PREDICTION OF PULP PRICES - A REVIEW TWO YEARS AFTER

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ABSTRACT

During the summer of 1982 the author made predictions of wood pulp prices for the period 1982 to 1986. The predictions were part of a decision on whether to sell a large pulping plant in Norway. This paper presents the predictions and the basis on which they were made. Next, the predictions are compared with actual data for the period 1982 to 1984.

The price predictions were based on the assumption that the international market for wood pulp is characterized by inventory cycle theory. According to this theory price oscillates with a 3-6 year wavelength primarily caused by the "production rate --> inventory --> production rate" loop.

This paper reviews the existing literature on inventory cycles, and extends the theoretical work to cover inventory oscillations at the industry level in some detail.

The resulting theory turns out to be supported by time series of quarterly data for international pulp production, pulp inventories and pulp prices over the 25 years prior to 1982.

The time series for pulp price, once corrected for inflation, demonstrate a clear 5-year fluctuation around an exponentially declining trend. The declining trend is probably due to technical advance in the production of wood pulp. The 5-year cycle is even more conspicuous in inventory statistics.

The price predictions were made by assuming:

i) continued technical advance - i.e. a continuation of the exponentially declining trend in prices

ii) continued inventory fluctuation - i.e. a continuation of the 5-year oscillation in prices around the trend.

Comparison with actual data demonstrates that this (simple) method of prediction yields good results. Interestingly, the unavoidable noise (due to random, unpredictable events in the market) appears too weak to hide the systematic features in the development of prices on which this method depend.

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PREDICTION OF WOOD PULP PRICES - A REVIEW TWO YEARS AFTER

1. INTRODUCTION

INVENTORY CYCLE THEORY

Inventory cycles is an old topic in the system dynamics literature. Periodical fluctuations in production, inventories and price are frequently observed in the economy, and have attracted the interest of system dynamicists since Forrester's original work on 3 to 6 year long cycles at the company level (Forrester, 1961).

Cycles of a 3 to 6 year wavelength can be observed both at the company, industry and economy level. In order to observe the cycles, one does need a longer time horizon than is common in economic affairs. To observe a pattern of waves where each wave is 3 to 6 years one must have knowledge of, or time series for, a period of at least 10 to 15 years. Further, yearly data is insufficient, - because they only give 3 to 6 observations per wave. Quarterly data, at the least, are necessary. Because of these reasons, inventory cycles are hard to observe and hence much less recognized than should be expected, given their prevalence.

Still, inventory cycles have been given extensive treatment in the system dynamics literature. Common to these treatments is

the belief that inventory cycles are endogenously generated; they are not seen as the result of some exogenous rhytmic driving force (like sun spots, wars, or parliamentary decisions). In his original work in Industrial Dynamics (Forrester, 1961) demonstrated how decision rules (policies) in the company cause regular fluctuations in the level of activity with a wavelength of some years. The interesting point is that fluctuations arise from policies that are common to most manufacturing businesses. Forrester shows that the common tendency to fill orders in proportion to the size of the order backlog - or equivalently to increase the utilization of installed capacity when there is a small inventory of finished goods - is sufficient to generate cyclicality when the company operates in an environment characterized by noise (e.g. random variations in demand, delivery delays, input prices or the like). The central role of order bakclogs - or product inventories - in this process is the basis for the name "inventory cycles".

The theme of inventory cycles was picked up by Meadows (Meadows, 1970) at the industry level in his study of the U.S. pork industry. Of course the cyclicality of the hog industry had been known for decades (see (Ezekiel, 1938) for the classic expositon) and commonly been used as an example of the cobweb theorem in textbook micro-economics. However, Meadows did describe the detailed decision process of the farmer. He demonstrated how "rational" decisions by individual farmers concerning breeding and slaughtering of pigs, add up to strong and unintended fluctuations in the industry, with periods of boom and depression following each other in endless succession.

Meadows' work was extended by Naill et al. (Naill,1973) who made the ties to the real world of the hog industry more obvious by by incorporating exogenous effects - like seasonality in the final demand for pork.

A weakness of all studies this far was a lack of statistical evidence of the inventory cycle. The studies were based on scant, if any, time series illustrating cycles in past developments. High quality time series were not published until 1979 (Høsteland, 1979); not for the hog industry, but for the Norwegian sulphite pulp industry. Høsteland gave a lucid illustration of the reality of inventory cycles (see figure 1 a) showing waves in production, sales, inventory and price over a 20 year period. The variables did interact in a pattern that was easy to understand in terms of the mechanisms described by earlier authors: Prices are slowly reduced when inventories are large. Production does respond to prices, and ultimately production rates are reduced below sales. Inventories start to contract. Production is not increased again, however, untill inventories fall so low that prices pushed upwards by worried customers - signal a new period of and boom in the industry.

Høsteland stressed - as did Majani and Makridakis (Majani and Makridakis, 1977) in an independent analysis outside the system dynamics tradition - the need to smooth the weekly or monthly data that is commonly used in the industry. Noise in the data obscures cyclical trends in production and sales and may explain the very slow adjustment towards market equilibrium. Production and sales statistics are so noisy that industry decision makers hardly can be expected to discover new market trends untill much time has passed.

At the same time, Randers (Randers, 1978) published several other indications of the 3 to 6 year cycle. He distinguished the

short inventory cycle from other periodicities that can be observed. He argued that the 3 to 6 year cycles in various industries are sufficiently strongly coupled to move in phase, and add up to "the business cycle" at the national level.

Another excellent illustration of the 3 to 6 year cycle at the industry level was assembled by Antun (Antun, 1981) in his study of the ferro alloy industry of Norway (see figure 1 b).

Outside the system dynamics tradition, the 3 to 6 year cycle at the level of the economy is probably best known as "the business cycle". The business cycle is rarely viewed as an endogenous phenomenom. This is, however, the perspective of the first system dynamics study of the 3 to 6 year cycle at the level of the economy by Mass (Mass, 1975). Mass' study can be seen as a further generalization of the inventory cycle studies at the company and industry levels. Mass defends the view that the 3 to 6 year fluctuation in the economy is rooted in adjustments in the use of labor (and not, as is more often hypothesized, in the use of capital). He argues that the adjustment of production rates to sales in the short run takes place primarily through adjustments in the utilization of existing capital, by alteration of such factors as the number of shifts, the average length of the work week, the extent of temporary layoffs etc. Furthermore, he argues that these adjustments are the primary cause of the short term business cycle.

Finally, it is worth mentioning the work of Low (Low, 1980), where he tries to bridge the gap between the system dynamics perspective on the short term business cycle and the more conventional macroeconomic perspective on economic dynamics. Starting with a simple Keynesian multiplier-accelerator model Low makes the fewest possible extensions to make the model dynamically complete. He shows that 3 to 6 year cycles do arise in the extended model, caused by variations in the utilization of the existing capital stock. Forrester (Forrester, 1982), using advanced mathematical techniques, has extended Low's work, adding much support to the hypothesis that adjustments in capital utilization, rather than variations in capital investment rates, is the prime force behind the short term business cycle.

PURPOSE OF THIS PAPER

One purpose of this paper is to present a detailed theory of inventory cycles at the industry level, using sulphate pulp as the example.

Another purpose is to fill in a missing piece in the line of work that was discussed above: Statistical work supporting the existence of the inventory cycle at the industry level - in an international perspective. This far, statistical work on inventory cycles has been restricted to one nation, in spite of the fact that available inventories probably impact on the level of prices, and on industry optimism and production rates, regardless of where the stocks are held. In this paper the sulphate pulp industry is seen in an international perspective. The sulphate pulp industry is ideally suited for the study of inventory cycles, because sulphate pulp is a stable, homogenous commodity that has been produced and traded internationally for several decades. The industry is dominated

by Canada, USA, Sweden, Finland and Norway. Statistical time series are gathered for these 5 nations covering the last 25 years.

A third purpose of the paper is to try and exploit the opportunity to use inventory cycles for the purpose of predicting future developments. One such prediction of future price was made in 1982. The method of prediction is described and the result compared with actual developments over the ensuing two years (i.e. the period 1982 to 1984).

2. THEORETICAL EXTENSION

BASIC MECHANISMS

Based on the work of the various authors described in section 1, it is possible to propose the following view of inventory cycles at the industry level, and their underlying causes. This view - or theory - forms the fundamental hypothesis which the present paper seeks to test. The sulphate pulp industry is used as an example.

The prime characteristic of the 3 to 6 year cycle is the following: in periods when inventories are larger than normal, prices tend to fall. When inventories are lower than normal, prices tend to increase.

This relation between inventories and price is easily understandable. Both buyers and sellers know when there is much pulp in the market, and buyers understandably use the opportunity to negotiate prices. Oppositely, when inventories are depleted, containing enough pulp only to cover demand for a short period of time, producers see a possibility to increase prices. And buyers have to follow suit, for fear of not being able to feed a continuous stream of pulp to their paper machines.

But depleted inventories and high prices furthermore tempt pulp producers to increase production rates. Ultimately production rates exceed sales, and inventories once more begin to accumulate. Inversely, production rates have to be lowered when inventories exceed storage capacity, or when prices fall below production costs.

The link between inventory size and production rate closes the

negative feedback loop portrayed in figure 2. This loop is hypothesized as the basic mechanism behind the 3 to 6 year inventory cycle at the industry level.

To some observers the wavelength of the inventory cycle appears surprisingly long. Many find it hard to believe that the "inventory-production rate"-loop is capable of generating waves measuring 3 to 6 years between peaks. The explanation rests with the many delays in the pattern of behavior over one cycle. When inventories are swelling and prices start to fall, producers start to reduce production rates. The process, however, takes time. First of all inventory statistics have to be gathered, not only nationally, but internationally. Statistical evidence and industry gossip have to convince management that the ongoing inventory buildup is not only temporary. Falling prices in the spot market adds weight to gossip, but even faced with falling prices management often hesitate, hoping for a imminent reversal of negative trends. But as inventories continue to accumulate, there is finally no way around the bitter decision to change production plans, reduce the labor force (or at last the hours worked), - i.e. to reduce utilization of installed capacity.

This lengthy process of adjustment takes place in all pulp producing companies more or less simultaneously, given that they all respond to the same signal: international price and inventory levels. As a result, aggregate production of pulp finally falls below aggregate consumption of pulp, and inventories of finished pulp start to contract.

With time inventories decrease so much that pulp buyers no longer feel certain that there will continue to be a surplus of readily available pulp. They increase their orders, securing raw materials for additional days of production - "just in case". As a consequence there appears a stronger tendency in the market, and prices stabilize. Given the higher demand for pulp, existing inventories appear smaller (inventory "size" is best expressed as the number of weeks of sales that can be supported by the inventory). As inventory coverage declines, buyers become increasingly worried about insufficient availability. Orders are increased, and with time buyers also become willing to pay higher prices to secure deliveries.

It takes more time, however, before increasing sales force pulp producers to up their production rates. After some months, however, producers' inventories are sufficiently depleted that plans must be made to increase production rates. Implementing the plans also requires time, however, and before production actually exceeds sales, pulp inventories have become miniscule, the market hectic, and prices are forced upwards. The "good times" lure the pulp companies to maintain high production rates, and as a consequence, inventories once more start to accumulate. Gradually inventories build to "normal" levels, prices stagnate, and the industry is back to where it started some years earlier. It takes time, however, before growing inventories actually cause a new decline in prices. But finally price drops occur, first in the real price adjusted for inflation and later even in the nominal price per ton. This closes the cycle, and the pattern of behavior repeats itself.

Experience shows that one full inventory cycle last between 3 and 6 years. Roughly speaking, it takes a first year of low production rates to reduce inventories from their peak to "normal"

levels. Then it takes a second year while inventories continue to decline, before prices increase sufficiently to call forth production rates that exceed sales. Next, it takes a third year of high production rates to move inventories back up to "normal" levels. And, finally, a fourth year before steadily increasing inventories do result in price declines which in turn force producers to reduce their capacity utilization, thereby halting the accumulation of inventories.

The reference mode is summarized in figure 3.

ELABORATION

The theory of the inventory cycle at the industry level described above, can be supplemented with the following hypotheses:

1. The price of pulp will be influenced by the total, international inventory of pulp. Pulp is reasonably simple to transport. Hence, prices will not increase much if, say, Norwegian inventories are depleted, as long as foreign producers (or consumers) have bulging inventories.

2. Producers will tend to give discounts to get rid of pulp when their inventories are swelling. Consequently, achieved price is not the same as listed price. The price actually received by producers is lower than listed price (the formally agreed price quotations) when the market is falling. Conversely, when pulp is scarce, suppliers may well charge above the listed

price of the industry.

3. The minimum level of prices in the 3 to 6 year cycle will be related to variable costs of production in those plants that still operate at the bottom of the price cycle. In fact, the great majority of pulping plants are still operating when prices are at their lowest. The pulp industry is a "cyclical" industry. Still, it is primarily inventories and, hence, prices, that fluctuate significantly during the cycle. Production rates tend to be more stable, moving perhaps 15% above and below the long term average. In other words, capacity utilization varies between approximately 70 and 100%. As a consequence, the lowest price in the price cycle must be related to the lowest price for which a majority of producers are still willing to produce. This minimum price is probably linked to an average of variable production costs in the majority of existing plants.

   Plants that have economic difficulties during price troughs include the oldest plants (having high variable costs due to oldfashioned technological standard) and the newest plants (having high capital costs because of high debt loads compared with industry average).

4. The price peaks have no relation to production costs. The maximum price reached during the cycle is determined by the scarcity of pulp when inventories are low. The extent to which

pulp becomes a scarce - and hence highly valued - commodity during inventory lows depends on unpredictable, random events like transient production problems, strikes, shortages of raw materials or other inputs, transportation bottlenecks, temporary surges in demand and so on. The occurence of such events are impossible to predict, as is the maximum price level they will generate. However, random events like those mentioned have strong effects when inventories are low, even though they would not have been noticeable if inventories were large.

5. Business cycling in the sectors that consume pulp - primarily paper, newsprint and cardboard production - tends to amplify the inventory cycle. The business cycle produces an exogenous 3 to 6 year wavelength in the consumption of pulp. This exogenous driving force will tend to resonate with the "inventory --> production rate"-loop, to generate stronger cycles.

3. MEASUREMENT OF PAST DEVELOPMENTS

PROCEDURE

In order to test the theory and the various hypotheses presented in section 2, time series data were collected for the bleached sulphate pulp industry, covering the period 1957 to 1984. 1) Quarterly data were collected for production, inventories and listed price, covering Canada, United States, Sweden, Finland and Norway. These countries are the major producers of bleached sulphate pulp in the Western world and completely dominate the international trade in this commodity. Their relative size is indicated by the following production figures for 1980.

	Production (mill.tons/year)	Market share
Canada	6.0	44
USA	4.0	29
Sweden	2.1	15
Finland	1.5	11
Norway	0.1	1
Sum "NORSCAN"	13.7	100

Over the last 25 years the ranking has remained as in the table, but the relative importance of Sweden and Norway has decreased.

1) Data were collected in 1982 for the period 1957 to 1982, and updated in 1984.

Canada, Sweden and Finland are the large exporters: Canada covers the US deficit; and Sweden and Finland sell to the European markets. During market down turns, North America typically tries to sell excess pulp in European markets.

To arrive at time series for total production rate in the "NORSCAN" countries (see figure 4), monthly production data for the five producers were added up to quarterly production figures. These in turn were multiplied by 4 to arrive at production rates expressed in million tons per year. As can be seen from figure 4, production grew fast until 1970, and somewhat slower in the following decade. Fluctuations around the long term trend were severe, particularly during the period of slower growth.

The time series for total inventories (see figure 5) include bleached sulphate pulp held by producers. The plot shows the sum of inventories in the five producer countries at the end of each quarter. No smoothing has been applied to the data. As can be seen from figure 5, inventories have fluctuated strongly over the last 25 years - with a wavelength of some 5 years. This regularity is more obvious when inventories are expressed as a number of days (i.e. measured as the number of days it would take to produce the amount of pulp held in inventory). To arrive at time series for this variable (see figure 6), total inventory at the end of each quarter (from figure 5) was divided by the production rate of that quarter (from figure 4), and the result multiplied by 365 days/year.

Finally, time series for the price of bleached sulphate pulp were gathered (see figure 7). First the quarterly listed price (in British £ per ton from 1950 through 1969, and in US $ per ton from

1970 on) was converted into Norwegian kroner per ton using quarterly averages for the exchange rate between £, $ and kroner. Then the Norwegian consumer price index at the end of each quarter was used to convert the series into constant 1979-kroner per ton of pulp. As can be seen from figure 7, the price of pulp has fallen gradually since 1950, with prices fluctuating around the long term trend. Figure 7 represents "international" prices as they appear from the point of view of an Norwegian exporter of pulp.

The starting point for figures 4 through 7 were industrial branch statistics obtained from the forest products industry.

DISCUSSION

In general figures 4 through 7 support the theoretical perspective and many of the hypotheses presented in section 2.

Starting with the general theory of the inventory cycle, over the last 25 years the sulphate pulp industry has been strongly cyclical. The cycle can be most clearly seen in inventory statistics, and can also be traced in price devleopments. The cycle is much harder to see in time series for the production rate. The phase relationship between the variables are as expected: Prices increase when inventories are below "normal" levels, and prices fall when inventories are above "normal". "Normal" appears to be between 3 and 4 weeks of coverage. The phase relations of the production rate is more complex, and is discussed below.

Although these conclusions follow easily from figures 4 to 7, they are not at all apparent in most time series describing the

industry. In order to display the desired results, time series must be sufficiently long to cover several wavelengths of the inventory cycle. Less than 12 years of data will not suffice. Secondly, yearly data are too coarse to portray a 3 to 6 year cycle: at least quarterly data are necessary. On the other hand, excessive resolution in time also disguises the inventory cycle. If monthly or, worse, weekly data are used, the 3 to 6 year periodicity is hard to see because of seasonal effects and noise. Thirdly, current prices can not be used because general price inflation hides both the downward trend and the 3 to 6 year cycle in prices. Fourthly, the data must cover a sufficiently large fraction of the total market. Individual country (or producer) inventories often move out of phace with the total, and hence may not be a good indicator of total inventories.

Next, figures 4 through 7 seem to support the following conclusions:

1. <u>There is a clear inventory cycle in the bleached sulphate pulp industry</u>. The cycle is most easily observable in time series for total inventories, but can be perceived in series for real price as well. The best indicator seems to be total inventory expressed in days (see figure 6).

2. <u>If one number has to be picked, the inventory cycle in bleached sulphate pulp should be described as a "5" year cycle</u>. The wavelength of the cycle apppears to have increased somewhat over the 25 years since 1957. Inventories have fluctuated with a clear 5 year wavelength since 1968. Prices have

followed the same cycle from 1958 or, possibly, 1953.

3. Inventories appear to cycle around a "normal" value of some 3 to 4 weeks of production. The total inventory held by producers rarely falls below 2 weeks. Maximum values of 5 weeks are common, and peaks of 10 weeks have been observed. Since 1970 inventories have fluctuated around a "normal" value of some 3 to 4 weeks, from troughs of 2 weeks to peaks of 7 weeks.

4. Inventory trough values vary less than inventory peak values. The decline in inventories are halted when the producers find it necessary to boost production rates above sales. This decision appears to be triggered simultaneously in all producing companies once inventory coverage falls towards two weeks.

Inventory peak values, on the other hand, are determined by a large number of independent factors. The extent to which producers are willing to hold large inventories is influenced by expectations about future sales, by interest rates, by current social attitudes towards lay-offs, by available storage space and so on. Even less predictable was the state subsidy "for extraordinary inventory accumulation" that was offered in the three Scandinavian countries during the middle 1970's (in order to avoid lay-offs in the pulp industry). The subsidy covered much of the interest cost of inventories and probably contributed significantly to the large inventory peak in 1975-77. The subsidy was discontinued in 1977.

5. The long term trend in the price of bleached sulphate pulp in constant dollars per ton) appears to be falling at a rate of 2 % per year. During the last decades, the long term trend in the price of pulp has sunk at a rate of approximately 2% per year. This is probably because of increased plant size, cheaper raw material and general increases in productivity. As a consequence, the minimum price in one cycle may be up to 10% below the minimum price of the preceding cycle. The rate of decline in the long term trend appears to be slower during periods of low growth in capacity, i.e. when few new plants come on stream.

6. There is a "5"-year cycle in the real price of pulp around its long term trend. As for inventories the wavelength varies somewhat over time, but 5 years is a fair approximation if one number has to picked. Price troughs have been 3 - 16% below the long term trend, with an average of 11%.

7. The peaks in pulp prices lie 3 - 43% above the minimum price of the preceding cycle, with an average of 19%. The exception was the boom of 1951, when the real price of pulp peaked more than 100% above the preceding minimum.

8. The price of pulp moves 90° ahead of inventory in the cycle. The time series show that prices increase when inventories are higher than normal. More precisely, inventories have to fall

below 3 to 4 weeks of coverage before the industry increases the listed price (in real terms). And conversely, inventories have to grow beyond 3 to 4 weeks before the listed real price actually is reduced in real terms. The result is that the price wave lies 90° (or 1.25 years) ahead of the inventory wave.

9. The listed price appears to lag behind the achieved price. Even though it takes time before the listed price is reduced, spot price and company income may well decline rapidly when inventories start to accumulate. Most likely producers are willing to give discounts (in order to get rid of excess pulp) long before the listed price is lowered through formal agreements. Conversely, spot prices and company income may well increase faster than listed price, when inventories are depleted and pulp is getting scarce.

This conclusion does not follow directly from figures 4 through 7, since we have no time series for achieved price, only for listed price. The conclusion is supported, however, by common sense and by Høsteland's data (see figure 1). His data indicate that the achieved price responds rapidly to inventory changes. Listed price may lag half a year behind achieved price.

10. The level of price peaks are less predictable than the level of price troughs. The peak value of prices is determined by the pressure in the market at the time of minimum inventories. Accidental shortages may send prices soaring - at least the

the pressure in the market at the time of minimum inventories. Accidental shortages may send prices soaring - at least the spot price, but even the listed price if supply problems endure. The price minima develop in a more predictable fashion, probably due to their relation to the slowly decreasing real costs of production in the industry. Achieved prices (spot prices corrected for discounts and expressed in local currency) probably reflect actual production costs when inventories bulge. In periods of excess inventories, pulp buyers find it easier to press prices towards the producer's variable costs. Producer costs are typically expenditures in local currency. Thus a Norwegian seller may well have to accept a $ price below the listed $ price in times when high exchange rates give him a larger amount of kroner per $.

11. Pulp sales appear to move 180° behind inventories in the cycle. In other words, pulp sales are large when inventories are small and vice versa. This conclusion is derived by combining the inventory statistics (figure 5) and the production figures (figure 4). This indirect method is used, since data for pulp sales are not available. From pure logics it follows that if inventories grow (fall), sales must be lower (higher) than the production rate. Applying this algorithm, one obtains the rough outline of historial sales shown in figure 8. As can be seen by comparing figures 6 and 8, low (high) sales coincide with high (low) inventories. This conclusion is also corroborated by Høsteland's data (figure 1).

But why should sales be large when producers' inventories are small? And vice versa? The likely explanation is that both producers' and consumers' inventories are large at the same time. Throughout the period of excessive production, not only producers', but also consumers' inventories gradually fill. The result is a non-causal, but strong, correlation between large producers' inventories and small sales. Because large inventories also coincide with falling prices, one has the surprising conclusion (at least in theoretical micro economics) that sales are small when prices are falling. And conversely, booming sales coexist with increasing prices at other points in the inventory cycle. Thus consumers will need less pulp (because their inventories are full) just when the producers would want to sell more pulp (because their inventories are full).

12. The pulp production rate can best be viewed as a lagged version of pulp sales. There is no simple phase relation between the production rate on the one hand and inventory or price on the other. Production rates tend to be high when inventories are below normal and when prices are above the trend. But neither relationship is unambiguous.

It is better to view pulp production as a lagged version of pulp sales, with a lag of some 6 to 12 months. This conclusion is also supported by Høsteland's data (figure 1). This relation of sales to production is caused by the coupling through producers' inventory, which is kept within rather strict limits.

13. The Norwegian sulphite pulp industry and the international sulphate pulp industry move in phase. There is an extraordinary degree of correlation between Norwegian sulphite pulp inventories (in figure 1) and NORSCAN sulphate pulp inventories (in figure 5). The degree of covariation is all the more surprising given the vast differences between the two products, the two producer groups and the tonnages involved. The covariation in prices is not less impressive. This is but another example of the fact that the 3 to 6 year inventory cycle in most industries are in phase, presumably because increases in production rates in one sector require output from other sectors. Bullish tendencies tend to spread throughout the economy, as do bearish (Randers, 1978).

The foregoing results and conclusions concerning past developments in the sulphate pulp industry are summarized in figures 9 and 10.

Figure 9 portrays the phase relationships that appear to exist between central variables in the inventory cycle. The figure should be viewed as an extension of figure 3. Two important perspectives follow from figure 9:

i) Production can be seen as a lagged version of sales. When sales fall, production is pulled after - because the two are couped through inventories. Inventories would grow out of hand if production were not stopped. When sales increase, production must follow, lest inventories shall be depleted. In short: production rates are primarily governed by inventory size.

ii) Price does have some effect, however. Higher prices cause production to increase, but only <u>relative</u> to sales. If sales are declining of other reasons, production may fall even when prices are growing.

Figure 10 portrays the system structure that appears to underlie the inventory cycle at the industry level. The structure deviates from the structures proposed by earlier authors (Meadows, Høsteland, Antun) in that production and sales depend more on inventory size and less on price. The conclusion is derived primarily from the phase relationships in the time series data reviewed (sulphite pulp, ferro silicon, sulphate pulp). These phase relationships are not easily explained by the traditional structures. The proposed structure does, however, require for the study.

4. PREDICTION OF FUTURE DEVELOPMENTS

PROCEDURE

Prediction of future price is of great interest to decision makers in the pulp industry. Production plans, sales strategy, and investment policy - all depend on opinions about the future price of pulp.

Scientifically speaking, price prediction in socio-economic systems is often impossible, except with wide margins of uncertainty. The system structure and the amount of noise often cause enough uncertainty in the forecast to make it useless for practical purposes. (This of course does not exclude the possibility of doing crystal ball guesswork - <u>without</u> indication of the margin of uncertainty).

The preceding sections reveal that the sulphate pulp industry is characterized by a system structure and a level of noise which make useful price predictions possible on a 1 - 5 year time horizon. The system structure creates a stable inventory cycle with a 5 year wavelength in inventories and price. The noise characteristics are such that quarterly data are well behaved and smooth.

It is important to add that this conclusion does not necessarily hold for price predictions on a shorter or on a longer time horizon. In both cases price developments are determined by other factors than those responsible for the inventory cycle. These factors constitute systems with different stability and noise characteristics, which may well make useful (i.e. high certainty) predictions impossible.

The recommended procedure for 1-5 year prediction of pulp prices, based on inventory cycle theory, is as follows:

i) An exponentially declining, long term trend $\left[Ae^{-\alpha(t-t_0)}\right]$ is fitted to the longest available quarterly time series of the real price of pulp.

ii) The exponentially declining trend is extended into the future using the same rate of decline $[\alpha]$ as during the preceding decades.

iii) A sinusoid $\left[B_0 + B_1 \sin\left(2\pi \frac{t}{T} + \beta\right)\right]$ is fitted to the quarterly time series of the total inventory of pulp, expressed in days of production. The sinusoid is used to determine the wavelength $[T]$ in the price development.

iv) Furthermore, the sinusoid is used to locate the position of future troughs and peaks in the price of pulp by assuming that price moves 90° ahead of inventories in the cycle, i.e. that price is proportional to $\sin\left(2\pi \frac{t}{T} + \beta - \frac{\pi}{2}\right)$.

v) The amplitude of the price wave is determined from a time series of the ratio between the original price and the exponential trend (i.e. $\text{ratio}_t = \text{price}_t / Ae^{-\alpha(t-t_0)}$). The amplitude $[C]$ is derived by fitting a sinusoid with the "correct" phase $\left[1 + C\sin\left(2\pi \frac{t}{T} + \beta - \frac{\pi}{2}\right)\right]$

to this time series.

vi) The extension of the sinusoid is added to the extension of the exponential, giving the most likely prediction of price $\left[Ae^{-\alpha(t-t_0)} \times \left(1 + C\sin\left(2\pi \frac{t}{T} + \beta - \frac{\pi}{2}\right)\right)\right]$.

vii) A margin of uncertainty is added, based on the standard deviations in the estimated values of the rate of decline, the wavelength and the amplitude.

DISCUSSION

The fitting of the exponential and the sinusoid to historical data can be done quantitatively, using standard regression techniques, or manually, by hand in graphical plots. The last procedure does not necessarily give inferior results; but it is less reproducible. The manual procedure does have the advantage of being simple, fast and transparent, even for non-mathematicians.

The crucial point in the recommended procedure is to use <u>inventory</u> series to determine the wavelength and to locate the position of troughs and peaks. The inventory fluctuations are much more accentuated - and easier to observe - than fluctuation in other variables like price, production and sales. Furthermore, inventory statistics are easily available, and they show little seasonal fluctuations given that they are true levels or accumulations. The position of <u>price</u> peaks and <u>price</u> troughs are found by shifting the inventory wave one quarter wavelength ahead. Rather than relying on this phase relationship, one may choose to fit a sinusoid with the right wavelenght to the price series in order to determine the phase relation between price and inventories.

Even if inventories play a crucial role in the recommended method of prediction, one should of course use all other available time series to check consistency and to remove ambiguities in the location of troughs and peaks.

5. COMPARISON OF PREDICTED AND ACTUAL DEVELOPMENT

RESULTS

Figure 11 shows the result of applying the manual method of prediction, based on time series for the period 1952 to 1982. The graph is copied from an consulting report by the author dated September 27, 1982.

Figure 11 also shows how prices actually developed over the first two years of the prediction period. Figures 4 through 7 did display that actual developments over these two years were in accordance with inventory cycle theory. The inventory cycle has continued in the sulphate pulp industry in the 2 years following 1982, as it did in the 25 years preceding 1982. In retrospect it is easy to see that the price prediction was sufficiently precise for its intended purpose: to determine whether pulp prices would start to increase within the next few years, creating a more favourable climate for the planned sale of a large pulping plant. The consulting report concluded that pulp prices would halt their decline in the 4th quarter of 1983 (±2 quarters) and reach a new peak in the 1st quarter of 1986 (±2 quarters). Hence the sale of the pulping plant ought to be postponed to 1984/85.

In fact, prices did reach a minimum in the 1st quarter of 1983. Afterwards prices have inched upwards, while inventories have declined. The most recent available statistics (May 1984) show inventories in the process of falling towards the magical limit of some 3 to 4 weeks of coverage which formerly has signalled significant price increases. The spirit of the sulphate pulp industry is once more rising. One has come a long way from the 1982. The price of pulphing plants are substantially higher - and increasing.

DISCUSSION

In principle the total, global inventories of pulp influence the price of pulp. All finished pulp - resting with the producer, in transit to consumers, in consumers' inventories and elsewhere - is in principle available and thus acts to press price. The current work seems to indicate, however, that the producers' inventories give a good indication of market conditions. This is advantageous from a practical point of view, since producers' inventories are the most readily available inventory statistics.

The individual supplier of pulp is most interested in the price he can achieve, i.e. listed price less the discounts he has to give in order to sell his pulp. The achieved price is closer to spot price than to listed price. But time series for spot prices are hard to define as are time series for achieved price. Hence it appears more practical to base price predictions on time series of listed price, keeping in mind that achieved price may well deviate from the listed price - increasing before it does and declining ahead of it. Finally, using listed price makes it unnecessary to smooth the price series, since the listed price is itself a "running average" of spot prices. The listed price is quoted roughly once every quarter and is representative of the current going rate.

Even simpler than the manual method of prediction, is to

establish a long, quarterly time series of inventories and use this curve as a rough indicator of one's present position in the inventory cycle. Inventory figures in tons, from one major supplier of pulp, may suffice for this purpose. But quarterly data measured in days of production covering a significant fraction of the international market, gives a much better indication of the state of affairs.

6. CONCLUSION

This paper has elaborated on the inventory cycle theory and proposed a detailed theory for inventory cycles at the industry level. The detailed theory is supported by time series obtained for the sulphate pulp industry, covering some 25 years.

A method for prediction of pulp prices, based on the detailed theory, was proposed. The method was used in 1982 to forecast the price of sulphate pulp. Comparison with actual developments over the two ensuing years showed that the method gave good results.

The method of prediction is most likely applicable in other industries producing commodities.

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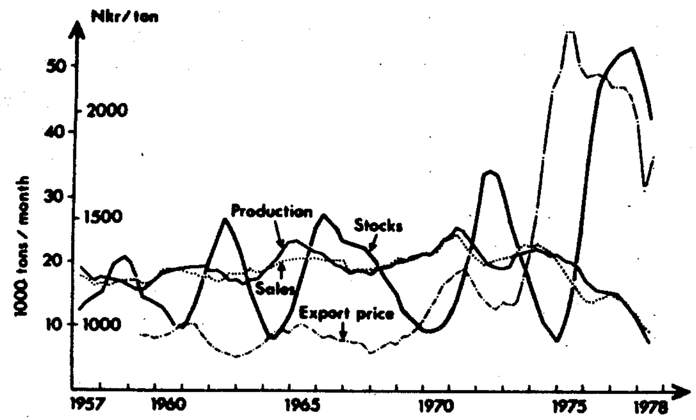

Figure 1a. The inventory cycle in the Norwegian sulphite pulp industry. (From Høsteland, 1979. 12 month running averages of monthly data. Quarterly data for "achieved" price.)

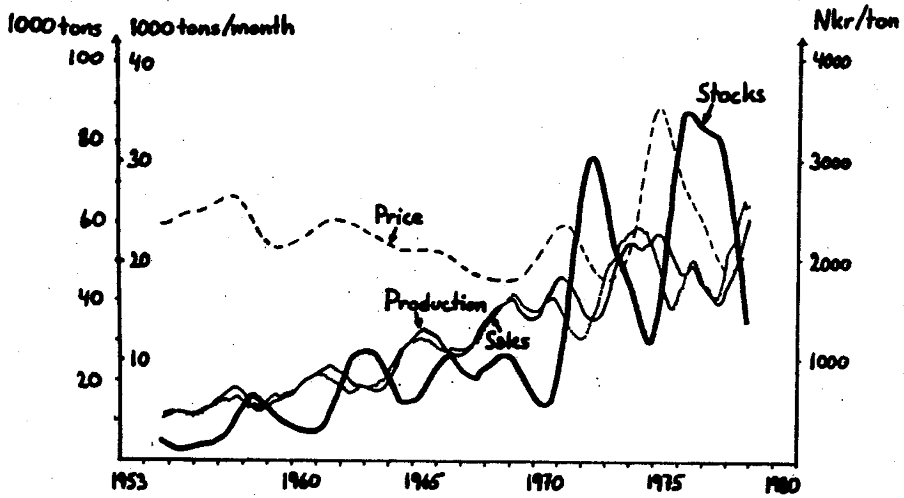

Figure 1b. The inventory cycle in the Norwegian ferro silicon industry. (From Antun, 1981. Exports from the A/S FESIL & Co. group of companies. th order running averages of monthly data. Quarterly data for "achieved" price in constant 1977-kroner.)

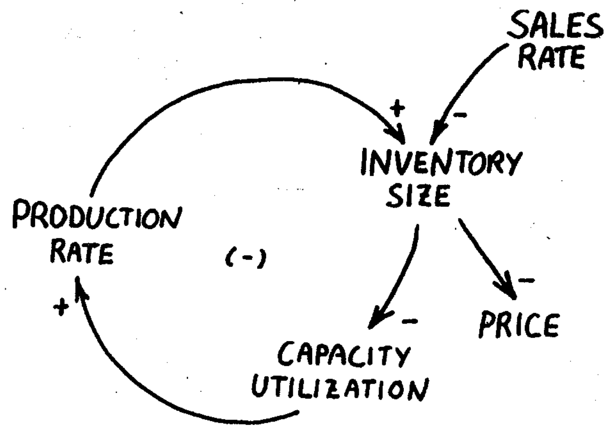

Figure 2. The basic mechanism behind the inventory cycle.

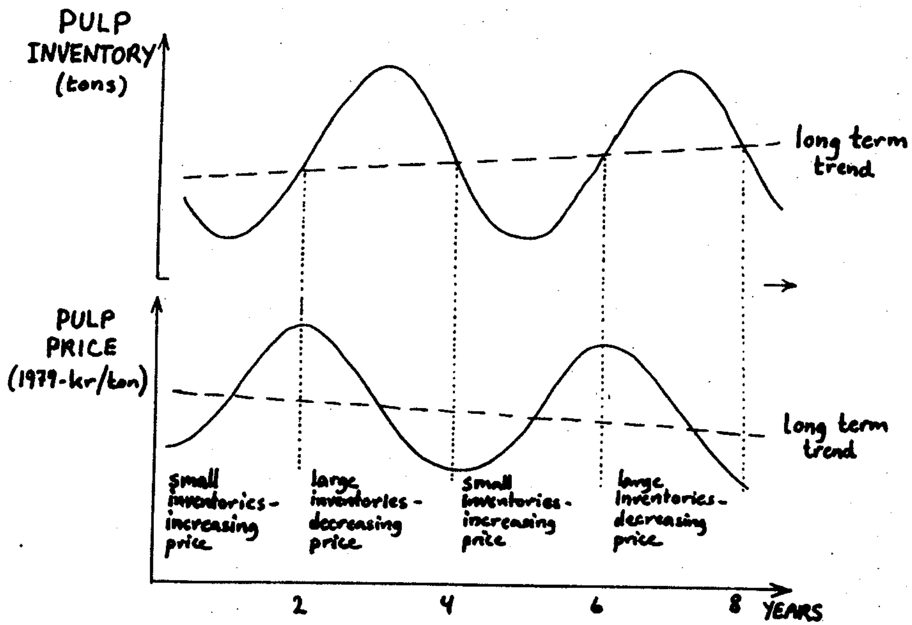

Figure 3. The reference mode of the inventory cycle theory.

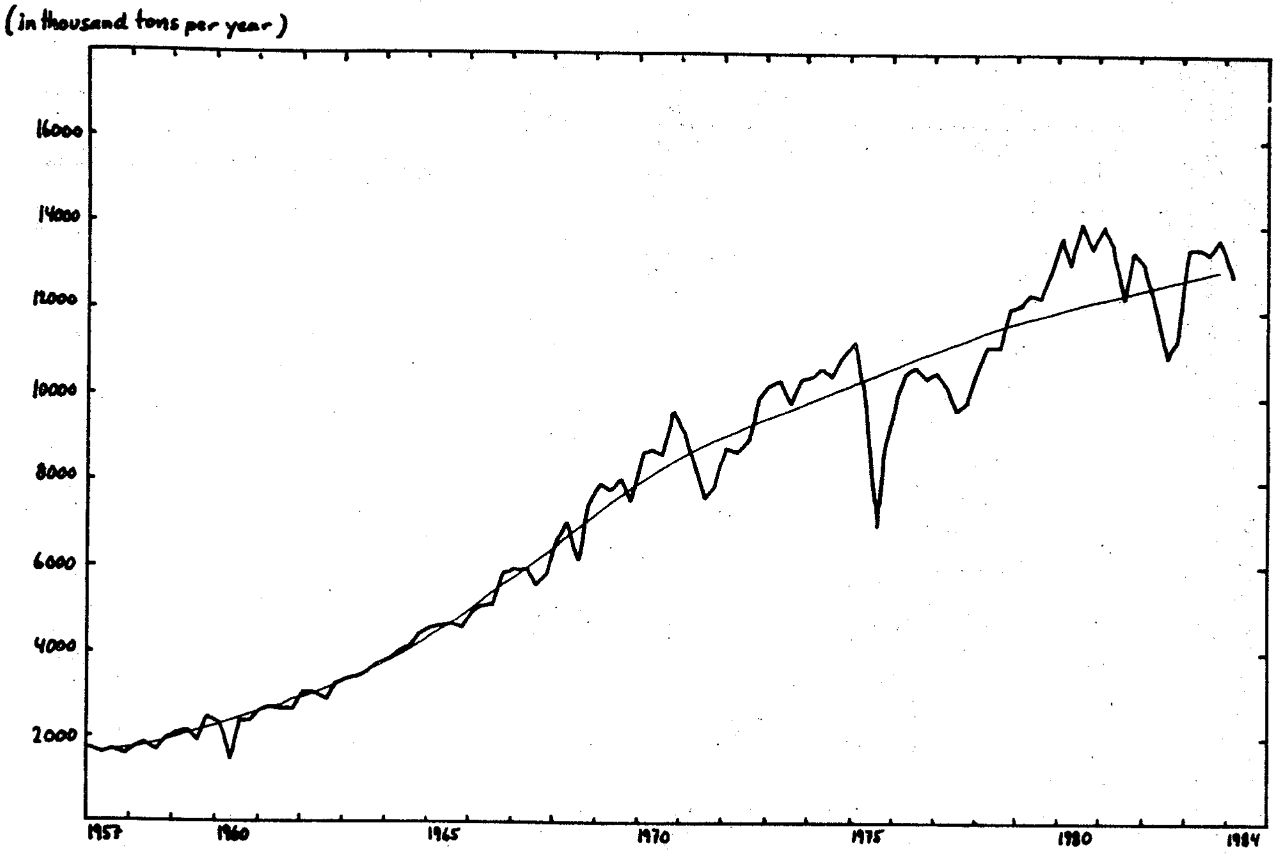

Figure 4. Production rate.
Quarterly data for the NORSCAN countries - production of bleached sulphate pulp.

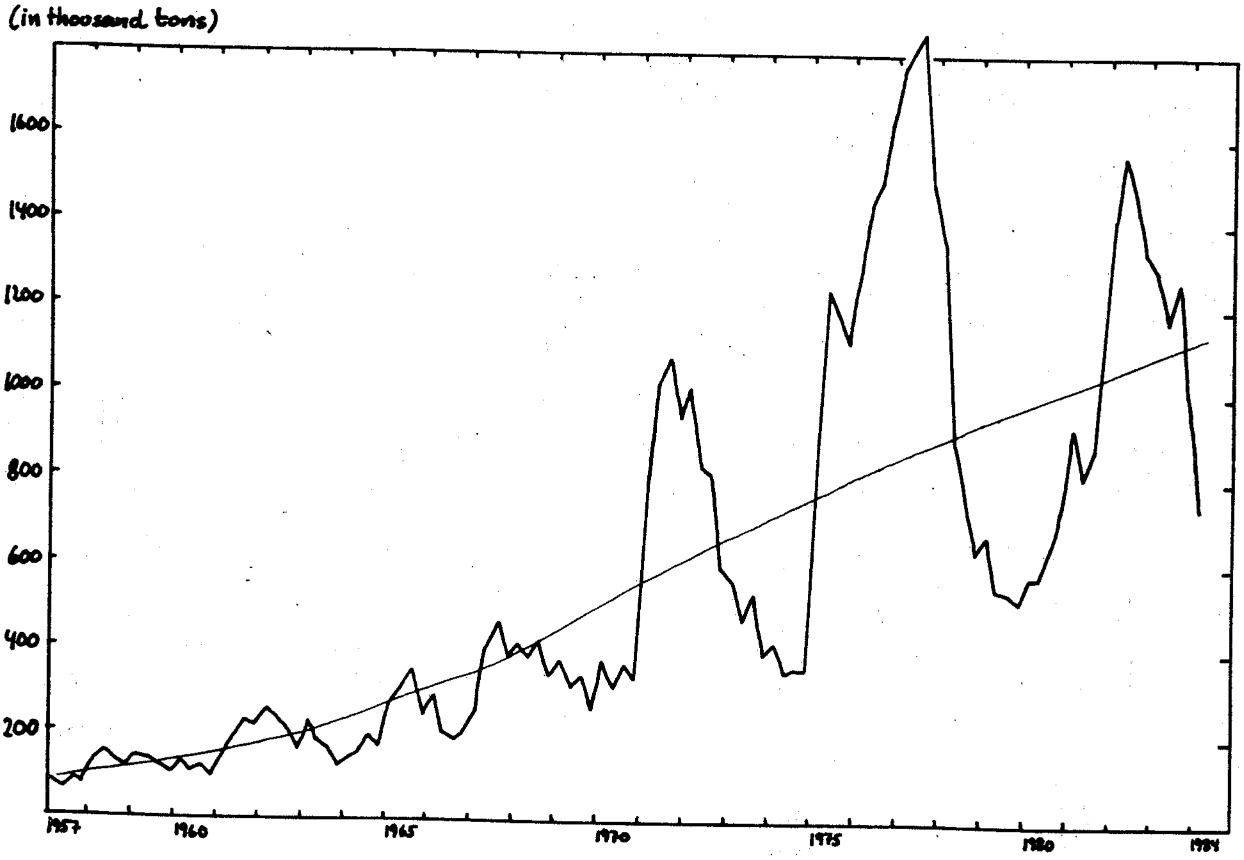

Figure 5. Inventories in tons.
Quarterly data for the NORSCAN countries - producers' inventories of bleached sulphate pulp.

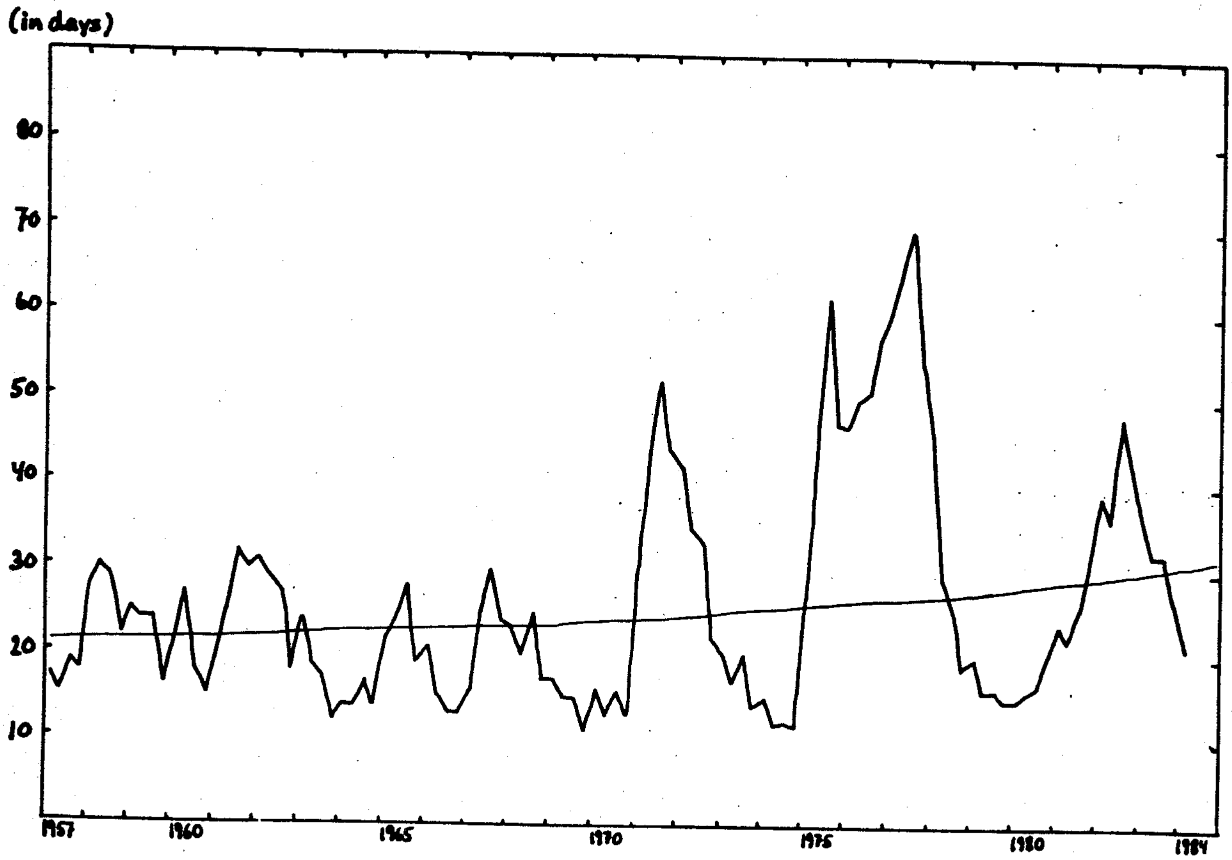

Figure 6. Inventories in days.
Quarterly data for the NORSCAN countries - producers' inventories of bleached sulphate pulp measured in days of production .

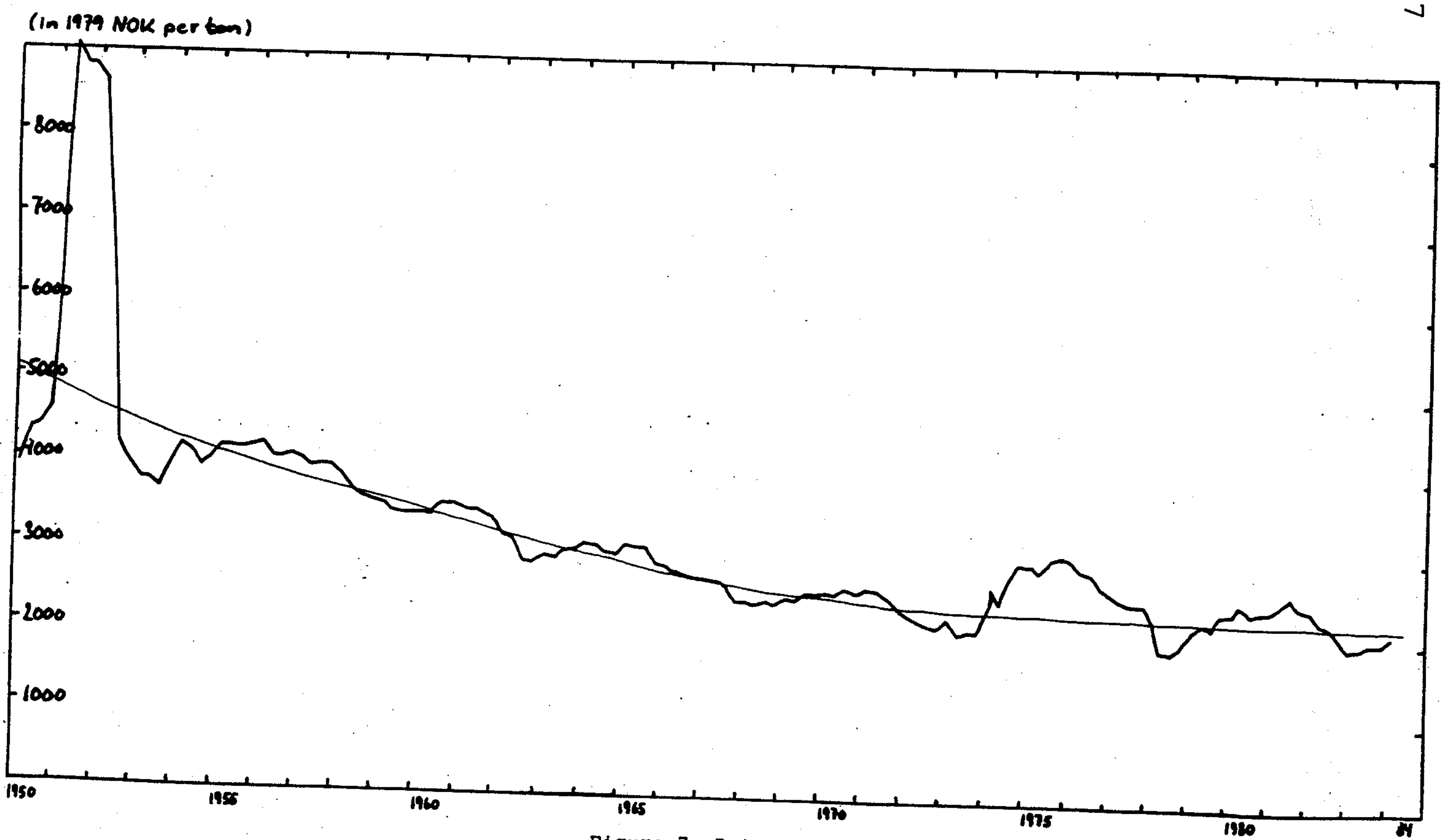

Figure 7. Price.
Quarterly data for the "listed price" of bleached sulphate pulp expressed in constant kr/ton.

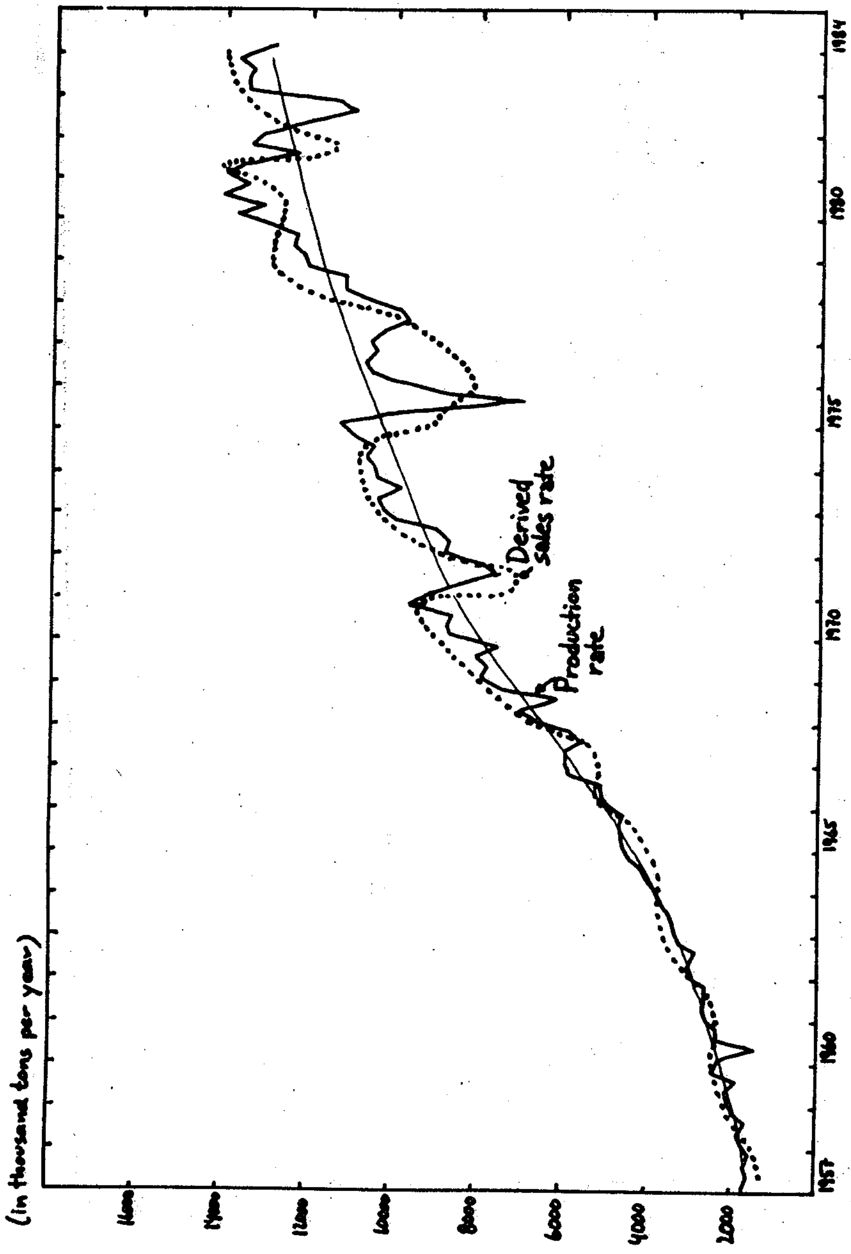

Figure 8. Derived sales rate.

Sketch of sales from the NORSCAN countries, derived by combining inventory and production figures.

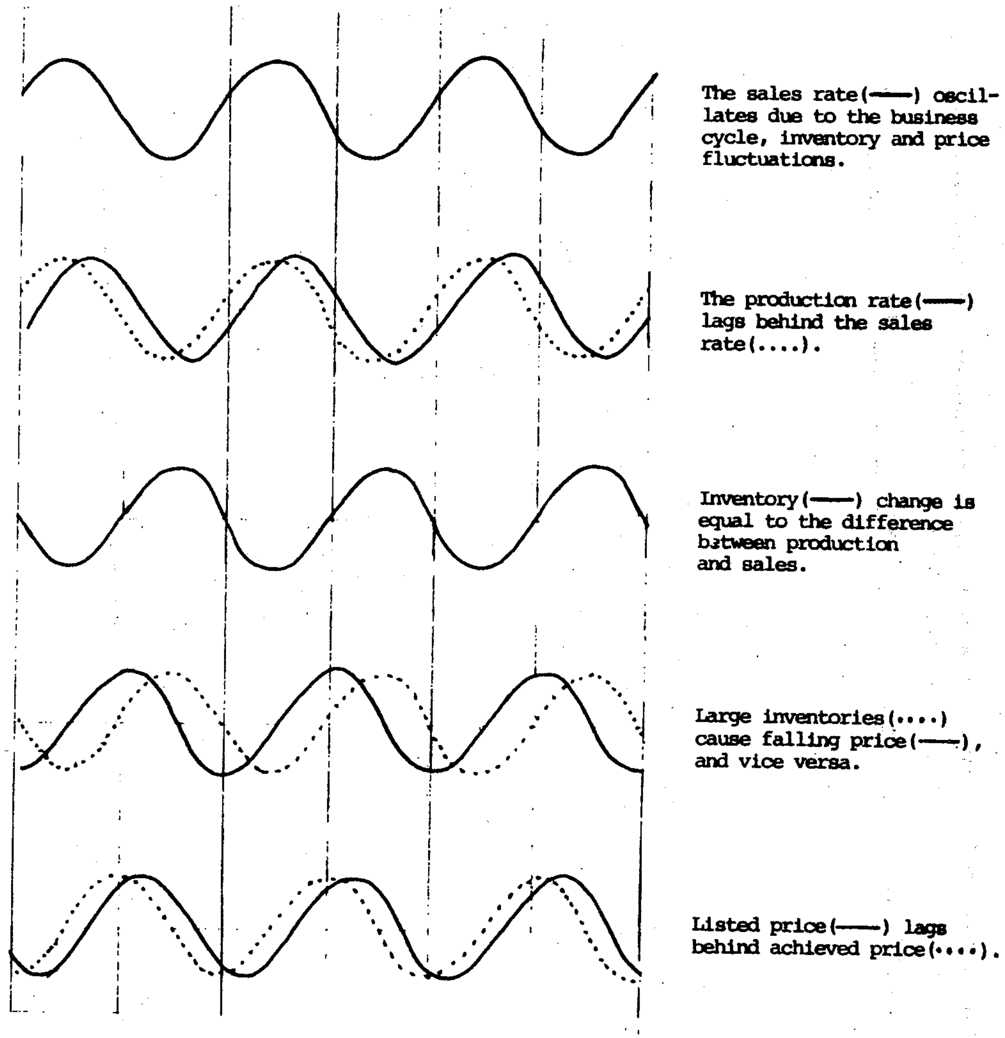

Figure 9. Summary of phase relationships in the inventory cycle.

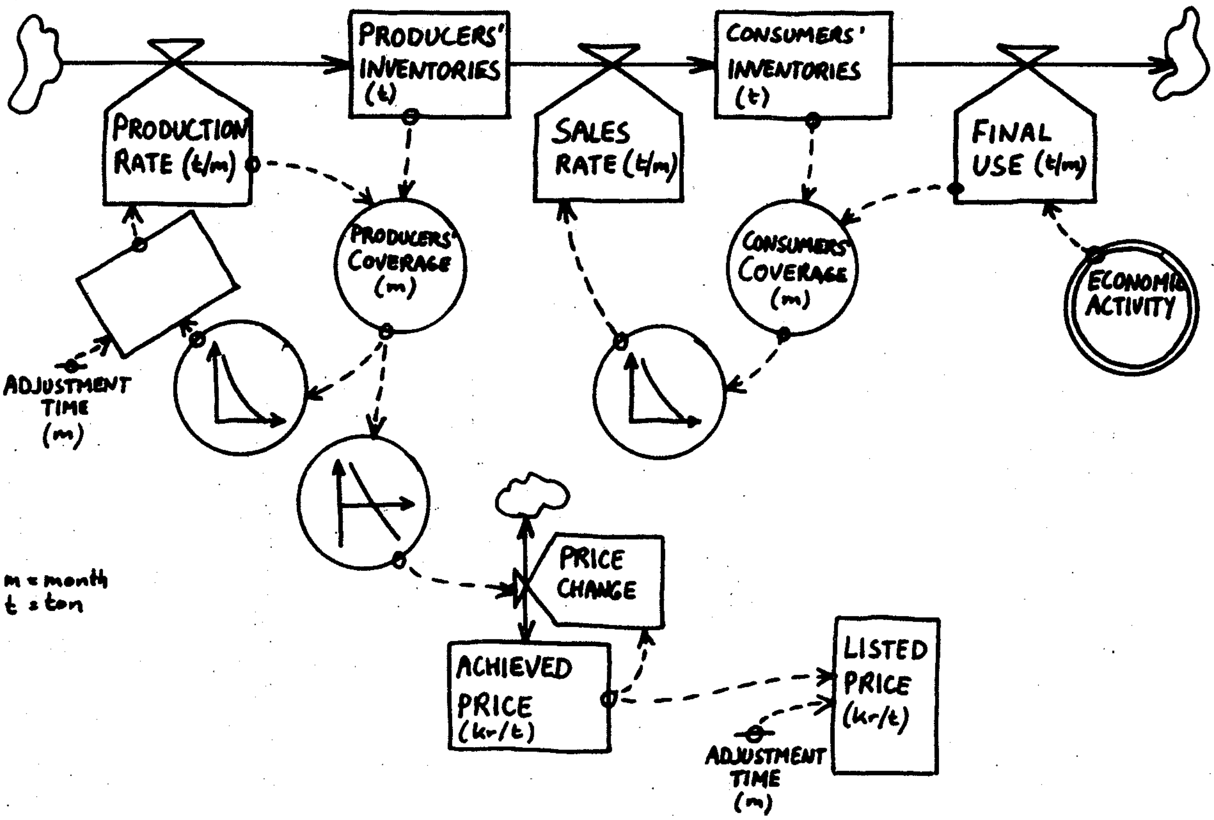

Figure 10. Summary of the system structure behind the inventory cycle.

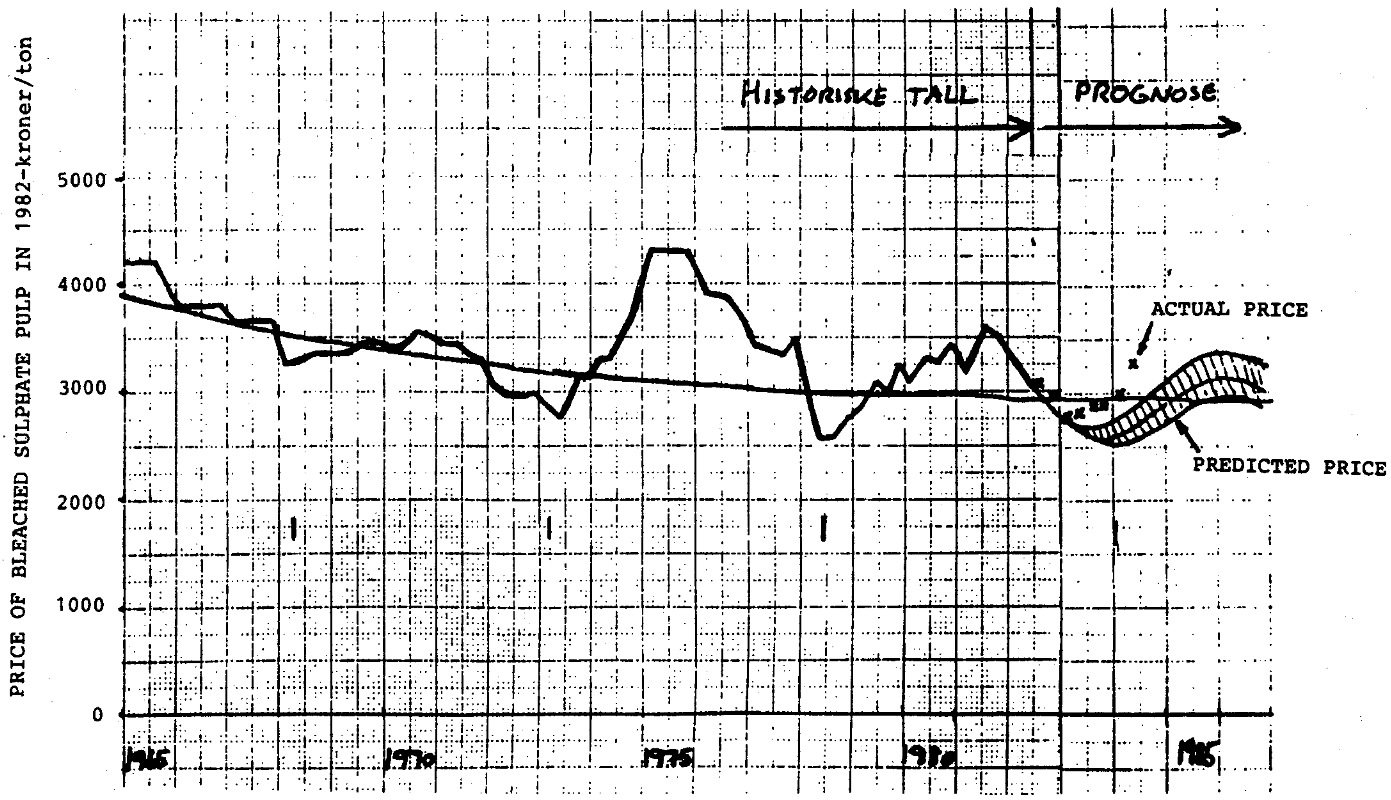

Figure 11. Prediction of the real price of bleached sulphate pulp made in September 1982 compared with actual development in price. (2. quarter 1984 provisional.)