.

In all but two of the cases, both the R^2 and adjusted R^2 were in excess of .900. This means that in nearly all of the cases the variation in the dependent variable, sawn timber production, was well explained by the variations in the independent variables, persons engaged (F.T.E.) and kilowatts.

JUSTIFICATIONS FOR ACCEPTING THE EQUATIONS.

It was argued that, although there were problems with some of the statistical aspects of the equations (particularly the t tests), taken as a whole, they should be accepted. The following arguments are advanced to support this contention.

A. Parsimony

A model can never be a completely accurate description

of reality; to describe reality, it would be necessary to develop such a complex model that it would be of little practical use. Some amount of abstraction or simplification is inevitable in any model building. Occam's razor or the principle of parsimony states that a model be kept as simple as possible. A model is important if it explains much by little, and all minor and random influences are consigned to the error term.

B. Identifiability

This means that for a given set of data, the estimated parameters must have unique values, or what amounts to the same thing, there is only one estimate for a given parameter. Thus, attempting to increase the uniqueness of parameters' values by increasing their number, sets up the danger of autocorrelation and over specification.

C. Goodness of Fit

Since the basic thrust of regression modelling is to explain as much of the variation in the dependent variable as possible by the explanatory variables included in the model, a model is judged good if this explanation, as measured by the R^2 and adjusted R^2 is as high as possible. Very high R^2 values were obtained, so it was argued that variation in the dependent variables well was explained by the independent variables.

E. Common Sense

An appeal to common sense suggested that in general, two factors were responsible for the output of sawn timber - Labour and Capital. The only indicators available to describe these parameters were persons engaged (F.T.E.) and kilowatt ratings. Therefore, they were used.

4.4.1. Single Estimated Equations for the Total Time Span.

Following estimation of the equations by five yearly intervals, as described above, a single equation was estimated using the same variables for the total time period, 1880 to 1990, using the five yearly data from above. The estimated equation conformed to the generalised type, equation 4.1, above.

Following this it was decided that the possible effects of technology should be allowed for. Clearly, technological effects could not be seen directly using these methods, but the effects of technology could be seen through time. Accordingly, a second overarching equation, similar to that above was estimated, but with a third independent variable included, this being time. The assumption behind this method was that it was "convenient" to assume that technology was some function of the time measured chronologically. In this situation it was believed that a measurable variable affecting Y (sawn timber production)

was so closely related to time that it was easier to introduce the time variable itself rather than the basic variable. The general form of this hypothesized equation was;

$$Y_i = B_1 + B_2X_{2i} + B_3X_{3i} + B_4X_{4i} + u_i$$

Where	Y	=	sawn timber volume
	B ₁	=	"Y" intercept term
	B ₂	=	sawn timber attributable to the action of labour
	X ₂	=	persons engaged in sawming (full time equivalents)
	B ₃	=	sawn timber attributable to the use of non human power
	X ₃	=	power rating of sawmills (kilowatts)
	B ₄	=	sawn timber "attributable" to technological change occurring over time
	X ₄	=	time (coded)
	u _i	=	error term

Equation 4.2

4.4.2. Results.

The "over arching" equation for the entire time period, 1880 to 1990, without the time variable was as follows;

1880-1990	Prod'n =	203469 +	66.6L +	17.7K
	S.E.	(99633)	(28.69)	(1.266)
	t	(2.04)	(2.32)	(13.88)
	P =	(.055)	(0.031)	(0.00)
	R ² =	.976	R ² (adj.) =	.973
Anova	F =	402.57		
	P =	0.0		
	df=	22		

Thus, taken as a whole, the t tests showed that the null

hypothesis, that the level of production was not influenced by labour and kilowatts could not be rejected. Moreover, the Anova showed that the null hypothesis that the regressors' means were the same was rejected. Both the R^2 and the adjusted R^2 were very high, meaning that variation in the dependent variable, sawn timber production, was well explained by the independent variables, persons engaged (F.T.E.) and kilowatts. Lastly, signs of the coefficients were all positive, meaning that each had a positive effect on the production of sawn timber.

An interpretation of the equation was that holding the effects of "kilowatts" constant, each full time equivalent person engaged was responsible for the production of 66.6 cubic metres of rough sawn timber, while each kilowatt was responsible for the production of 17.6 cubic metres of timber, assuming "persons engaged" was held constant. This amounts to an "average" result through the 110 years studied, and clearly, it is not sensible to hold other variables constant, so, assuming the existence of one person and one kilowatt, then a result of 84.2 cubic metres is obtained. This, when added to the Y intercept of 203469 gives a result of 203553.2 cubic metres.

The effects of "technology" were estimated in the next relationship, which gave the following estimated equation;

1880-1990	Prod'n =	172070 +	55.6L +	15.6K +
		2402Yr		
	S.E.	(98950)	(28.79)	(1.781)
		(1607)		
	t	(1.74)	(1.93)	(8.78)
		(1.49)		
	P =	(.098)	(0.068)	(0.00)
		(0.151)		
	R ² = .978		R ² (adj.) = .975	
Anova	F = 285.68			
	P = 0.0			
	df= 22			

The result supports the idea that the effects of technology were such as to increase production over and above the level of production implied by given levels of labour and capital. The only statistically difficult area was the high P value on the "Year" variable. It implies that the null hypothesis, "that time (as a proxy for technology) has no effect on the production of sawn timber", could only be rejected at a confidence level of 84.9%. Most hypotheses are rejected with around 95% confidence. However, the equation was accepted on the grounds that a loss of 10% confidence was more than compensated for by the other statistical tests, and by the usefulness of the equation itself.

It states, *inter alia*, that holding all other variables constant, sawn timber production was estimated to increase at the rate of 2402 cubic metres per year as a result of technological change, through time.

4.5.1. Production Trends; 1880 - 1990.

To gain some idea of the trends in the growth (or otherwise) of the factors of production and output, the following variables were examined over time and various equations estimated for their rate of growth; rough sawn timber (M^3), full time equivalent persons engaged, kilowatts and value added. Then, production of rough sawn timber per employee and per kilowatt and real value added per employee and per kilowatt were found. Lastly, the ratio of the number of kilowatts per employee was considered over the time period. The data were by five yearly intervals, in the same sequence as detailed above.

The reason for doing this was to examine in more detail the effects of technological change on sawn timber production. Therefore it would be possible to gain an understanding of the variables' growth rates themselves, and to get some understanding of the changes of the variables against one another, and therefore assess their relative impacts on sawn timber production. For example, the capital/labour ratio examined over time would indicate whether technological change has been labour saving or capital saving or neutral. By examining value added by itself and per unit factor of production, some idea of the role of profits on technological might be ascertained.

4.5.2. The Growth of Sawn Timber Production.

Sawn Timber Production was graphed against time to aid

visual examination of the trends. The result is the jagged line in figure 4.1. Next, the ordinary least squares regression line was plotted on the same graph, and this is the straight line labelled "trend" in the same figure. Lastly, the log of "cubic metres" was found and this was regressed against time to give the graphed line labelled "growth" in figure 4.1.

It was suspected that the log - normal relationship was a better description of the change in sawn timber production over time, so all the above data and hypothesized lines were plotted to log normal scale, and the result was figure 4.2. In this figure, the previously straight "trend" line became curvi linear and the "growth" line became linear. In both figures 4.1 and 4.2, the log - normal relationship appeared to be the best fit. This was verified when regression equations were estimated for both forms. (discussed later).

Visual examination of the data revealed that the growth of sawn timber production could be divided into two distinct phases. The first phase, from 1880 to around 1935 showed a gradual, if erratic, rise in production, whilst the period from 1935 to 1990 showed a rapid and relatively persistent growth in production.

Explanations for these phenomena may be that the early period was typified by the sawing of indigenous timbers by

Figure 4.1 Sawn Timber Production

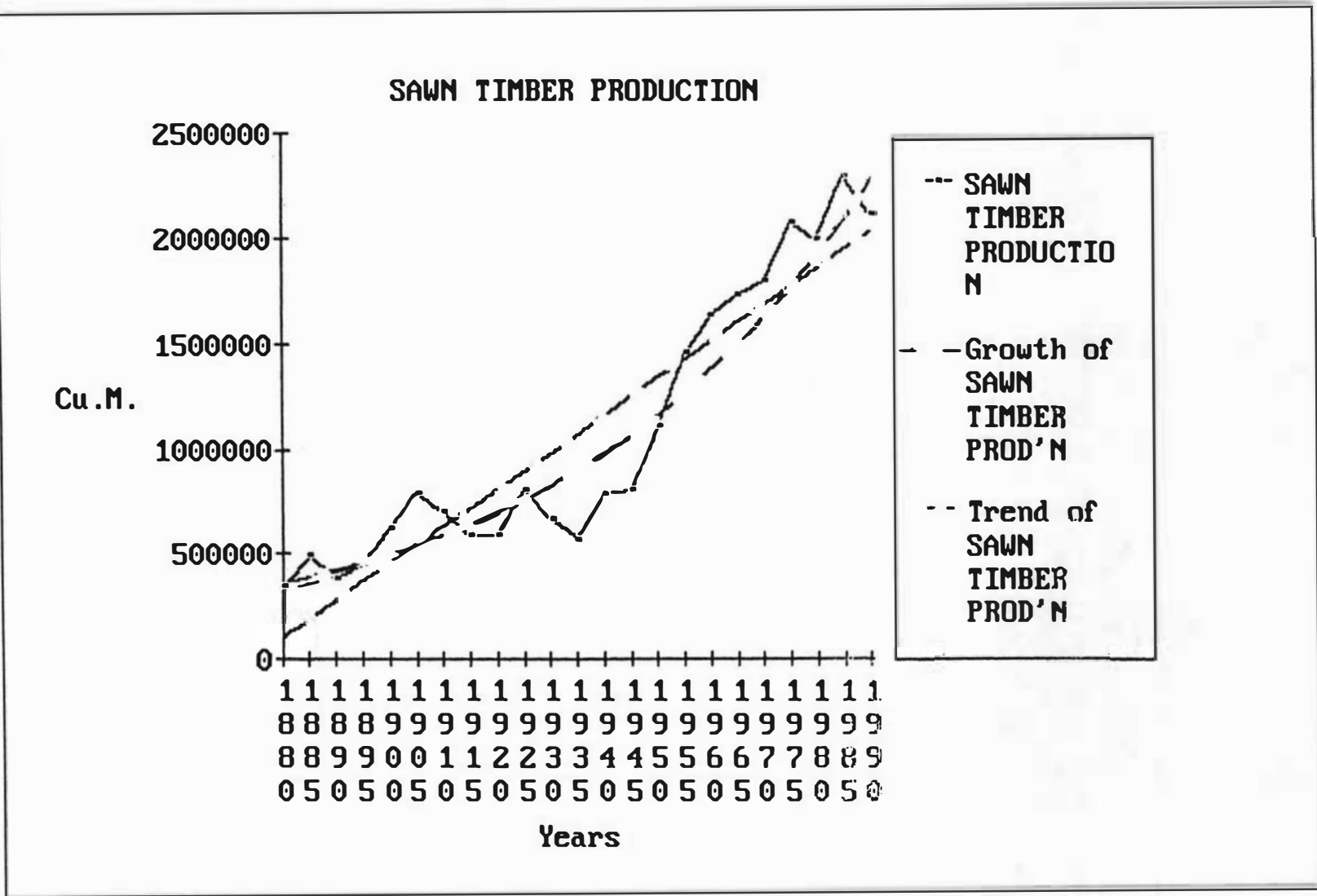
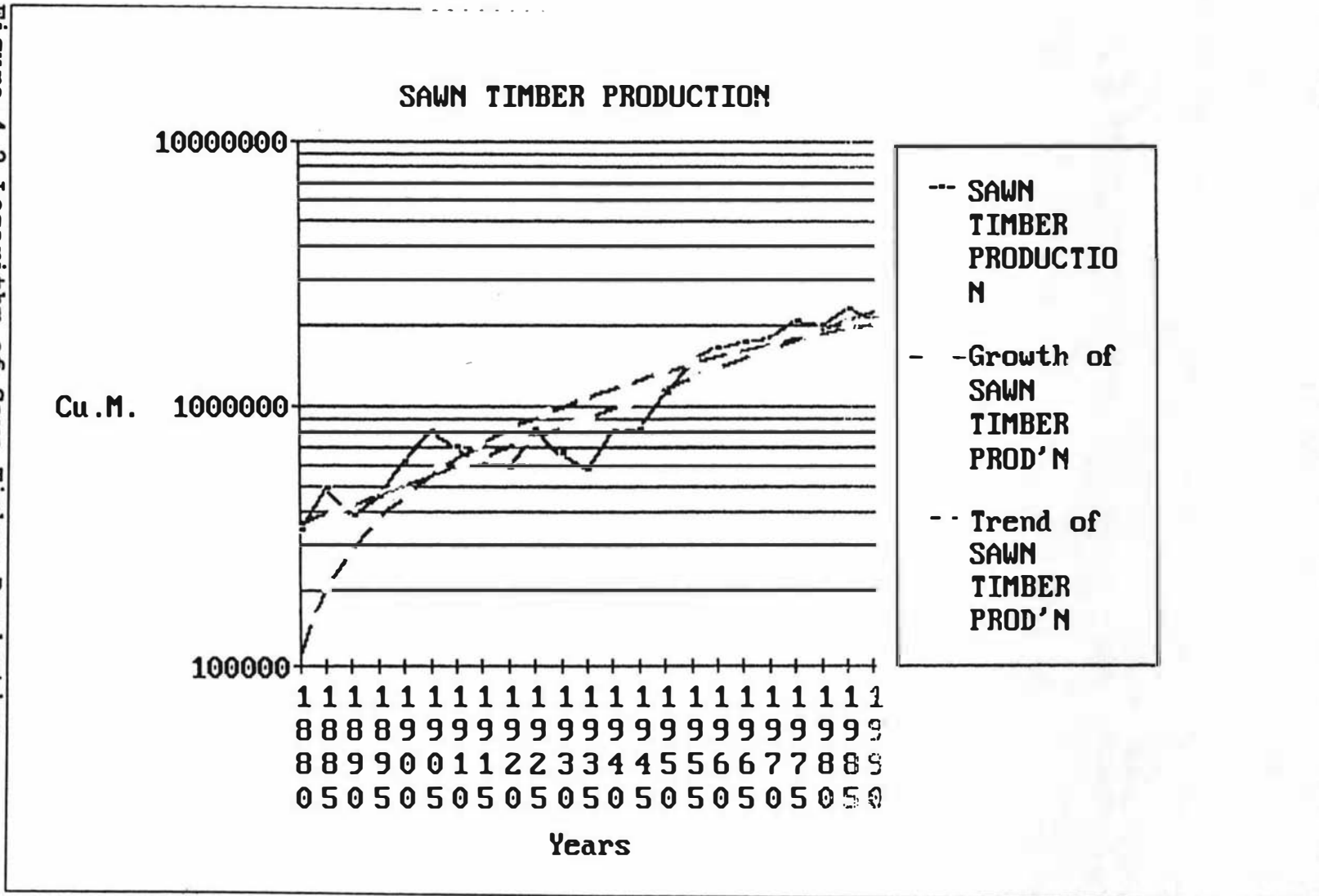


Figure 4.2 Logarithm of Sawn Timber Production



such techniques as pit sawing, by small sawmills powered by water and steam, using circular saws and vertical reciprocating saws for primary (and secondary) breakdown, and a relative absence of powered or automated log moving technologies within the mills.

The later period, starting around the time of the second world war, saw the development of integrated exotic sawmills that were designed to take large volumes of relatively small logs, particularly as the harvesting of exotic pines such as radiata gathered apace. These new mills incorporated such mass production technologies as powered log movement in the mills, bandsaws for primary breakdown, high volume edgers, steam and electrically and hydraulically powered log carriages and so on. Through time, these technologies were developed and improved as, for example, electricity replaced steam and so on. Indeed, the growth of sawn timber production has been exponential.

Sawn timber production was regressed against time to gain some idea of the secular trend in sawn timber production.

Details of the estimated regression equation were;

1880-1990	Prod =	-33053030 +	17641 Years
	S.E.	(3069015)	(1586)
	t	(-10.77)	(11.12)
	P	= (0)	(0)
	R ²	= .855 R ² (adj)	= .848
Anova	F	= 123.74	
	P	= 0	
	df	= 22	

The equation was a useful one in that all the summary statistics, t values, f values, R^2 , etc. are acceptable. In essence, it means that sawn timber production was increasing, on average, at about a rate of 17,614 cubic metres per annum. This could be described as the secular trend. However, as mentioned above, the growth of sawn timber production could be described as occurring in two distinct phases, one of slow initial growth, followed by an era of rapid growth.

A second regression equation was hypothesized which stated that growth of sawn timber production was occurring at a rate such that the variable, sawn timber production, was best described as the natural log of sawn timber production.

$$\ln Y_i = B_1 + B_2 X_{2i} + u_i$$

Where	In	Y	=	natural log of sawn timber volume
		B_1	=	"Y" intercept term
		B_2	=	sawn timber production occurring over time
		X_2	=	time (years)
		u_i	=	error term

Equation 4.3

The resulting regression equation was;

1880-1990	InProd=	-18.8	+	0.0168	Years
	S.E.	(2.397)		(0.001238)	
	t	(-7.84)		(13.57)	
	P	= (0)		(0)	
	R ²	= .898	R ² (adj)	=	.893
Anova	F	= 184.14			
	P	= 0			
	df	= 22			

The summary statistics were all acceptable, given that each null hypothesis could be rejected. Moreover, there was an improvement in each of the coefficients of determination. Thus, the logarithmic relationship was a slightly better descriptor of the growth of sawn timber production than the untransformed version.

The equation was converted into the "exponential" form, as follows;

		$Y = ae^{cx}$
where	e	= 2.71828
	a	= the intercept term
	c	= the hypothesized growth constant
	x	= time in years

Equation 4.3

$$\text{sawn timber production} = (6.84 * 10^{-9}) e^{(16.81 * 10^{-3}) \text{ years}}$$

4.5.3. The Growth of Labour Employment Levels.²

The numbers of persons engaged (full time equivalents) in the sawmilling industry was graphed against time. At the

same time, the ordinary least squares regression line was superimposed upon this graph, and was labelled "trend", as was the regression line of the logarithm of persons engaged, and this was labelled "growth". The result was figure 4.3. Following this, figure 4.4 was constructed, which shows persons engaged (employee numbers) on a logarithmic scale (Y axis) against time to normal scale (X axis).

Visual examination of the data revealed that the period from 1880 to 1935 was typified by erratic changes in the numbers of persons engaged, although the secular trend was mildly positive. Three major collapses in the numbers of persons engaged during this era could be put down to economic recessions. The period from around 1885 to 1895 was a time of a major world recession, and there was a levelling of in world economic growth trends just prior to the second world war. The Great Depression of the 1930's showed a slump in numbers as well, falling to those of the turn of the century.

After about 1935, through to the late 1950's, there was a rapid and persistent increase in employment levels, and thereafter growth of numbers of persons engaged became more or less static.

The persistent growth for the 20 to 25 years from around 1935 could be put down to any one (or all) of a number of

Figure 4.3 Persons Engaged

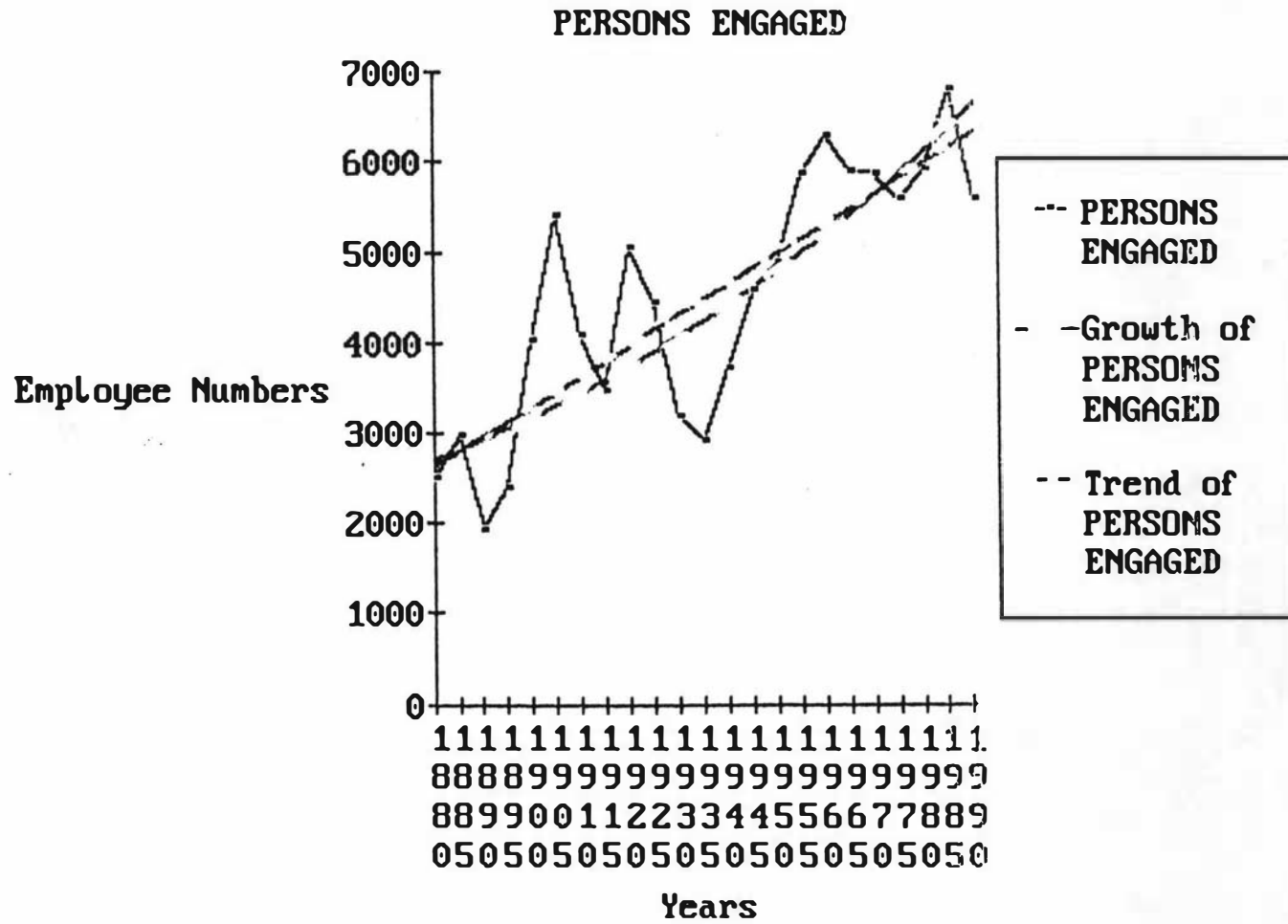
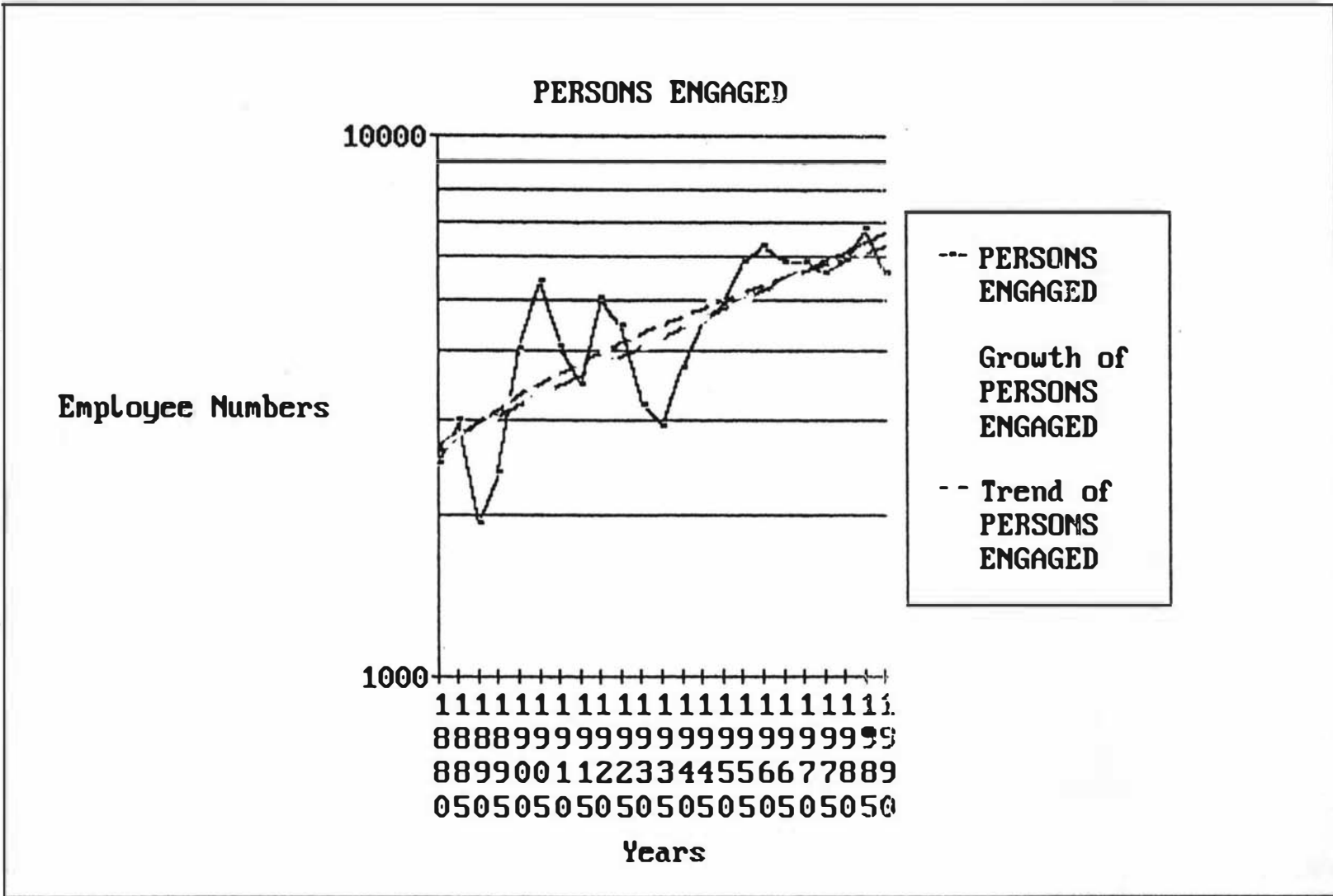


Figure 4.4 Logarithm of Persons Engaged



factors. Firstly, following the worst years of the Great Depression, around 1932, the world (and New Zealand) economy began and continued a recovery that eventually became a boom.³ Secondly, the second world war fuelled demand for many commodities, including sawn timber.⁴ Thirdly, and as mentioned in the section on sawn timber production growth, new sawmilling technologies sawmills were innovated into New Zealand to handle the vast volumes of small piece sized logs that were coming on stream from the exotic plantation forests. Increasing amounts of labour were drawn into the relatively productive, modern, integrated sawmills during an important expansion phase.

Since around 1960, there has been only minor change in employment levels as the industry apparently moved into a phase of relative stability in employment.

The numbers of persons engaged (F.T.E.) were regressed against time to ascertain the secular growth trend. The most suitable equation was of the untransformed type, and its details were;

1880-1990	Person=	-60749	+	33.7	Years
	S.E.	(10174)		(5.257)	
	t	(-5.97)		(6.41)	
	P	= (0)		(0)	
	R ²	= .662	R ² (adj)	=	.646
Anova	F	= 41.14			
	P	= 0			
	df	= 22			

Whilst the t values and anova were of a suitable level, the

coefficients of determination were low, indicating that only around 65% of the variation in persons engaged was "explained" by time. None the less, this equation does describe a secular trend in employment levels in the industry, showing that, on average, about an extra 34 people per year were engaged (directly or indirectly) in the sawing of boards from logs.

4.5.4. The Growth of Kilowatts.

The kilowatt rating of all sawmills engaged in the industry was graphed against time in years. Then ordinary least squares regression line of the two was super imposed on the same graph, and was labelled "trend". Lastly, logarithms of "kilowatts" was regressed against time and the resulting line was also super imposed, as above. The result was figure 4.5. Following this, the same data were drawn on a "log normal" graph, with the result being figure 4.6.

The first thing that was noticed about the kilowatt time series was their relative smoothness compared with any over the other variables that graphed in a similar manner. Trends were not erratic and growth was very persistent when it occurred, particularly after 1935 - 1940.

As with sawn timber production and persons engaged, the "kilowatt" time series could be broken down into two or three distinct phases. The first phase, from 1880 to 1935 -

Figure 4.5 Kilowatts

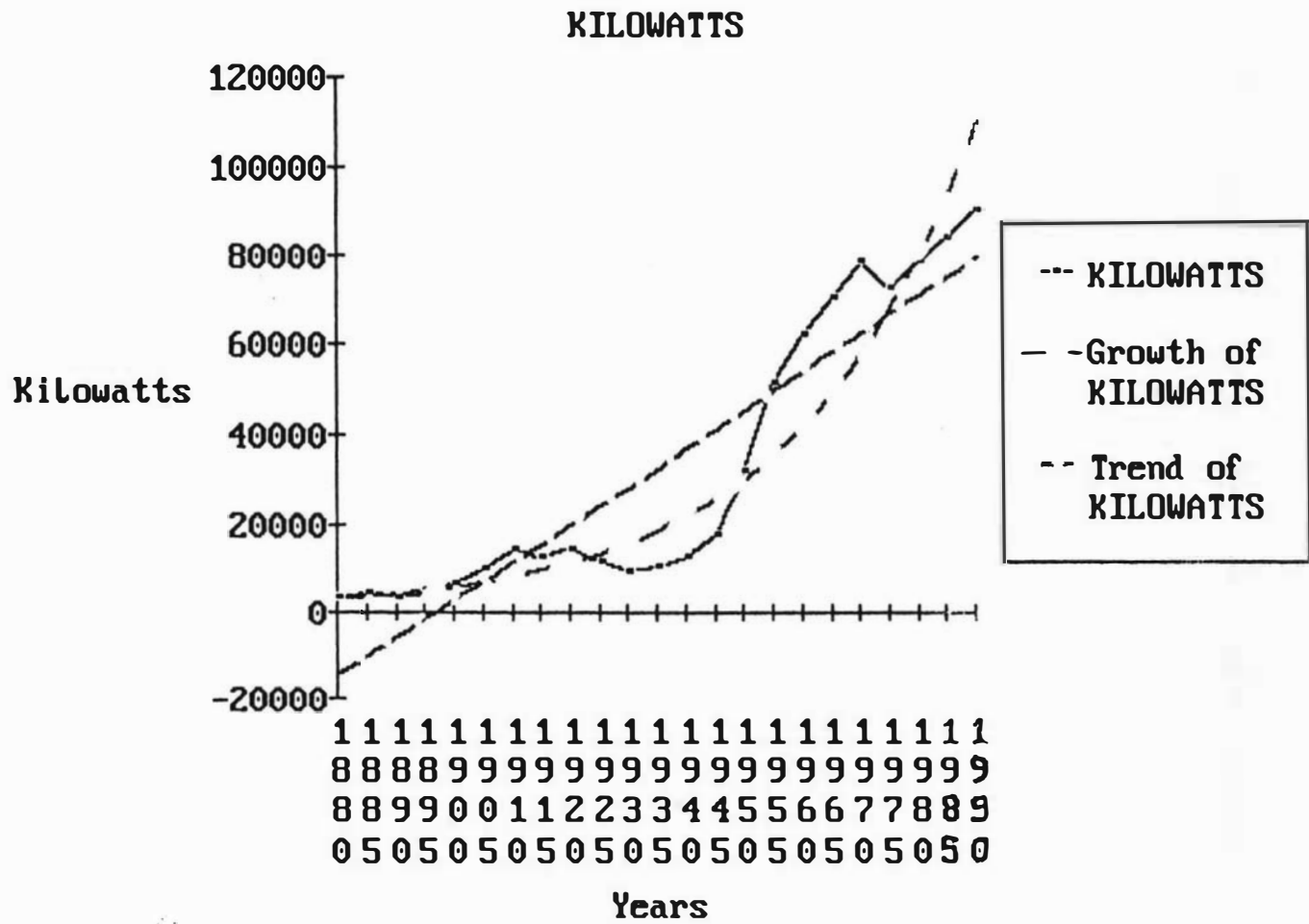
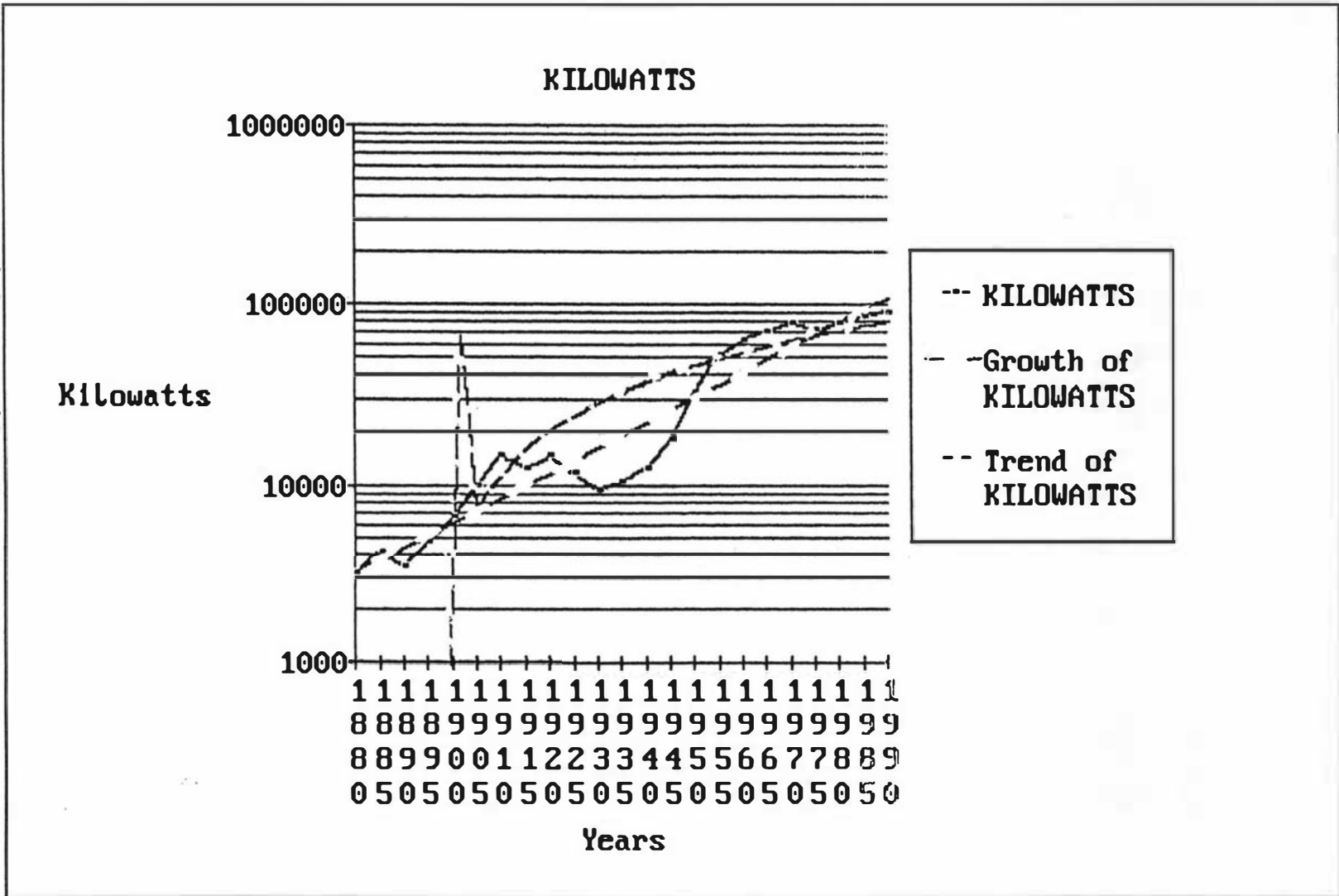


Figure 4.6 Logarithm of Kilowatts



1940 showed a period of relatively stable levels of kilowatts in the industry, with a maximum of 14531 kilowatts in 1910. This was the era of indigenous sawmilling, of numerous mills using relatively small power sources (water wheels, reciprocating steam engines, etc.), with a relatively small throughput capacity of wood. Indigenous logs typically showed a highly variable piece size, with some species (e.g. beech [*Nothofagus spp.*], kahikatea [*Podocarpus dacrydoides*]), having large amounts of defect, and highly variable sawn timber grade out turn. Millers typically had no need for large throughput mills, and sometimes whole days were spent on just sawing one large log. In addition, not much power was used to move logs and sawn timber within the mill; most of this was done by human beings.

After 1940, the amount of power in the industry increased rapidly as exotic timber sawmills were built. Their chief characteristics were that a high throughput of relatively small softwood logs was required, along with increasing levels of automation of timber and log handling within the mills. After 1965 - 1970, the rate of increase of kilowatts in sawmilling fell off, and this trend continues to the present where there is a new and increasing emphasis on maximising grade out turn on logs, rather than attempting ever high higher volumes of throughput.

Visual examination of the kilowatt time series would lead

the observer to conclude that an equation describing a sigmoid growth curve would be adequate as a descriptor of trends. Certainly, the computation of a linear curve via ordinary least squares gave a coefficient of determination of .828. However, it was found that taking the natural logarithm of kilowatts and regressing this against time gave a coefficient of determination of .919. The equation so computed was;

1880-1990	InKw	=	-52.39	+	0.0321Years
	S.E.		(4.018)		(.002076)
	t		(-9.85)		(10.05)
	P	=	(0)		(0)
	R ²	=	.919	R ² (adj)	= .916
Anova	F	=	239.51		
	P	=	0		
	df	=	22		

In exponential form, the equation is;

$$\text{Kilowatts} = (1.932 * 10^{-23}) e^{(.0322 \text{ years})}$$

4.5.5. Value Added.

The calculation of real value added was achieved by taking nominal value added through time and then deflating this by an appropriate deflator.⁵ Thus, real value added was a figure that was adjusted for the effects of inflation.

Figure 4.7 shows the trend of real value added by years. It describes a relatively steep, if erratic, rise in real value added for the production of sawn timber. Major falls

in the level of real value added were seen in the years 1910-1920, 1930-1935, 1965-1970, and 1980-1990. Figure 4.8 shows the natural logarithm of real value added by years.

The decade, 1910-1920, might well be explained by the first world war and its aftermath. During such times, given that the decade showed no major technological changes, labour and resources would have been drawn into the war effort, thereby forcing up prices of the factors of production used in logging. Thus, the price of the raw material, logs, would have risen. Simultaneously, government policies aimed at price stabilisation would have held the price of sawn timber in check. Squeezed from both ends, sawmillers would have faced falling real added values.

The second major decline, during 1930-1935, could be put down to the Great Depression. Demand for housing and construction generally fell away, thereby creating surplus inventories of sawn timber and surplus capacity throughout the industry. Therefore, sawn timber prices would have been forced down, leading to collapse in the level of real value added.

So far as 1965-1970 is concerned, there was a recession which hit New Zealand, particularly in 1967-1968. The building and construction industry was badly hit in that there was a fall off in the demand for housing, and therefore in sawn timber.

Figure 4.7 Real Value Added

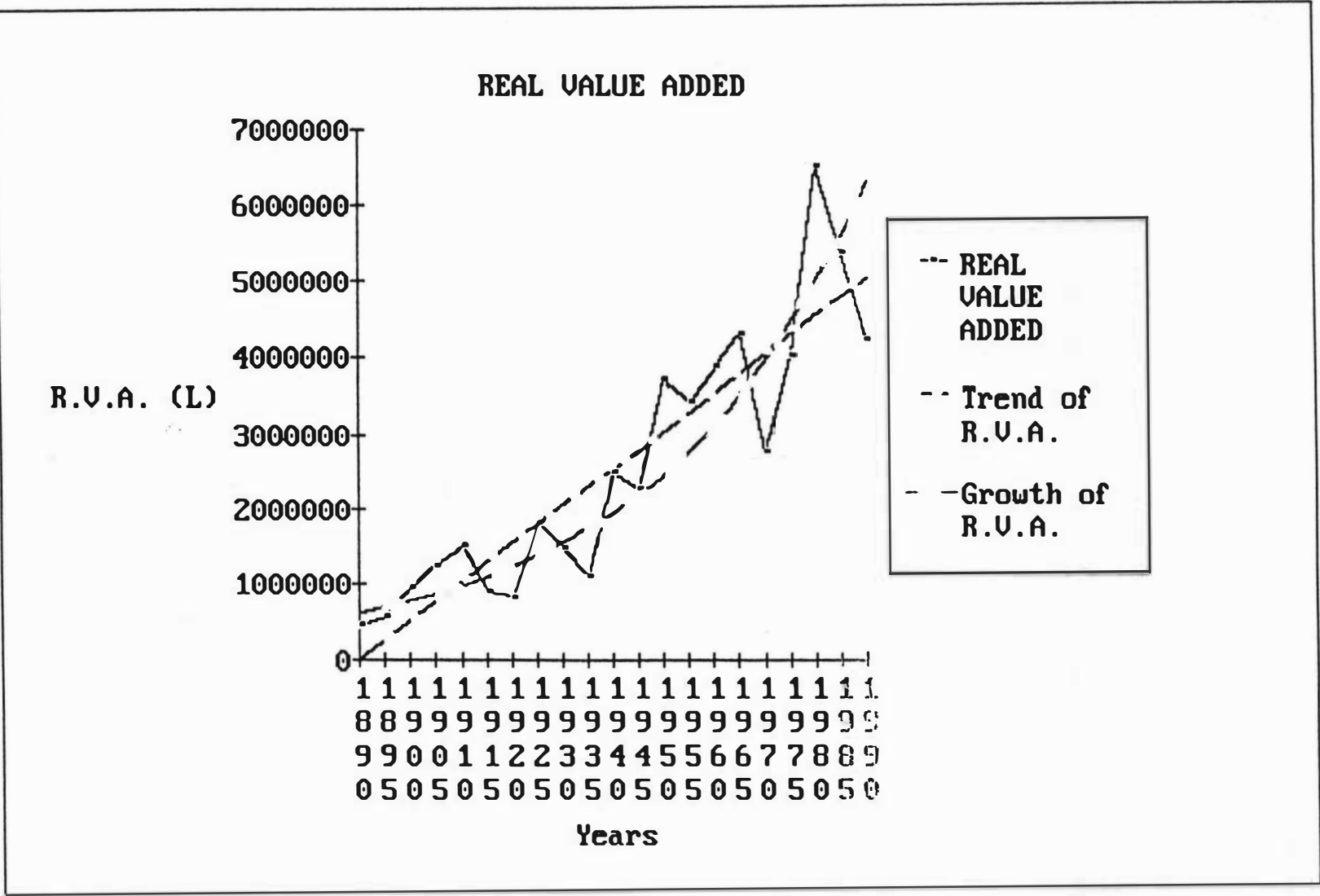
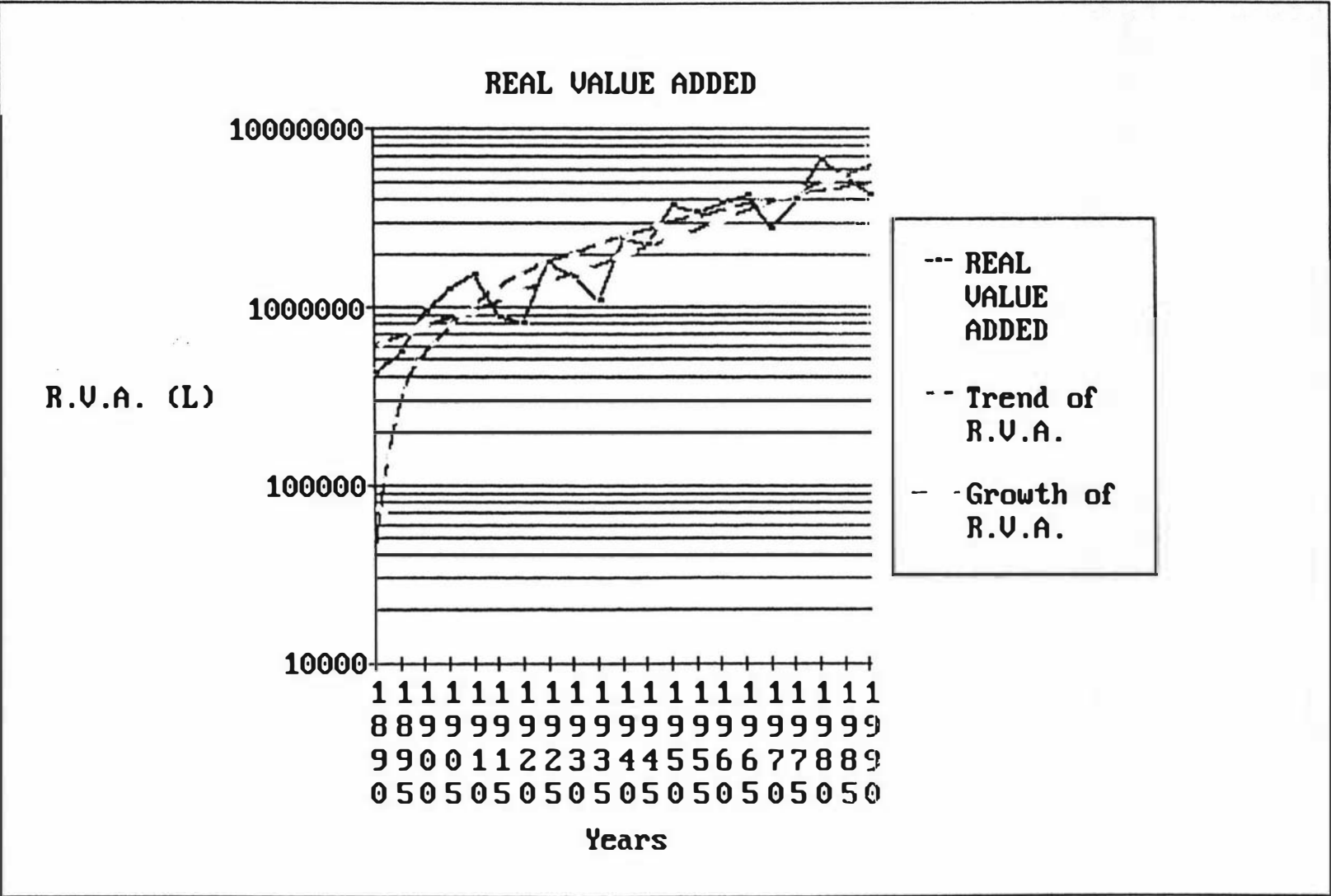


Figure 4.8 Logarithm of Real Value Added



The most recent decline in real value added could be put down to a rise in the price of sawlogs. The availability of sawlogs in the Pacific Rim has been falling since around 1980, with a consequence that prices have been rising internationally. During this time, government imposed sawlog price controls were scrapped, with the result that forest owners were able to sell their logs to all comers, and at the highest price. Thus, international log buyers have forced prices up for New Zealand domestic sawmillers. Additionally, New Zealand has been in the grip of a severe economic recession, with the usual fall off in building activity. Thus demand for sawn timber has fallen off quickly.

Despite the falls in real value added, it is true to say that there was a marked rise in real value added over the years 1890-1990, taken as a secular trend. The ordinary least squares equation was;

1890-1990	RealVA=	-95052536 +	50315 Years
	S.E.	(10648162)	(5488)
	t	(-8.93)	(9.17)
	P	= (0)	(0)
	R ²	= .816	R ² (adj) = .806
Anova	F	= 84.05	
	P	= 0	
	df	= 20	

The equation represents an average growth in real value added of 1.1 percent per annum.

It was found that a slightly better coefficient of

determination was obtained by using the logarithmic transformation of real value added and regressing this against time. The ordinary least squares equation so obtained was;

1890-1990	InRVA =	-30.8	+	0.0233Years
	S.E.	(4.264)		(0.002198)
	t	(-7.22)		(10.62)
	P	= (0)		(0)
	R ²	= .856	R ² (adj)	= .848
Anova	F	= 112.81		
	P	= 0		
	df	= 20		

Expressing the equation in exponential form gives;

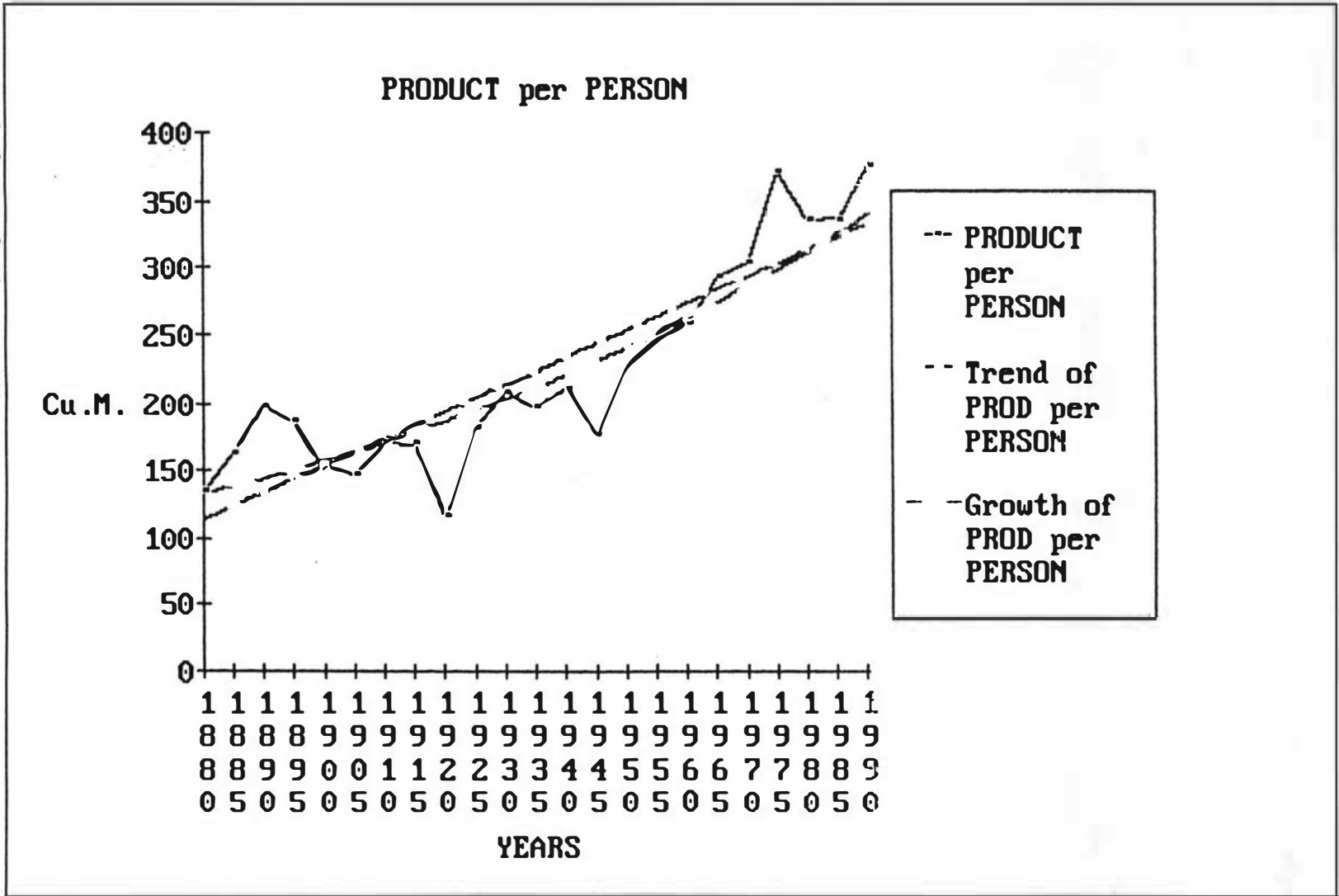
$$\text{real value added} = (4.2046 \times 10^{-14}) e^{(.023256 \text{ years})}$$

Given that both equations yield similar coefficients of determination, and that there will probably continue to be a fall in real value added as a result of international price shocks, it is argued that the normal linear equation is the best descriptor for the time series.

4.5.6. Product per Person Engaged.

The ratio, "product per person" was graphed against time and the result was figure 4.9. The trend line shown in the same figure is the ordinary least squares regression line for the two variables, whilst the line labelled "growth" shows the log of product per person against time.

Figure 4.9 Product per Person



The figure revealed that there was a steady, if erratic, growth in the ratio, "product per person". It was 135 cubic metres per person in 1880 and 379 cubic metres in 1990. However, there were many instances of this measure falling.

It fell during the years 1915-1920, 1940-1945, and 1980-1985. The first two cases coincided with world wars. Explanations for this might be that with the emphasis on increasing production during times of national crisis, at any cost, more and more of the variable factor, labour was added to a relatively fixed amount of capital. Thus diminishing returns were encountered, meaning that labour productivity fell, even though the absolute level of production rose. Another explanation could lie in the fact that relatively skilled sawyers were inducted into the armed forces in the early years of the war, and were replaced by comparatively unskilled labour. A learning curve would have confronted the new labour, which would have taken some time to traverse.

All this ignores the possibility that labour may have been a relatively cheap factor of production, compared with capital during these years, so labour could have been substituted in place of capital, thereby lowering its physical product.

In contra distinction to the above assertion, the introduction of new technologies (e.g. exotic sawmills)

from overseas, reflected a capital / labour use ratio that might not have been relevant in the New Zealand cost environment. Thus the New Zealand sawmilling industry would have been forced to use more labour in the production of sawn timber than would otherwise have been the case.

This is a tenuous hypothesis at best, since Western (non third world) production functions tend to be labour saving rather than labour using.

Lastly, it could have been the case, given rising demand for sawn timber (and allied products), that it became expedient to use more labour in the production of sawn timber, given that its unit value would have been rising, while the costs of labour were relatively steady.

In general, as mentioned above, there has been steady rise in the physical output of sawn timber per unit labour. This should not be unexpected. Most forms of technology tend to be labour saving and capital intensive, which reflects the relative prices of capital and labour; labour being usually more expensive than capital. Moreover, through time, the capital intensity of industry tends to rise, whilst labour intensity tends to fall. This process is aided by generally increasing levels of education and training on the part of the workforce, making labour ever more productive, and being able to master and operate more complex production methods.

The equation that best described the trend in sawn timber production per person was obtained using an ordinary least squares regression of product per person against time the result was;

1880-1990	Prod/Pers=	-3684	+	2.02	Years
	S.E.	(454.4)		(0.2348)	
	t	(-8.11)		(8.61)	
	P	= (0)		(0)	
	R ²	= .779	R ² (adj)	=	.769
Anova	F	= 74.081			
	P	= 0			
	df	= 22			

This means that there was an average growth rate in this productivity measure of 0.64 per cent per annum, for the time period considered. In other words, the physical product of labour more than doubled during 110 years.

4.5.7. The Growth of Product per Kilowatt.

Figure 4.10 depicts the actual changes in the measure "product per kilowatt", which is the jagged line. The straight line is the ordinary least squares regression line, and is used to depict the secular trend of the actual data. The curvilinear line shows the relationship between the logarithm of product per kilowatt and time. Figure 4.11 shows the same data and trend lines on a log - normal graph.

In contrast with the measure, "product per employee", product per kilowatt has shown a downward trend through the

Figure 4.10 Product per Kilowatt

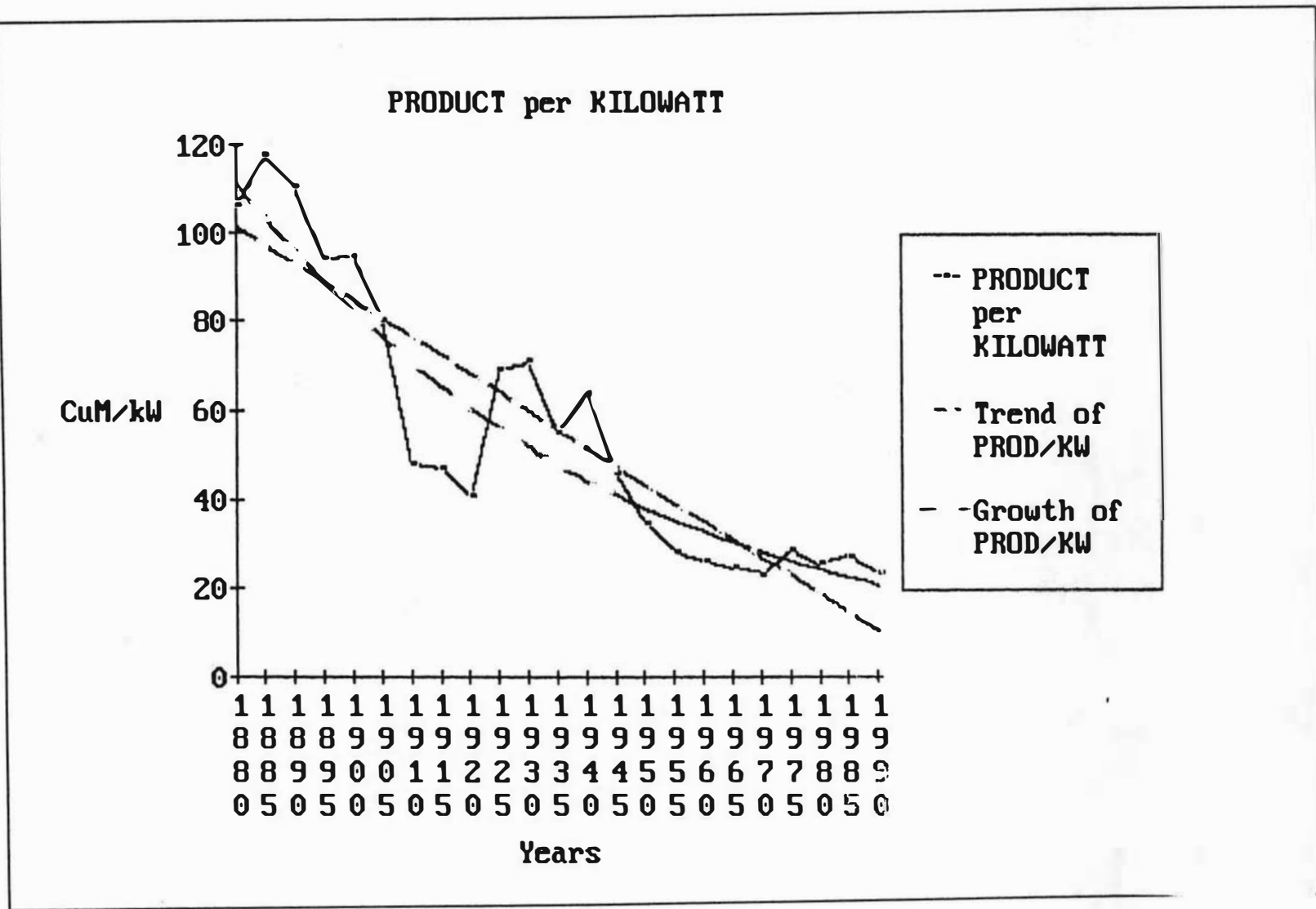
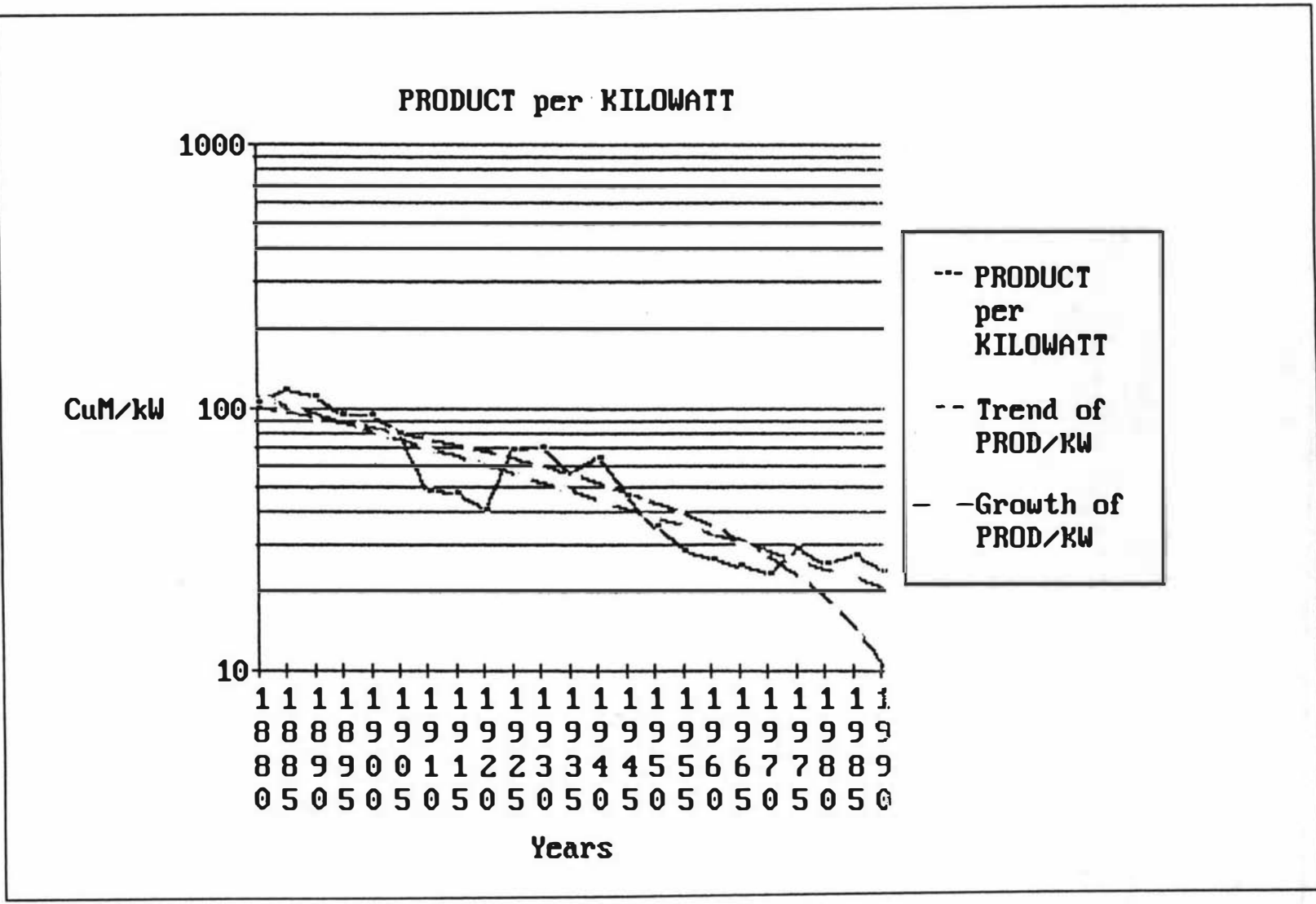


Figure 4.11 Logarithm of Product per Kilowatt



110 years examined. In 1880, the measure stood at 106 cubic metres of sawn timber per kilowatt, whereas, by 1990, the figure was 23 cubic metres per kilowatt.

This is expected, since western technology tends to be capital using and labour saving. Thus through time, more and more capital tends to be used in production, and in this sawmilling example, capital could be represented by the amount of kilowatts which are inherent in it. This is to say that more machine power is used to saw wood than human power, through time.

There was a particularly dramatic fall in production per kilowatt in the years 1905-1920. This era marked the zenith of the Auckland Kauri sawmilling industry; returns were good, and given a reasonable demand, high levels of investment pertained and more and more physical capital was employed to get the production of sawn Kauri timber up.

The secular trend was found using ordinary least squares regression. It was;

1880-1990	Prod/Kw=	1665	+	0.831	Years
	S.E.	(170.3)		(0.08801)
	t	(9.77)		(-9.45)
	P	=	(0)		(0)
	R ²	=	.810	R ² (adj)	= .800
Anova	F	=	89.24		
	P	=	0		
	df	=	22		

This means, that on average, the physical product of

kilowatts (in terms of sawn timber) was falling at just under 1 percent per annum. For the whole 110 years, the fall represents a factor of 2.88 times down on the initial measure.

It was found the regressing the natural logarithm of product per kilowatt against time gave a slightly improved coefficient of determination. The following details pertained to the regression;

1880-1990	InPR/Kw=	33.6	+	0.0154Years
	S.E.	(2.687)		(0.001389)
	t	(12.51)		(-11.07)
	P	= (0)		(0)
	R ²	= .854	R ² (adj)	= .847
Anova	F	= 122.62		
	P	= 0		
	df	= 22		

The exponential form of this equation is;

$$\text{product per kilowatt} = (3.911 \cdot 10^{14}) e^{(-.0154 \text{ years})}$$

Based on the findings in this work, it may be argued that it is better to use the natural logarithmic form of the regression equation as a descriptor for two reasons;

1. It gives a slightly better coefficient of determination than the straight linear form.
2. The straight linear form predicts that by the year 2005, there will be zero product per kilowatt, which is an absurdity. On the other hand, a visual examination of the data revealed

that since about 1953, there has been a steady falling off in the decline of kilowatt productivity. That is to say that some logarithmic function best describes these later years. Moreover, the exponential form of the equation predicts that by 2005, there will be about 15 cubic metres of sawn timber produced for every kilowatt of power in the sawmilling industry.

4.6.8. Real Value Added per Person.

The nominal figure for value added was corrected by the composite price index, and then converted to 1955 pounds. The symbol "L" means "pounds".

The figure for real value added was divided by the number of persons engaged in the industry. These results were plotted as a time series and are shown as figure 4.12. The straight line is the ordinary least squares regression of the measure against time, whereas, the curvi linear form is the logarithm of real value added per person regressed against time. Figure 4.13 is simply the same detail plotted in a log - normal relationship.

In general, between the years 1890 to 1990, there was an erratic, though persistent rise in real value added per person engaged. In 1890, around L223 (1955) of value was

Figure 4.12 Real Value Added per Person

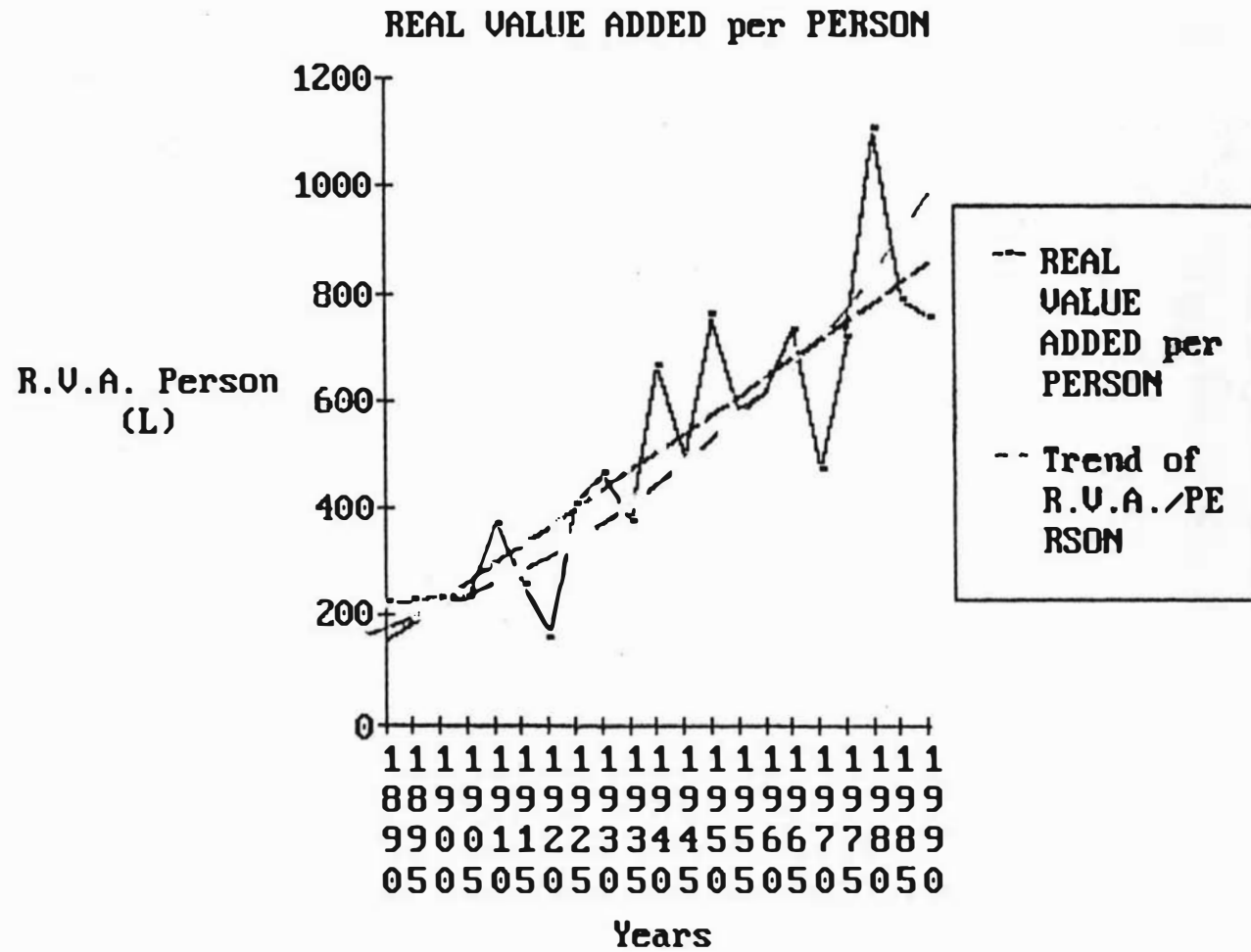
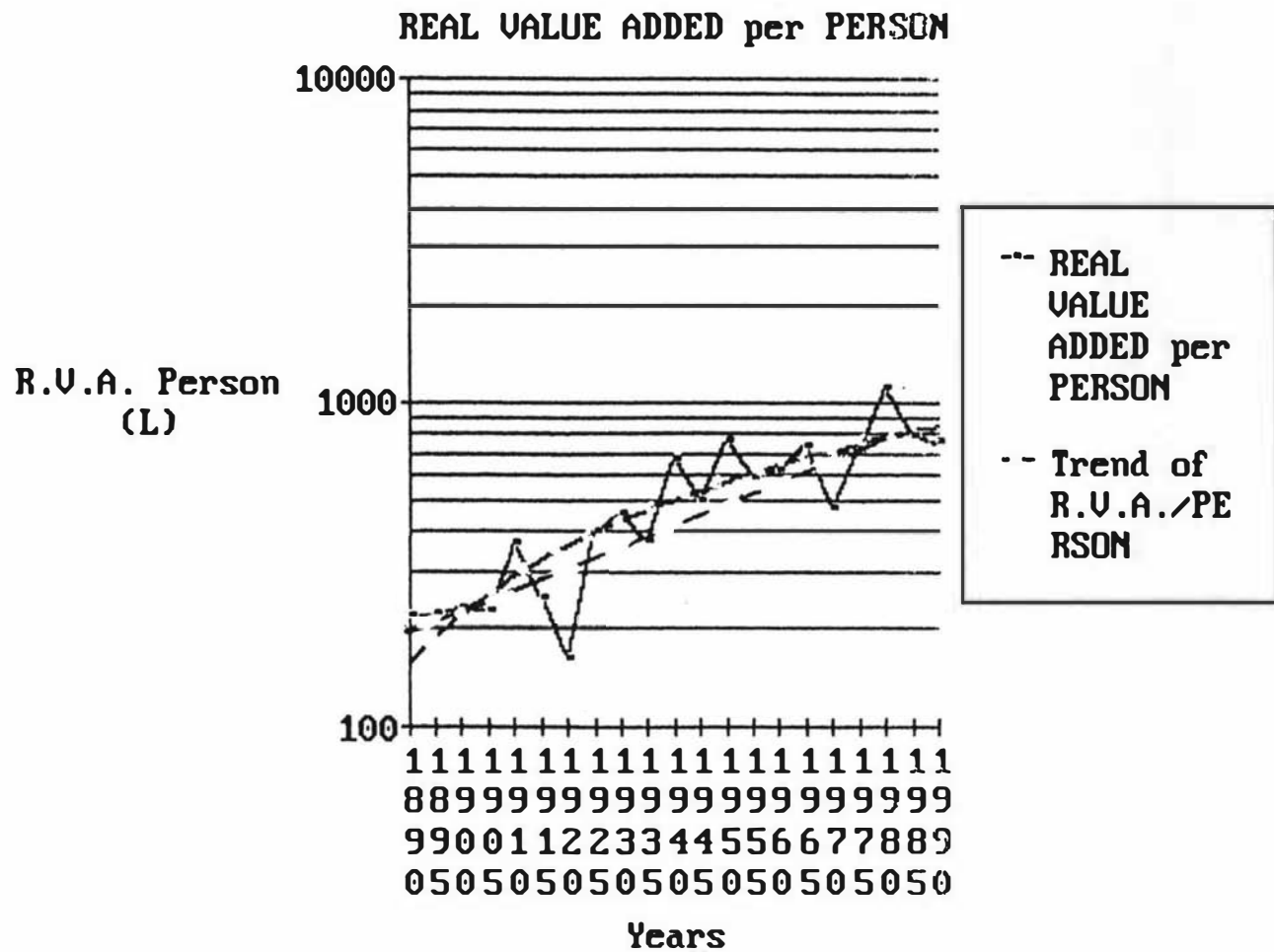


Figure 4.13 Logarithm of Real Value Added per Person



added per person engaged, and in 1990, the figure was L756 (1955).

Sharp rises in real value added per person occurred during 1920-1925, and again during 1970-1980. This apparent rise in productivity could be put down to falling employment levels in sawmilling, coupled with relatively stable real value added trends. This implies that as workers were shed, increasing returns to the variable factor, labour, were gained as the industry moved down the sigmoidal returns curve.

Given the general rise through the 100 years, it was possible to postulate that sawmilling technologies tended to be more labour saving through time. In other words, the capital intensity of the industry increased. It is difficult to attribute the source of incremental added values. Technology, with a tendency to be labour saving, might well have been responsible for the incremental added value, but then the definition of technology allows for the changing (and growing) expertise of labour. That is to say that capital may have become more productive, but equally (and simultaneously), so might labour. Moreover, as the stock of capital per unit labour increased, so the technical demands placed upon labour would increase, implying a conjoint increment in productivity for both factors. The problem is one of identifying the returns to the factors.

Whatever the case, the rising value added trend for labour points to a steady (if undramatic) rise in the "competitiveness" of sawmilling. Steady economizing of the more expensive resource (labour) with rising added values, meant that more economy in the use of capital was possible. For example, the wise use of capital machinery could mean increasing product variety, differentiation and shorter production runs.

Real value added per person was regressed against time using ordinary least squares, and the resulting equation was;

1890-1990	RVA/Per=	-13080	+	7.0	Years
	S.E.	(1784)			(0.9194)
	t	(-7.33)		(7.62)	
	P	= (0)		(0)	
	R ²	= .753	R ² (adj)	=	.740
Anova	F	= 58.02			
	P	= 0			
	df	= 20			

The equation implied that in general, there was about a 1 percent rise per annum in real value added per person through the 100 years.

4.5.9. Real Value Added per Kilowatt.

The figure for real value added was divided by the number of kilowatts engaged in the industry. These results were plotted as a time series and are shown as figure 4.14. The

straight line is the ordinary least squares regression of the measure against time, whereas, the curvi linear form is the logarithm of real value added per kilowatt regressed against time. Figure 4.15 is simply the same detail plotted in a log - normal relationship.

In contrast to the measure of real value added per person, real value added per kilowatt described a very erratic and almost imperceptible fall. In 1890 the figure stood at L125 (1955) value added per kilowatt, and in 1990 it stood at L47 (1955) value added per kilowatt. While a fall of L78 (1955) might appear large, consideration of the ordinary least squares regression of real value added per kilowatt against time produced the equation;

1890-1990	RVA/Kw =	1576	-	0.762	Years
	S.E.	(523.7)		(0.2699)	
	t	(3.01)		(-2.82)	
	P =	(0.007)		(0.011)	
	R ² =	.295	R ² (adj) =	.258	
Anova	F =	7.962			
	P =	0.011			
	df =	20			

This equation was considered unacceptable because of the low value for the coefficient of determination. This was verified by visual examination; there was no real obvious trend in the data.

Probably the only thing that could be said was that given no obvious change in the value for real value added per

kilowatt, was that the price of capital, as represented by kilowatts, kept pace with its productivity, as measured by real value added per kilowatt. This, taken in conjunction with the upward trend in real value added per person engaged, points to a relatively static cost of capital in terms of productivity and a rise in the productivity of labour. However, these trends were only evidence for the changing productivities; it was difficult conceptually to disentangle the effects of capital from the effects of labour, as argued in the previous section.

4.5.10 Kilowatts per Person Engaged.

The number of kilowatts used in the industry in any one year was divided by the numbers of persons engaged in the industry in the same year. The resulting measure was called "kilowatts per person"

The numbers of kilowatts and persons engaged in the sawmilling industry have both been rising through time. Throughout the 110 years examined, the number of kilowatts has been rising more quickly than the number of persons engaged. Therefore, a visual examination (see figures 4.16 and 4.17) of the number of kilowatts per person employed through time revealed an initial slow rise in the ratio, and a second phase of accelerating increments to the ratio, particularly after 1940. This was not unexpected, because from 1940, investments in new sawing technologies took of

with the need to saw the new exotic timber species coming "on stream" from the plantation forests.

Kilowatts per person was regressed against time to reveal the following ordinary least squares equation;

1880-1990 Kw/Pers=	-252	+	0.134 Years
S.E.	(24.14)		(0.012438)
t	(-10.45)		(10.71)
P =	(0.0)		(0.0)
R ² =	.845	R ² (adj) =	.838
Anova F =	114.72		
P =	0.0		
df =	22		

Consideration of the errors arising from this regression showed a systematic change in their distribution, being a "U" shaped curve when plotted against time. Therefore, a natural logarithm transformation of kilowatts per employee was carried out and the results were regressed against time in an attempt to increase the value of the coefficient of determination and to eliminate the systematic error terms. Both aims were achieved. The coefficient of determination rose to .928 and an entirely random set of error terms was obtained. The regression equation was;

1880-1990 InKw/Ps=	-44.8	+	0.0239Years
S.E.	(24.14)		(0.001457)
t	(-15.88)		(16.42)
P =	(0.0)		(0.0)
R ² =	.928	R ² (adj) =	.924
Anova F =	269.48		
P =	0.0		
df =	22		

Figure 4.14 Real Value Added per Kilowatt

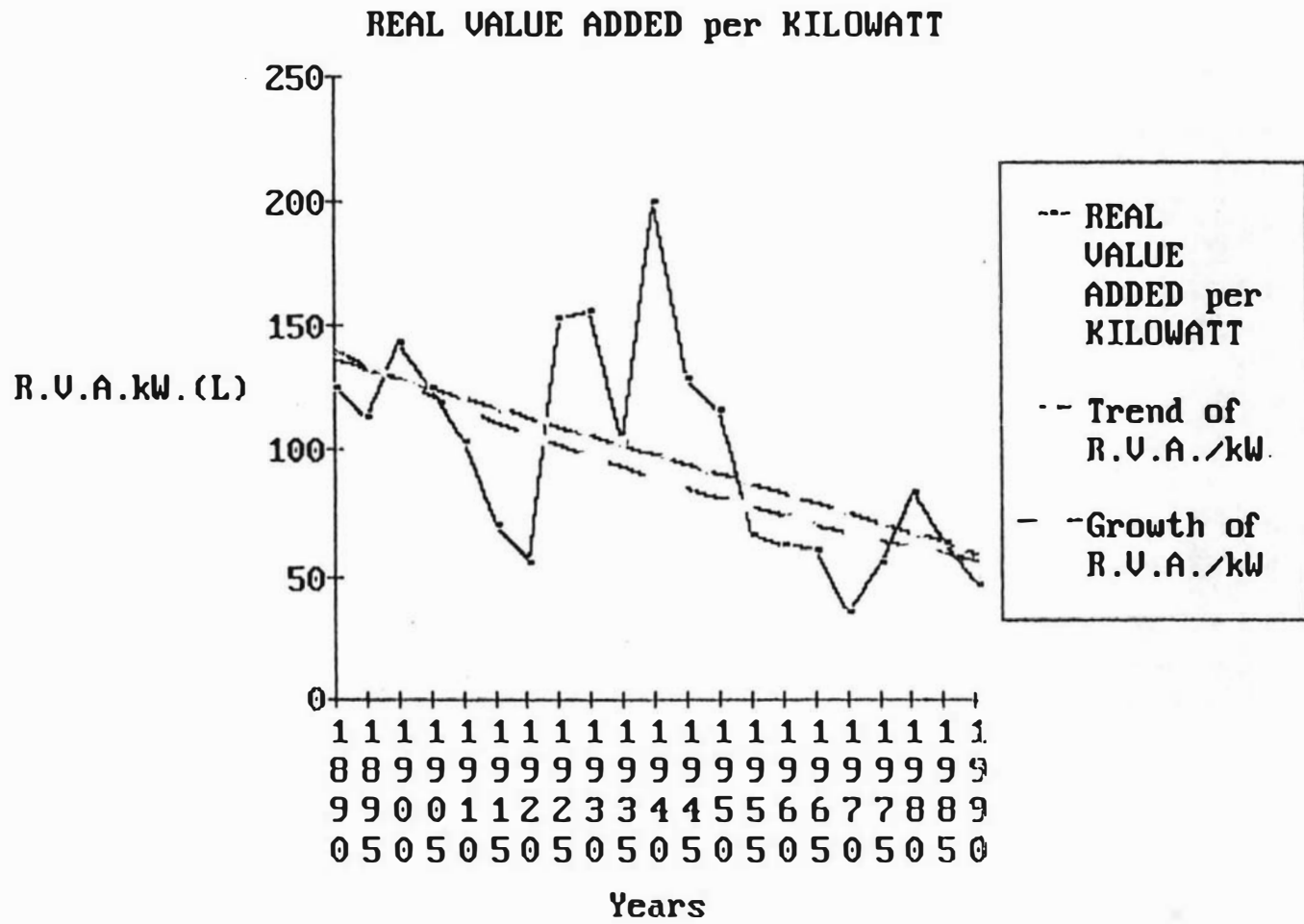


Figure 4.15 Logarithm of Real Value Added per Kilowatt

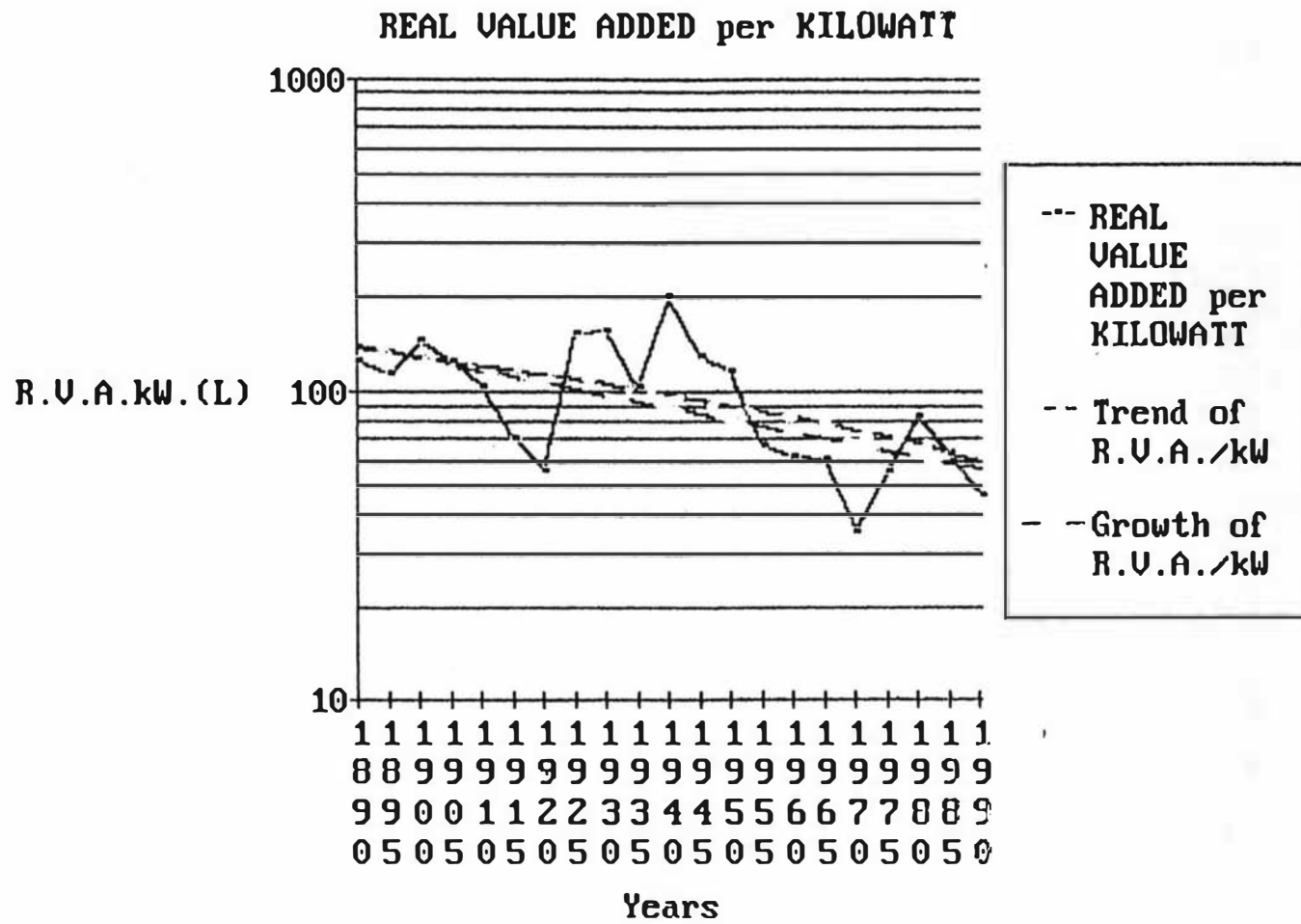
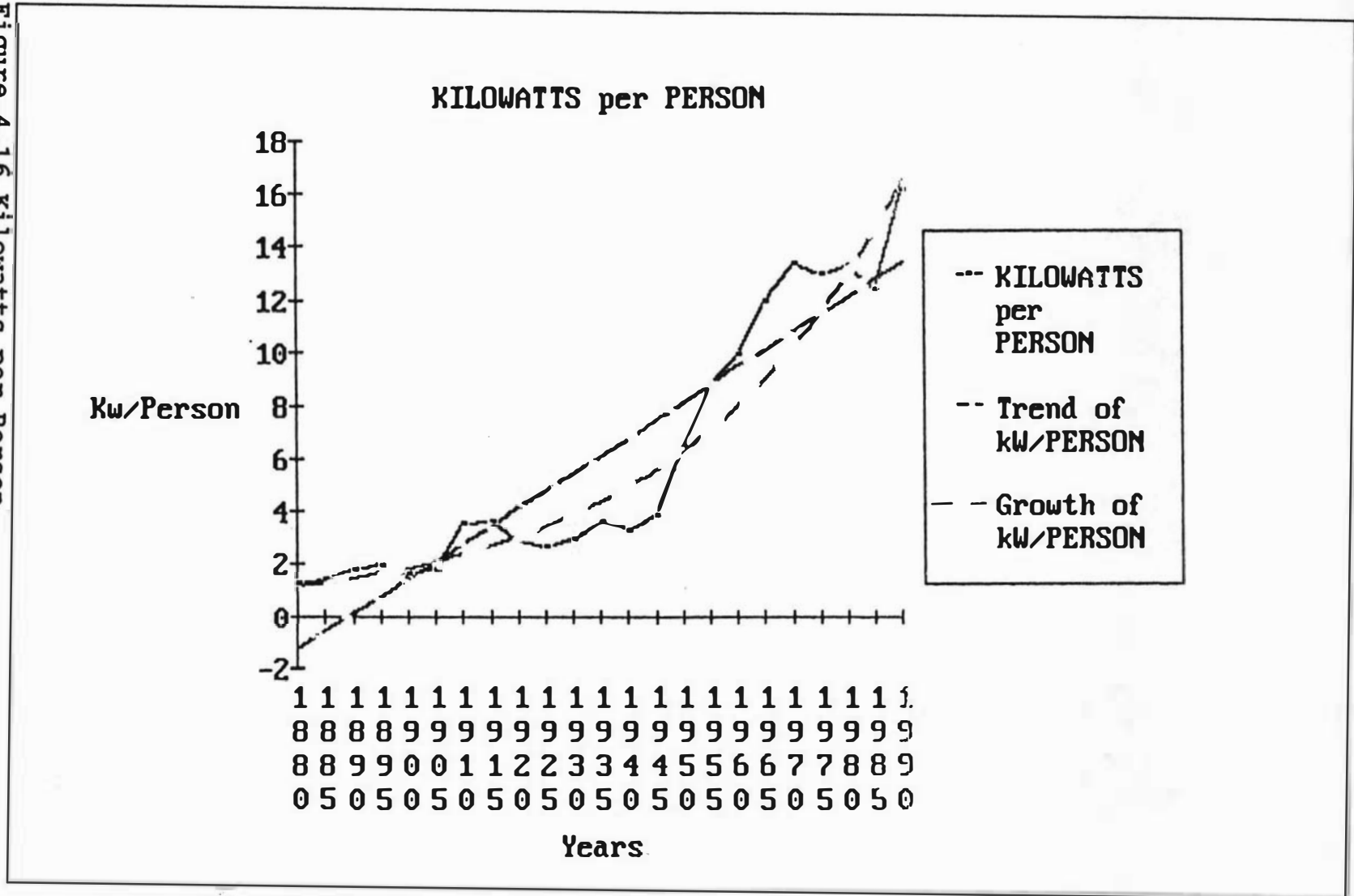


Figure 4.16 Kilowatts per Person



The exponential form of this equation was;

$$\text{In kW/Person} = -2.86 \times 10^{19} e^{(.0239 \text{ years})}$$

This form was regarded as the best descriptor for the trends in kilowatts per person.

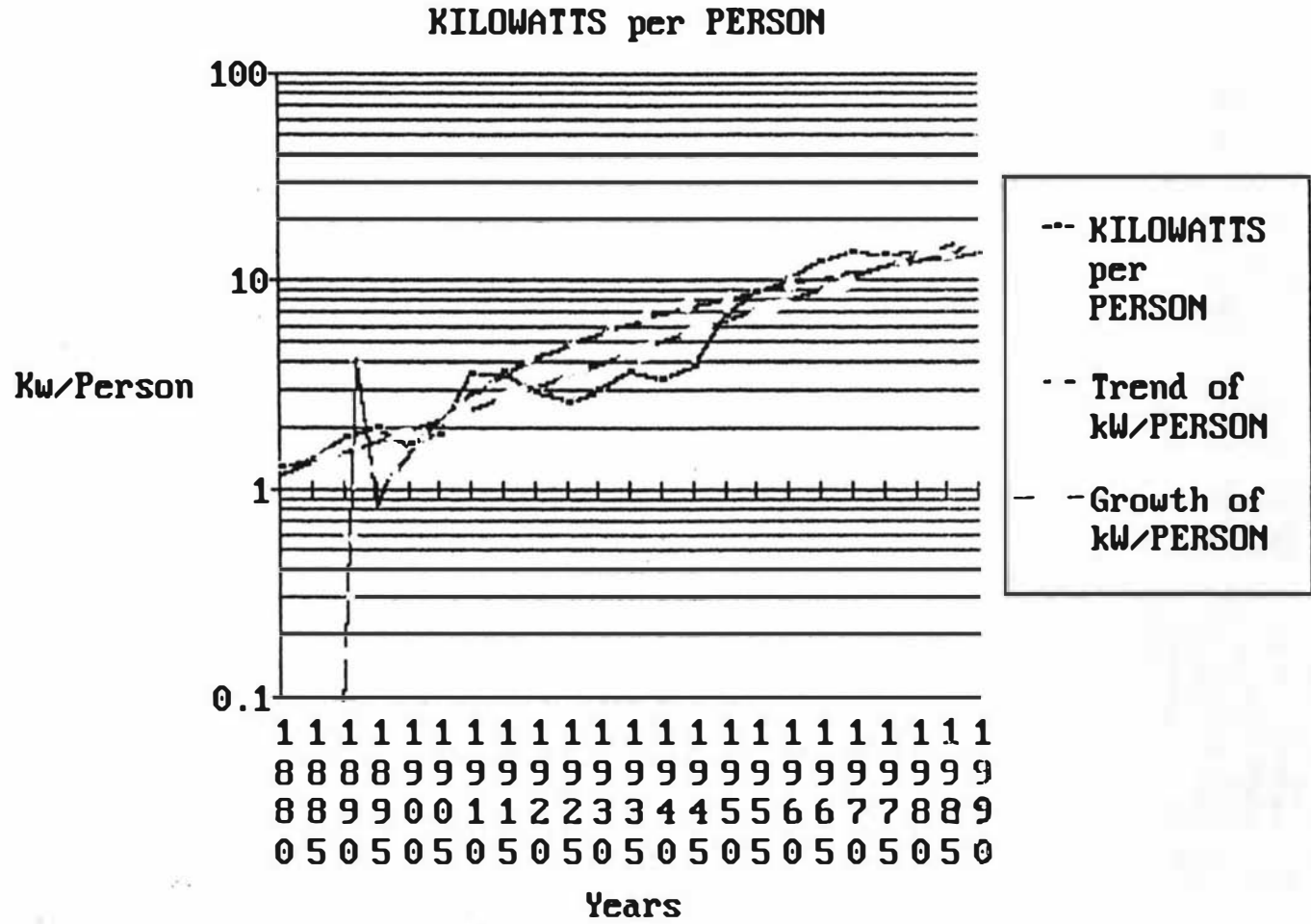
An interpretation of this finding was that capital has been replacing labour at an increasing rate in the sawmilling industry. It is an indirect sign of technological change, since the introduction of any new technology does not imply a consistent relationship between the levels of capital and labour from one period to the next. Nevertheless, it does suggest increasing technological sophistication (maturation?), rising labour force skill levels and rising productivity.

4.6. Conclusion.

This chapter examined the economic effects of technological change from a production function point of view.

General conclusions were that the production of sawn timber in New Zealand has been increasing at an exponential rate, that there has been a slow but steady increase in the number of persons engaged in the industry, that the number of kilowatts in the industry has been increasing very rapidly, that value added, while somewhat erratic, has been

Figure 4.17 Logarithm of Kilowatts per Person



rising, and that the level of value added per person have been rising, whilst the level of value added per kilowatt has been more or less static, or at least shows no discernible trend.

It was concluded that capital has been substituted for labour in the production of sawn timber, either because capital has been cheaper than labour in New Zealand, or that the imported capital reflected relative labour and capital productivity levels that pertain to the country of its origin. Without the increase of capital in the saw milling industry which gathered apace from the 1940's on, there would not have been the massive increase in sawn timber production that occurred in the latter half of this century. Moreover, this increment in the output of sawmills was also accomplished by the increasing skill levels of labour which was necessary to position, use and adapt the capital equipment in New Zealand conditions. Doubtless, there was much improvement to the capital equipment through time as New Zealanders conducted their own ongoing and incremental innovations, both to the processes involved in sawing timber and to the nature of the sawn timber product itself. For example, devising sawing patterns for the exotic species that were grown in New Zealand, considering the development of timber grading rules and standards, various timber treatment techniques and so on.

It was estimated that through time, the effects of

technological change were such that an additional 2,402 cubic metres of sawn timber were added to the national output every year, puerly as a result of technological improvement itself.

This production function approach to the examination of the New Zealand sawmilling industry provides no evidence that technological change has moved in the direction of increasing economies of scale. What has been found is that the rate of increase of sawn timber production has been exponential and that the capital \ labour mix has been altered in favour of capital. Thus, the increasing output of sawn timber has been, apparently, facilitated by increasing the inputs of the factors of production in like fashion.

While this chapter has been concerned with the production and economic effects of technological change in the New Zealand sawmilling industry, the next chapter will consider the direction of the development of the technology itself. The aim is to use the theory of technological trajectories to ascertain both the direction (or quality) of any technological change, and to gain some understanding of its velocity.

References.

1. Ryan, T. A., Joiner, B. L., and Ryan, B. F., "Minitab Student Handbook." Duxbury Press. 1976.
2. Note that throughout this work, "persons engaged" refers to all persons engaged in the sawing of timber in the industry, including working proprietors, administrative personnel and

sawyers etc., expressed as full time equivalents; "value added" refers to the amount added to goods and services by the contributions of capital and labour (i.e. the costs of bought in materials and services being deducted from the total value of output.); "product per kilowatt" is the amount of sawn timber (in cubic metres) produced in any given year divided by the number of kilowatts used in the sawmilling industry in that particular year.

3. Brooking, T., "Economic Transformation." in The Oxford History of New Zealand, Oliver, W. H., & Williams, B. R. Oxford University Press. Auckland. 1981.

4. Hawke, G. R., "The Growth of the Economy." in The Oxford History of New Zealand. Oliver, W. H., & Williams, B. R. (eds). Oxford University Press. Auckland. 1981.

5. The deflator was a composite calculated from various sources which covered the time span 1880 to 1990. Specific sources for the initial indices were;

McIlraith, J. W., "The Course of Prices in New Zealand." Government Printer. Wellington. 1911.

"New Zealand Official Year Book, 1956." Government Printer. Wellington, 1956. p 950.

"New Zealand Official Year Book, 1979." Government Printer. Wellington, 1979. p 887.

"New Zealand Forestry Statistics, 1991." Ministry of Forestry. Wellington. 1991. p 98.

SUMMARY OF STATISTICS

Year				
1880	Prod'n =	-174 +	53.3L +	38.4K
	S.E.	(7236)	(25.95)	(45.12)
	t	(-0.02)	(2.06)	(0.85)
	P =	(.982)	(.086)	(.427)
	R ² =	.929	R ² (adj.) =	.906
Anova	F =	39.49		
	P =	0		
1885	Prod'n =	5085 +	186L -	85.5K
	S.E.	(8130)	(32.76)	(53.12)
	t	(0.63)	(5.67)	(-1.61)
	P =	(.555)	(.001)	(.159)
	R ² =	.989	R ² (adj.) =	.986
Anova	F =	277.2		
	P =	0		
1890	Prod'n =	-17775 +	24L +	165K
	S.E.	(10316)	(132.2)	(127.3)
	t	(-1.72)	(0.18)	(1.3)
	P =	(.136)	(.864)	(.243)
	R ² =	.934	R ² (adj.) =	.912
Anova	F =	42.57		
	P =	0		
1895	Prod'n =	-29107 -	18.7L +	189K
	S.E.	(10631)	(46.72)	(39.74)
	t	(-2.74)	(-.40)	(4.76)
	P =	(.034)	(.703)	(.003)
	R ² =	.954	R ² (adj.) =	.938
Anova	F =	61.90		
	P =	0		
1900	Prod'n =	-14608 +	87.0L +	39.4K
	S.E.	(8742)	(48.77)	(49.80)
	t	(-1.67)	(1.78)	(0.79)
	P =	(.146)	(.125)	(.458)
	R ² =	.972	R ² (adj.) =	.963
Anova	F =	104.2		
	P =	0		
1905	Prod'n =	-24451 -	14.3L +	129.2K
	S.E.	(14504)	(118.5)	(113.0)
	t	(-1.69)	(-.12)	(1.14)
	P =	(.143)	(.908)	(.296)
	R ² =	.967	R ² (adj.) =	.956
Anova	F =	87.36		
	P =	0		
1910	Prod'n =	7889 +	101L +	5.6K
	S.E.	(11840)	(47.97)	(21.43)
	t	(0.67)	(2.11)	(0.26)
	P =	(.527)	(.073)	(.801)

	$R^2 = .928$	R^2 (adj.) = .907
Anova	F = 44.84	
	P = 0	
1915	Prod'n = -2292 + 88 L + 24.4K	
	S.E. (8832) (64.70) (14.19)	
	t (-0.26) (1.36) (1.72)	
	P = (.803) (.216) (.129)	
	$R^2 = .960$	R^2 (adj.) = .949
Anova	F = 83.89	
	P = 0	
1920	Prod'n = -4232 + 92.9L + 20.4K	
	S.E. (4641) (16.77) (5.398)	
	t (-0.91) (5.54) (3.78)	
	P = (.392) (0.00) (.007)	
	$R^2 = .989$	R^2 (adj.) = .986
Anova	F = 317.88	
	P = 0	
1925	Prod'n = 6426 + 85.9L + 31.1K	
	S.E. (7649) (46.05) (18.36)	
	t (0.84) (1.86) (1.70)	
	P = (.429) (.105) (.134)	
	$R^2 = .973$	R^2 (adj.) = .965
Anova	F = 125.43	
	P = 0	
1930	Prod'n = 292 + 301 L - 31.4K	
	S.E. (7756) (91.26) (26.95)	
	t (0.04) (3.29) (-1.17)	
	P = (.971) (.013) (.282)	
	$R^2 = .964$	R^2 (adj.) = .954
Anova	F = 93.71	
	P = 0	
1935	Prod'n = 3300 + 120 L + 18.6K	
	S.E. (6656) (90.06) (24.49)	
	t (0.50) (1.33) (0.76)	
	P = (.635) (.225) (.473)	
	$R^2 = .962$	R^2 (adj.) = .951
Anova	F = 87.84	
	P = 0	
No disaggregated data were available for the years between 1940 to 1950, inclusive.		
1955	Prod'n = 7692 + 58.0L + 3.1K	
	S.E. (27379) (76.30) (12.85)	
	t (0.28) (0.76) (0.24)	
	P = (.787) (.472) (.819)	
	$R^2 = .78$	R^2 (adj.) = .717
Anova	F = 12.38	
	P = 005	
1960	Prod'n = -26064 + 212 L + 8.96K	

	S.E.	(16276)	(30.18)	(5.325)
	t	(-1.60)	(7.03)	(1.68)
	P =	(.153)	(0.00)	(.136)
	R ² =	.996	R ² (adj.) =	.995
Anova	F =	989.54		
	P =	0		
1965	Prod'n =	-2685 +	303 L -	0.43K
	S.E.	(8675)	(14.31)	(2.305)
	t	(-0.31)	(21.29)	(-0.19)
	P =	(.766)	(0.00)	(.857)
	R ² =	.999	R ² (adj.) =	.999
Anova	F =	5523.76		
	P =	0		
1970	Prod'n =	46285 -	72.8L +	14.7K
	S.E.	(21327)	(27.72)	(4.416)
	t	(0.22)	(-2.63)	(3.32)
	P =	(.834)	(0.034)	(.013)
	R ² =	.679	R ² (adj.) =	.588
Anova	F =	7.41		
	P =	0.019		
1975	Prod'n =	-40137 -	711 L +	2.05K
	S.E.	(17588)	(31.53)	(4.24)
	t	(-2.28)	(22.56)	(0.48)
	P =	(.056)	(0.0)	(.643)
	R ² =	.999	R ² (adj.) =	.998
Anova	F =	2648.68		
	P =	0.0		

CHAPTER 5. TECHNOLOGICAL DEVELOPMENT.

5.1. Introduction.

The previous chapter considered the economic and physical production effects of technological change in the sawmilling industry from a production function point of view. Such a view gave an insight into the nature of technological change, but did not consider it in, and of, itself. This chapter will consider the direction and velocity of technological change itself within the industry and relate the findings to both the notions of technological paradigms and trajectories, and to the rate of innovation in sawmilling.

5.2. The Framework.

To meet one of the major aims of this work, to ascertain the direction (or nature) and velocity of technological change in the New Zealand sawmilling industry, it was necessary to utilise various production and output variables in the sawmilling industry within a framework that facilitated isolation of those major technological changes and their direction.

The framework¹ assumed that a process (or product) consisted of two sets of characteristics, called technical characteristics and service characteristics. In general,

the service characteristics are what interest the users of a process or product, whereas the technical characteristics are of interest to the makers of a process or product.

Thus, the top speed of a car may be interest to the user of a car, but the kilowatt rating is of interest to the makers of the car. The two characteristics are related (kilowatt rating having an effect on the top speed), but each is of differing importance to makers and users.

In this work, the product of sawmilling technology included such service characteristics as the production rate of sawn boards, the value accruing to sawn boards, etc., as well as the profit making potential of the technology. Therefore, the 'product' was considered to be used by the owners of the technology to make profits. On the other hand the technical characteristics of the technology would aid in the efficacy of the service characteristics, but would not be of such importance to the owners. Technical characteristics include such things as the kilowatt rating of sawmills, the amount of labour required to operate the mills, the price of labour and capital, and the types of saws in the mills.

In general, technical characteristics are related to service characteristics by a pattern of mapping, and this pattern gives the relative efficiency with which each technical characteristic contributes to each service characteristic. Moreover, some of the technical

characteristics may map to more than one of the service characteristics, and the service characteristics may be mapped onto by more than one technical characteristic. For example, the type of saw, its metallurgy and the power being delivered to the cutting face of the saw, all impact upon the rate of sawn board production, which is a service characteristic.

It is argued² that the changes in technology will take place in the form of changes in service or technical characteristics levels, their mapping relationship, or by the appearance of new characteristics.

In a sense, this distinction between types of characteristics both derives from, and reinforces Joseph Schumpeter's³ notion about the pursuit of monopoly profits. The lure of profits acts on entrepreneurs to bring new or improved products and services to markets. Moreover, most competition was (is) not of the "price" variety, as suggested by the neo classical model of perfect competition, but of the "non price" variety, typically found in markets with some degree of monopoly. The reason for this was that the resources required to develop these new products and services could only come from supernormal profits made available in markets and industries with some degree of monopoly. A highly competitive market could lead to the highest efficiency only in a static world, with a constant set of products or services made available to

customers at ever decreasing costs. Firms maximising static efficiency precluded the development of new products, whereas monopolies and oligopolies, while statically inefficient, allow for the introduction of new products, leading to greater dynamic efficiency.⁴

Thus in this work, any sawmill owner would only be interested in the acquisition of say extra power (kilowatts) only if the service characteristic of monetary returns pointed to the opportunity to make extra monopoly profits. Additionally, the resources available to any such owner to purchase the new power could only have come from supernormal profits which accrue as a result of a monopolistic market state.

It was suggested in chapter three of this work and elsewhere⁵ that often the firms in an industry converge over time on a dominant technological approach, and directions for technological improvements tend to be very similar. Nelson and Winter⁶ have proposed the concept of natural trajectories to represent these common directions for improvements within a technological regime. Natural trajectories are defined as heuristics guiding the search for improvements within technological regimes.⁷

Dosi⁸ has brought these ideas together in his notions of technological paradigms and technological trajectories. Technological paradigms are the counterpart of a

technological regime in that they are "patterns of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies."⁹ A technological paradigm defines contextually the needs that are meant to be fulfilled, scientific principles utilised for the task and the material technology itself. On the other hand, a technological trajectory is "the activity of technological progress along the economic and technological trade-offs defined by the technological paradigm."¹⁰ Thus, while a technological paradigm reflects what is scientifically possible, the actual path of a technological trajectory is what happened because it reflects what is socially possible.

Given all the points above, the aim of this section therefore was to collect information on various service and technical aspects of sawmilling technology, and then to analyse them to see if any technological trajectories could be discerned, and if there were any, to enquire as to their velocity. Thus something could be said about the rate of innovation in sawmilling, the motivations that lead to this innovation and then to say something about the future. Basically, this means that the notion of technological trajectories could be used to analyse the technological development of the New Zealand sawmilling industry.

5.3. Method.

Data on six variables concerning the sawmilling industry were collected by five year intervals for the period from 1880 to 1990. The data, which were collected by statistical district, were the total kilowatt ratings of all mills in each district, the total number of full time equivalent persons engaged in converting logs to sawn boards in each district, the total amount of sawn timber (in cubic metres) produced in each district, the total value of the sawn timber produced in each district¹¹, the total amount of added value accruing to sawmilling in each district, the total amount of wages paid to people converting logs to sawn boards in each district, and the total number of sawmills in each district. By dividing the first six variables above by the last (mills), a theoretical or archetypical or average mill for each district was obtained for each of the five yearly intervals.

A distinction was then made between the six variables, according to whether they were either technical characteristics or service characteristics of sawmilling technology. The variables, value of sawn timber output, value added and the physical amount of sawn timber were categorised as service characteristics, whilst kilowatts, full time equivalent persons engaged and wages paid were considered technical characteristics.

The distinction between service and technical characteristics was somewhat subjective. In this work, the

three service characteristics were likely to be of more interest to the users or owners of the technology. Changes in the technology such as increased kilowatt ratings, full time equivalent persons engaged and wages paid were only going to be of interest to the owners if they improved the level of services available, or the cost or efficiency of production in sawing timber.

Each sawmill "typology" could be represented as a point in six dimensional space, with each dimension being formed by one of the variables or characteristics. All of the points would form a cloud within the same space. It would be theoretically possible to track shifts of these points through time as sawmilling technology changed, but this would be difficult to achieve in practice since firstly, no simple graphical representation would be possible, and secondly, it would be difficult to discern the major and important shifts in the technology, given the number of variables, points and possible directions of movements.

The problem could be solved by reducing the number of variables or dimensions down to manageable level of one or two. Such a reduction was achieved by the use of principal components analysis. (P.C.A.)¹² P.C.A. is a data reduction technique for identifying a small set of variables that account for a large proportion of the total variance in the original variables.

P.C.A. initially recognizes that the variables are given in differing units of measurement, and therefore standardizes the variables such that the means of the variables are zero, with their variances set equal to one. Following this, the technique locates the direction (in six dimensions in this instance) along which the variation of the data is greatest. This direction and distance of variation becomes the first principal component . Thereafter, a second principal component is located by finding a direction and distance which is orthogonal to the first, whereby the remaining variation of the data is greatest, then a third and fourth principal component and so on is located, until all, or nearly all, of the variation is eliminated.

If the first one or two principal components explain a sufficiently large proportion of the variation of the data under observation, they define either a one or two dimensional space as an approximation to the six dimensional problem mentioned earlier. Thus, six dimensions would have been usefully reduced to one or two.

Projections are made from the data points to each of the principal components. The sum of the squared projections gives rise to a measure called the eigenvalue. There will be as many principal components as there are eigenvalues, and the aim is to select the most relevant and powerful principal components as possible. The significance of the

eigenvalues is that their sum will equal the number of principal components, and if there were to have been an equal spread of variation across all the initial variables, the eigenvalues would each have a value of one. This is rarely the case, and the usual basis for selection of principal components rests upon Kaiser's Criterion¹³, which retains all principal components whose eigenvalues are greater than one. This is logical because originally the amount of information contained in each variable is one. Those principal components with eigenvalues less than one would contain a lesser amount of information than the original variable, and therefore should be eliminated.

5.4. Results.

Using Minitab,¹⁴ the six variables, value of sawn timber output, value added, volume of sawn timber output, kilowatts, full time equivalent persons engaged, and wages paid, were analysed for their principal components, for the time period 1880 to 1990. The results are depicted in table 5.1.

Principal Component	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	4.437	0.646	0.488	0.276	0.099	0.054
Proportion	0.740	0.108	0.081	0.046	0.017	0.009
Cumulative	0.740	0.847	0.928	0.974	0.991	1.000

Table 5.1

Consideration of the eigenvalues showed that the six variables could be resolved to, and described by, one principal component. This principal component, which is labelled "PC1" in table 5.1, has an eigenvalue of 4.4374, indicating that explains 74% of the variance.

The existence of one principal component points to the probability that the process of technological change in sawmilling during the years studied was unidirectional and was probably motivated by only one economic force. Before expanding on this, it was necessary to interpret the meaning of the principal component, and then to gain some understanding of the direction and strength of technological change.

Tests for correlations of each of the six variables were run against the principal component, and the three highest correlations were found to be:

Production: ¹⁵	.918
Value:	.883
Wages:	.887

Table 5.2: Correlation Coefficients

Given these results, it appears that technological developments in sawmilling have been in the direction of greater production of sawn timber, thereby realising higher levels of monetary returns, whilst implying that more wages have been paid to achieve the higher production levels. These factors point to a shift to the employment of increasing economies of scale. Faster throughput of sawn timber implies that labour saving technology steadily replaced the more labour intensive forms, and given that less and less labour was used with each unit of capital, then labour productivity will have risen, leading to increased returns to labour in the form of higher wages. Given that the direction of technological change emphasized throughput and economies of scale, this implies that throughout the period studied, there was increasing efficiency of investment in capital.

In contradistinction to the argument that there were increasing economies of scale, there is plenty of evidence and argument to suggest that economies of scale are difficult gain in sawmilling. For example, Sutton¹⁶ argued that with increases in mill size, labour costs per unit volume of production fell and that conversion efficiency¹⁷ improved. However, these economies were eroded by increasing capital and depreciation costs with increases in plant size. Moreover, the size of the log catchment area necessary to service the expanded production capacity

increased as mill size increased. Thus, transport costs rose rapidly as logs were brought in from locations further and further away from the mill itself. However, this argument presupposed that transport technologies were static over the period under consideration.

In this work, which covered 110 years, the range and speed of log transport technologies underwent radical changes. Around 1880, logs would have been transported using animal power, bush tramways, sailing ships and steamers. Thus, the potential to expand a mill's log catchment area would have been severely limited. Scale economies achieved within a mill itself would have been wiped out by the transport cost and range constraints. By 1990 log transport technologies were such that catchment areas were radically increased by the almost universal employment of the internal combustion engine on well made, high speed roads.

For the purposes of this work, it is argued that the main result of the thrust of technological change was such as to emphasize throughput in sawmills, although there were some secondary results from increasing scale economies as potential log catchment areas increased with changing log transport technologies.

The variables, production and value, were both service characteristics. This implies that sawmill owners tended to be driven by the pursuit of increased profits as they

upgraded their sawmills or bought new sawmill technologies. The variable, wages, was labelled a technical characteristic, and its appearance in this way implies that increasing wages were an adjunct to the purchase of technology that increased profits. The result was not unexpected; labour skills are bound to increase as the level of capital employment rises, and these skills have to be paid for.

The findings point to the Schumpeterian¹⁸ hypothesis that only in markets with a degree of monopoly can technological change occur. Sawmill owners would have invested in technologies that enhanced their abilities to make supernormal (monopoly) profits, and these profits would have provided the funds to acquire the technologies in the first instance. Thus, sawmill owners bought technologies that emphasized throughput of timber by way of enhanced scale economies at the sawmill, and which coincidentally, economised on the most expensive factor of production, labour. To put it another way, wages were rising, but the units of labour employed per unit capital were falling.

To summarise this section, a name was attached to the principal component which best described the nature of the technological change. It was "increasing throughput".

5.5. The Velocity of Technological Change.

It was stated earlier in this work that some idea of the rate of innovation in the sawmilling industry might be useful in understanding the competitive position of New Zealand sawmillers. Innovation is difficult to pin down in itself, although technological change could be used as a good proxy. Therefore, consideration of the velocity of technological change could be used to help understand the rate of innovation.

To gain some understanding of the velocity of technological change, the years 1880 to 1990 were broken up into three eras, as below;

ERA	YEARS
1.	1880 to 1915
2.	1920 to 1950
3.	1955 to 1990

Then the three variables that were most closely correlated with the principal component were examined to ascertain their rate of change, with the principal component, in each of the eras. The three variables were production, value and wages, as discussed above.

A crude measure of velocity was computed for each of the variables, in conjunction with the principal component. Broadly, the range of the given variable was divided by the number of years in the era. The results were as follows;

VARIABLE	ERA	VELOCITY
PROD	1880-1915	200
PROD	1920-1950	113
PROD	1955-1990	700
VALUE	1880-1915	692
VALUE	1920-1950	443
VALUE	1955-1990	14286
WAGES	1880-1915	169
WAGES	1920-1950	120
WAGES	1955-1990	960

For each of the variables, the velocity of technological change started at a given level in the first era, 'decelerated' in the second era, and showed tremendous 'acceleration' in the last era.

These phenomena can be explained by the development of the industry, as detailed in the appendix which contains a brief technological history of the New Zealand sawmilling industry. Initially, incremental gains accrued to productivity of sawmill technology, for instance, by the use of steam replacing water power, improved steam engines, improving saw metallurgy and so on. Typically, sawmills of the first era were designed to handle New Zealand's indigenous timbers, which arrived at the mill site as large, cumbersome logs; these had to be largely manhandled

into position, and were broken down by circular saws or reciprocating frame saws. Within any species (indeed within any log), there was a wide variety of quality of wood that could be expected, so breaking down was a slow and relatively human controlled process. Sawyers had to open the log up plank by plank, rolling the log after each pass of the saw(s) to maximise grade out turn.

During the second era, 1920 to 1950, the Great Depression hit New Zealand and the sawmilling industry. There was a downturn in the demand for sawn timber and consequently in its production. Investment in new technology stagnated across the economy as a whole, as producers economised to survive. Sawmilling was no exception. However, it was also during this time that the need was recognised of the necessity to build mills that could handle the new exotic timber species from the plantation forests. These mills would have to handle logs of a smaller piece size, with more even quality, meaning that they would have to harness scale economies to maximise timber throughput. The first such mill was built at Waipa in Rotorua in 1940.

The expansion of the industry's exotic sawing capacity occurred during the last era, 1955 to 1990, and the amount of timber sawn, its value, and the wages paid to workers accelerated. Hence, the velocity of this era is explained.

5.6. Discussion.

Dosi's¹⁹ notions of technological paradigms and their subsequent trajectories were well illustrated by this mode of analysis. A sawmilling technological paradigm was established when a serrated metal cutting edge was first used to saw woody materials. A set of problems that needed solution then had their genesis. For instance, work was necessary to improve the cutting edge, the metallurgy of the saw itself, the transport and presentation of logs and sawn boards in the mill itself, the power available at the cutting edge to increase the cutting rate, the throughput of wood, and so on.

Given the range of problems to be solved, a programme of research would tackle some of them only, and usually the research programme would be predicated upon the requirements of the user as an element in the ambient economic system. Therefore, the actual development of technology, which is called by Dosi its 'technological trajectory', is in large measure dictated by the requirements of the economic system.

In this instance of New Zealand sawmilling technology, the technological trajectory has been 'guided' by the economic necessity of producing high volumes of sawn timber while ensuring incremental labour efficiencies by using relatively high capital intensity technologies. This is to say that there was an economic need to husband labour resources, and this was done by substituting labour with

capital.

5.7. Summary.

This chapter determined that the technological trajectory of sawmilling in New Zealand, during the years 1880 to 1990, could be described as one which was guided by the necessity to saw increasing amounts of timber, and thereby raise the throughput of sawn timber in any given sawmill. Scale economies accrued to the sawing of wood itself, and there was a substitution of labour for capital, but many of the scale economies gained would have been wiped out by increasing transport costs as the mills' log catchment areas widened.

The findings also allowed for the concept of the Schumpeterian 'technological push' type of technological change. The existence of varying levels of monopoly in the sawn timber markets facilitated the development technological change in the industry.

The rate of technological change accelerated after about 1950, and so it is argued, did the rate of innovation in the sawmilling industry.

The next chapter will provide an overview and general discussion of this work, as well as giving some consideration to the implications of the technological

trajectory followed by the New Zealand sawmilling industry to date. In a sense, the world is now entering a new production and trading paradigm which calls for more directed and careful niche marketing of products, and this implies that there will be a necessity for shorter production runs, and perhaps less outright grading sawing to stock. Thus, sawyers will have to cut to orders, with frequent production run changes and smaller lot sizes. Clearly, which ever way sawyers view their future, a far more conscious effort at planning and adopting strategies is called for.

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15. Production = physical volume of sawn timber produced.
 Value = money value of sawn timber produced.
 Wages = wages paid to persons engaged in sawmilling.

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17. Conversion efficiency refers to the ratio of sawn boards (an output) to logs (an input). Thus, a typical conversion ratio of .6 means that the volume of sawn boards is 60% of the volume of logs initially input into the sawing process. The reduction in volume by such an amount might startle some people, but it has to be remembered that sawmilling is about converting circular logs to rectangular boards, that the logs have taper, whereas the sawn boards do not, and that the speed at which a saw cuts wood is directly proportional to the strength of the saw teeth themselves, and this strength is directly proportional to the cross section of the teeth. Thus, faster cutting requires a wider tooth kerf, which means more wood is lost as sawdust.

18. Schumpeter, J. 1976. *Ibid.*

19. Dosi, G. 1982. *Ibid.*

CHAPTER 6. CONCLUDING DISCUSSION.

6.1. Introduction.

The analysis of six characteristics of sawmilling technology within a principal components framework showed that sawmilling's technological trajectory was in the direction of increasing throughput of timber. Since this implies that increasing volumes logs were converted to sawn boards, it is held in this work that the industry, over the 110 years studied, held a production focus as opposed to a productivity focus in its selection and development of technologies.

A number of reasons could be advanced for this phenomenon, and the following will be discussed in this chapter; the absence of scale economies in sawmilling technologies, the nature of the New Zealand economy throughout the period studied, and lastly, the fact that sawmilling technologies, being mostly imported, reflected production conditions overseas and not in New Zealand.

6.2. Scale Economies in Sawmilling.

In the previous chapter it was argued that there was a tendency for scale economies gained in the actual sawing of timber to be negated by the implied increasing size of the log catchment necessary for the higher levels of sawn

timber production. This peculiarity of sawmilling was put into perspective by the argument that given the 110 years studied, many of the transport problems confronting sawmillers with large log catchments, were partly overcome by the use of the internal combustion engine on high speed roads, in place of animal power transport, bush tramways and the steam engine.

However, as a general conclusion, the sawmilling diseconomies of scale probably did have a role in directing sawmillers down the technological trajectory of "throughput", since they would have been confronted with the transport technologies of their time, and could not wait for, let alone predict, improvements in this area.

6.3. New Zealand Economic Conditions.

From the first year of this study, 1880, through until about 1920, the sawmilling industry had relatively easy access to New Zealand's standing timber, paying low stumpages and operating within a system of loose controls.¹ Timber cutting licences were issued by the government at low cost, and sawmillers were in a position to cut for various markets (overseas and domestic) without paying too much heed to their costs. It is argued here that the nett effect of this was to place an emphasis on the throughput of sawn timber for the hungry Australasian markets, as opposed to an industry policy of husbanding the

resource and cutting for maximum profit. Of course, this statement would have to be modified when the effects of economic recession were considered, but even then, the response of most sawmillers was to cut back on production, and not be overly concerned with their cost structures, since these were minimal anyway.

After 1920, the State Forest Service was formed, and there was concern that the standing timber resource was being squandered.² Accordingly, a set of controls was put in place to ensure that the forests could be utilised in some sort of sustained yield pattern. The controls were implemented by a series of policies which, *inter alia*, resulted in the payment of higher stumpages by sawmillers and meant a completely new and tighter method of assessing timber quantities for stumpage charges. Moreover, in later years, particularly during the second world war, price control was introduced for the sale of sawn timber.³

The effect of these controls was to shelter the industry from the vagaries of international timber price movements, although surprisingly, the Dominion Sawmillers' Federation took exception to them from the very beginning.⁴ It has been argued⁵ that price controls on sawn timber and the below market supply price of logs sheltered the industry from market forces, and the progressive removal of these controls since 1984 has changed the face of, and the challenges presented to, the industry. Given the sheltered

nature of the industry, the production (as opposed to productivity or profit) emphasis mentioned above, was reinforced through to around 1984.

To summarise, there has been a production or throughput emphasis in the New Zealand sawmilling industry for most of the years of its existence. Initially this was because sawyers had access to a resource for which they were not paying an economic rent, and for which there was a consistently strong demand. Then, this emphasis was reinforced by government policies which effectively sheltered the industry from competition, and which emphasized production without much consideration for the costs involved.

6.4. Imported Sawmilling Technologies.

In general, the sawmilling technologies which were (and are) used in New Zealand were made in countries with different economic circumstances prevailing, and the technology reflected these circumstances. Thus, the inherent capital to labour ratios within the technologies would have reflected the relative factor prices in the countries of origin. Accordingly, the thrust of the technology towards increasing throughput of timber, could arguably have arisen as a result of a need to achieve increasing throughput in the originating countries. Doubtless, the technology was moderated by users to reflect

some of the economic circumstances prevailing in New Zealand. Furthermore, the economic circumstances confronted by New Zealand users of sawmilling technology would probably be similar to those of any western capitalist country throughout most of the years studied. This is to say that the technology was probably not inappropriate for New Zealand conditions.

6.5. Future Technological Trajectories.

Much of the discussion of economies of scale for various industries comes down to optimal plant size, with the optimum size being set by the lowest point(s) on the industry's "U" shaped cost curve. This mode of analysis is probably inappropriate in sawmilling. The actual cost of sawing does not appear to be dependent upon mill size⁶, so it might be more fruitful to examine sawmills in terms of their products and the specific market niches they cut for. Thus, technological trajectories would be seen as being more dependent upon their social milieu, and would certainly be more diverse than the one found in this work. It is suggested here that the world is entering upon a new production and trading paradigm, from which any number of possible trajectories might flow. There are a number of reasons for this.

Firstly, there has been a globalisation of manufacturing⁷, in which the location of any manufacturing operation is not

absolutely its source of raw or semi processed materials as in the past. Manufacturing location has been determined by a wider set of considerations in recent times. Thus, labour force skills and productivity, political stability, exchange rates and other broad economic phenomena, capital costs, as well as infrastructural considerations are becoming more important.⁸

Secondly, a firm's (or an industry's) competitive advantage is determined, in part, on how well its products conform to the requirements of often quite specific and small markets. Quality standards have become more tightly defined than previously, and there is less of a requirement to manufacture to say, industry specifications, but to specific customer requirements.

Thirdly, manufacturing technology is evolving to meet the requirements of the new world manufacturing and trading order.⁹ The revolution of silicon chip technology has meant that coordination and control of manufacturing processes has tightened and is more likely to be real time. Thus, manufacturing can be done to specific and small orders and set up costs have been reduced. For example, flexible manufacturing systems (FMS) can produce families of parts, and are capable of producing different parts simultaneously and in random order. Moreover, the number of different designs a firm can handle is essentially infinite since the F.M.S. will automatically adjust to small

variations in design.¹⁰

So far as sawmilling technologies are concerned, the past 20 to 30 years have probably seen more advances in timber manufacturing technology than in all history.¹¹ For example, methods have been developed for measuring volume and sorting and processing small logs at high speed, chipper headrigs make chips and sawn timber simultaneously, the best opening face method of log breakdown has been innovated, scanners and computers have been used to implement the best opening face method, and all these trends have paralleled by computerised process control in manufacturing in general. The way appears to be open for the introduction of flexible manufacturing systems (FMS) into sawmilling.

Flexible manufacturing systems would permit the pursuit of several production strategies simultaneously within the one sawmill. FMS means that quite narrow quality standards could be assured in the sawing of any one order, and that many and varied orders could be accepted and cut by any mill for a wide range of customers. FMS reduces retooling and set up times dramatically, and so the unit of operation within any sawmill could be the customer, rather than the number and type of logs delivered to the mill by the forest owner. Moreover, anything cut within any sawmill could be done to fill an order, and nothing else. Thus, there would be a large reduction in the size of timber storage space

currently needed by mills, and an implied economy of scale accruing as the capital costs of inventory and land would be reduced.

All this evidence points to the probability that sawmilling is entering upon a new technological paradigm, as is illustrated by the discussion below.

McLachlan¹² has suggested that several sawmilling technological options are available to producers of sawn timber. Each option implies a different strategy. Broadly, the options are;

The European option with high production and conversion through log sorting.

The North American Option with high production and conversion through scanning and computer control.

The Japanese option with high surface quality and conversion through slow feed speeds and very accurate sizing.

Even though there are two high volume options available in this schema, the methods of achieving the high volumes are different, and the mill strategies would be different. The European option implies that the investment in the strategy is largely confined to the careful purchase of logs of a

uniform size and quality from the grower, and in the careful evaluation of the logs at the mill site prior to cutting. Against this, the North American option means that most of the investment in the miller's strategy is in the purchase of capital equipment that ensures a rapid throughput of logs of a wider quality than in the European case. The Japanese option means that there is an emphasis on the quality of the sawn board output, and less concern for gaining high cutting rates. Presumably the customer would be willing to pay a premium for the higher quality uniform finish.

Mclachlan's¹³ trichotomy is probably too simple a description of the variety of sawmilling technologies and strategies that are feasible. For example, Williston¹⁴ has suggested a spectrum of technological trajectories when looking at mill configurations and equipment. Amongst many types, he argued that there were "Stud" or framing mills, small random length dimension mills, large common and grade mills, various sub types of large common log mills and large grade-log mills. Thus the argument that there are probably only one or two strategies cannot be sustained. Moreover, given the advances accruing to computing technology, automation, scanning equipment and so on, more than one strategy might be available to any one mill.

6.6. Summary.

The New Zealand forest products industry is probably the pre eminent industry in the country. It is estimated that by 2010 it will be the number one foreign exchange earner, ahead of the traditional primary industries that have previously occupied this position. Despite this bright outlook, forest products also present some reasons for disquiet. This is because the opportunity to add value to the raw wood resource by New Zealand based processors is dependent upon how innovative these producers are.

Innovation must occur throughout the entire industry, in processes and products, in organisational structures and marketing as much as in "hard" technologies.

Given that forest products are generally traded as commodities in international markets, it is important that a competitive advantage be seized by New Zealand wood processors to ensure the viability of the industry as a known quality producer, and not simply as a grower and occasional processor of wood. Innovation is the strategy to bring this situation about.

Within the forest products industry as a whole, sawmilling occupies a pivotal position, because it provides a critical link between forest growing and the reconstituted board industries, as well as providing some of the furnish for the pulp and paper industries. All this in addition to producing sawn boards.

The success or otherwise of any given industry or economy has been conventionally measured by its rate economic growth. The major contributing factors towards growth have generally been recognized as capital accumulation, growth in population and technological progress or technological change. Whilst the first two are important to economic growth, the last indispensable to economic development , since it ensures the alteration of capital and labour ratios, efficiencies in production, the provision of appropriate (or desired) goods and services to consumers, and a rising quality and quantity of life. Yet, in economic theory, the role of technological change is least understood.

Traditionally, technological change was treated as exogenous to economic systems, implying that it was a characteristic of the external environment of economic systems. It was not, for instance, considered that bringing new work methods or new hard technologies into a production and marketing system was an economic act. Yet such actions would have been economically motivated. That is to say that such things were done in the expectation of material gain.

Joseph Schumpeter, in seeking to identify an endogenous explanation for the role of innovation (and therefore technological change), used the role of profits as a starting point. Profits were seen to act as a lure to entrepreneurs to innovate, whilst the resources to innovate

were seen as coming from past profits. The profits which accrue to entrepreneurs as a result of successful innovation are considered in economic theory as being supernormal or monopoly profits. Thus, for Schumpeter, it was in markets that are characterised by some degree of monopoly that innovation occurred. A highly competitive market could lead to the highest efficiency only in a static world, with a constant set of products or services made available at ever decreasing costs. Firms maximising static efficiency preclude the development of new products, whereas oligopolies and monopolies, while being statically inefficient, allow for the introduction of new products, services and processes, leading to greater dynamic efficiency.

Schumpeter's schema maintains the implicit assumption that technologies are available "off the shelf" for entrepreneurs to pick up and innovate into an economic system. Consequently, the view has been labelled the "technology push" hypothesis, and its major shortcoming is that it doesn't take the role of demand into account.

Jacob Schmookler corrected this fault with elaboration of the demand pull hypothesis. Broadly, demand was seen as a stimulus to investment which lead to the innovation of new goods, services and processes in an economic system. Schmookler did not argue that demand forces were the only determinants of inventive and innovative activity, but was concerned to correct the opposite imbalance according to

which it was only the exogenous flow of inventions which could create innovations and new economic activities.

Reviews of studies of the relationships between market structure, firm size and innovation indicates strong industry effects and that the technological opportunity at industry level may be a major influence on the rate of innovation and technological change.

Given the existence of technological opportunities , there is the possibility that technology at any given time could be both described as having a set of potentialities, and yet simultaneously evolving along a given pathway, determined largely, by what is socially possible.

Giovanni Dosi has considered these ideas and has suggested the notion of a technological paradigm as being a "pattern of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies." For Dosi, a technological paradigm defines contextually the needs that are meant to be fulfilled, the scientific principles utilised for the task, and the material technology itself. In a sense, the paradigm helps define the set of possible pathways that may be followed, and it is through the interaction of social forces that the actual pathway is determined.

Dosi has called the pathway a technology follows its

technological trajectory and has defined it as "...the activity of technological progress along the economic and technological tradeoffs defined by the technological paradigm." Thus, it is possible to decide not only how a technology develops, but also to understand why it takes a given developmental line. Throughout, the social and economic forces are the determinants of technological development, and therefore innovation can be seen as being endogenous to an economic system.

The New Zealand sawmilling industry has obviously described a particular technological trajectory since its inception with the arrival of Europeans to New Zealand in the late eighteenth century. Some understanding of this trajectory is necessary to gaining an appreciation of what the future might hold for the technological status of sawmilling into the twenty first century.

The industry was analysed using an econometric framework, by five year intervals from 1880 to 1990. The broad findings of this analysis were that the production of sawn timber in New Zealand has been increasing at an exponential manner, that there has been a slow but steady increase in the number of persons engaged in the industry, that the number of kilowatts in the industry has been increasing very rapidly, that value added to timber, while being somewhat erratic, has been rising, and that the level of value added per person has been rising, whilst the level of

value added per kilowatt has been more or less static, or at least shows no discernable trend. It was concluded that capital has been substituted for labour in the production of sawn timber, either because capital has been cheaper than labour in New Zealand, or that imported capital reflected relative labour and capital productivity levels that pertain to the country of its origin.

Without the increase of capital in the sawmilling industry which gathered apace from the 1940s on, there would not have been the massive increase in sawn timber production that occurred in the latter half of this century. Moreover, this increment in the output of sawmills was also accomplished by the increasing skill levels of labour which was necessary to position, use and adapt the capital equipment in New Zealand conditions. Doubtless, there was much improvement to the capital equipment through time as New Zealand sawyers conducted their own ongoing and incremental innovations, both to the processes involved in sawing timber, and to the nature of the sawn timber product itself.

It was estimated that through time, the effects of technological change were such that an additional 2,402 cubic metres of sawn timber were added to the national output every year, purely as a result of technological change itself.

The econometric analysis did not show any evidence to suggest that economies of scale were developed or harnessed. There is plenty of evidence to suggest that scale economies are difficult to achieve in saw milling.

It has been argued that with increases in mill size, labour costs per unit volume of production fall and that conversion efficiency improves. However, these gains are eroded by increasing capital and depreciation costs with increases in plant size. Moreover, the size of the log catchment area required to service any expanded production capacity increases as mill size increases. Thus transport costs rise rapidly with the increasing log catchment sizes.

The econometric framework provided the opportunity to consider the physical and economic effects of changing technology in sawmilling, but did not offer the opportunity of considering the technology and technological change on and of itself. Consequently, the development of New Zealand sawmilling technology was considered using a principal components framework.

This analytical framework relied on the notion that sawmilling technologies have a set of outputs which can be considered for any variation inherent in them, and that these variations might present some patterning which could reveal a reduced number of variables which account for a large proportion of the total variance in the original

variables.

The analysis revealed that six technological output variables in New Zealand sawmilling could be resolved to, and described by, one variable. The existence of one variable pointed to the probability that the process of technological change during the years studied was unidirectional and was probably motivated by one economic force. Thus, the technological trajectory of New Zealand sawmilling could be described as one which was guided by the necessity to saw increasing amounts of timber, and thereby raising the throughput of timber in any given sawmill. There was no case to be made for the existence of scale economies. The trajectory was therefore labelled as "throughput".

The findings also allowed for the concept of the Schumpeterian "technological push" type of technological change. The existence of varying degrees of monopoly in the sawn timber markets facilitated the development of technological change in the industry.

Lastly, it was found that the rate of technological change accelerated after about 1950, and so it was argued, did the rate of innovation in sawmilling.

So much for the technological history of New Zealand sawmilling. The future might well be somewhat different

from the past. The world is now entering a new production and trading paradigm which calls for more directed and careful niche marketing of products, and this implies that there will be a necessity for shorter production runs, and perhaps less outright grade sawing to stock. Thus, sawyers will have to cut to orders, with frequent production run changes and smaller lot sizes. Clearly, whichever way sawyers view their future, a far more conscious effort at planning and adopting strategies is called for.

In the end, successful innovation is about persistent and directed human adaptability.

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APPENDIX. SAWMILLING DEVELOPMENT.

A.1. Introduction.

The aim of this appendix is to examine in summary form, the history of the development of sawmilling in New Zealand. Specifically, it will consider the development of sawing technologies from the earliest times, through to pitsawing in New Zealand, then various forms of powered sawmilling (water and steam), the development of the integrated, softwood sawmill and, finally, a look at some of the latest and emergent technologies available to the sawmiller.

A.2. Sawmill Technology.

Trees grow in more or less cylindrical form, whereas human beings prefer to use wood in squared or rectangular form, and so various means have been found to alter the shape of a round tree to fit into a square use. Primitive cultures have typically used fire and adzing to change the shape of trees for human use, but probably the most efficient and convenient technology was, and is, the use of the saw.

The saw is the heart of sawmill technology and it involves the use of a relatively finely serrated metallic edge to cut logs to shapes and dimensions suitable for a variety of human uses. The serrated edge is brought into contact with the log (or semi processed planks) in either a reciprocating motion, or passed continuously through the

cutting zone by way of a spinning circular metal blade or a revolving or rotating metal band.

The rate of production of sawn timber can be increased by the application of increasingly more intensive sources of power which drive the serrated edge through the wood, while (usually simultaneously) using non human or non animal powered means to automate the processes which move the log towards and through the sawing processes and which remove, grade, preserve, dry and stack the sawn timber.

The use of serrated edges to cut woody plant materials probably dates from the Neolithic age (New Stone Age), around 10,000 B.C. to 6,000 B.C.¹ This development coincided with the advent of agriculture. During the bronze age (circa 3,500 B.C. to 800 B.C.), metal working developed in the near east, and it was during this era that primitive saws were probably first fashioned.² However, it seems likely that it was not until the iron age, from 800 B.C. onwards, that efficient wood saws made from iron were made.³ From this point, technologies involving metal hardening and sharpening evolved which contributed to the efficiency and durability of timber sawing implements, and this improvement continues to the present day.

A.3. Sawmill Technologies in New Zealand.

Prior to the arrival of Europeans in New Zealand, there

were no timber sawing technologies. The Maori used stone adzes to shape wood from tree trunks, and hollowed out tree trunks for canoes by a combination of adzing and fire.

The first time a ferrous saw bit into a New Zealand tree trunk would have been in the second half of the eighteenth century, and the tree would probably have been used as a ship's spar. Captain Cook observed in 1769 that New Zealand trees, with a bit of preparation, " ...would then be such masts as no country in Europe can produce."⁴ In a relatively short time a vigorous trade in spars from New Zealand was underway, although this is of no direct relevance to this account, since sawmilling was not involved in spar manufacture.

However, New South Wales based timber merchants and entrepreneurs, who were the major factors in the spar trade, also started dealing in sawn New Zealand timbers. This was primarily because Australia was (and is) endowed with limited merchantable forests and had to rely on imports for much of its sawn timber requirements. By the 1820s and 1830s, New Zealand shore based timber trading incorporated both spar operations as well as sawn timber operations.

A.3.1. Pitsawing.

In the early days, the conversion of tree trunks into sawn

boards was accomplished by the use of pit sawing techniques. Pit sawing involved the use of manual labour sawing through logs by one of two basic techniques. Logs were supported on beams placed across a large pit in which a sawyer stood. Another sawyer stood above and over the log, and working as a team with a long pit saw, both workers broke the log into planks of sawn timber by working the saw in a reciprocating or undulating motion. An alternative method, probably used just as frequently as the first, involved placing the logs to be sawn on a raised platform (made of logs) instead of using a pit. Obviously, the work was physically demanding, particularly for the sawyer operating beneath.

Production figures for this sawing technique are hard to come by and very anecdotal, but some indication of the sawn timber output can be gained by considering the evidence that follows immediately below.

" Pitsawing smaller sizes of timber was done relatively quickly, but it was a lengthy process to break down a large log. To pitsaw in half a 1.5 metre diameter by 9 metre log was nearly a day's work [for two men]."⁵

" Good pitsawyers could saw 1000 super feet (sawn board measure [herein after s.b.m])⁶ per day. A large Kauri could contain 6,561 super feet."⁷

Presumably, the second quote refers to the breaking down of an entire Kauri tree into various grades and dimensions of sawn timber. Thus, on average, it would take around six and a half days to completely saw a large Kauri tree into constituent boards, and of this, nearly one whole day just to saw it in half, lengthways. (according to the first quote).

A.3.2. Water Powered Sawmills.

The use of water has always been important in the timber getting and sawing industries; as a means of transporting logs to mills and as a source of power in the sawing process itself, harnessed either by way of water wheels or steam engines. This section deals with water wheels.

It is probable that the first sawmill in New Zealand was a water wheel powered mill built at Mercury Bay by Mr. G.D. Browne and Captain R. Dacre, which began operation in either 1837 or 1838.⁸ Over the years, many water wheel type mills were used, and some were still in operation as late as the 1940s and 1950s. Their basic mode of operation was that the motive power offered by the spinning water wheel was converted into a reciprocating motion by the use of a connecting rod running off a crank shaft. A saw could thus be moved up and down through a log, provided the saw was installed into a frame running off the connecting rod. Typically, the cutting stroke was limited to the down

stroke of the saw, and the up and down motion of the saw frame was also used to move the log carriage forward into the saw by means of a system of levers and a ratchet. (See figure A.1)

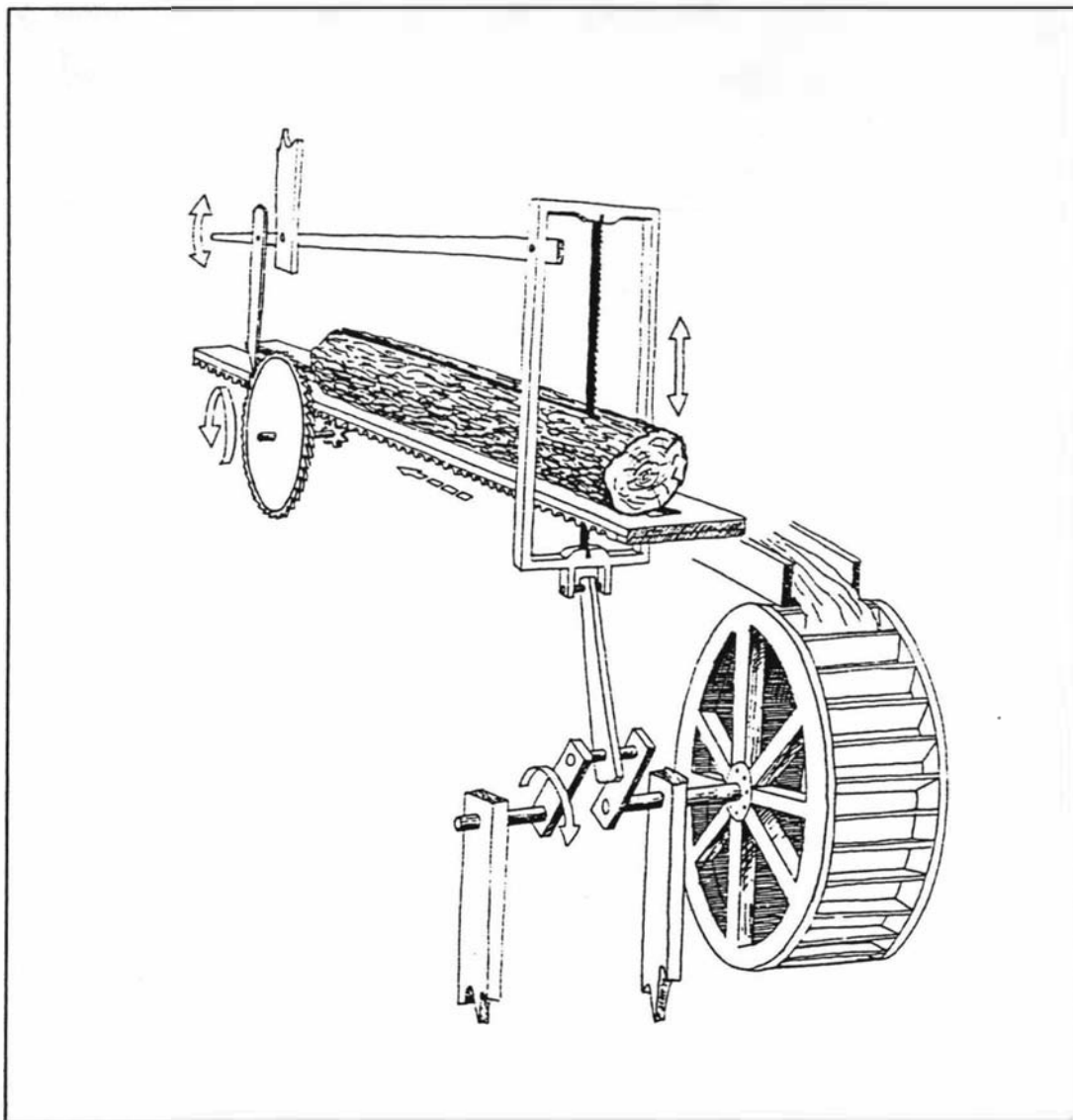


Figure A.1 Water Powered Sawmill

There were variations on the basic theme of harnessing water power by this particular means, and the following details of the last watermill ever to operate in New Zealand, given by T.E. Simpson⁹ gives some idea of these

variations.

Basically, the system was initially built in 1872, and was a 24 foot diameter overshot wheel with 48 inch by 14 inch buckets. Speed for the buckets was obtained through a 12 inch diameter crown wheel fixed to the water wheel and a 15 inch pinion and pulleys. In 1909, the overshot was changed to a 7 inch diameter pelton wheel drive. A pelton wheel is turned by water under pressure directed through a nozzle at the cups on the bottom of the wheel and, according to the pressure available, may be driven at terrific speeds. The pressure for this mill was obtained from a 30 foot fall with a 5 inch nozzle at the bottom of a 30 inch diameter pipe. This particular mill was moved to another site where a 220 foot head of water was available which increased to operating power available to saw wood. At this time it was producing something in the order of 5000 super feet of timber per day (s.b.m.).¹⁰

A.3.3. Steam Powered Sawmills.

Probably the first steam powered sawmill operated in New Zealand was set up by the New Zealand Manukau and Waitemata Company, whose main aim it was to settle an area of lands adjacent to the Manukau Harbour.¹¹ The mill probably began operations in the second half of 1842 and was powered by a high pressure steam Cornish Beam engine, with frame and circular saws, and was considered modern for its time.

The operation of a steam engine, in broad terms, is fairly simple, and so doesn't require over elaboration here. However, steam from a heated boiler is passed into a cylinder under pressure and a piston is forced by this pressure out and along the cylinder. The piston is attached to a fly wheel which converts the reciprocating motion into a circular motion, so that on the "down stroke" the piston is forced back up the cylinder against the head of steam. At the top of the stroke, the steam pressure exerts itself again and the piston is once again forced outwards. Meanwhile, the circular motion obtained by the fly wheel can be used to drive a wide variety of machinery, including sawmills.

Early on in the development of steam powered sawmills, frame saws were typically used, although circular saws were coming increasingly into their own.

A typical example of a steam powered saw mill is found in the plant operated by the Whangarei Timber Company in 1917.¹² The steam engine developed 14 horse power from a 100 horse power boiler. The engine powered the entire mill, and as such it powered the headrig, which was a vertical breakdown frame saw, a travelling bench saw, a circular breast band saw, 2 deal frame saws, a goose saw, two winches and creeper belts used for saw dust disposal.

A.3.4. Timber Saw Technologies.

As has been mentioned in the section on pitsawing, a pitsaw was (is) basically a thin piece of steel about 1.5 to 2 metres long and, on average, about 15 centimetres to 20 centimetres wide, with appropriate handles at each end. However, some discussion needs to be given over to the type, uses and shortcomings of the various types of saws used in powered sawmills.

The earliest sawmills used only one or two circular saws, usually in conjunction with pitsawing to initially break down the log with a lengthways transverse cut.¹³ Within a relatively short space of time however, large frame saws arrived and were used as the initial slab maker, or primary breakdown saw, or vertical breakdown saw in many mills. The Blue Books¹⁴ record sawmilling machinery, a steam engine and boiler and a frame and circular saws costing \$400 (200 pounds sterling) as arriving in Auckland from Great Britain in May 1842.

Simpson¹⁵ argues that the first band saw used in New Zealand was at Weraroa, Levin, in 1887. From notes made by an official of the Liberal Party at the time, it appears that the saw had a very narrow kerf and could cut as thin as 19 gauge. Moreover, the same saw could cut ten to fifteen times as much as that of the horizontal, or single blade frame saw and compared with the rack circular saw, could turn out considerably more work, wasted only a quarter of the wood and required considerably less power.

These same notes go on to point to the importance of invention (and ultimately, innovation) in the process of economic development. It is worth quoting directly from the notes.

"...So rapid has been the progress of **invention** recently with this description of saw, that a new patent saw sharpening machine has been specially brought out to work in conjunction with band saws. This machine can sharpen the teeth automatically at the rate of 100 teeth per minute..."¹⁶

The use of band saws, as against the use of circular saws and frame saws is important from the point of view of efficiency in timber usage. Having narrow kerfs, facilitating ease of handling of logs and powered log carriages in the mill etc, meant that less wood was wasted as sawdust, offcuts, odd sizes and so on. The importance of having the most suitable saws for the different stages of conversion of the sawlogs cannot over stressed, but in the interests of timber conservation and of operational economics it is equally important that the best sawing techniques be applied in their use, especially in the breaking down stage.

A.4. Exotic Timber Sawmilling.

So far as can be ascertained, the first instance of

sawmilling Pinus radiata (hereinafter, radiata) was in Canterbury in 1873.¹⁷ However, at that time it was only something of a novelty.

As the extent of suitable indigenous forest diminished, it became apparent that hand planted forests would have to be established as a replacement for the indigenous timbers. This was done, with booms in planting occurring during the depression years and before, and the major species planted was radiata.

As the exotic softwood forests matured, they became available for harvest and utilisation. The logs produced by these forests presented a different set of problems to saw millers than the indigenous species. Generally, radiata logs tend to smaller (in terms of volume, length and diameter), of lower degrees of taper, and of much more even quality than their indigenous counterparts. Moreover, they were generally less valuable, and so demanded more efficient and quick handling and processing than had hitherto been the case in indigenous sawmills.

Given the increased uniformness in the quality of radiata logs, the solution to the handling requirements immediately presented itself in the idea of mechanisation of sawmill handling methods.

Although the 1940s were to stand out as the era of

mechanisation, it could be said that mechanisation had been going on for some time. For example, the building of the first sawmill in 1838 represents a huge step forward in terms of mechanisation. Other instances of mechanisation can be seen in the use of straddle trucks and power driven (live) rollers in 1925, jib crane loaders in 1937, and the use of frontend and forklift trucks in 1940.¹⁸ What was to differ in the building of a sawmill to handle exotic logs was that a huge amount of automation and mechanisation arrived on the scene in one hit, and this may have been a paradigm shift in the thinking of sawmillers and sawmill engineers in New Zealand.

Concurrent with this integrated mechanisation was the search for alternative power sources. Electricity came increasingly to be used. It was cheaper and cleaner than steam, and could be taken right into the sawmilling operation by the use of electric motors rather than by a series of shafts, pulleys and wheels as was the case with steam.

In addition to the above issues, indigenous sawmills tended to present pine timber badly,¹⁹ and it was clear that their being developed for the large, medium density logs from the indigenous forests, meant they were ill suited for the small, low density logs from the plantations. To introduce efficient methods, plans were made to set up state owned forest industries, comprising sawmills, box factories,

planing mills and wood preservation plants. These plants were to act as demonstration, control and salvage units for the exotic and indigenous forests. The methods and philosophies were worked out and demonstrated by the opening of the State Mill at Waipa in 1940. The private sector got the message and quickly followed suit.

Broadly, the Waipa plant comprised of two Swedish log frames and edgers (designed for small softwood logs) box factory, seasoning kilns and non pressure plant for preservation treatment. Mechanical handling equipment for moving timber through successive processes was a feature of the mill and it included straddle trucks, live rollers, forklifts, gantries, automatic log inhaul chains, mechanical log kickers and turners, fast log carriages, multiple trim saws and edgers, reversible line rollers and transfers, four way sorters and so on. In effect, this mechanical revolution was less to do with the application of raw power to the primary breakdown saw, as steam had been, and more to do with using available energy in wood movement through the mill. Within two years, Waipa was enlarged and its output doubled.

Up till this time, there was either no or little mechanisation of timber handling in mills. Logs, flitches, semi processed planks and final product were moved by muscle power using hand cranked timber jacks, cant hooks, and rollers.

Other integrated mechanised mills were built as the exotic logs came on stream, and nowadays, the old fashioned, steam powered, twin circular breakdown saw is a rarity, if not a museum piece.

A.4.1. The Modern Sawmill.

The modern sawmill is characterised by a number of features that distinguish it from older mills which were predominantly designed with the indigenous log resource in mind.

For one thing, the energy source is likely to be electricity, as opposed to water or steam of the earlier mills. Also, there is a higher degree of automation, which is increasingly being coupled with computerised sensing and control equipment. These changes allow for higher volume throughputs of material, coupled with the ability to saw to precise and exacting specifications.

According to Tillman²⁰, the state of the art sawmill is best viewed as a multiproduct plant. Its objective is not to maximise timber production, but to maximise cashflow generation, through the sale of sawn timber, pulp chips, particle board furnish, fuel and specialty products (e.g. landscaping and gardening bark, sawdust for cattle feed, chicken litter, etc.).

This concept of a sawmill as a multiproduct cashflow generator is important for two reasons. First, it has provided the basis for the establishment of integrated sawmill - pulpmill complexes (such as the Tasman operation at Kawerau) and second, it has provided support for many innovations, for instance, particle board and thermo - mechanical pulping.

Typically, operations in a modern sawmill can be best shown as a material flows scheme in the following diagram (figure A.2).

A.4.2. Unit Operations of the Modern Sawmill.

The exotic log sawmill includes the following unit operations or machine centres: (1) debarking, (2) log merchandising, (3) primary breakdown [the headrig], (4) board edging, (5) board trimming, (6) product drying, (7) product planing, (8) pulp chip production, and (9) fuel production [hogging]. Although mill controls are not an operation *per.se.*, they are a necessary consideration within the individual component context. The unit operations where major advances have occurred in the past 10-15 years include: (1) log scanning and merchandising, (2) the headrig, (3) edging, (4) drying, (5) planing, and (6) system controls.

A.4.2.1. Innovations in Machine Centre Operations.

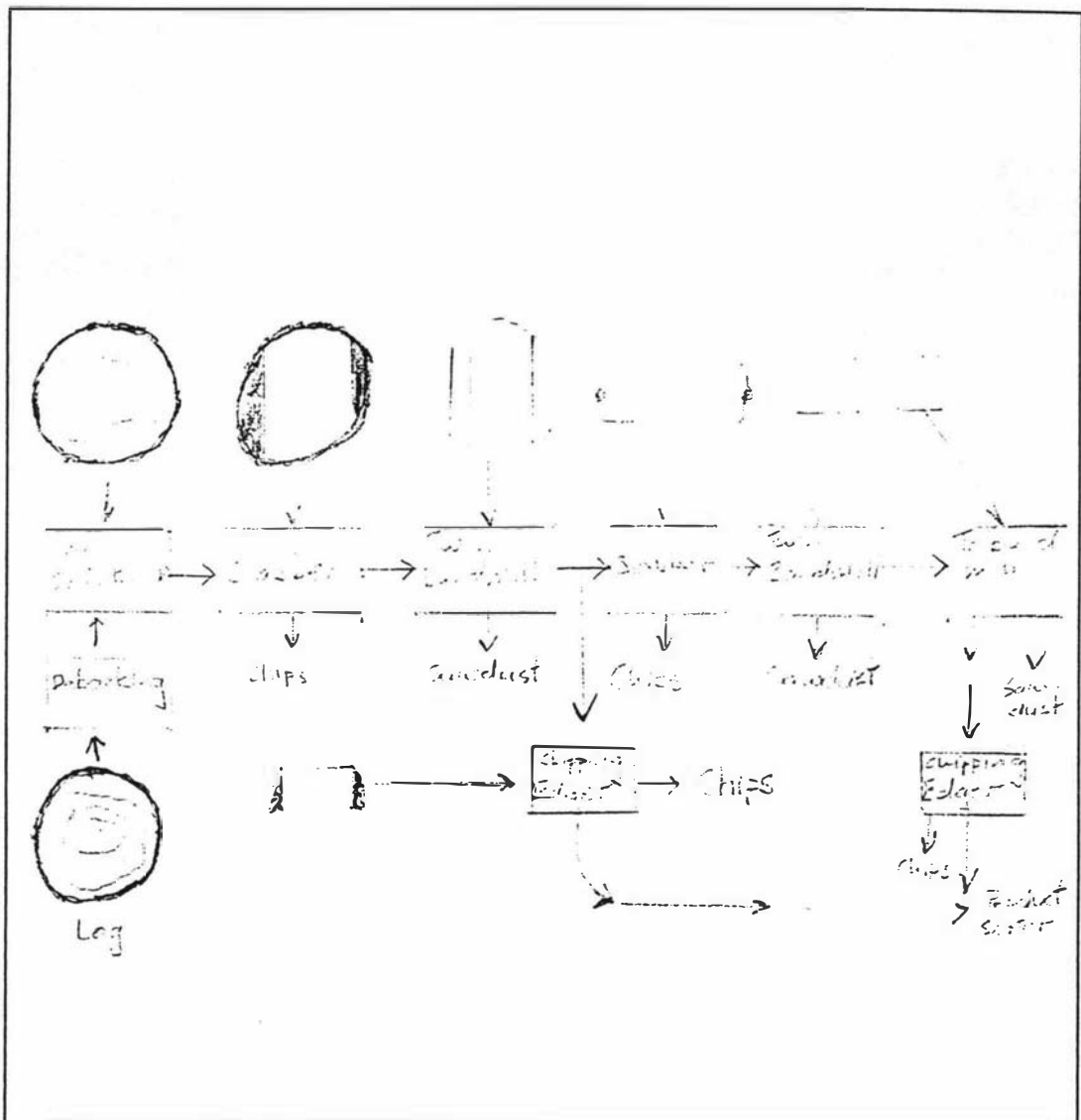


Figure A.2 Operations in a Modern Sawmill

Innovations in individual machine centres have been proposed continuously based upon the high priority for improving sawmill yield, and the fact that each individual cut in the log or cant decreases the degrees of freedom for all subsequent cuts.²¹

Headrig innovations centre around the following breakthroughs: (1) the shaping head lathe headrig [although this technology has been used more in conjunction with the

sawing of hardwood species and is not of particular importance in New Zealand], (2) slicing headrigs, which are a use of the veneer slicing technology to headrig operations for the purpose of increasing yields, (3) water jet and laser headrigs, wherein water jet and carbon dioxide laser cutting are based upon technology transfer from other industries to the timber processing industry. The technologies reduce the kerf width substantially and increase yields in the sawing process, although the cutting rates so far attained by contemporary machinery is low.

Kiln drying technologies had a major boost during 1972 - 1980 during the oil crisis, as attempts were made to use this drying fuel more efficiently. Moreover, there have been advances in the use of alternative energies for drying, and the possibilities of solar drying units have been advanced²². Also, the concept of micro wave drying has been around since the 1930s, although it seems best suited for special purpose situations.²³

Advances in control and information systems were largely an outgrowth of the computer hardware and software revolutions, and followed the development of numerical controls in the machine tool industry. Innovations in this area include:

- (1) 3-dimensional CT scanning of logs at the merchandising and headrig centres in order to minimise

yield losses due to knots and defect;

(2) microprocessor control of all machine centres, including the dry kiln;

(3) computer connection of all microprocessors in order to communicate process problems to all machines upstream and downstream of the point of difficulty.

A.5. Summary.

This appendix reviewed major technological developments in sawmilling and considered, in a cursory fashion, some of the productivity effects of advancing technological change.

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5.Daimond, J. T., & Hayward, B. W., "Kauri Timber Days; a pictorial account of the Kauri timber industry in New Zealand." The Bush Press. Auckland. 1991. p22.

6.One super foot is 12 inches by 1 inch by 12 inches, or multiples thereof. For example, it could be 6 inches by 2 inches by 12 inches. The measure "sawn board feet" or s.b.m. was the amount of wood sawn by the sawyers after they had sawn the log up. This was typically also the basis of payment.

7. Taken from an exhibit on pitsawing at the Matakohe Pioneer Museum. Matakohe. Northern Kaipara region.

8. Simpson, T. E., "Kauri to Radiata." Hodder and Stoughton. Auckland. 1973. pp 40-41.

9. Simpson, T. E. 1973. *Ibid.* pp 187-188.

10. It should be noted that a straight out comparison of production figures between the various types of sawing techniques (pit, water, steam, electric, etc.) is complicated by the fact that manning levels are required by each type of operation. Thus, in the case of pitsawing, two men could saw 1000 super feet per day, pointing to a labour productivity figure of about 500 super feet per day. Without knowing the manning level of this particular water mill, it is impossible to say what a rough labour productivity figure would be. Moreover, this problem is exacerbated when it is considered that capital productivity has to be taken into account. How much, if any, of the increased production is due to the use of an alternative power source (water), and any automation that might be present?

11. Roche, M., "History of New Zealand Forestry." New Zealand Forestry Corporation Ltd., in association with G. P. Books. Wellington. 1990. p 50.

12. These notes are taken from an exhibit at the Matakohe Pioneer Museum, Matakohe, Northern Kaipara region.

13. Simpson, T. E. 1973. *Ibid.* p 185.

14. The Blue Books of New Zealand, resident at the National Archives, Auckland and Wellington, were a sort of forerunner of the modern "Year Book" and record many statistics on New Zealand.

15. Simpson, T. E. 1973. *Ibid.* pp 185-186.

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21. Tillman, D. A. 1985. *Ibid.* p 197.

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