A SYSTEM DYNAMICS STUDY OF THE TRANSITION FROM AMPLE TO SCARCE WOOD RESOURCES+

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ABSTRACT

The Scandinavian countries are approaching full utilization of the regrowth in domestic forests, and the forest industry is facing a period of much slower expansion in volume than in the past. Slower growth implies problems for the industry, forestry, and society at large. The "transition" from ample to scarce wood resources could take several forms, depending on actions taken both inside and outside the forest sector. A system dynamics simulation model has been constructed to describe different possible transition paths, and to highlight potential problems. The model purpose is not to predict what will actually happen in the future, but to describe possible futures in an internally consistent way. Such insights about the consequences of various management strategies are useful to interest groups as a basis for discussing how to reach their goals. Within the industry, there is a tendency toward temporary overexpansion of capacity. The forest sector's ability to survive under slow growth conditions could be enhanced by technological and organizational remedies. The necessary remedies will be less traumatic the earlier one accepts and acts upon the problems of finite wood supply.

+ Originally published in the Proceedings of the XVIth IUFRO World Congress, Oslo, June 1976.

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INTRODUCTION

The Scandinavian countries are approaching full utilization of the regrowth in their domestic forests. Except in the unlikely event of ever increasing fibre imports, the Scandinavian forest industry[1] is facing a period of much slower expansion in volume than was common over the last seventy-five years. The industry will approach fibre constraints before its competitors in international commodity markets, and must decide how to survive while expanding less rapidly than the competitors. Constraints on volume, implying one more obstacle in the unceasing search for lower production costs, are serious in an industry with economies of scale and rapid technological innovation. From a societal point of view, unless wood products become the unlikely beneficiaries of everlasting increases in value added, the presence of limits will necessitate a steady reduction in forest sector employment whenever productivity increases. Wood constraints will consequently force painful adjustments where rural populations traditionally rely on fibre processing. Over the next few decades, of course, the "transition" from ample to scarce wood resources can take several forms, depending on actions taken both inside and outside the forest sector.

This study[2] was undertaken to clarify the possibilities and threats inherent in the coming transition, and to establish an internally consistent basis for discussing goals and possible strategies to make the transition less disruptive. A causal simulation model has been constructed to highlight the forces thought to govern the transition, and to elucidate various possible development paths through the forthcoming critical 10 to 50 year period. The model structure and behaviour, as well as insights gained from their analysis, should help to provide a background for strategic choices posed by the forest industry transition. The modeling effort focuses on long-term developments

averaging approximately 5 years in length -- for instance, seasonal variations in wood removals, the imbalance in fibre supply and consumption, inventory fluctuations, and business cycles. In fact, all variables explicitly discussed here could be considered 5-year running averages of their real-world counterparts.

The analysis focuses on "Scandinavia" (here defined as Norway, Sweden, and Finland), but should be applicable to other situations where an export-oriented forest sector is approaching the end of an era of rapid expansion in production volume. Since most of the conclusions to this study are relatively independent of the parameter values used here, the study should have wider applicability than might initially be expected.

HISTORICAL OVERVIEW

Developments in the Norwegian forest industry between 1900 and 1975 are typical of the whole Scandinavian region. Therefore, the following historical sketch of Scandinavian developments is illustrated well by the Norwegian time series in Figures 1 through 8. The Scandinavian forest industry has been expanding relatively uniformly since 1850, except during World War II (Figure 1). The associated increase in fibre use was made possible largely by shifting wood from fuel purposes to industrial processing, and by removing a larger fraction of the gross increment (i.e. the annual fibre production in the forest). From the late 1950's Norway also relied on some imports, mainly from Sweden. In Sweden, industrial use of wood increased by only 50 per cent. Currently, industry consumes more than 90 per cent of total removals. Total fibre use now approximates or exceeds gross increment in all Scandinavian countries, although a new emphasis on silvicultural activities may change this pattern

(Figure 2).

The last 75 years have seen limited improvements in the sector's roundwood yield, defined as the aggregate product volume obtained per cubic metre of roundwood delivered to industry (Figure 3). Improvements reflect higher fibre utilization in forestry, and less waste and increased recycling in the industry. Gains have approached 40 per cent in Sweden.

Most of the output from the forest industry has been exported, mainly to European markets. Finland and Sweden, with per capita production volumes 3 and 2.5 times that of Norway, are particularly export-oriented, but even Norway exports a significant fraction of its production (Figure 4). The degree of refinement (or value added per cubic metre of wood) has increased, particularly in the post-war period, probably reflecting higher labour costs and emerging wood constraints (Figure 5 and Figure 6).

Industry growth has been based upon rapid expansion of production volume, thereby making possible quick adaption to new technological and market conditions. As a result, real costs of production have fallen at a rate similar to costs of foreign competitors. Much of the reduction has been realized through exploitation of economies of scale, particularly in the pulp and paper industry, but lately also in sawmilling (Figure 7). Further increases in the average scale of production seem likely.

In the forest industry, scale increases have engendered higher labour productivity and an ability to pay competitive wages. In forestry, mechanization has led to the same results. Productivity has increased sufficiently quickly, both in forestry and the forest industry, so as to lower total employment (Figure 8). Similarly, the average scale of production has increased faster than the total volume of production, thereby forcing a reduction in the number of production sites (Figure 7). Both centralization and reduction in total employment have had negative effects, particularly in one-company towns and

THE TRANSITION PROBLEM

Costs of slow growth

The historical overview suggests that the Scandinavian forest industry is approaching the maximum wood consumption possible without reliance on foreign supplies. To be able to sustain domestic consumption, Scandinavia apparently must reduce the growth rate in industrial use of fibre to the growth rate in sustainable fibre supply -- a disturbingly low figure compared to the 5 per cent per year growth in volume over the last 30 years. The wood constraint is actually somewhat less rigid because new forest resources have usually become available during past periods of scarcity. However, the industry will likely encounter increasing difficulty in expanding capacity at the traditional pace.

The real reason for concern about wood limits is the costs -- financial and intangible -- associated with slow growth in production volume. Such costs tend to reduce profitability, possibly enough to force a decline in the economic activity of the forest sector. Such an outcome would be more likely, first, if foreign competitors continue to expand rapidly, making larger scale of production feasible, and second, if the Scandinavian industry remains a producer of commodities, and thereby is subject to continued competition from foreign commodity producers.

At the company level, a fixed fibre supply implies that new plants cannot be constructed without a simultaneous closing of enough other production facilities to release the necessary fibre. The industry can face such a situation in two ways, each associated with increased production costs. In periods of expanding capacity, firms tend to continually add capacity in excess of closings. A large fraction of existing plants are therefore "modern" (construcper unit produced. Moreover, the average "modern" plant can be kept in operation long enough to spread investment costs over a large production volume, implying a low average capital cost per unit produced. At stable volume, on the other hand, additions to capacity must be equaled by closings. The firm can i) maintain traditional addition rates and increase closings, or ii) maintain traditional closing rates and cut back on additions. Excess investment funds can be used to renew existing plants without changing capacity. The first strategy under stable volume entails shorter productive life for the average plant by dint of a higher capital cost per unit produced. The latter strategy implies that the average plant will be more "oldfashioned" -- that is, entailing higher variable cost per unit -- because plants are less well adapted to current market preferences and technological conditions. In short, limits on volume induce higher production costs in single firms. By "higher" is meant <u>higher relative to the foreign competitors</u> who have sufficient wood to expand at the optimal rate.

Limits on the industry does not necessarily mean limits on individual firms, which can expand at each other's expense. Still, limits on the industry must eventually increase costs for the single firm. If the failing firms are acquired by successful firms in an orderly fashion from the outset, the production cost increases described above will be absorbed by the remaining companies all along. But as long as many small firms stay in the industry, the process of concentration is more likely to be associated with losses diffused among owners and creditors. Production cost increases only start to appear in the books of surviving producers when they are so few and big -- as will eventually happen due to the pressures of economies of scale -- that the industry cannot accept anything but orderly fusions for fear of damaging its image and thereby increasing the cost of credit. Furthermore, as time goes by, firms in the industry will be plagued by the higher wood costs of less accessible re-

Limits on volume entail other costs, aside from the uncertainty inflicted by a sagging industry: reduced employment for workers as productivity increases, fewer production sites for rural districts as plant scale increases, and possible strain on the forest ecosystem due to the scarcity of wood.

Commodity exporters

Our analysis of the implications of cost increases brought about by slow growth begins with a clarification of our assumptions about the nature of the Scandinavian forest industry. The consequences for the study conclusions of relieving the most uncertain assumptions are discussed at the end of the paper.

Output largely commodities

Scandinavian forest industry output is largely commodities. That is, the product origin or brand name is irrelevant to the consumer who could as well turn to alternative suppliers. This characteristic is likely to remain true. Processing the enormous volume of fibre (around 100 million cubic metres per year) into custom-made products at a distance from the consumer seems improbable. The bulk of the volume is not likely to be processed beyond planed sawnwood, medium quality paper, and impregnated fibre- and particle board.

Production mainly for export

Current production in Scandinavia far exceeds domestic consumption. Finland, Sweden, and Norway export 60, 60, and 15 per cent, respectively, of their sawnwood, and 90, 80, and 70 per cent of their paper production. In addition, each exports roughly one-third of its pulp production. The Scandinavian countries, with the possible exception of Norway, seem destined to be exporters for a long time to come, even with rapid growth in domestic consumption.

Limited possibility to dictate prices

The Scandinavian industries cannot dictate product prices at will, because the output is a commodity and because the three countries have relatively small market shares. Norway's export is sold largely in markets where the Norwegian share is around 10 per cent of imports and much less of total consumption. All of Scandinavia, however, often covers about one-fourth of a foreign market, which could give the region some influence if the producers could manage to establish an efficient cartel.

Significant economies of scale

Economies of scale are pronounced in pulp and paper production: in 1970, the production cost in a 30 000 ton per year plant was typically twice the cost in an optimal plant -- at that time 300 000 tons per year. Smaller, but similar economies are present in sawmilling.

Rapid, internationally available, technological advance

The rapidity of technological advance is illustrated by the optimal scale in pulp and paper production moving from the order of 100 000 tons in the 1950's to 300 000 tons in the 1970's and planned integrated plants of 800 000 tons per year in the early 1980's.

E l a s t i c l i m i t s

The Scandinavian forest industry has approached apparent limits before, but has usually overcome shortages through various remedies. When it is impossible to increase wood supplies through relocation or improved transportation, the sector is left with the following six ways of increasing production volume in a sustainable way.

Less fibre to non-industrial use

Much of the recent expansion of the forest industry was based on wood released from fuel and farm uses. Currently, only 10 per cent of wood production goes for non-industrial purposes, signaling an end to this alternative source.

More import of fibre

One obvious suggestion is to import wood, but the regional industry appears uneasy about excessive dependence on foreign suppliers. Such suppliers may not even be available in the future, since individual countries increasingly want to utilize their own raw material. The analysis presented in this paper is based upon the assumption that no import of wood takes place.

Increased reuse of fibre

Since the fibre in paper and paper board can be reused several times without losing all its strength, collection of used fibre would seem to be a significant source of raw material. That is so, but not in countries exporting around 80 per cent of their paper production. Only through a costly, large-scale importation of used paper could recycling supply more than 10 per cent of the demand in pulp production.

Higher fibre yield in industry

More output can be obtained from a given input of fibre through reduced emissions, increased use of sawmilling residue, and less use of fibre as fuel. In spite of some past savings, around 40 per cent of the fibre still leaves the production processes as waste, mainly during the production of cellulose.

Increased fibre utilization in forestry

One can increase deliveries of fibre to industry per conventional unit of roundwood by processing bark, branches, tops, and roots; by using other species, and removals with smaller dimensions; and by reducing the natural loss. In this way, fibre production could probably be increased by 50 per cent above the current level without an increase in the gross forest increment.

Increased forest growth

Increased forest growth per hectare and year over the rotation period should be attainable through silviculture, use of new species, and further expansion of the forested area. Norwegian estimates predict a potential increase in forest increment of about 60 per cent; Swedish estimates are somewhat higher.

In sum, the listed remedies could theoretically sustain a production volume 4.6 (= 1.1 x 1.1 x 1.0 x 1.4 x 1.5 x 1.8) times greater than today's -- a 300 per cent increase. However, this rosy prospect actually would have to surmount serious difficulties -- possible ecological danger, intelligent use of ligning -- whose solution would extend the long delays inherent in the rotation period. If a century were to expire before full exploitation of the increased, potential yield, volume maximally could grow 1.3 per cent per year during this period, much slower than the average of 5 per cent per year since World War II. The cost of obtaining fibre in some of the suggested ways could also prove prohibitive, further slowing the growth in production volume.

Expanding competitors

Currently, almost all of Scandinavia's forest product export goes to Europe. The major foreign competitors in these markets are, besides any local industry, Canada, the USA, and the USSR, countries whose forest resources could well accomodate another 10 to 30 years of expansion at traditional rates without

prohibitive cost increases. Global shortages and high prices may still surface in the short term (over 5 years or so), but the resulting high profitability would only hasten the seemingly inevitable entry into the market of tropical countries backed by essentially unlimited fibre volumes. So, except for brief interludes while technologies are being developed and capacity installed, the Scandinavian forest sector will probably continue to face competitors unhampered by wood constraints and capable of expanding volume at the optimal rate for market and technological conditions. As Scandinavian growth stalls, these competitors will come to dominate the markets and set prices according to their own (low) production costs.

Entering the transition

The following view emerges: the Scandinavian forest industry is one of many expanding competitors in an international commodity market. The Scandinavian industry is currently approaching flexible wood constraints that will increase fibre costs and slow further growth in Scandinavian production volume, while the competitors are free to continue their traditional expansion. In summary, the transition problem can be phrased as follows: If

- the Scandinavian forest industry continues to focus on the production of commodities for international, competitive markets, and if
- significant economies of scale in investment and production or rapid technological advance in production equipment continue, and if
- foreign competitors continue their rapid expansion in production volume with ample wood resources available to support such expansion,

then constraints on wood availability and the resulting slower growth in total capacity is likely to bring about an increasingly uncompetitive cost level in the Scandinavian forest sector, and possibly a reduction in sector activity. Such a decline will take time, decades rather than years, and could well be counteracted by movements in other factors affecting relative costs, including labour costs and exchange rates.

A PERSPECTIVE ON THE TRANSITION

Growth pressures

What forms might the transition from ample to scarce wood take? Will the tradition of growth prevent needed restraint? Will stable volume cripple the forest industry? A better perspective on growth pressures and constraining forces would help clarify potential forest industry trends over the next 50 years. The conventional wisdom argues that "growth is necessary", but the underlying reasoning is rarely brought forward. Various groups desire expansion in the production volume of individual plants, of production sites, and of the industry as a whole for a variety of reasons:

Individual forest products producers

As previously discussed, constant volume implies higher costs. Therefore, individual producers whose goal is to remain competitive and profitable vehemently oppose such an equilibrium condition. The impression that companies value growth above all explains why expansion in production volume is the simplest strategy for reducing costs. Although investments will be maintained at the highest possible pace, the resulting benefits will be less when constraints on volume become tighter. If rigid limits are placed on volume, some stop-gap measures may be substituted for further expansion. A company can reduce costs by terminating investment, and hope that lower capital costs would more than compensate for the higher variable costs incurred by increasingly outdated plants. Or, the company might reduce unit transportation costs by

focusing on a nearby market. Moving into other product lines only helps in the short term; there is little reason why profitability should remain higher for certain types of product in a market with relatively free entry for new producers. Finally, rapid changes in the product mix can often meet resistance in markets. But such solutions are not lasting, and expansion of scale seems necessary to keep abreast of competitors using all means to reduce costs, including increased scale. Tremenduous pressure will therefore be brought to bear to expand capacity. One method of so doing is to acquire the wood supplies of domestic competitors by building huge, new plants capable of offering the highest wood price.

Forest industry workers

Forest workers seek relatively stable employment and wages in line with the (growing) economy average. The necessary accompanying increase in output per person is achieved most simply through increased scale, implying expansion. A rigidly fixed production volume would force a decline in employment in proportion to productivity when the product mix is held constant. The likely response to such a decline would be pressure for increased value added and therefore more potential employment per cubic metre of fibre.

Local communities

Local communities dependent upon forest production will naturally try to maintain their economic base. Attracting new business is difficult, and the community will fight to avoid closing local plants. Their action is often equivalent to lobbying for expansion of capacity. The cost to the local community of closing -- loss of jobs and, ofter, the basis for a small service sector -- is nearly always severe. If local economic survival is threatened by ridig wood limits, a likely response would be to press vigorously for continued operation of local facilities and chanelling of the investible surplus to continuous renewal at constant capacity, simply to delay the time of negative gross margin. This measure can only be a stop-gap because the cost reduction per invested dollar is much lower if not accompanied by the additions to capacity in which foreign competitors indulge.

Forestry workers

The simplest way for forestry labourers to secure enough, reasonale well-paid work is to push for increased harvesting. Fixed limits on removals and increased productivity will together reduce employment. A likely response then would be pressure for increased silviculture which may, however, push wood costs beyond the industry's capacity to pay for fibre.

Industry spokesmen

Organizations such as The National Association of Forest Products Producers seek a smooth and profitable development of the industry. Their task is much simpler if wood is ample and the coupling between firms is loose. In response to a growing scarcity, spokesmen would publicize concerns about factors perceived as limiting supply -- inactive forest owners, restrictive tax policies, biased estimates of forest growth, thereby hoping to get sanctions for increased removals. When faced with rigid constraints and barred from wood imports, industry spokesmen would be likely to press hard for horizontal integration into fewer and bigger plants to maintain industry profitability. Other industry suggestions could include proposals for vertical integration, demands for tax breaks, subsidies, and even devaluation of the currency.

L a y e r s o f c o n s t r a i n t s

In total, the aspirations of several involved groups manifest themselves

as a vigorous pressure for expanded fibre use. The growth pressures are countered, on the other hand, by forces tending to limit utilization of domestic forest resources:

The institutional constraint

Society's interest in a continuing production of wood is reflected in institutions charged with keeping removals at or below the sustainable level. Examples are the set of values and practices embedded in the nation's practicing foresters and transmitted through forestry schools and the formal forestry legislation. Ideally, the institutional constraint would limit removals so as to equal the long-term average gross domestic increment. The constraint would take effect through regulations and financial incentives aimed at forestry and the forest industry. But measurements of forest productivity are inaccurate, and knowledge of the long-term effects of various forestry practices is incomplete; it is difficult to steer wildly fluctuating annual removals toward the proper long-term averages, and impractical to police development in tens and thousands of forests. Consequently, the institutional constraint is not rigid and probably cannot compel production to exactly lie at the sustainable level. But, over the long term, harvesting excesses will be obvious, evoking new and more effective guidelines.

The economic constraint

The economic constraint encompasses all usable (given current industrial capacity to utilize uncommon fibre) fibre, regardless of type, dimension, and origin, that would have been delivered to industry at current prices <u>if there were no institutional constraint</u>. The economic constraint has a subjective character -- depending on suppliers' personal judgments as to what represents activity worth his time and effort. At any given time, their decisions could drive the rate of supply to exceed the current increment by many fold, but even without institutional constraints, forest owners would probably decide to preserve some of the forest stock as a hedge against future shortages in fibre production and revenue. It becomes profitable to harvest a larger geographical area when wood prices increase and more roads increase accessibility.

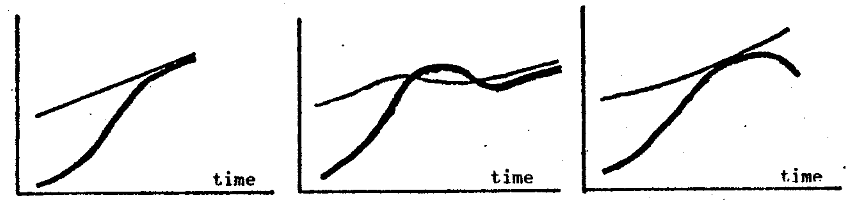
Physical constraints

The industry cannot cut more wood than is available in the current mature forest stock nor recycle more fibre than is available in suitable used materials. However, this physical constraint will not be approached, unless both the institutional and the economic constraints are inoperative.

I n s t a b i l i t y o r d e c l i n e ?

The relative dominance of the three constraints tends to vary over time with conditions in the forest sector. Normally, the institutional constraint is approximately equal to the sustainable fibre output. Its effect is felt more readily than the economic constraint, which in turn comes to bear before the physical constraint. This sequence of influences is understandable since institutional constraints have been established in essence to avoid arriving at the economic constraint. That is, without institutional regulation, it is normally profitable to remove most of the standing volume -- or becomes so as investments increase. But the development process over time can follow many paths.

The interaction of growth pressures and constraints, through a complicated web of causes and effects, is commonly expected to bring about the smooth transition sketched below (i). In this scenario, the industry is best served by expanding all the way to the institutional constraint, which instantaneously and successfully regulates industry to the sustainable level. But growth pres-



(i) smooth adjustment (ii) temporary overrun (iii) decline

——— sustainable fibre production

━━━ industrial capacity

sures tend to be strong and self-perpetuating; information is usually uncertain; and delays in observation and reaction are usually long. Consequently, the transition may well take the form of (ii), entailing a period of overexpansion before equilibrium is reached -- regulations becoming sufficiently effective to resist growth pressures only after the unambiguous documentation of overruns. Finally, regulation may be effective, but only by placing an unbearable strain on the industry - lowering profitability enough to bring about a decline in industrial capacity (iii). All three developments are possible, although smooth adjustment would normally be judged preferable, all else being equal. Policies designed to influence the transition behaviour ought to be guided by the answers to such questions as: What mechanisms amplify the tendency for overruns? What factors reduce the likelihood of industry survival at "constant" (sustainable) volume?

THE TRANSITION MODEL

Model structure

To obtain further insight into possible transition patterns, the views on structure and parameters embodied in the first three sections of this paper have been formalized into quantitative assumptions contained in a computer simulation model.[3] The intent is to depict possible forest industry development paths in an internally consistent way, not to predict in detail what will actually take place in the future. Consequently, although quantitative modeling techniques have been employed, the conclusions are qualitative.

The central model assumptions are: no wood imports, continued export of commodities, existence of economies of scale, and freely expanding competitors. The main chains of cause and effects implied by these assumptions are depicted in the causal loop diagram in Figure 9. The diagram represents the forces believed to underlie long-term trends in the Scandinavian forest sector.

Industrial capacity changes through the net effects of investment and closings. The rate of investment increases with past industry profitability, which generate an industry surplus and attract investors. Closings occur when plants are outdated or wood is unavailable. Profitability is determined by production costs (for processing and wood) relative to a sales price which equals the price-setting competitors' costs plus a mark-up that falls with increasing overcapacity in the market. Foreign competitors adjust their capacity according to market conditions, but are unaffected by wood constraints. The market for forest products is assumed to expand exponentially. The processing costs of the Scandinavian industry are affected by the average scale of production and by how well existing plants and product lines are adapted to current technological and market conditions. The average degree of adaption increases not only with new investments, but also with closings, which eliminate the least profitable

plants. Transfers from other domestic sectors, in such forms as easy credit, subsidies, and tax breaks, can sustain profitability in times of declining profits, while reverse transfers drain the industry in good times. Average plant scale follows optimal scale (determined abroad and assumed to increase exponentially) with a lag which is longer when there is popular resistance against large-scale facilities due to rapid centralization in the past. The number of production sites falls when capacity grows slower than the average scale.

Wood price, relative to the competitors, increases when a large fraction of existing fibre must be utilized because a bigger geographical range and broader selection of fibre qualities must be exploited. Wood price falls when the removal infrastructure grows. Investment in forestry increases with stumpage, which in turn moves parallel with return on investment in the industry. The recommended cut, representing the institutional constraint, equals gross increment plus a positive (negative) correction for too much (little) mature forest. The regrowth, natural decay, and age structure of the forest are determined by its history of removals (of mature forest), and by silvicultural activities (which increase the increment per hectare in young forests). Sector employment depends upon total production value and the exogenously determined wage level.

The model explicitly contains three expected reactions to increasing fibre scarcity: 1) increased silvicultural activity, 2) increased roundwood yield (representing increases in fibre utilization in forestry, in industrial fibre yield, and in reuse of paper), and 3) increased value added up to the maximum possible while remaining a commodity producer.

S i m u l a t i o n r u n s

The eight simulation runs in Figures 10 - 17, starting from the same initial conditions, but conducted with slight parameter differences reflecting real-world policy alternatives, illustrate the behavioural tendencies of the model system. The runs are also presented as hypothetical descriptions of the behaviour of the Scandinavian forest sector over a 150-year period.

Basic run

Run 1 (Figure 10) shows a mode where the initial phase of rapid expansion in industrial capacity I turns into a long period of slowly declining capacity, even though the wood supply is ample (the forest stock S increases monotonously). The industry stagnates when more intense utilization of the forest drives up the wood price W, paid by the forest industry, sufficiently to reduce the return on investment R until additions to capacity no longer exceed closings. Reduced investment activity also means an increasingly outdated industry relative to foreign competitors (indicated by the decline in relative scale of production l). As a result, costs will increase further relative to international market price and the initial decline in profitability will be accentuated. As capacity declines while the forest stock accumulates, wood becomes more abundant (gross increment G climbs steadily) and ultimately depresses wood prices enough to create the profitability, in spite of rundown machinery, necessary to spur a new growth period. In summary, Run 1 shows industrial stagnation and decline caused by timber prices that are too high for industry to meet in the long run.

Reduced timber prices

The obvious remedy is to reduce timber prices. Such a policy, feasible when the price is centrally negotiated, amounts to a reduction in stumpage. Run 2 (Figure 11) shows the result of a 20 per cent reduction in timber price. Following a spectacular growth phase, capacity peaks earlier and declines faster -- a result opposite to that intended. The "obvious" response does not succeed in the long run because the lower price also reduces investment in forest roads and other support facilities, thereby leaving a larger fraction of the fibre inaccessible at a given harvesting cost.

More accessible wood

The challenge of Run 1 is to make timber available at a given cost over the long run. One solution might be to have the government establish a sufficiently dense network of forest roads to make all wood accessible at acceptable harvesting costs. Run 3 (Figure 12) shows that the result is indeed an extended growth phase, but at the cost of a tremendous subsequent decline. The reason is that forest owners now gain by harvesting more than the gross increment G, which soon thereafter reduces the forest stock S and ensuing removals. In other words, the economic limit now exceeds the sustainable level. Expansion is still ultimately curbed and reversed by eccessive costs. But now the costs spring not from expensive harvesting, but from efforts to raise the roundwood yield Y as traditional sources of wood are fully committed. Cheap access to all forested land encourages a tendency for over-cut where institutional regulations cannot stop expansion at an early stage.

More transfers

A typical response to initial signs of falling profitability, capacity, and employment would be for industry to seek government support. Run 4 (Figure 13) shows how increased transfers T induce a further expansion and deeper subsequent decline than in Run 3 -- another result contrary to the intention. But transfers are often difficult to observe, when for instance they take the form of a tax reduction. Transfers both increase available funds and make the industry appear more healthy. They not only reduce bankruptcies and closings, but also facilitate continued investment and expansion. Furthermore, the recovery at the end of Run 4 is delayed because the society gradually removes its transfer-based support when conditions improve. Increased transfers tend to amplify instability by partly disguising the feedback signals concerning the wood situation.

Stricter regulation

The declining forest stock S in Runs 3 and 4 signified over-cut and insufficient regulation of expansion. Run 5 (Figure 14) shows the effect of a tighter institutional constraint. After an initial phase of rapid growth, a phase of rapid horizontal integration ensues as industry attempts to remain competitive while butting against the rigid institutional ceiling. In a third phase, the resulting opposition to rapid centralization (decline in number of production sites N) forces industry to delay closing oldfashioned plants. Simultaneously, the wood scarcity pushes industry toward greater reliance on non-traditional, more expensive fibre resources (roundwood yield Y increases). The total effect is several decades of gradually decreasing competitive strength (falling return on investment R), ending in an industrial decline which only halts when there is room for a new expansion wave. Strict regulation entails costs associated with slow growth which exceed what industry can manage in the long run.

Small scale technology

The decline in Run 5 is partly due to an inability to utilize plants as large as those operated by competitors. Run 6 (Figure 15) assumes a breakthrough in small-scale technology: the development of a small plant with lower processing costs than any other type of plant. All plants are now assumed to be built at this optimum small scale (relative scale 1 equals 1.0). Employment E remains the same, while the number of production sites N increases rapidly relative to the earlier runs, completely eliminating the distress induced by rapid centralization. The policy has the further advantages of postponing and softening the industry's decline (which is still brought about by the other costs of regulations), and enabling an earlier comeback in sector activity after the decline. The competitive small-scale technology reduces the severity of the decline instigated by a forced slow growth in industrial capacity.

Support to recycling and increased yield

The industry can also be assumed to overcome another cost of pressing against limits -- the extra expense of developing and operating effluent regeneration and paper-recycling programmes, thereby increasing the "roundwood yield" or the tonnage of final products obtained from each cubic meter of wood. Run 7 (Figure 16) shows the effect of shifting all extra costs of increased roundwood yield from industry to the government. As a result, the industry's decline is greatly reduced. The small dip in capacity around year 100 reflects a hole in the forest age structure -- a lack of mature forests -- caused by intense removals in the preceding 50-year period. However, the problem solves itself through the resulting ageing and accumulation when capacity temporarily drops below the maximum sustainable level.

More silviculture

The dip in Run 7 might be avoided by increased silvicultural activity as wood limits are approached. Run 8 (Figure 17) shows that the most prominent effect of the resulting higher gross increment G is to allow industry to repeat the pattern of Run 7 at a higher absolute level of production. The increased silvicultural activity simply moved the set of constraints outward, giving room for more of the same behaviour.

Relief of central assumptions

One model run costs 50 cents and takes two minutes. A virtually unlimited number of policy experiments are therefore possible. For instance, any of the current, central model assumptions of no imports, commodity production, export orientation, and freely expanding competitors could be dismissed just as the assumption of existing economies of scale was eliminated in Run 7. In general, the effect of removing any of the central assumptions would be to improve the long-term situation in the model, and presumably for the Scandinavian forest sector. However, completely eliminating all conditions leading to wood constraints must mean a corollary assumption of ever growing imports, or everlasting shifts to new, more valuable products, or an ability to sell the full production in domestic markets at cost plus a mark-up, or competition becoming subject to similar constraints on wood as the Scandinavian sector.

EPILOGUE

The objectives of our study are to attract attention to the coming "transition" from ample to scarce wood resources in the Scandinavian forest sector, to describe the different possible transition paths, and to highlight potential problems. Hopefully, the model described here embodies these aspects of Scandinavian forestry and the regional forest industry in an internally consistent way. The goal is to establish a holistic basis for the strategic decisions that will shape actual future development. Since the various societal groups with interest in the forest sector are not likely to agree on one "proper" response to the transition problem, our study does not seek one "optimal" strategy. Instead, the search is directed toward outlining the consequences of several strategies. Such insights would make a valuable addition to the basis upon which each interest group decides how to attain their respective goals.

Different people will draw different conclusions from our analysis. However, some general points must be agreed upon by all parties. The process of adjusting industrial capacity to gross increment tends to be unstable, and more so whenever the existence of constraints is not confronted squarely. The ability of industry to survive over the long term while expanding no faster than the gross increment itself, can be greatly enhanced by technological and organizational remedies, thereby stretching the potential slack over a longer period.

N O T E S

1. Terminology used in this paper: Fibre = raw material in any form for the forest products industry: roundwood, chips, dust, etc. Wood = fibre in the form of conventional roundwood. Forestry = the part of the domestic economy which produces fibre. Forest industry = the domestic producers of fibre-based products: sawnwood, pulp, fibre- and particle board, newsprint, paper and paperboard. Forest sector = the part of the economy involved in or affected by the production, processing, and sale of fibre-based products -- that is, forestry, the forest industry, their dependents, conservation groups, part of the government, part of the research establishment, etc. Competitors = the forest industries of foreign nations that compete with the domestic forest industry in international commodity markets. Production volume = the aggregate physical output of the forest industry, measured in metric tons of dry weight, not in value. 1 cubic metre of sawn products is registered as .5 tons. Production scale = the output per production site, measured in tons per year.

2. This paper provides a preliminary summary of a six person year project entitled "Society and Forest" sponsored by the Norwegian and Swedish technical research councils (NTNF and STU) to study the utility of the system dynamics approach for analyzing social problems. The problem definition and model analysis are largely based on the collective experience of three eight-person discussion groups, recruited from the Scandinavian forest sector, which met extensively throughout the project in Oslo, Stockholm, and Helsinki. Since the paper covers a wide area in a few pages, it is necessarily more assertive and less carefully defended than desirable. More information about the project is available from the Resource Policy Group, Gaustadalléen 30, Oslo 3, Norway.

3. The formal model is a state-determined set of highly non linear differential equations that are solved through numerical integration from a given initial state. The model is written in DYNAMO.

A C K N O W L E D G E M E N T

Without the support and help of my friends Lennart Stenberg, Kjell Kalgraf, Westye Egeberg, and Bente Jones during many years, this paper could not have been written.

Oslo, September 8, 1976

JR/bj

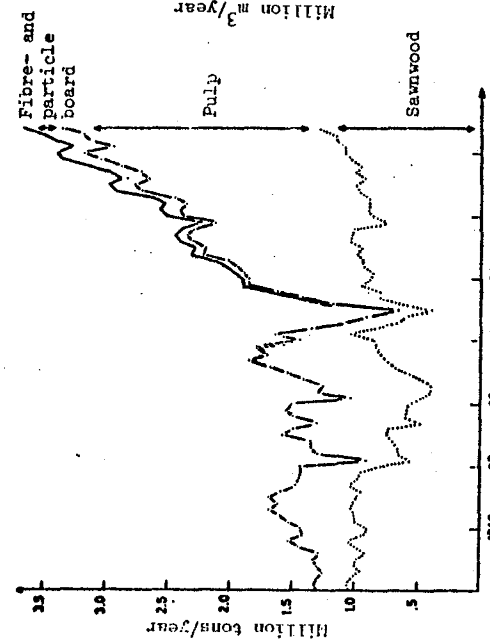


Figure 1. Forest industry production. Norway 1900-1974.

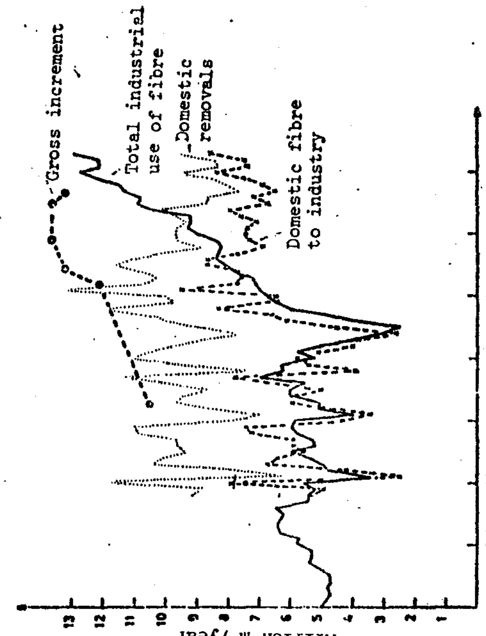


Figure 2. Wood resource development. Norway 1900-1973.

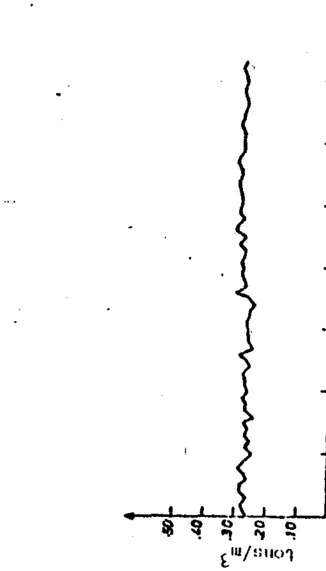


Figure 3. "Roundwood yield" (defined as total production of sawnwood, pulp, fibre- and particle board divided by total industrial use of wood). Norway 1900-1973.

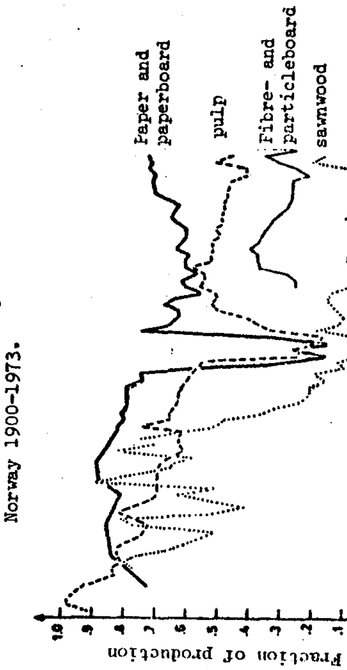


Figure 4. Forest industry exports. Norway 1900-1974.

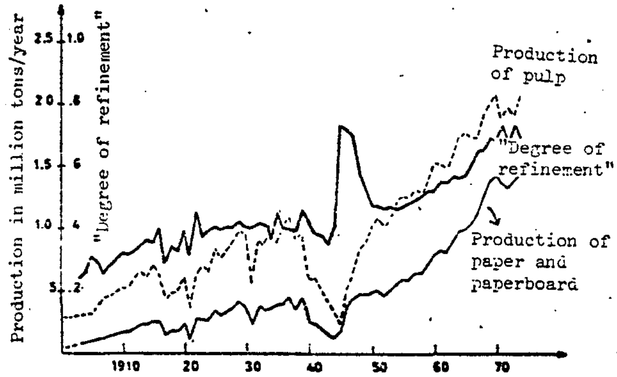


Figure 5. "Degree of refinement" (defined as production of paper and paperboard divided by production of pulp) in the pulp and paper industry. Norway 1900-1974.

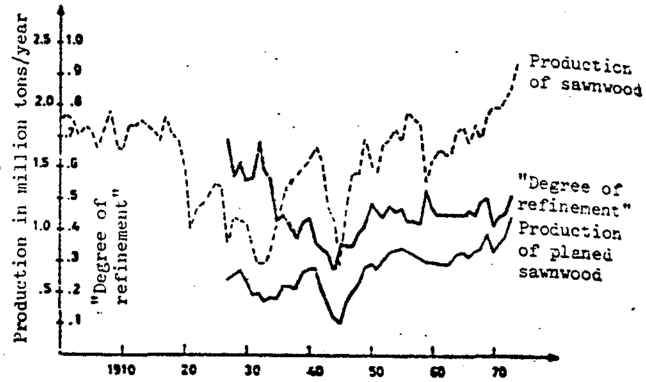
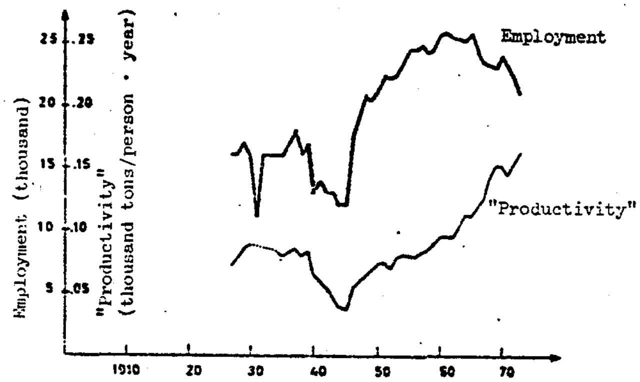


Figure 6. "Degree of refinement" (defined as production of planed sawnwood divided by production of sawnwood) in sawmilling. Norway 1900-1973.



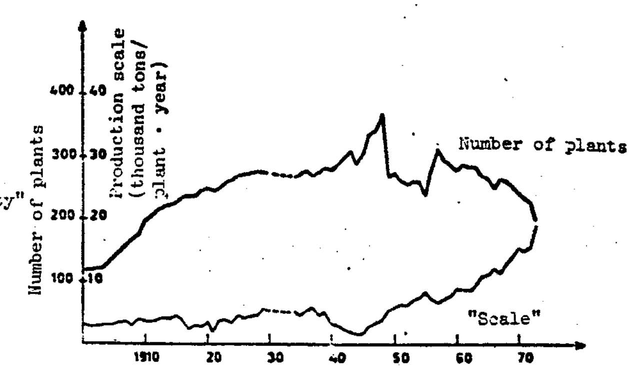


Figure 7. Number of production sites and "average scale" (defined as production of pulp, paper, and peperboard divided by number of plants) in the pulp and paper industry. Norway 1900-1973.

Figure 8. Employment and "productivity" (defined as production of pulp, paper, and paperboard divided by employment) in the pulp and paper industry. Norway 1900-1973.

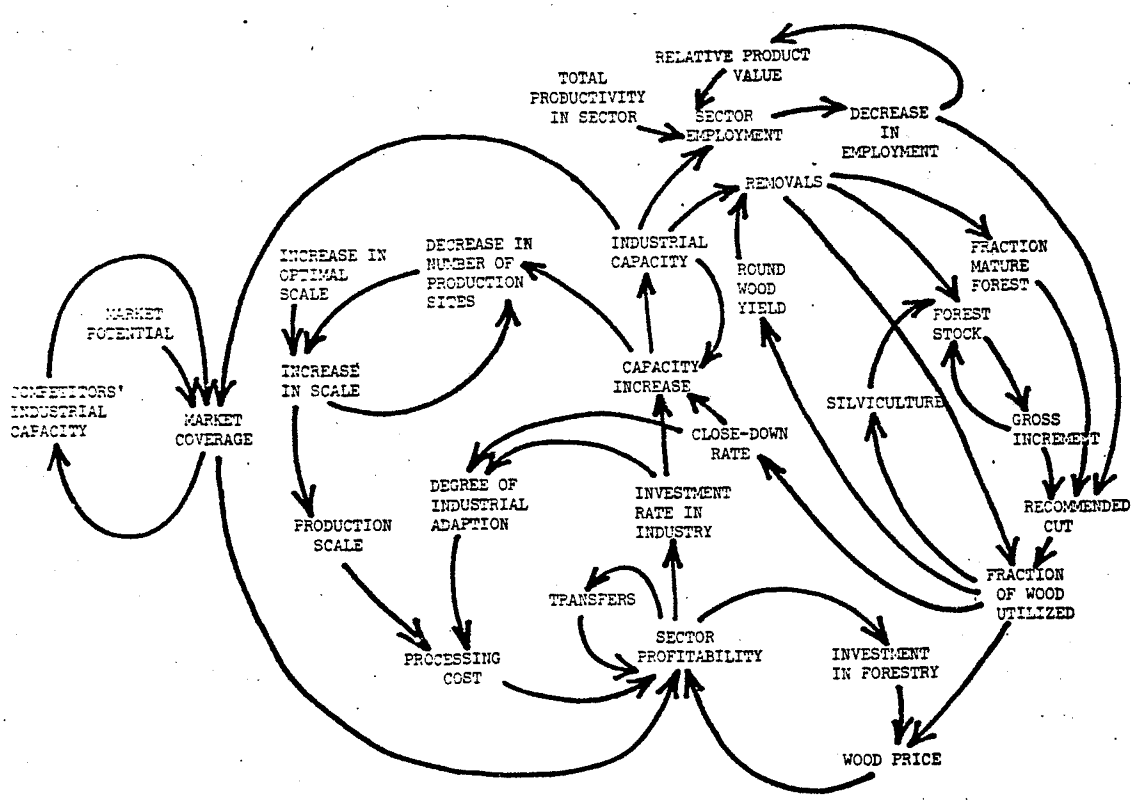


Figure 9. Causal structure.

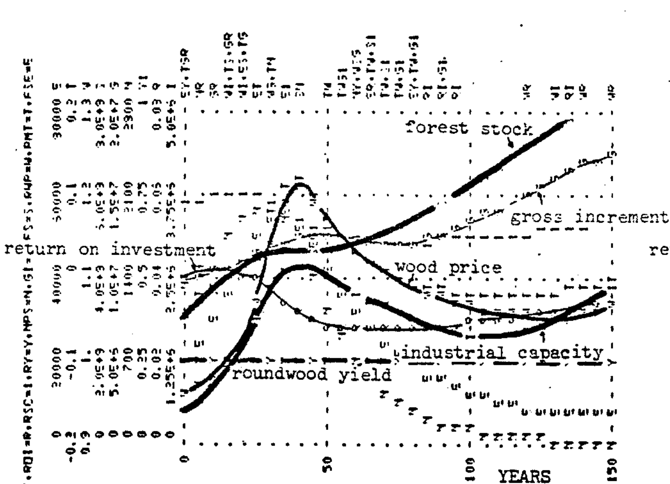


Figure 10. Run 1: Basic.

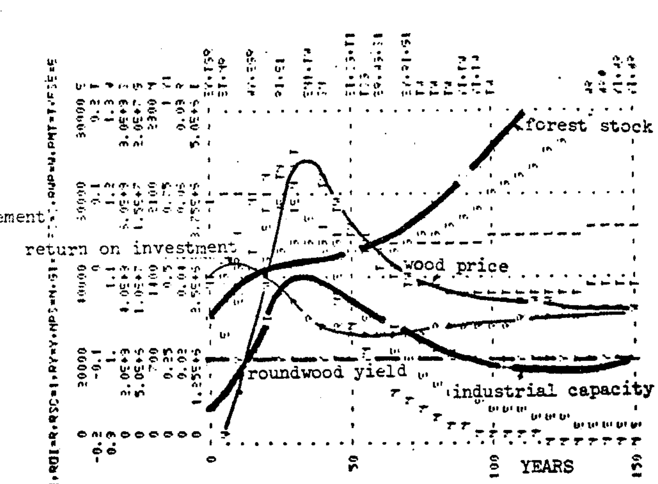


Figure 11. Run 2: Reduced timber price.

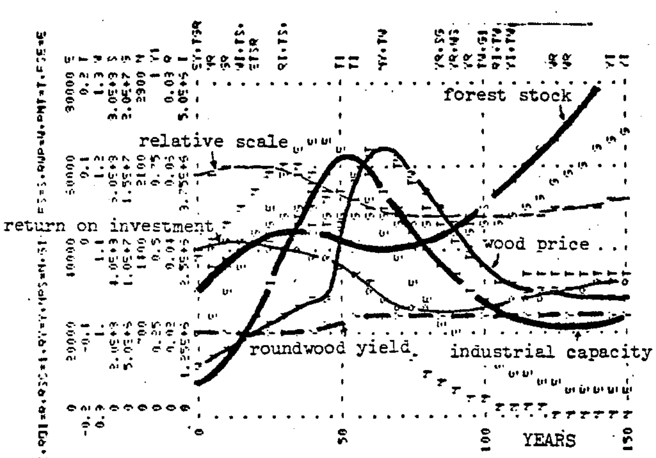


Figure 12. Run 3: More accessible wood.

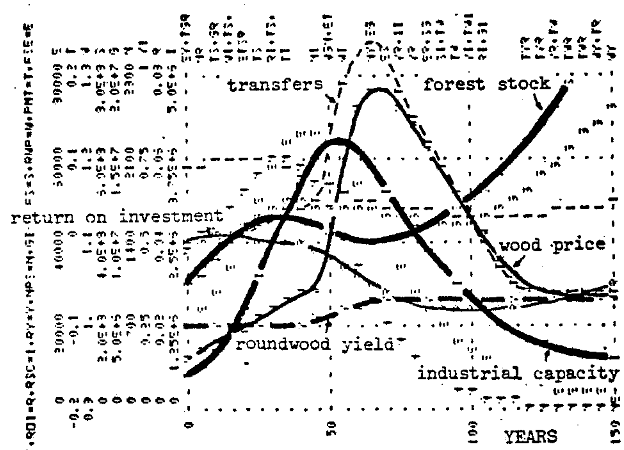


Figure 13. Run 4: Accessible wood, more transfers.

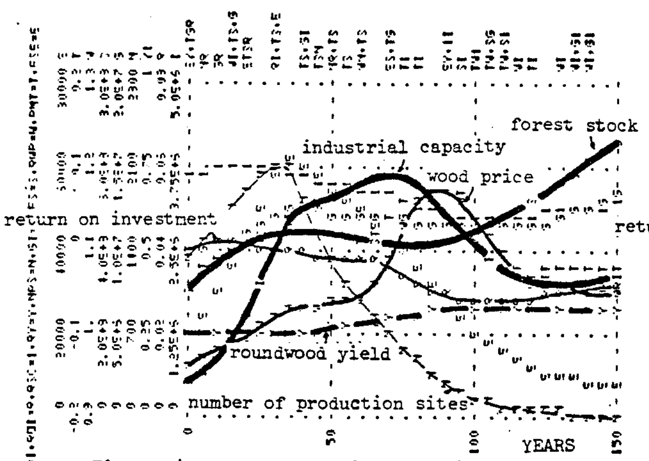


Figure 14. Run 5: Accessible wood, stricter regulation.

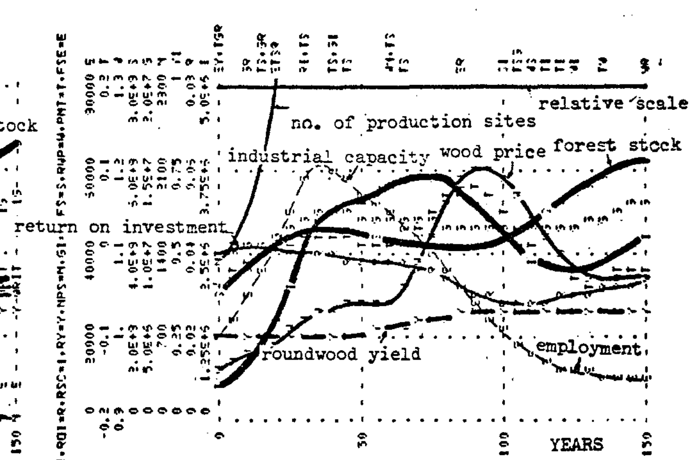


Figure 15. Run 6: As run 5, plus elimination of economies of scale through small technology.

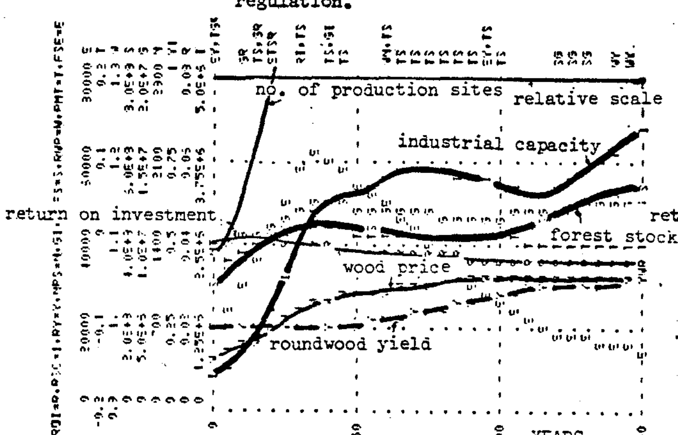


Figure 16. Run 7: As run 6, plus support to increased recycling and industrial yield.

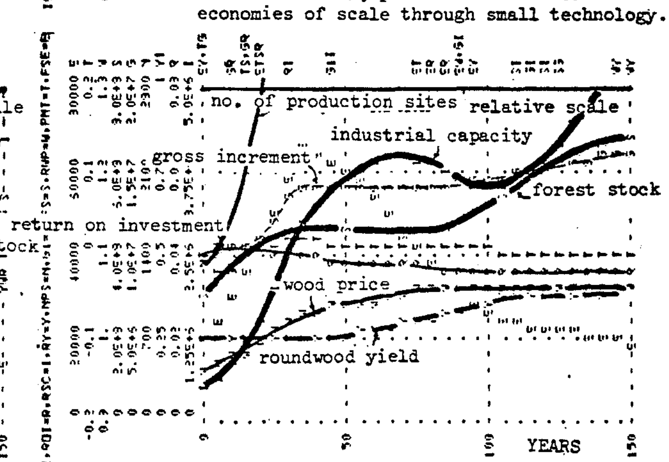


Figure 17. Run 8: As run 7, plus intensified primary production.