Kondratiev Revisited – After One Kondratiev Cycle*

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The clear insight of Kondratiev into the ***inspirations and expirations of economic activity***, as Trotsky put it in its relation to the Third World Congress of Komintern, had a checkered success. Only now do we begin to appreciate how deep and pervasive is the process, even beyond the strict limits of economic activity.

The contribution of this paper is mainly in terms of empirical evidence, taken over a broad set of subjects and for periods as long as possible. Usually the limit is the availability of sound statistical series for long stretches of time. The assembly of such series by economic historians would certainly be a contribution of primary importance to future studies in the area.

The main characteristic of this study is its almost exclusive focus on physical indicators: quantities, number of objects, sets of dates. Monetary and financial indicators are more ambiguous, a weak point of the original analysis of Kondratiev, aptly cited by his critics. On the other side, being originally a physicist, I tend to look at things for which I have more confidence.

I met with the long cycles when studying the invention and innovation processes in Western societies. By 1975, Mensch had collected data and performed an analysis. In 1979 I reprocessed the data using the idea that inventions and innovations are cultural pulses and as such should be analyzed using the population dynamics of Darwinian origin, coded into the Volterra-Lotka equations (see Mathematical Appendix).

The results are reported in Figure 1, using the Fisher and Pry (1970) notation. Each line represents the cumulative number of inventions (1,3,5,7) or innovations (2,4,6,8) in a pulse, expressed as a fraction F of the total final number in that pulse. The extreme regularity of the process is evident, and in particular that the center points of the innovation waves are spaced 55 years apart (Figure 2). We can zoom into one of the waves, e.g., the first are analyzed (1,2) to look into the details. The cumulative number of inventions or innovations has been fitted with a logistic equation. The chart reports the specific parameters, the time constant, time between 10% and 90% of the objects coming in, the midpoint date, and the center date halfway between the innovation midpoints and invention midpoints.

The process is then described numerically as a basis for forecasting certain features of waves to come. In fact, the numerology of three waves described has sufficient regularities to make the next waves predictable. We are now witnessing the 1984-2002 innovation wave to be centered in 1993. The spirit is certainly there and in ten years we may start checking the forecast.

These innovation waves are obviously very important to keep the economy expanding in industrialized countries, as innovations open new markets and areas of activity, compensating for the saturation of old markets with the consequent reduction in activities. In fact, they constitute *time markers* for business and social processes in general. The objective of this paper is to show a number of these synchronizations in different fields.

The first case, already reported in previous papers, but sufficiently important to repeat here, is that of primary energies whose introduction is strongly correlated with innovation waves (Figure 3). In fact, at the outset of each of the previous three waves, a new primary energy source has been introduced: coal, oil, and gas, respectively. At the outset (calculated!) of the present wave, nuclear energy (factual!) has been introduced. The same reasoning gives a forecast for the introduction of the next primary energy (fusion ?). It will happen around 2025.

An analysis of energy consumption in the US, both in the form of primary energy and electricity was made by B. Stewart (1982) of Nutevco, by fitting the secular trends with logistics and extracting the residuals. As it appears in Figure 4, residuals oscillate, with a period of about 55 years and an amplitude of about 20%. We found this measure of global metabolism to be a very useful clock. The upward segments can be associated with booms and the downward ones with recessions. Our recession should end in 1995 and, as will be seen in numerous examples taken from our times, many things saturate around 1995. Incidentally, the dip of the previous recession was around 1940.

As shown in Figure 5, world steel production during the last 100 years come in two waves of logistic growth, one saturating around 1940 with saturation point around 100 MT, and the following one predicted to saturate in 1995 at about 750 MT (+ 100 MT of the previous step).

This aggregate picture sums up a variety of local situations. Steel production will not grow for ever, and the producing areas keep changing in time as a consequence of changes in technology, localization of resources and age of the steel companies. The case of Britain is reported in Figure 6. Here we go deeper into the past, and we see the phase-out process in action. The chart refers to crude steel production, not to products.

A possible interpretation of the chart is that UK steel industry will import crude steel in form of ingots, e.g., from Brasil or the Soviet Union. After all, iron ores are generally imported to benefit from the special conditions of some open mines over very large ore bodies like in Brasil or Africa. Although transport costs for the ores are acceptable, it is certainly easier to carry steel imports to be processed into a great variety of finished products at the user end. To look at the detailed dynamics of these global substitutions is certainly a fascinating subject for a future study.

Steel can be classified as a commodity, and we can look to see whether other commodities show similar patterns. However, a feature we have recurrently observed is that the processes can start at any time, *but saturation always arrives toward the end of the cycle.* This means late comers have shorter time constants.

This is particularly evident in the penetration of cars in various markets of the world, during the second wave, i.e., after World War II (Figure 7). The US, being the first to move, has a long time constant of 45 years, and Japan, being the last in the row, a very short time constant of 12 years. However, in both cases car population saturates around 1995.

Coming back to commodities, we can look at *capacity* for aluminum production in the US (Figure 8) and find two waves, one saturating in the 1930s and the other in the 1980s (at 6 MT/yr). The lump in the 1940s is obviously due to World War II efforts in the US, and is remarkably well reabsorbed after the end of the war.

We can also look at commerce for a certain commodity, e.g., raw cotton, which was a very important export item for the US during the last century. In this case, there are two main waves centered 55 years apart, in 1842 and 1898 (Figure 9) with good logistic characteristics, followed by a shapeless period during which exports oscillated around a fixed value.

A somewhat similar situation applies with respect to coal extraction in the UK (Figure 10). Two waves of growth were followed by a wildly oscillating period (of 50-60 years). During the third Kondratiev a downward logistic took care of the death of the system. Curiously, the little "balcony" after 1975 was due to a post oil shock legislative measure fixing production at 125 MT/yr. Big miner (suicidal) strikes in 1984 brought things back to "normal".

Coming back to the US, we can examine rice production (Figure 11) and find the usual characteristics, i.e., saturation near the end of the cycle plus a high level of instability shown by the jagged curves in the last period of penetration. Incidentally, a living species entering a new habitat displays similar behavior, with smooth logistic penetration until the capacity of the niche is approached. Then instabilities begin, with occasional overshooting of the capacity level.

Let us now look at transportation, as an area where very good long-term statistical series make work easy and safe. *All* railway networks in the world were started two Kondratiev cycles ago (Figure 12). They seem to fill a niche, as their cumulative number is so well fitted by a logistic.

Their expansion, measured in terms of total laid track is reported in Figure 13. Growth is clearly in two pulses, the first saturating at $400 \cdot 10^3$ km and the second adding another $900 \cdot 10^3$ km. There is some overlapping between the two impulses, but their synchronization with the ends of the Kondratiev cycles is evident.

The situation is quite similar if we look at Europe (Figure 14). The final length of $400 \cdot 10^3$ km was reached in 1940 after two pulses of growth. Since then length has remained static, a good forerunner of the dismissal of this mode of transport during the next Kondratiev cycle. Because systems, like landslides, start rolling down in places before the big splash, we can see the process already at work, e.g., in Denmark (Figure 15), where 50% reduction of track length already occurred during *this* Kondratiev cycle. Freight in Denmark, however, keeps increasing, if in a very asthmatic way (Figure 16) . Also in France, a similar situation applies (Figure 17), with freight increasing by a factor of two in the third pulse. Here the fluctuations appear epileptic. The weak point of these systems is that they grow less than total traffic, losing shares to competitors (basically to road traffic). This means they will die in another Kondratiev cycle, functionally and not only structurally.

We can glance at the situation of motor vehicles at world level (Figure 18) and find the usual patterns, with the total number of motor vehicles increasing by a factor of ten during the second pulse. As usual, 90% of the saturation point is reached before the end of the Kondratiev cycle.

If we look at world production of motor vehicles, we see an increase of only a factor of six in the second pulse pointing perhaps to longer average life for the machines (Figure 19). Toward the end of the pulse, when the number of vehicles is saturating, the economy is also stagnating, and people become jittery about when to change their old vehicles. The market, which is basically a substitution market, strongly resents the irregularities of these decisions.

The situation is similarly fairly smooth if we look at car populations, e.g., in Europe (Figure 20). But here also production has become irregular during recession (Figure 21). In any case, saturation points lean nicely against the end of the Kondratiev cycle. The same can be said if we go down to small components. Figure 22 reports the case of car production by Mercedes-Benz. Coming back to the world, I have the impression that motor vehicles have already had their hay days. Human populations are imploding into dense cities were efficient public transport service can beat cars in speed, and cars cannot beat airplanes in intercity travel. But as in the case of trains, their number may stay constant during the next Kondra, perhaps with a change in geographic distribution.

If we look at transport as a service instead as an infrastructure, we find a similar situation. Figure 23 reports the case of air transport in terms of ton-km/yr. This graph is also remarkable for the fact it does not show the effect of two brisk increases in the price of jet fuel in 1974 and 1979. Frantic reorganization of the air system neatly compensated ***homeostatically*** for the abrupt change in external conditions. Just to give an idea of the depth of the details of economies made, planes were washed very often and waxed to reduce their drag – by 1%!

We can also look at underground urban transportation, i.e., the metro. Cumulative numbers of start ups, i.e., dates of opening of first lines (Figure 24), shows a structure similar to that of railway networks. The difference is that here there is a new burst for every Kondratiev cycle. The ups and downs of the economy are here reported as dashed lines. The first burst has only two points, London and New York, and cannot be structured. Its position, however, is well defined as the two openings were only five years apart.

We can also look at transportation of natural gas through global infrastructures, length of trunk pipelines (Figure 25), and through the level of international trade (Figure 26). The analysis of another sort of transport, that of electricity in the US, also shows interesting features locked to the Kondratiev cycle (Figure 27). An interesting detail is that generating capacity grew by a factor of 13 in the second impulse in relation to the saturation level of the first, and high voltage lines capacity by a factor of 16, showing the two systems are strongly conjugated.

Let's now move to another field, that of manipulation and transport of information: mail, telegrams, telephones, and computers. The historical overview of information transport in Switzerland for which reliable and long-term statistics are available, shows three pulses of growth for the number of messages sent, expressed as the sum of letters, telegrams, and telephone calls (Figure 28). The number grew by a factor of six during the second impulse and by approximately another factor of six during the third one. The substitution game reported in Figure 29 shows that telegrams played a negligible role, quantitatively.

Telephone connections in the US (Figure 30) show two pulses of growth where the second is more than seven times the saturation point of the first. Extensions are counted as posts. Although the separation of extensions is difficult, it could be we find again the factor six of Switzerland.

Looking at computers, the first glance is for mainframe computers in Japan, saturating at 140,000 around 1995. It may seem obvious this is only the first pulse, but with the intensive evolution of such machines, it is doubtful whether the concept of mainframe will survive to the next Kondra in the year 2000.

We can also look at the innovation inside the industry measured through the cumulative number of new models put on the market (Figure 32). The display is terrific, 1500 models have appeared to date. The perfect logisticity permits an accurate fitting, and the saturation level (> 90%) will be reached just after the end of the present Kondra.

Equally impressive is the cumulative number of new computer manufacturers (Figure 33), reaching a little farther in time and saturating at 700, just after the year 2000. Incidentally, each of them will have produced four models, as a mean. As the successful ones may produce 100 of them, most entrepreneurs will produce just one model and disappear, suggesting an entrepreneurs holocaust in capitalistic economies!

A special graph collecting all important mainframe computer manufacturers is reported in Figure 34. The first figure after the name indicates the total number of computer models generated up to saturation. The second number is the time constant (which extends from 10% to 90% of that number). All manufacturers seem to be in the same ball park, saturating around 1995, with IBM as the only exception. IBM appears to to ride two Kondratiev waves, and to be halfway to saturation (50% of saturation) just at the suture between two waves.

I would like now to end my set of samples, to go to more social affairs and show they too are strongly locked to the cycles. One is unemployment, at the borderline between social and economic phenomena (Figure 35). I just wanted to show that the phenomenon is global and structural, not an accident in any special society. Another borderline case is the number of corporations operating in a certain area (e.g., in the US, Figure 36). The number of corporations also seems to grow in pulses. In this case the second is double the first.

More strictly social (i.e., related to the organization and operation of society) is the adoption of certain forms of payment for certain services; e.g., the adoption of stamps for sending mail (Figure 37). The cumulative number of nations adopting stamps is logistic, showing a typical diffusion process, and saturates in 1885, in tune with the corresponding Kondratiev cycle.

So is the number of people receiving pensions in Italy, saturating at 20 M, just in 1995 (Figure 38). But the most striking, in my opinion, is the phasing between Kondratiev cycles and aggressive moods of society as expressed by homicides and suicides. The situation in the US is reported in Figures 39 and 40. The tuning is obvious and the details are amazing. Also the type of weapon used has a 55 year cycle, and so too has the ratio of women over men for homicides. In the case of suicides, the ratio women over men has a curious cuspidated form with half period!

All together I think the idea of 55 year cycles in the behavior of our society is one of the most penetrating and useful in organizing social and economic facts. Together with the innovation-diffusion concept that we are currently using, it provides a most crisp and internally consistent description of human affairs.

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MATHEMATICAL APPENDIX

The equations for dealing with different cases are reducible to the general Volterra–Lotka equations

$$\frac{dN_i}{dt} = K_i N_i + \beta_i^{-1} \sum_{n}^{j=1} a_{ij} N_i N_j \quad , \tag{1}$$

where N_i is the number of individuals in species i, and a, β, and K are constants. The equation says a species grows (or decays) exponentially, but for the interactions with other species. A general treatment of these equations can be found in Montroll and Goel (1971) and Peschel and Mende (1986). Since closed solutions exist only for the case of one or two competitors, these treatments mainly deal with the general properties of the solutions.

In order to keep the analysis at a physically intuitive level, I use the original treatment of Verhulst (1845) for the population in a *niche* (Malthusian) and that of Haldane (1924) for the competition between two genes of different fit. For the multiple competition, we have developed a computer package which works perfectly for actual cases (Marchetti and Nakicenovic, 1979), but whose identity with the Volterra equations is not fully proven (Nakicenovic, 1979).

Most of the results are presented using the coordinates for the linear transform of a logistic equation originally introduced by Fisher and Pry (1970).

The Malthusian Case

This modeling of the dynamics of population systems started with Verhulst in 1845, who quantified the Malthusian case. A physically very intuitive example is given by a population of bacteria growing in a bottle of broth. Bacteria can be seen as machinery to transform a set of chemicals in the broth into bacteria. The rate of this transformation, *coeteris paribus* (e.g., temperature), can be seen as proportional to the number of bacteria (the transforming machinery) and the concentration of the transformable chemicals.

Since all transformable chemicals will be transformed finally into bacterial bodies, to use homogeneous units one can measure broth chemicals in terms of bacterial bodies. So $N(t)$ is the number of bacteria at time t, and $\bar{N}$ is the amount of transformable chemicals at time 0, before multiplication starts. The Verhulst equation can then be written

$$\frac{dN}{dt} = aN(\bar{N} - N) \quad , \tag{2}$$

whose solution is

$$N(t) = \frac{\bar{N}}{1-e^{-(at+b)}} \quad , \tag{3}$$

with b an integration constant, sometimes written as t_0, i.e., time at time 0; a is a rate constant which we assume to be independent of the size of the population. This means that there is no "proximity feedback". If we normalize to the final size of the system, $\bar{N}$, and explicate the linear expression, we can write equation (2) in the form suggested by Fisher and Pry (1970).

$$\log\frac{F}{1-F} = at + b \quad , \quad \text{where } F = \frac{N}{\bar{N}} \quad . \tag{4}$$

Most of the charts are presented in this form. $\bar{N}$ is often called the *niche*, and the growth of a population is given as the fraction of the niche it fills. It is obvious that this analysis has been made with the assumption that *there are no competitors.* A single species grows to match the resources ($\bar{N}$) in a Malthusian fashion.

The fitting of empirical data requires calculation of the three parameters $\bar{N}$, a, and b, for which there are various recipes (Oliver, 1964; Blackman, 1972; Bossert, 1977). The problem is to choose the physically more significant representation and procedure.

I personally prefer to work with the Fisher and Pry transform, because it operates on *ratios* (e.g., of the size of two populations), and ratios seem to me more important than absolute values, both in biology and in social systems.

The calculation of $\bar{N}$ is usually of great interest, especially in economics. However, the value of $\bar{N}$ is very sensitive to the value of the data, i.e., to their errors, especially at the beginning of the growth. The problem of assessing the error on $\bar{N}$ has been studied by Debecker and Modis (1986), using numerical simulation.

The Malthusian logistic must be used with great precaution because it contains implicitly some important hypothesis:

- That there are no competitors in sight.
- That the size of a niche remains constant.
- That the species and its boundary conditions (e.g., temperature for the bacteria) stay the same.

The fact that in multiple competition the starts are always logistic may lead to the presumption that the system is Malthusian. When the transition period starts there is no way of patching up the logistic fit.

The fact that the niches keep changing, due to the introduction of new technologies, makes this treatment, generally speaking, unfit for dealing with the growth of human populations, a subject where Pearl (1924) first applied logistics. Since the treatment sometimes works and sometimes not, one can find much faith and disillusionment among demographers.

One-to-One Competition

The case was studied by Haldane for the penetration of a mutant or of a variety having some advantage in respect to the preexisting ones. These cases can be described quantitatively by saying that variety (1) has a reproductive advantage of k, over variety (2). Thus, for every generation the ratio of the number of individuals in the two varieties will be changed by $\frac{1}{(1-k)}$. If n is the number of generations, starting from $n = 0$, then we can write

$$\frac{N_1}{N_2} = \frac{R_0}{(1-k)^n} \quad , \quad \text{where } R_0 = \frac{N_1}{N_2} \text{ at } t = 0 \quad . \tag{5}$$

If k is small, as it usually is in biology (typically 10^{-3}), we can write

$$\frac{N_1}{N_2} = \frac{R_0}{e^{kn}} \quad . \tag{6}$$

We are then formally back to square one, i.e., to the Malthusian case, except for the very favorable fact that we have an initial condition (R_0) instead of a final condition ($\bar{N}$). This means that in *relative terms* the evolution of the system is not sensitive to the size of the niche, a property that is extremely useful for forecasting in multiple competition cases. Since the generations can be assumed equally spaced, n is actually equivalent to time.

As for the biological case, it is difficult to prove that the "reproductive advantage" remains constant in time, especially when competition lasts for tens of years and the technology of the competitors keeps changing, not to speak of the social and organizational context. But the analysis of hundreds of cases shows that systems behave exactly *as if*.

Multiple Competition

Multiple competition is dealt using a computer package originally developed by Nakicenovic (1979). A simplified description says that all the competitors start in a logistic mode and phase out in a logistic mode. They undergo a transition from a logistic-in to a logistic-out during which they are calculated as "residuals", i.e., as the difference between the size of the niche and the sum of all the *ins* and *outs*. The details of the rules are found in Nakicenovic (1979). This package has been used to treat about one hundred empirical cases, all of which always showed an excellent match with reality.

An attempt to link this kind of treatment to current views in economics has been made by Peterka (1977).

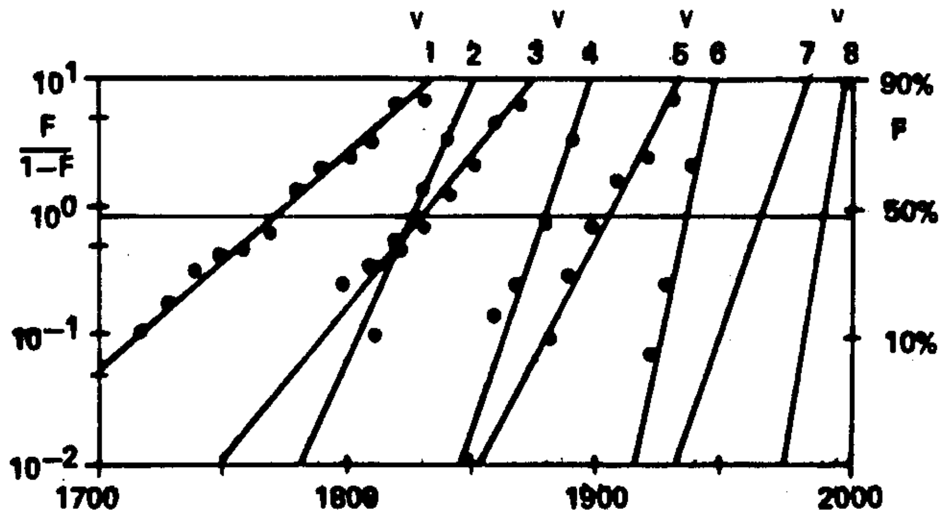


FIGURE 1. Cumulative number of inventions (odd numbers) and innovations (even numbers) in three historical waves, and one calculated (7,8). The fitting lines are logistic equations expressed in the Fisher-Pry transform (see Mathematical Appendix).

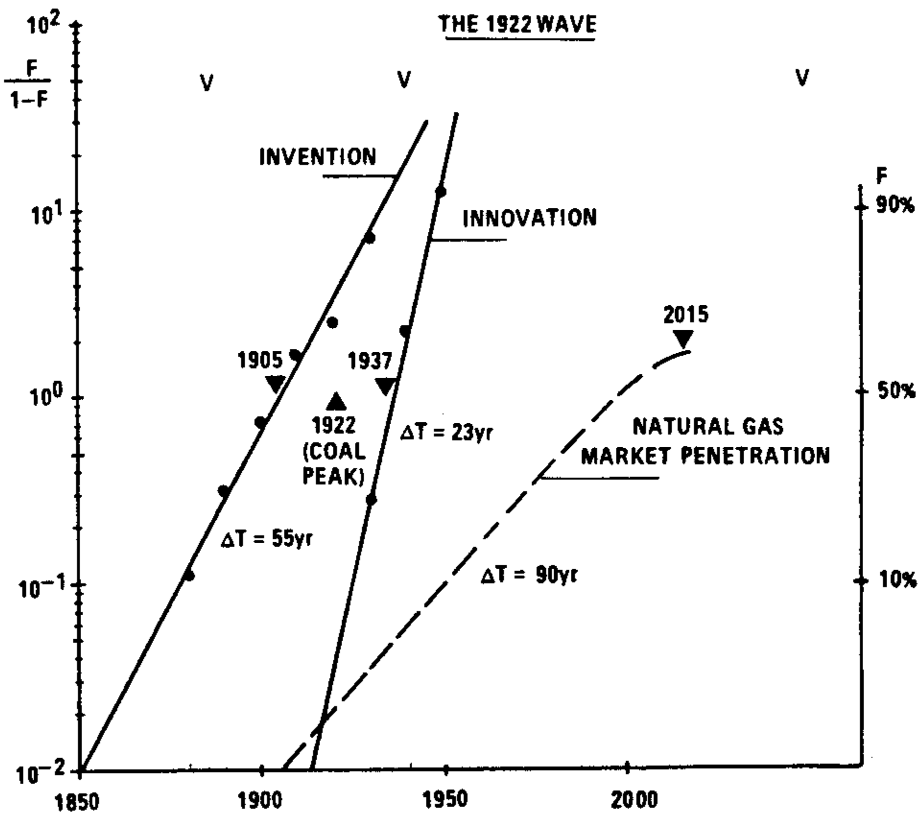


FIGURE 2. The wave (5.6) in Figure 1 is shown here in detail to give the fine print of the analysis. The penetration of natural gas in the world market is shown in the same notation. The ordinates are on the left, where F is the market fraction. On the right, F is reported for some points to facilitate first sight interpretation of the chart. ΔT is the time span between 10% and 90% of saturation and gives an idea of the *rate* of penetration. In the text it is called the time constant.

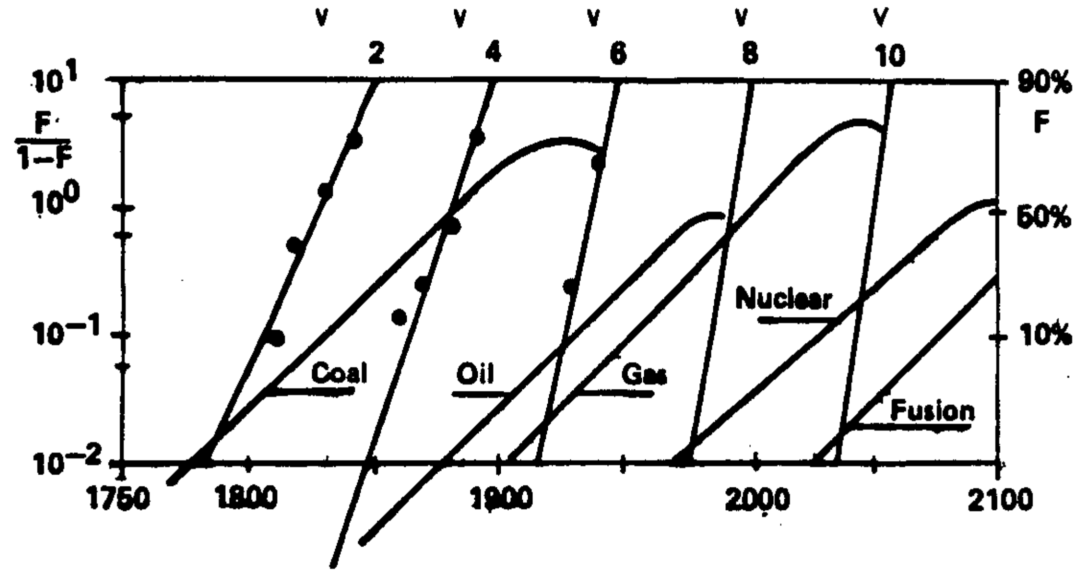


FIGURE 3. The exercise of Figure 2 is expanded to show that with every innovation wave is associated the introduction of a new primary energy in the world market. Waves 8 and 10 are calculated and the coincidence is remarkable between the introduction of nuclear energy (1% of total primary energy in 1972) with the beginning of the calculated innovation wave n. 8. The same logic would predict a new primary source of energy, *presumably* fusion, around 2025. The small V on top of the chart indicate the end of Kondratiev cycles of 55 years (1830, 1885, 1940, 1995, 2050).

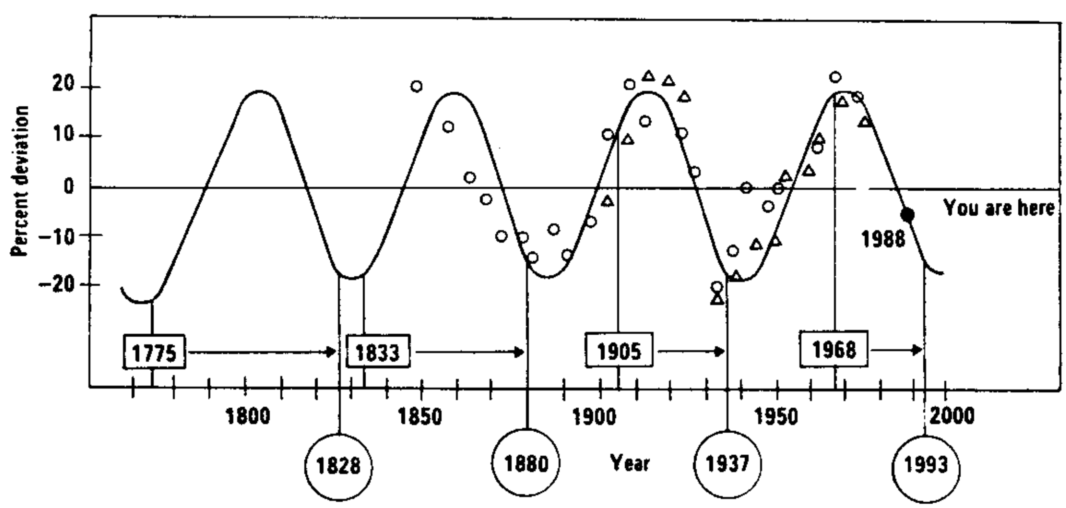


FIGURE 4. By fitting total energy and electric energy growth curves with logistics and plotting the residuals as percent deviations from the fitting curve, B. Stuart of Nutevco did obtain this chart. The sinusoid oscillation of the deviations has a period of 54 years, and we took it as a clock to measure social activity in an all encompassing form. The dates in a circular enclosure indicate the center point of innovation waves. They always occur around the deep of the wave, i.e., the end of recession. The centers of the invention waves, on the contrary, keep moving along the phases of economy, showing a much more independent behavior. The black circle indicates our position in the present cycle. *Recession should last another seven years.*

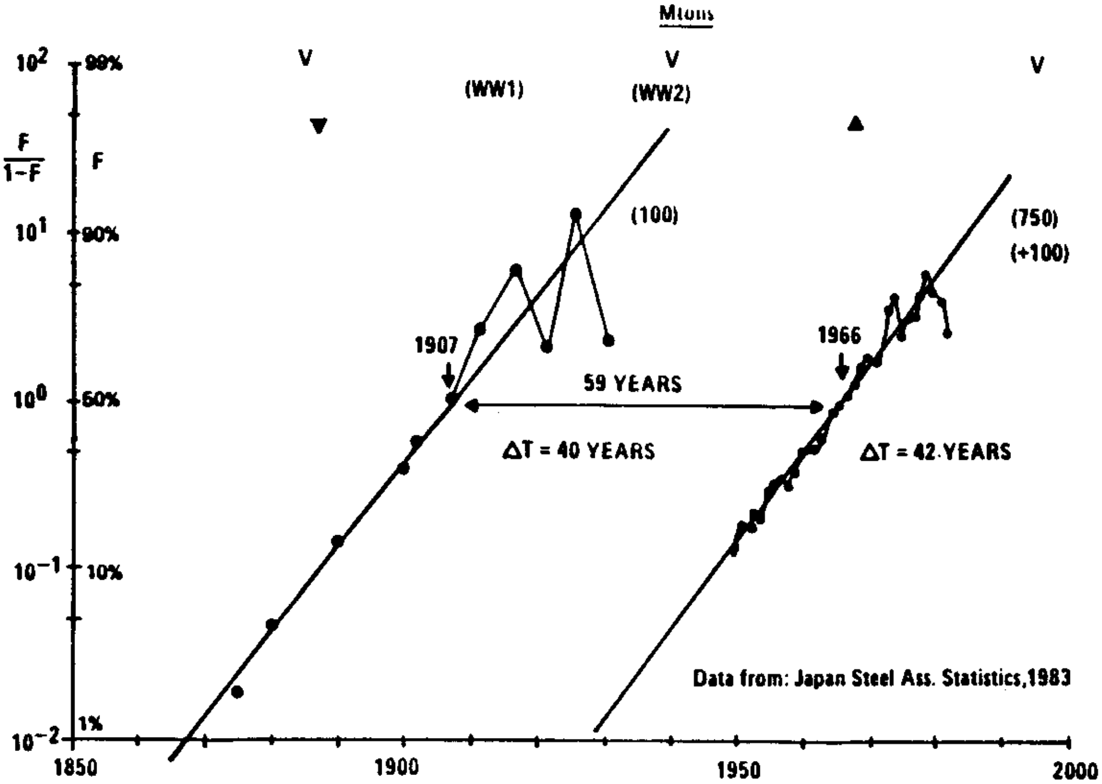


FIGURE 5. The output of raw steel production at world level is here reported. Two waves with jittery ends are clearly delineated. Saturation points lean at the end of the cycles and appear to begin (1%) before the end of the previous cycle. The position of World Wars I and II are also indicated.

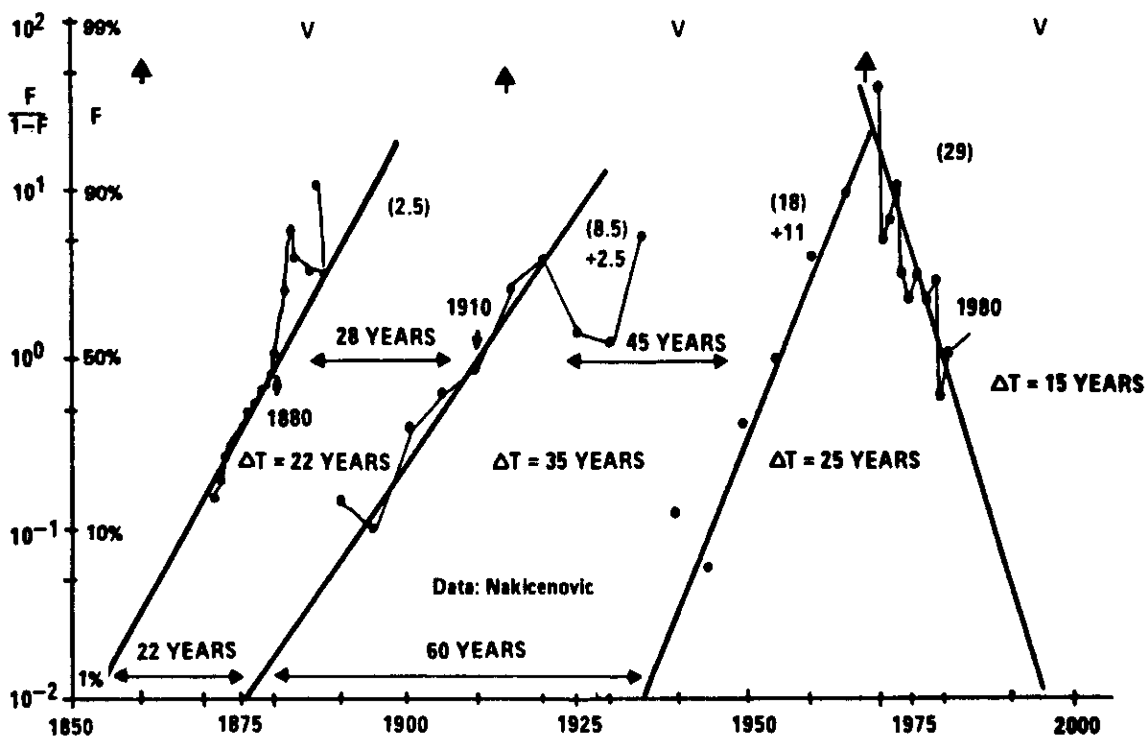


FIGURE 6. The case of crude steel production in Great Britain is here reported. Two logistic waves of growth are followed by one logistic wave of decline. The physical interpretation is that Britain will import crude steel to process in its finished steel industry. Switching from one mode of operation to another is not synchronous between various

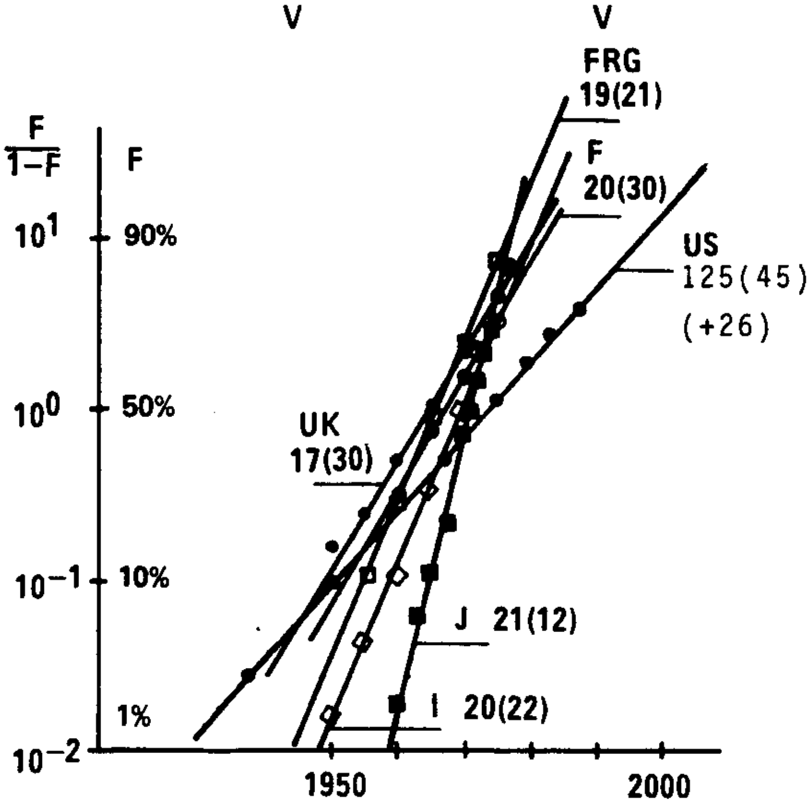


FIGURE 7. Penetration of automobiles in most of the industrial nations after World War II has been a very visible phenomenon. The Unites States and Great Britain had already a sizable car population before. Penetration started (1% of saturation) at different times in different countries, from the beginning of the cycle in the US and the UK, very late in Japan. The time constants, however, compensate for the difference in starting point, and everybody saturates around 1995, synchronically with the Kondratiev wave.

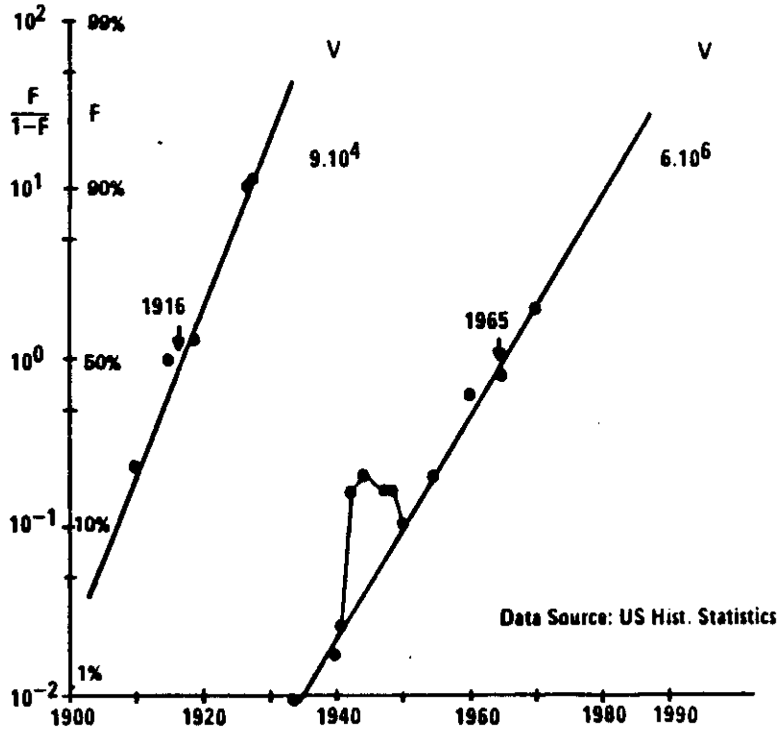


FIGURE 8. Two waves of penetration for aluminum production capacity in the US. To observe the large difference between the sizes of the two impulses, the second being almost 100 times larger than the first. The blob starting in 1940 is obviously due to World War II ... effects. It is very interesting to observe it has been neatly reabsorbed, the

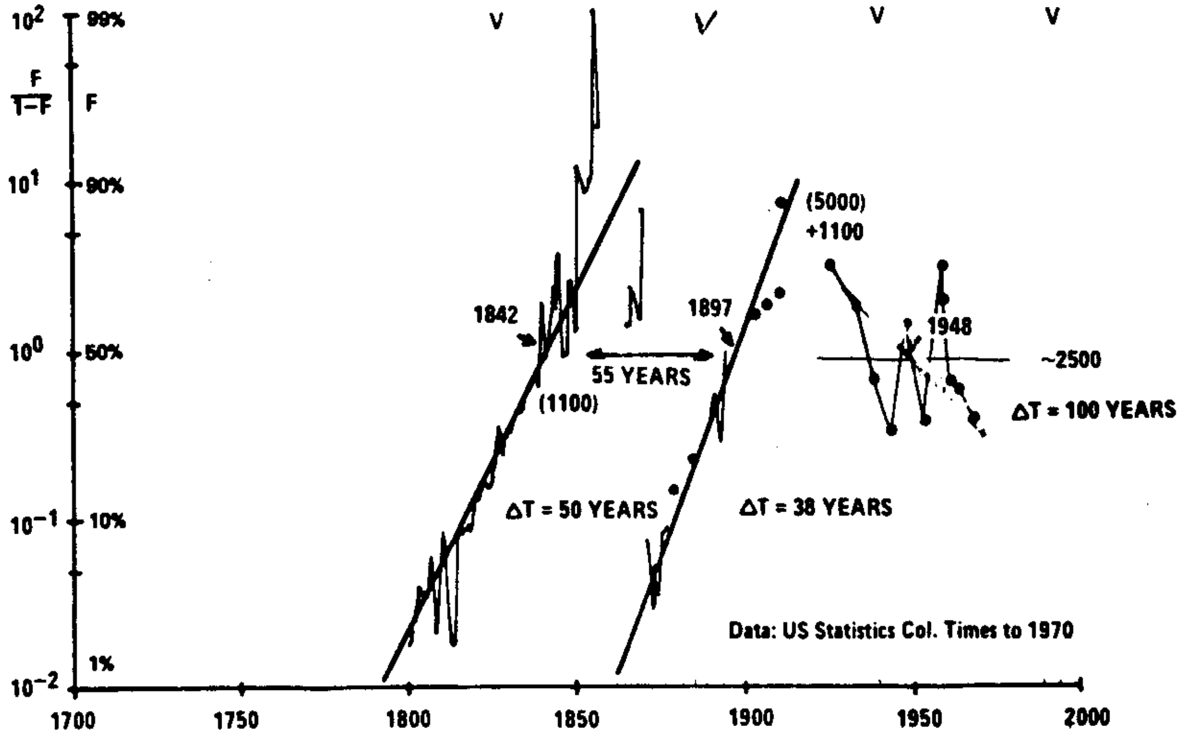


FIGURE 9. Here we observe two waves for the US exports of raw cotton, a very important commodity for the south of the country during the last century. The history of slavery in the US is much linked to cotton cultivation. This US dominance on the world market ended actually in 1900, not really with a downward logistic but with a jittery market basically stable at a much reduced level by respect to prewar.

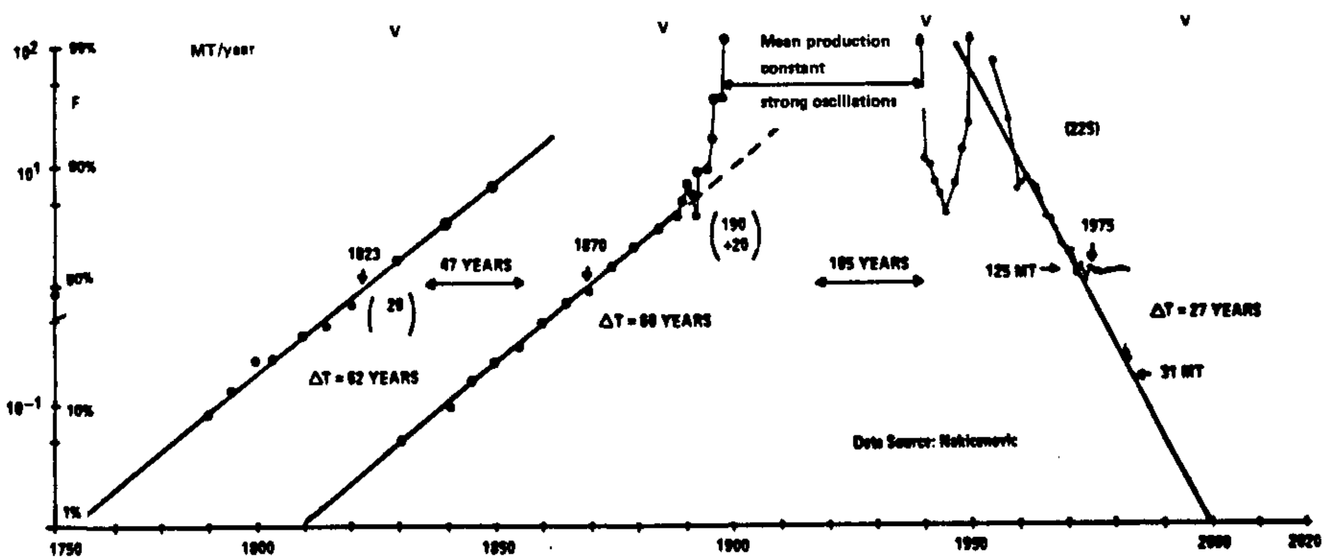


FIGURE 10. A similar course can be observed for coal *extraction* in the UK, where two waves of growth tuned to Kondratiev cycles are followed by a stable (and jittery) level of production during the Kondratiev ending in 1940, and by a downward logistic for the present Kondratiev. The horizontal segment starting in 1975 comes from a legislative decision fixing the level of coal production to 125 MT, as a protection against the oil crisis. After the extensive strikes of 1984, this position has been much eroded and production is now near the fitting logistic, in spite of the still high cost to the tax payer.

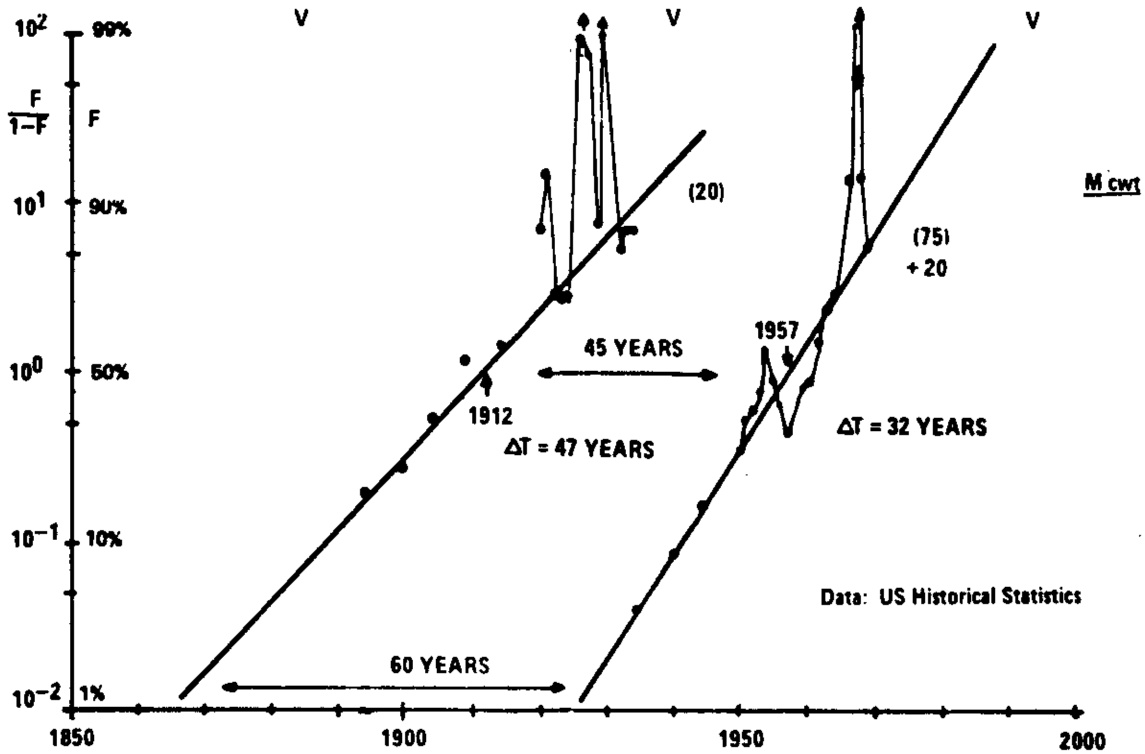


FIGURE 11. US rice production is here reported to show the jittery behavior at the end of the K-cycles is not typical only of industrial production. This is obviously due to market uncertainties. Climate uncertainties operate all the time as no 55 year climatic cycle is apparent. But perhaps one should look deeper into detailed characteristics of weather and climate in relation to vegetation and crops.

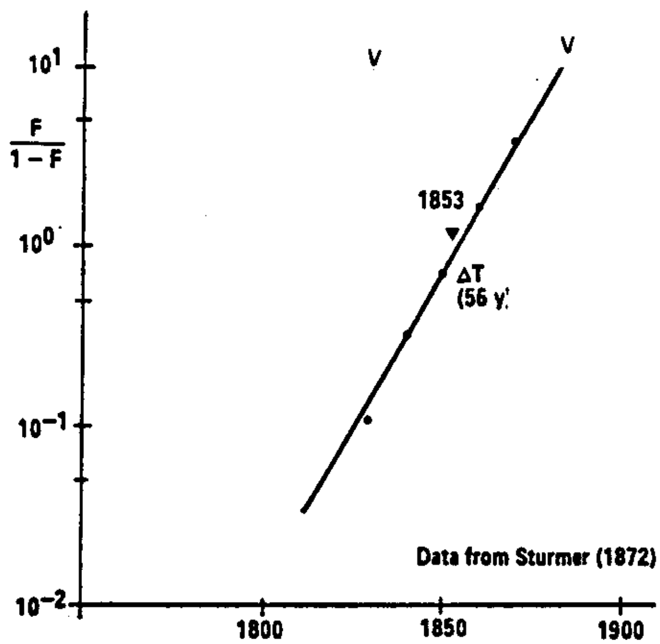


FIGURE 12. This chart reports the cumulative number of openings of railway stretches that later developed into networks. Basically the cumulative number of nations that adopted railway technologies. The precise piling up of their number into a logistic shows clearly a diffusion process at work, in a culturally well integrated world. The wave of adoption is neatly contained into the K-wave 1830-1885. No new network was started after 1885.

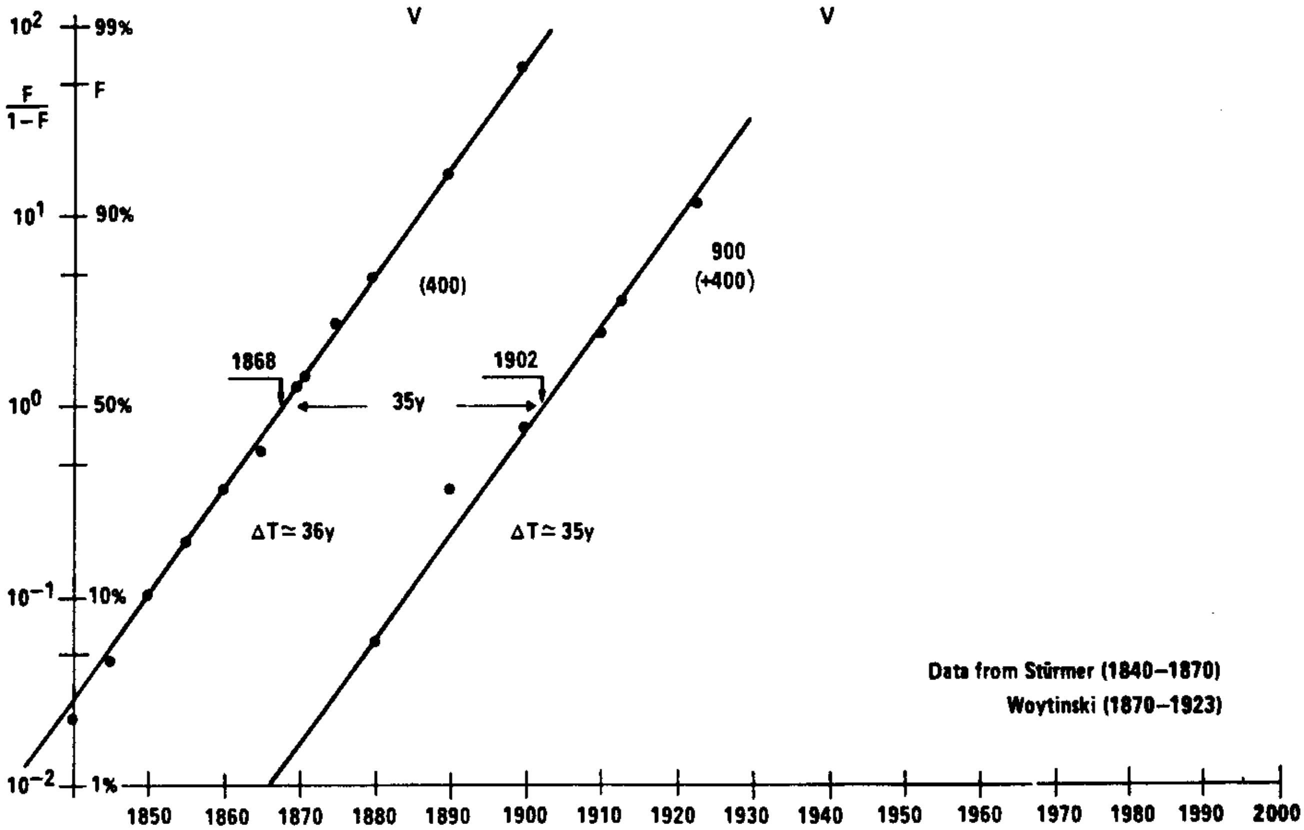


FIGURE 13. After inauguration of the first line, railway tracks did grow at a brisk pace, reaching a total of 400,000 km at the end of the first cycle. Extension of networks did continue during the following cycle adding another 900,000 km of track. During the third cycle, track length has remained constant, menacing a logistic phase out during the next K-cycle, starting 1995. The signs are already there as most railways losts their traffic to the road and are now bankrupt.

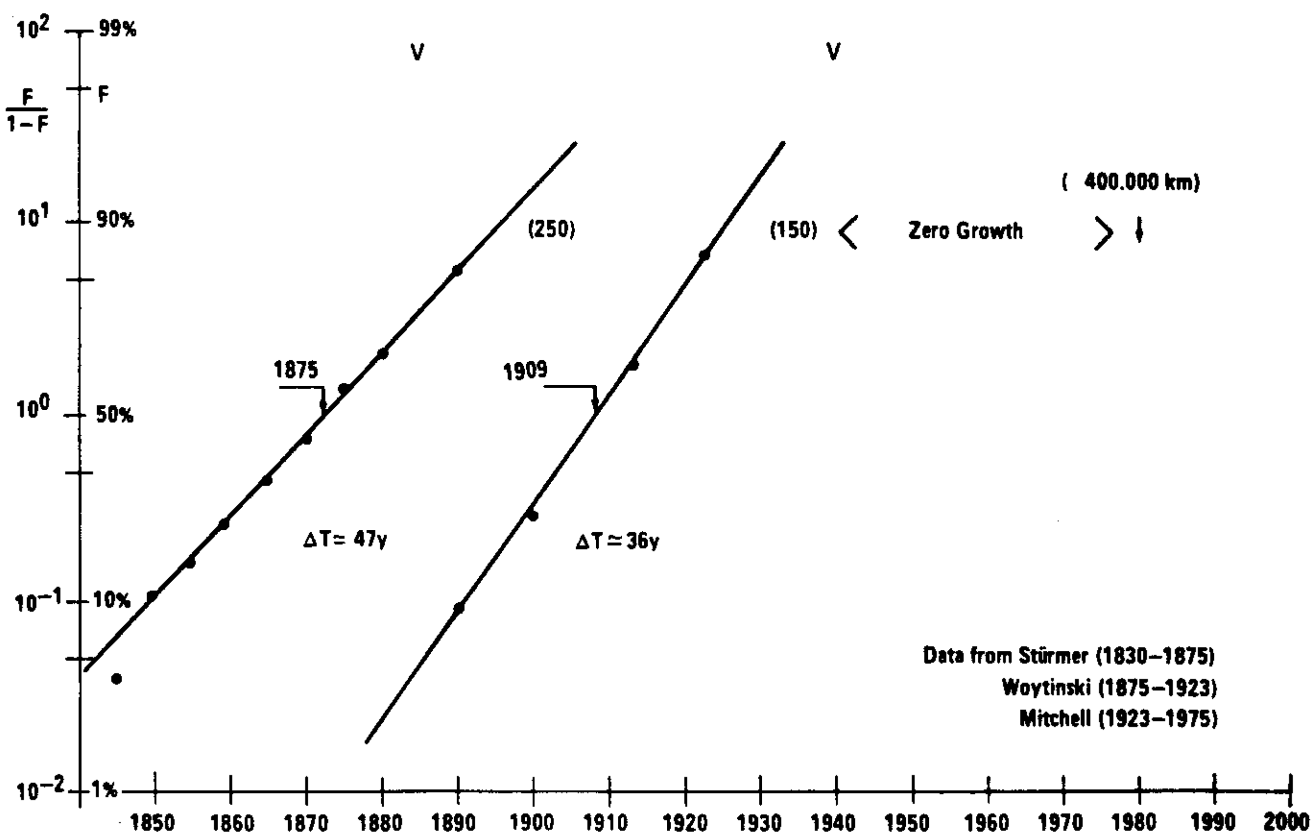


FIGURE 14. World situation is mirrored by that of Europe which started first but lay laggard due to the impetus of construction in the US. The length of track did stay almost

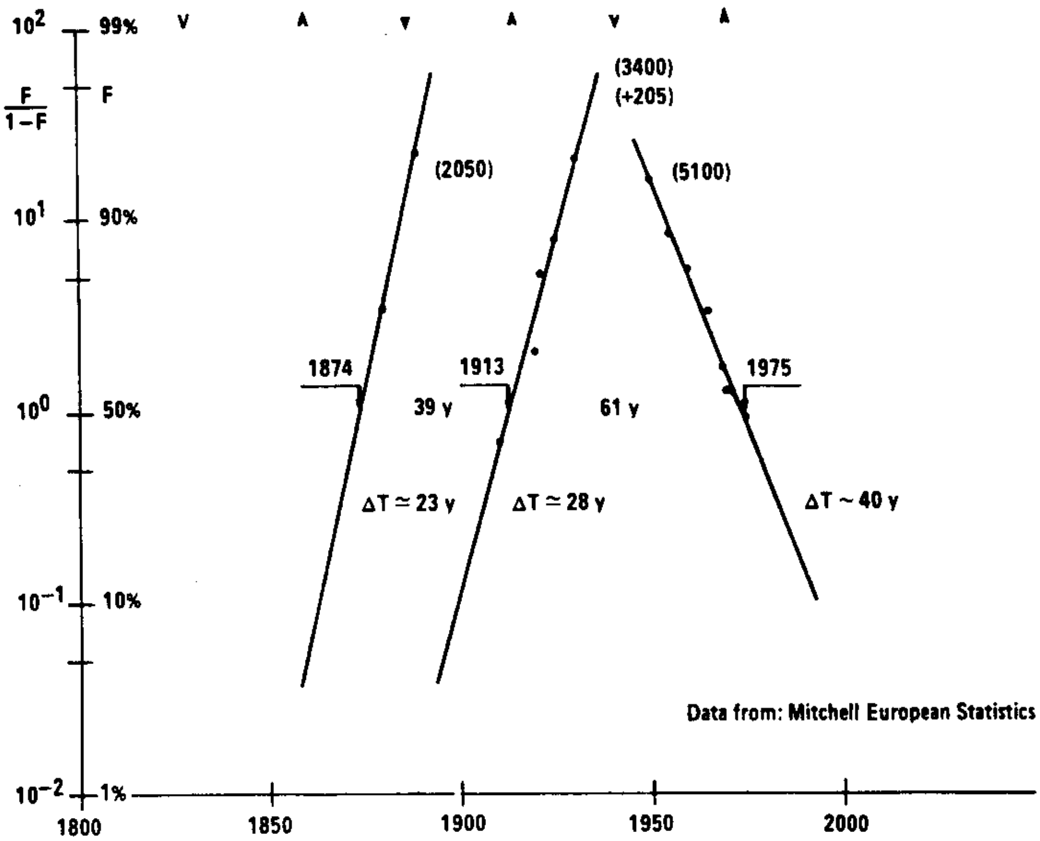


FIGURE 15. As usual we can search for geographical locations were the next wave is nucleated, and here the case of Denmark is reported where about half of the track has been closed during the present K-wave, in a neat logistic curve downward, resembling that of the UK's for steel or for coal.

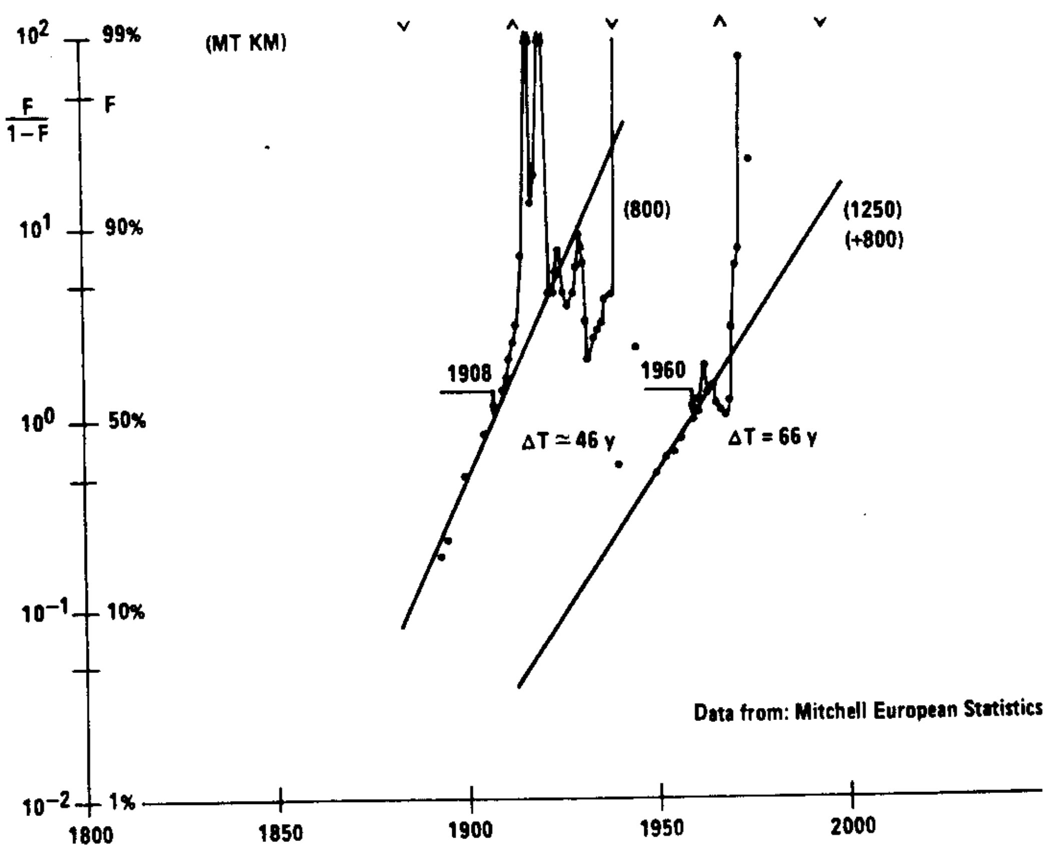


FIGURE 16. Freight traffic in Denmark kept, however, increasing if at a modest rate.

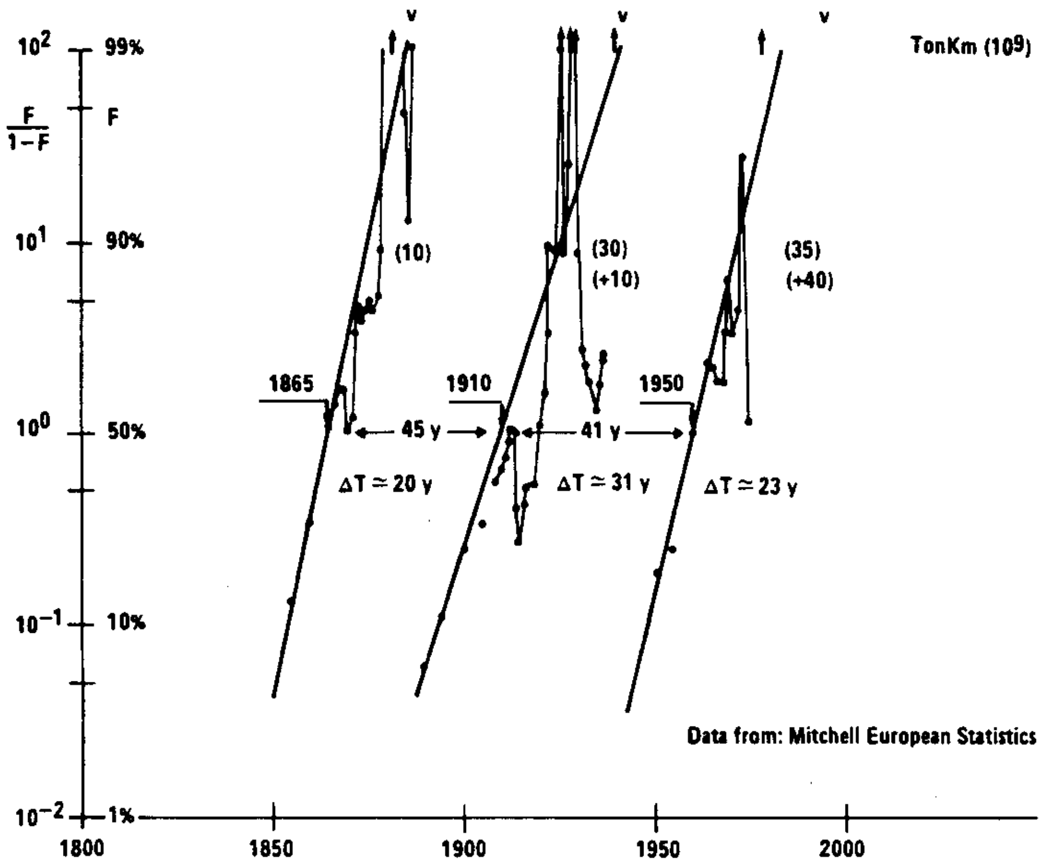


FIGURE 17. Here in France three waves of growth of freight traffic are fairly clearly delineated, in spite of the great volatility of the volumes (ton-km!) transported. It is interesting to observe that during the second wave traffic did increase by a factor of three by respect to the previous one, and in the third wave it just doubled. French railways might be one of the last adopters of phase out, staying level during the next K-wave.

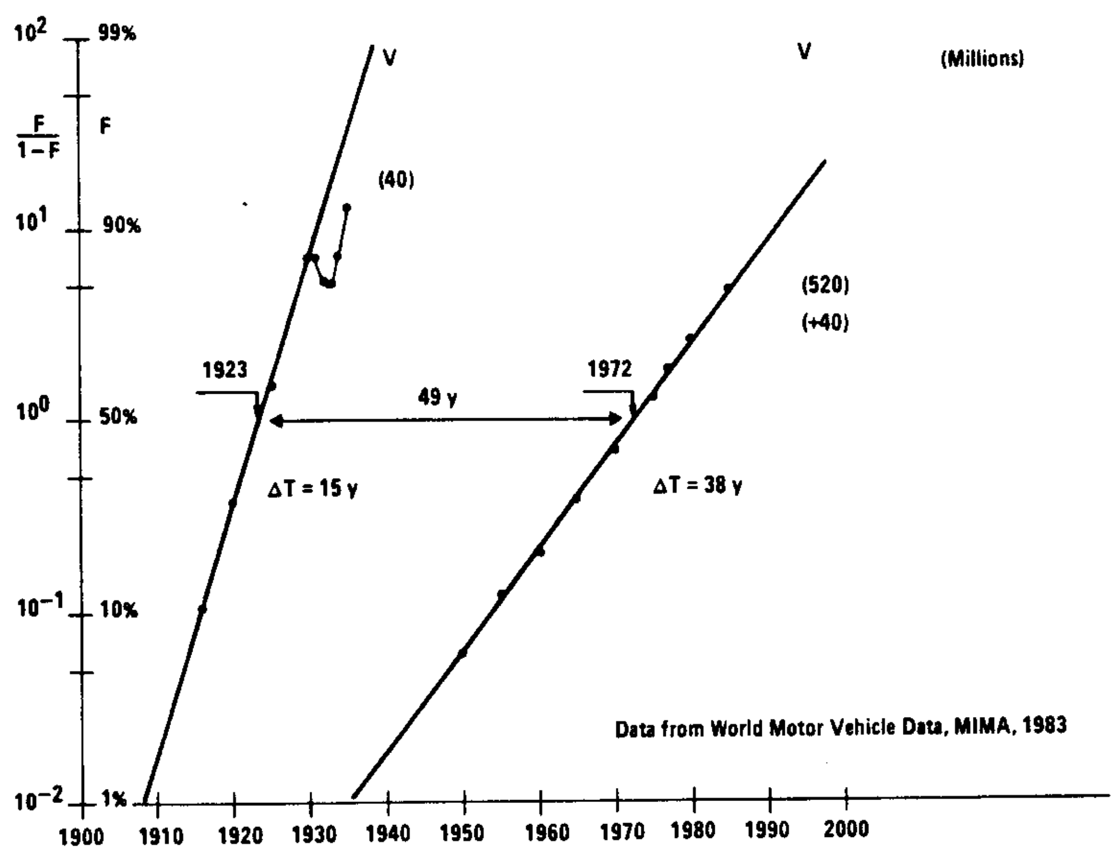


FIGURE 18. The technology of railways started in the K-cycle beginning 1830, and the automobile industry in the following one starting 1885 and expanded explosively in the

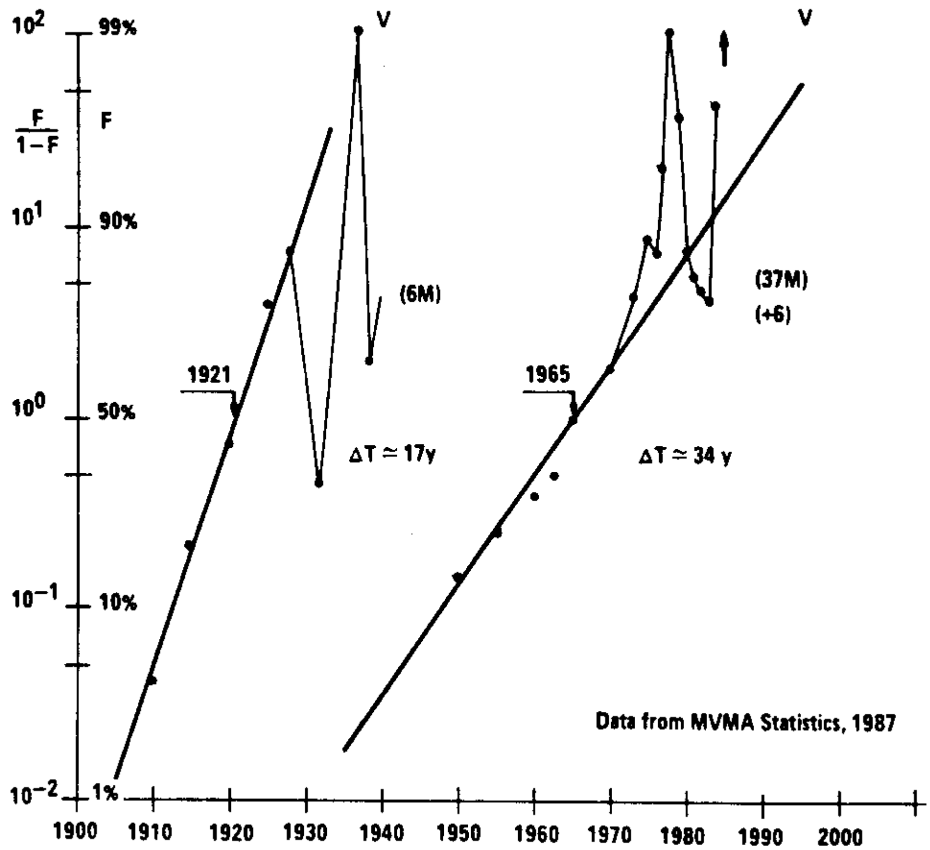


FIGURE 19. The situation of motor vehicle population of Figure 18 is reflected in that on motor vehicles production. It is interesting that where vehicles population grows, industry grows smoothly. When vehicle population approaches saturation, production starts oscillating revealing uncertain markets. We were not able to really pinpoint the deep reason of that uncertainty. The fact that vehicle population did grow more (x 13) than vehicle production (x 6) points to substantially longer lifetime of the machines produced.

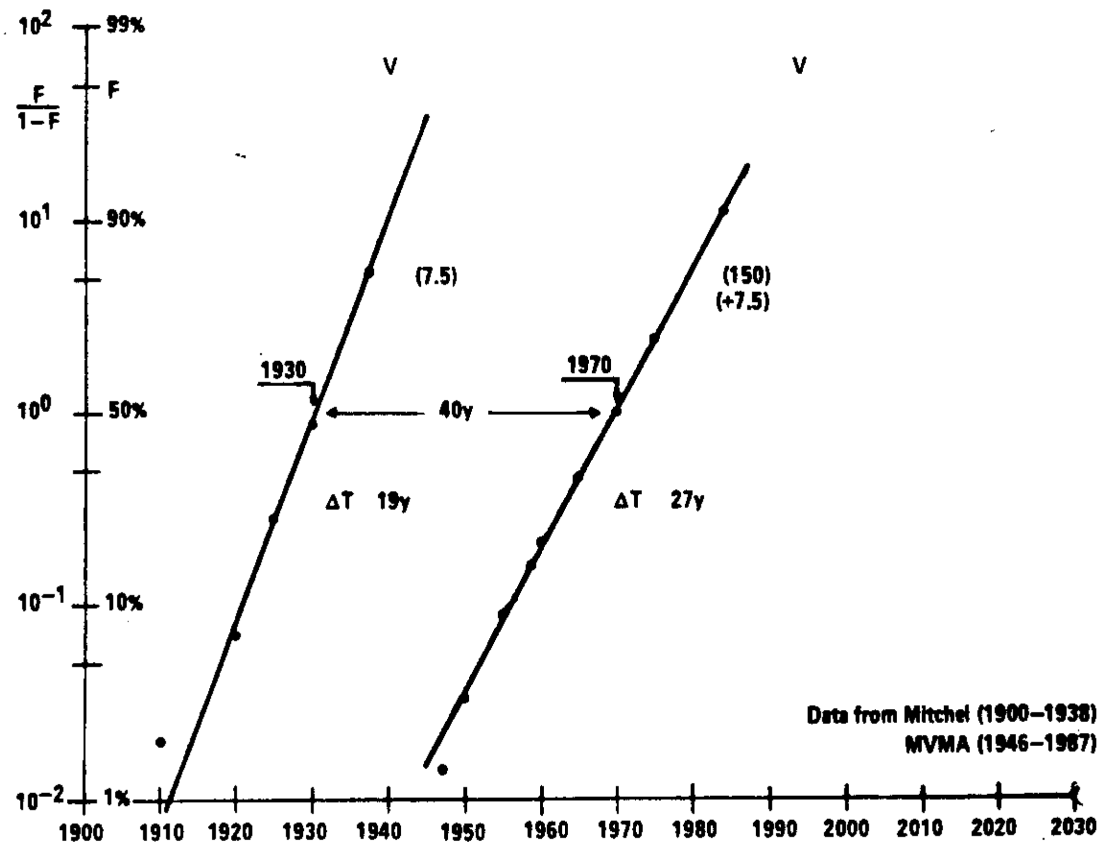


FIGURE 20. If we go to car circulation (Europe), we get a similar picture, with no hook

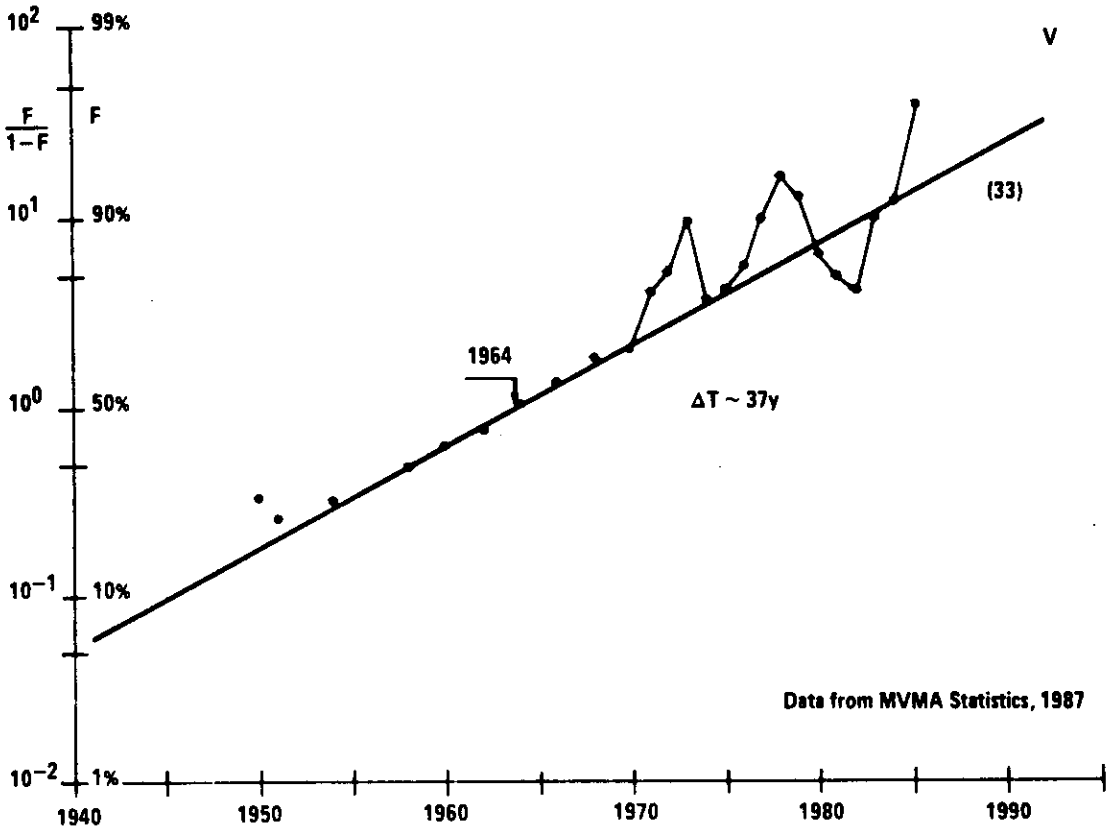


FIGURE 21. Production of passenger cars, here at world level and only for the present K-cycle, shows that even maximum aggregation does not cancel instabilities in the upper part of the penetration curve, when the end of the K-cycle is approaching.

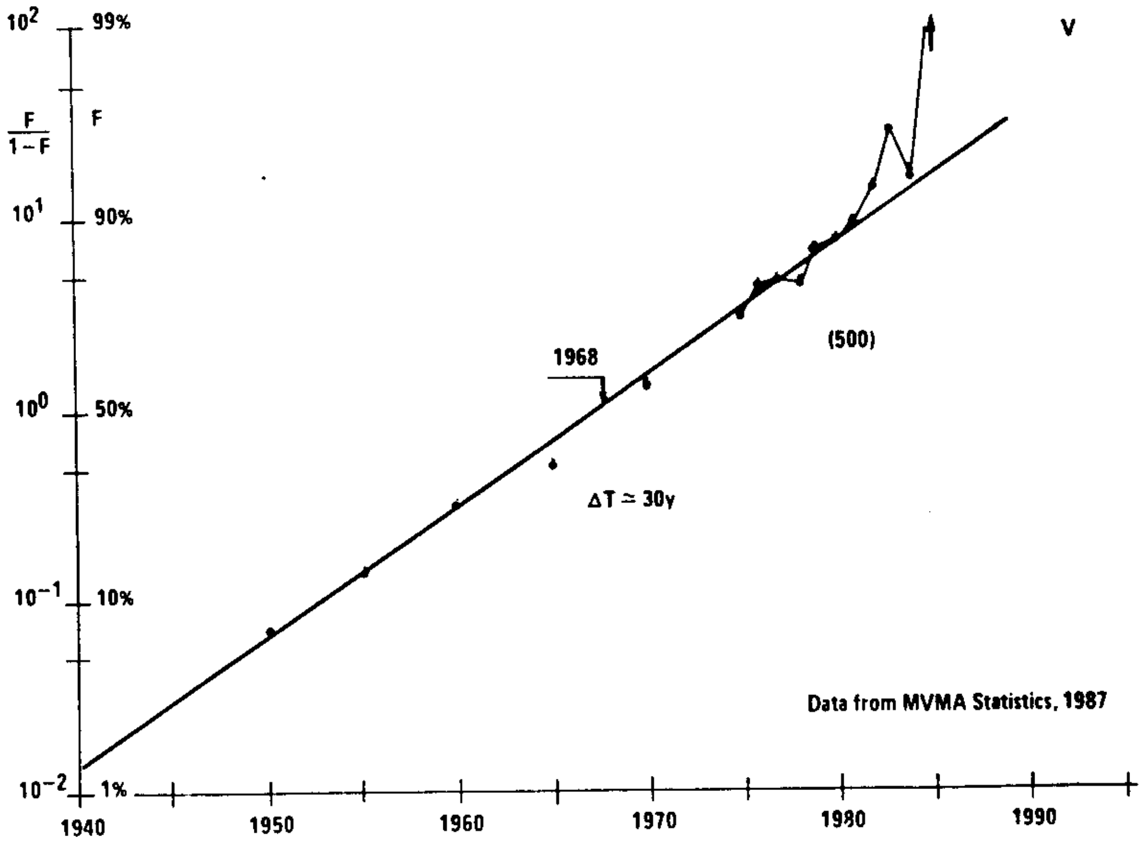


FIGURE 22. Car production by single companies can also be fitted by logistics saturating toward the end of the cycle. Through the many case studies Mercedes did appear by

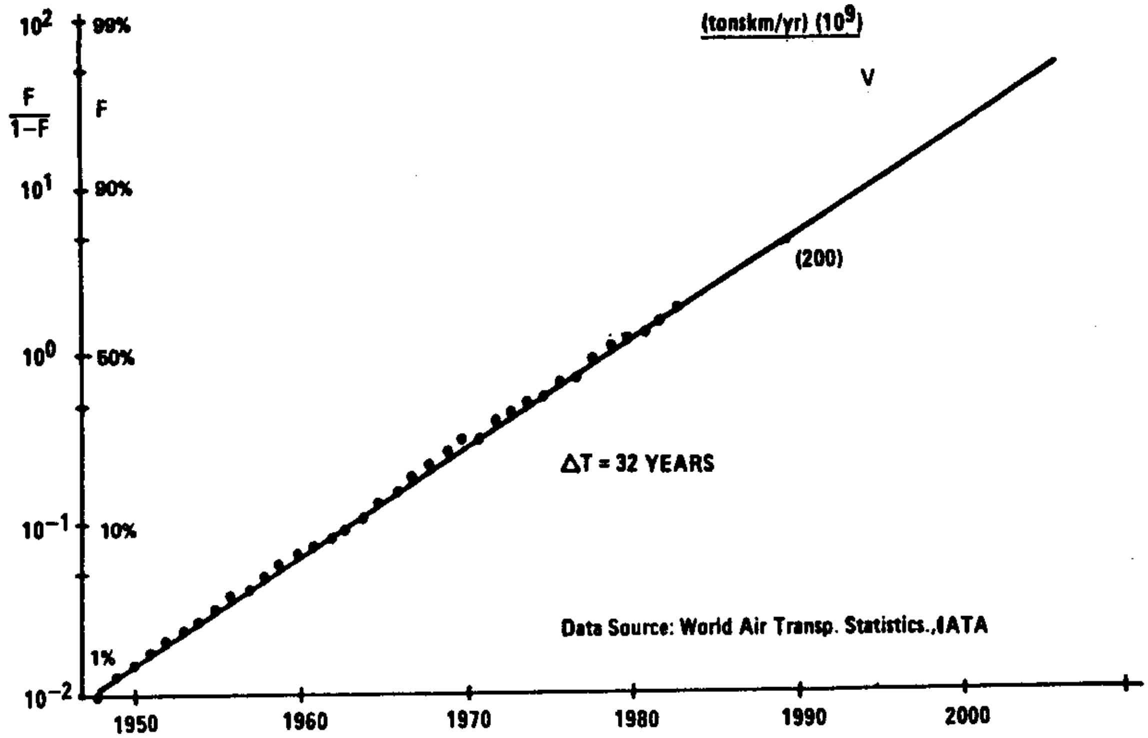


FIGURE 23. Moving from the production of goods to the delivery of services, we find analogous patterns. World air traffic (passengers at 100 kg each and cargo) in ton-km can be fitted very snugly by a logistic equation saturating toward 1995. Remarkable the absence of perturbations due to stiff increases in the price of jet fuel in 1974 and 1979. *Homeostasis* at work!

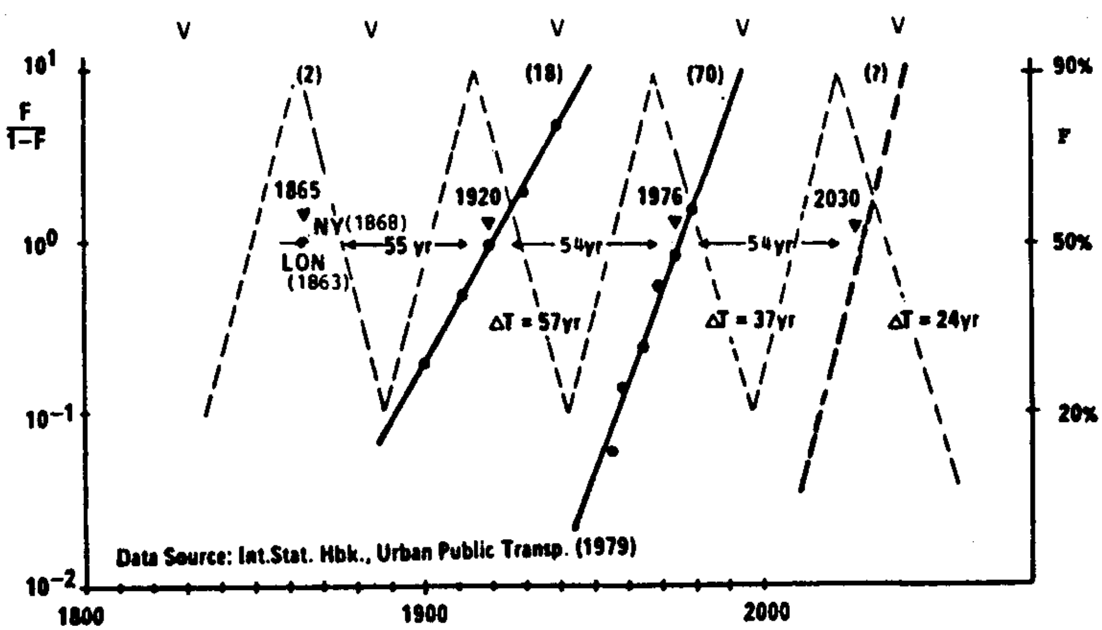


FIGURE 24. If we look at metro transport for cities we find here a pattern quite different from railways. Every K-cycle seems to spawn a new population of metro networks. The chart reports cumulative numbers of cities opening the first metro line. There were only two in the first wave and 18 in the second. For the present wave there should be 70. Another wave is calculated using regularities in the first three. Distance between center points of waves is 55 years.

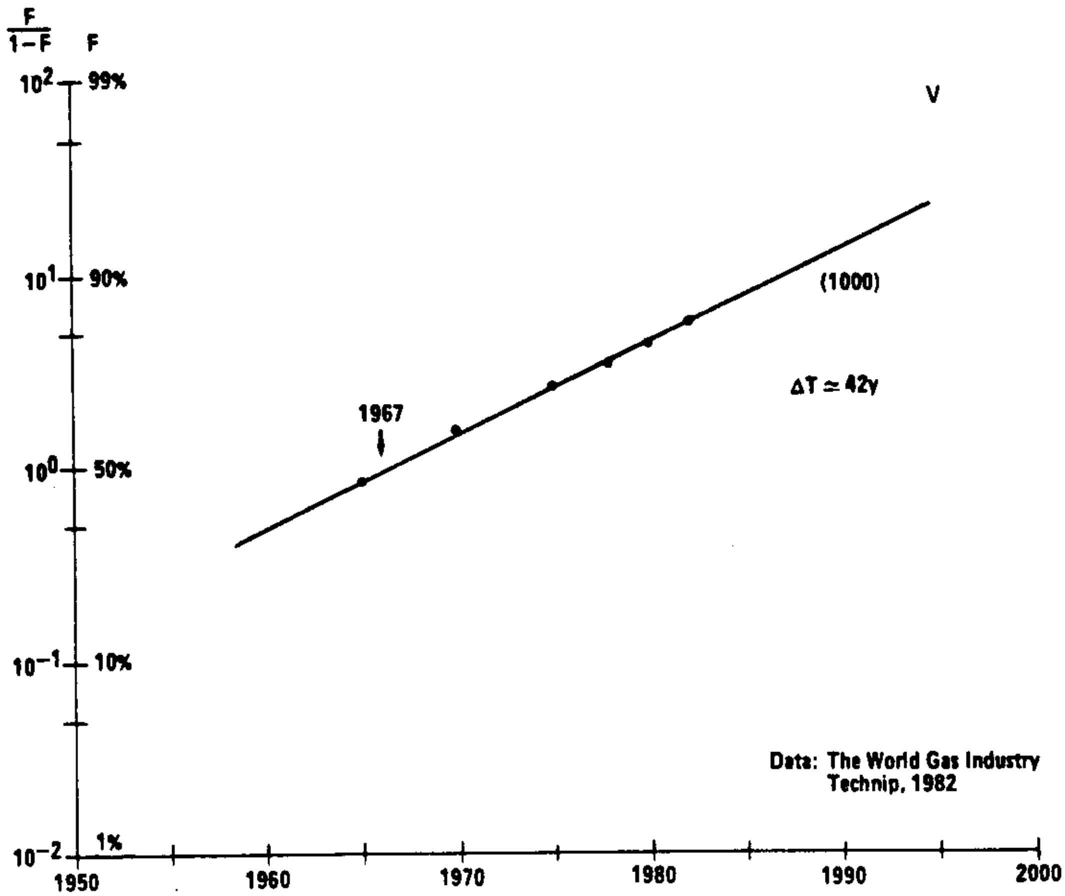
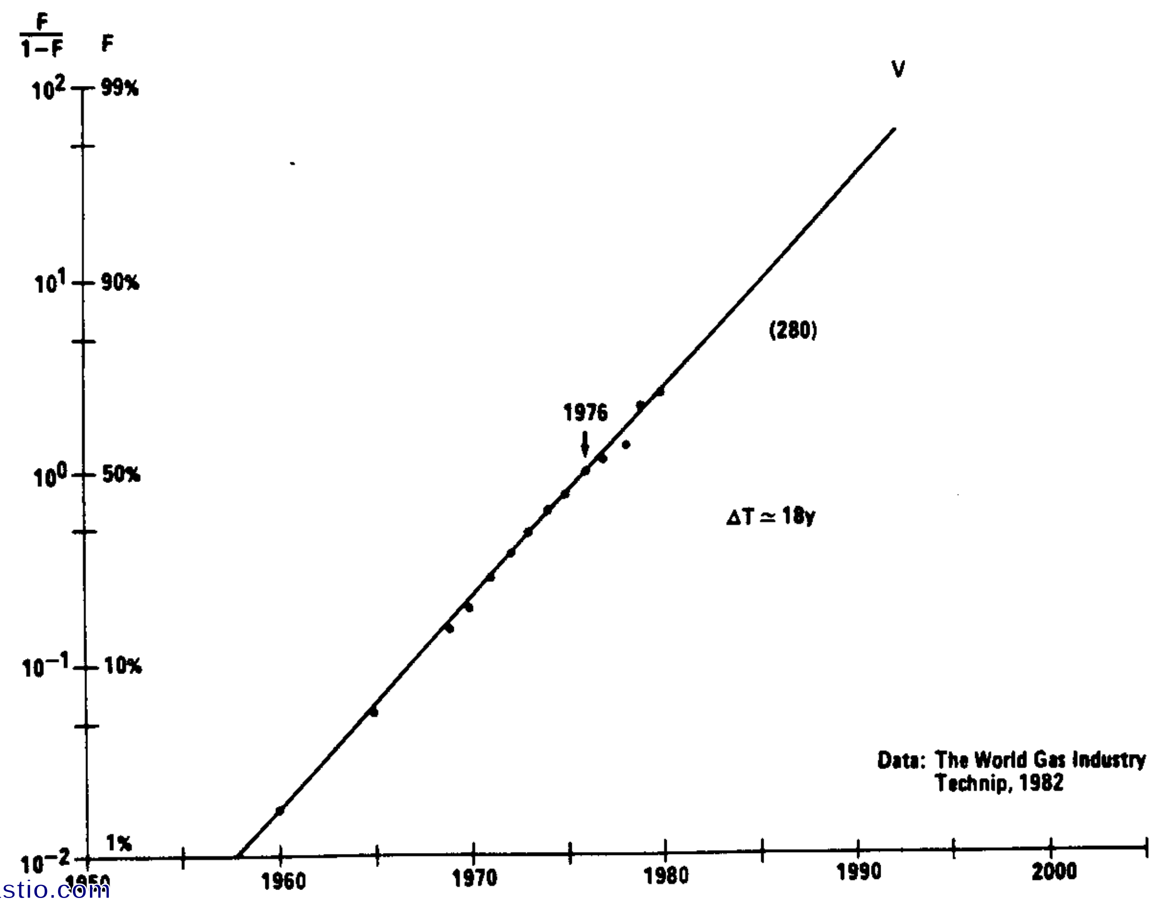


FIGURE 25. Pipelines are an important vehicle for fluids, primarily water, oil, and gas. We did examine the evolution of infrastructures for the last case, limiting our analysis to gas trunk lines. The evolution of their total length is logistic, and saturates again around 1995 at the level of one million kilometers.



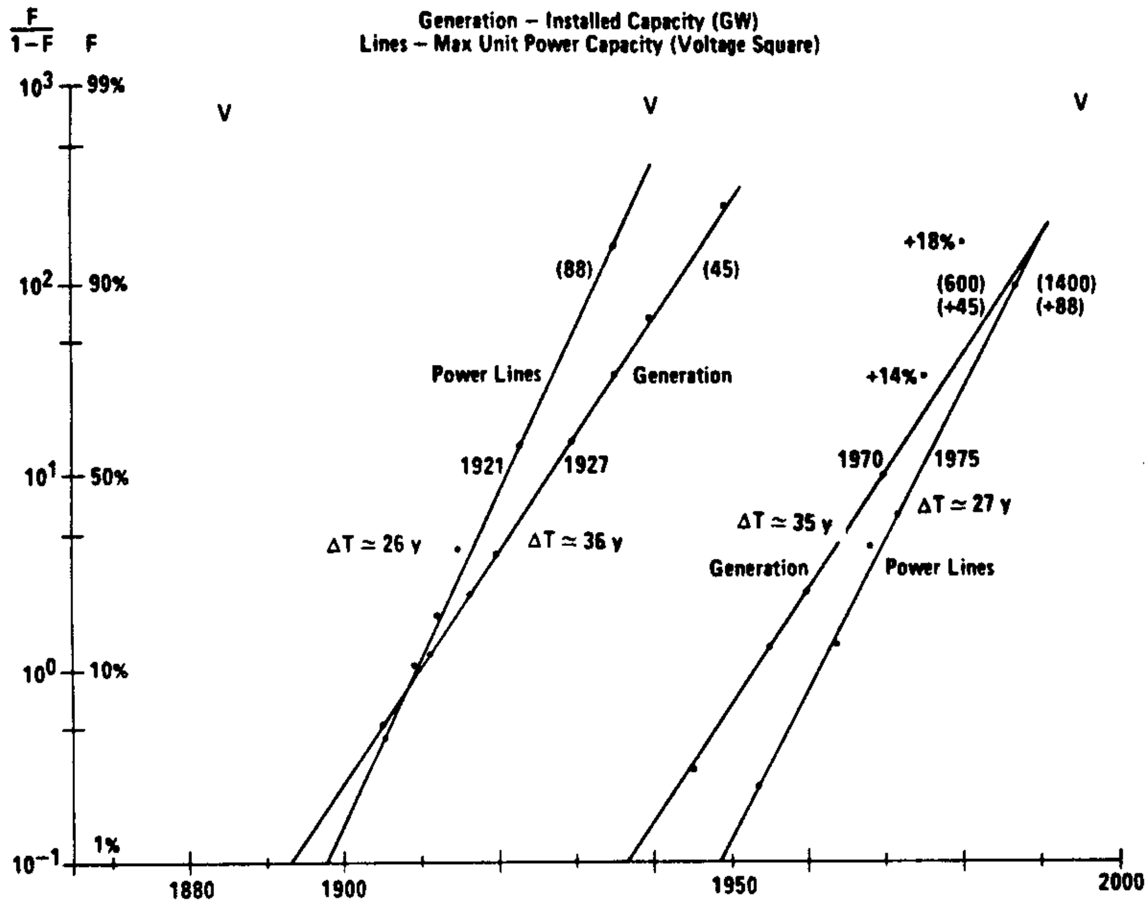


FIGURE 27. This chart shows some interesting internal links in the development of a large system, like the electrical one in the US. It is a current opinion between electrical engineers in the US that high voltage, high capacity lines were a clever idea after World War II to spread reserve capacity between neighboring networks. The above chart shows the idea must have always existed, as high voltage lines' capacity always grew in parallel with system's capacity, and in tune with Kondratiev cycles. Electrical capacity in the US is now $\approx$ 18% above the extrapolation of the past (up to 1975). This overcapacity is recognized in current literature, although at a somewhat lower level. It derives from the assumption that growth should be always exponential, and it would not have occurred if the context of logistic growth and *K-cycles* had to be taken into account. The cost of this idle capacity can be estimated in the range of 200 billion US$, and is roughly equivalent to all installed nuclear power in the US.

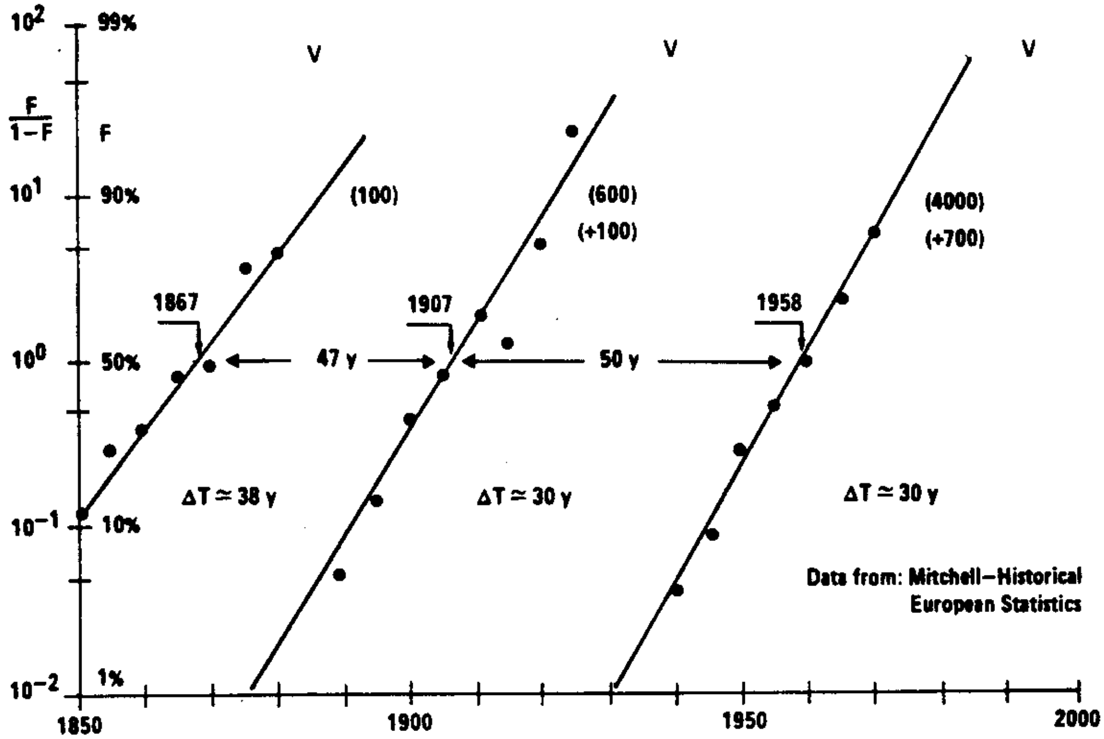


FIGURE 28. Moving one step higher in abstraction, we can measure other forms of socioeconomic activity, e.g., the exchange of messages via mail, telegrams and telephone calls. The analysis here is done for Switzerland in terms of messages exchanged. A three pulse situation is clear with appropriate saturation points and distance between center points. The size of the second pulse is six times the previous one, and another factor of six appears in the third pulse.

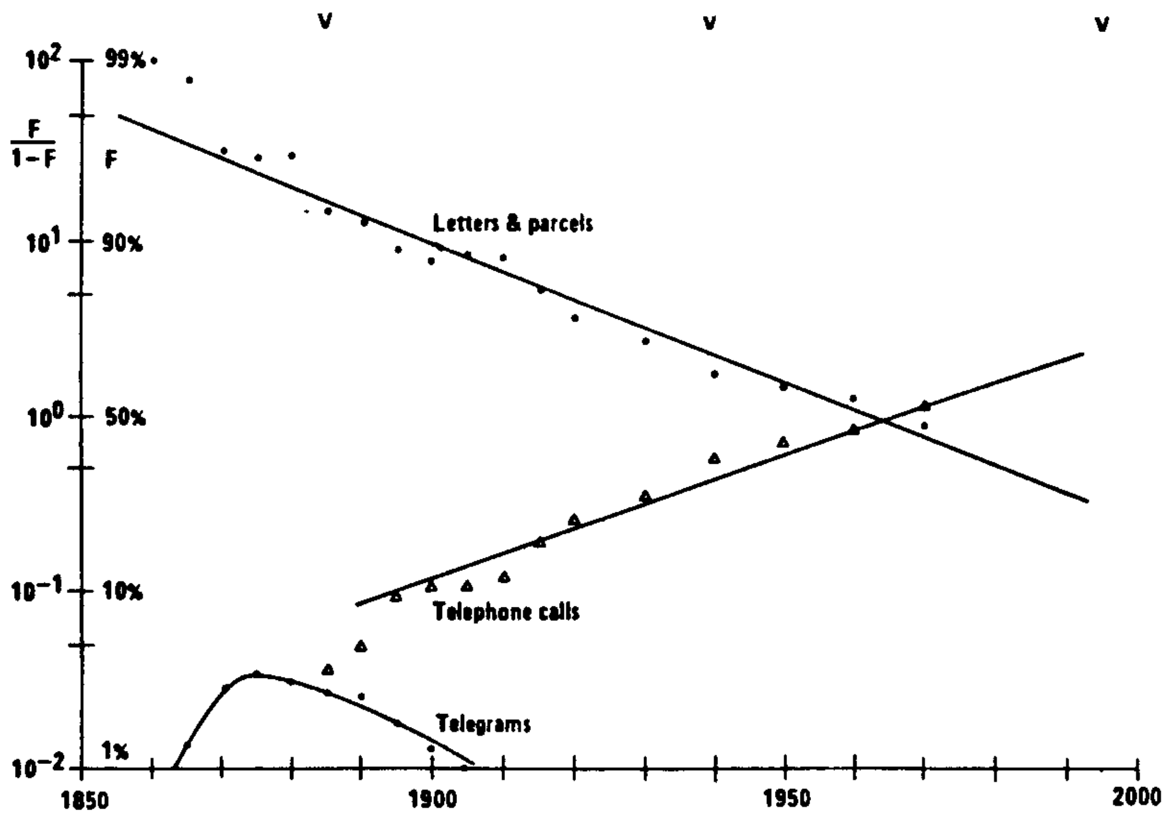


FIGURE 29. The same data of Figure 28 are here presented with modal split: It is apparent the basic competition between telephone and letters, telegram playing a quantitatively minor role.

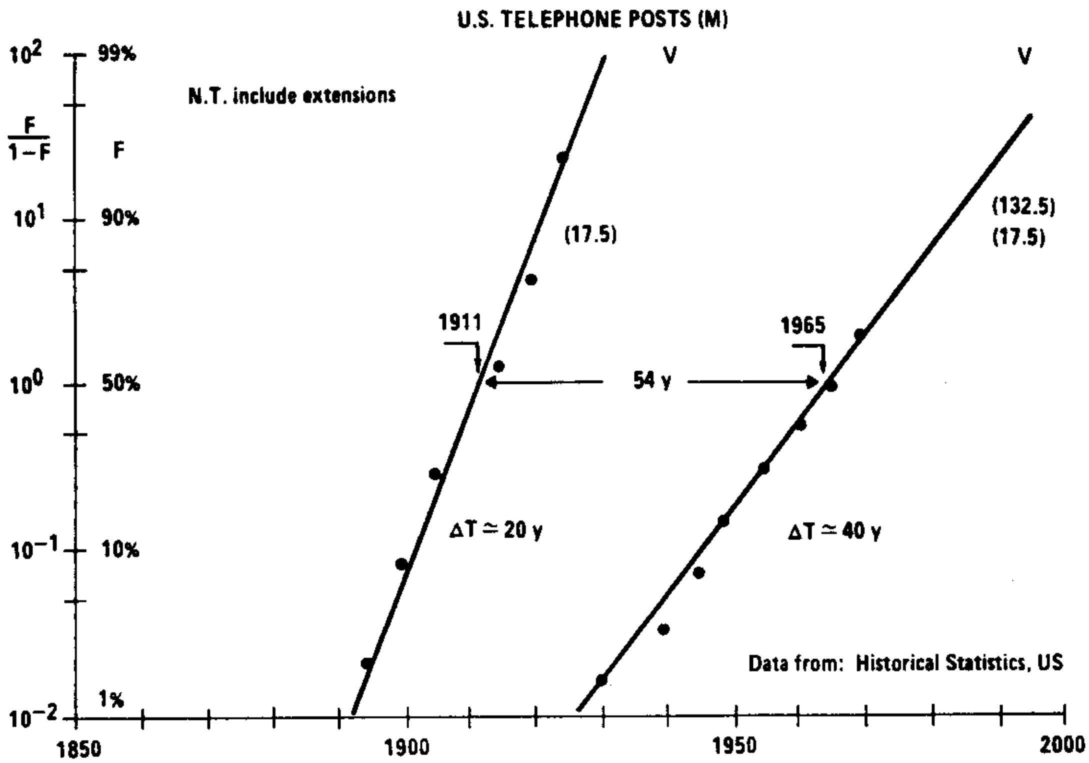


FIGURE 30. From the function to the hardware. Here the case of telephone posts (including extensions) are reported. Apart from the disturbing effect of extensions, difficult to evaluate, it seems the multiplication factor between pulse one and two is again around six as in the case of total communication in Switzerland.

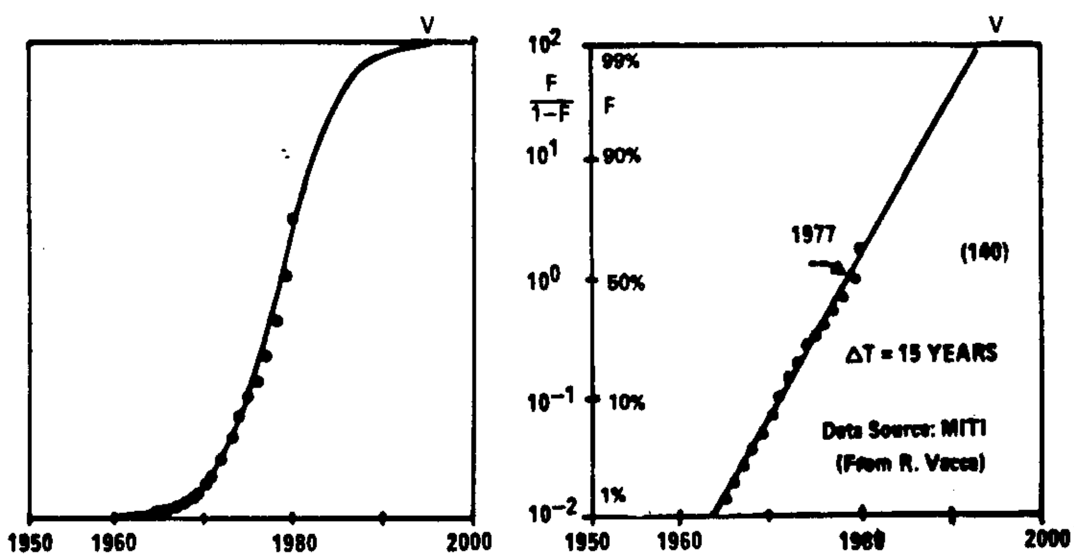


FIGURE 31. The "explosion of informatics" is a well recognized phenomenon, considered of very recent origin and expanding exponentially into the far future. The analysis in the following charts shows familiar patterns under the strict control of the K-cycles. This chart reports growth of *main frame computers* in operation in Japan. Their saturation point of 140,000 should occur around 1995.

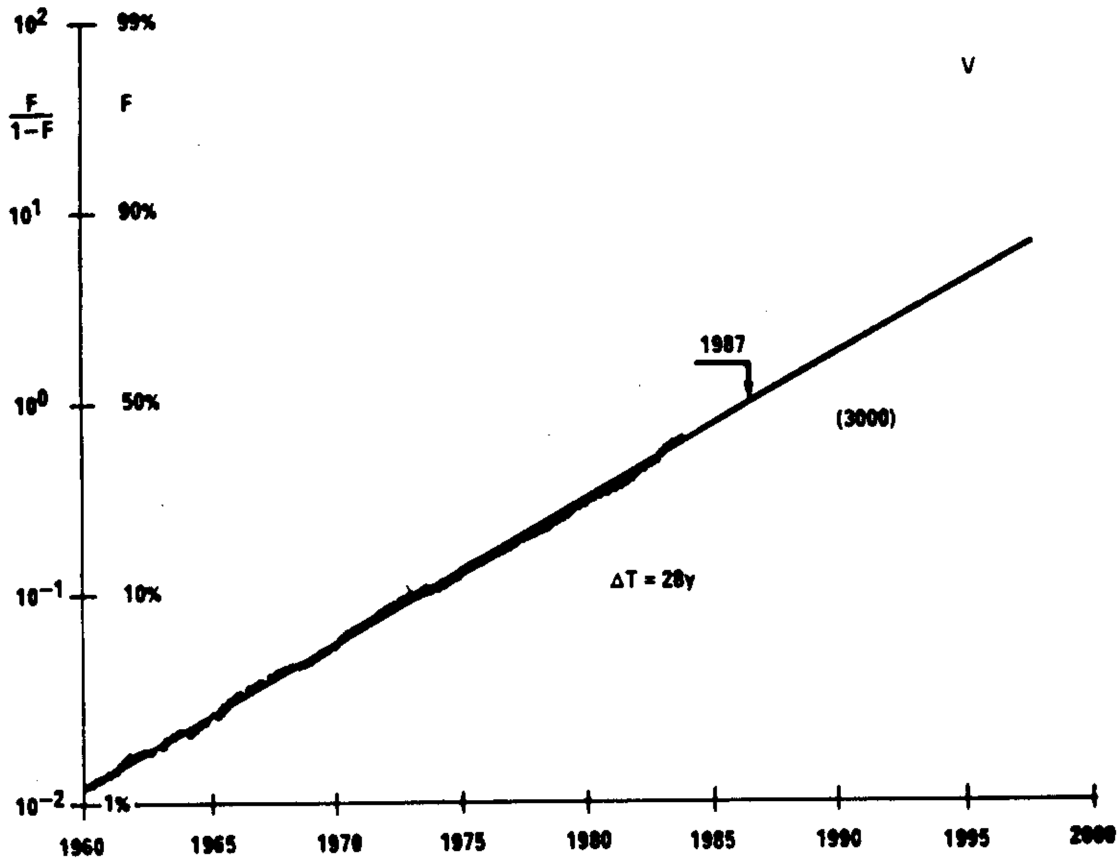


FIGURE 32. We can go one notch higher in abstraction and instead of main frame computer machines look at *main frame computer models*. A logistic fits well again their cumulative number since 1980, saturating at the respectable number of 3000 toward the year 2000. The chart includes all computer manufacturers.

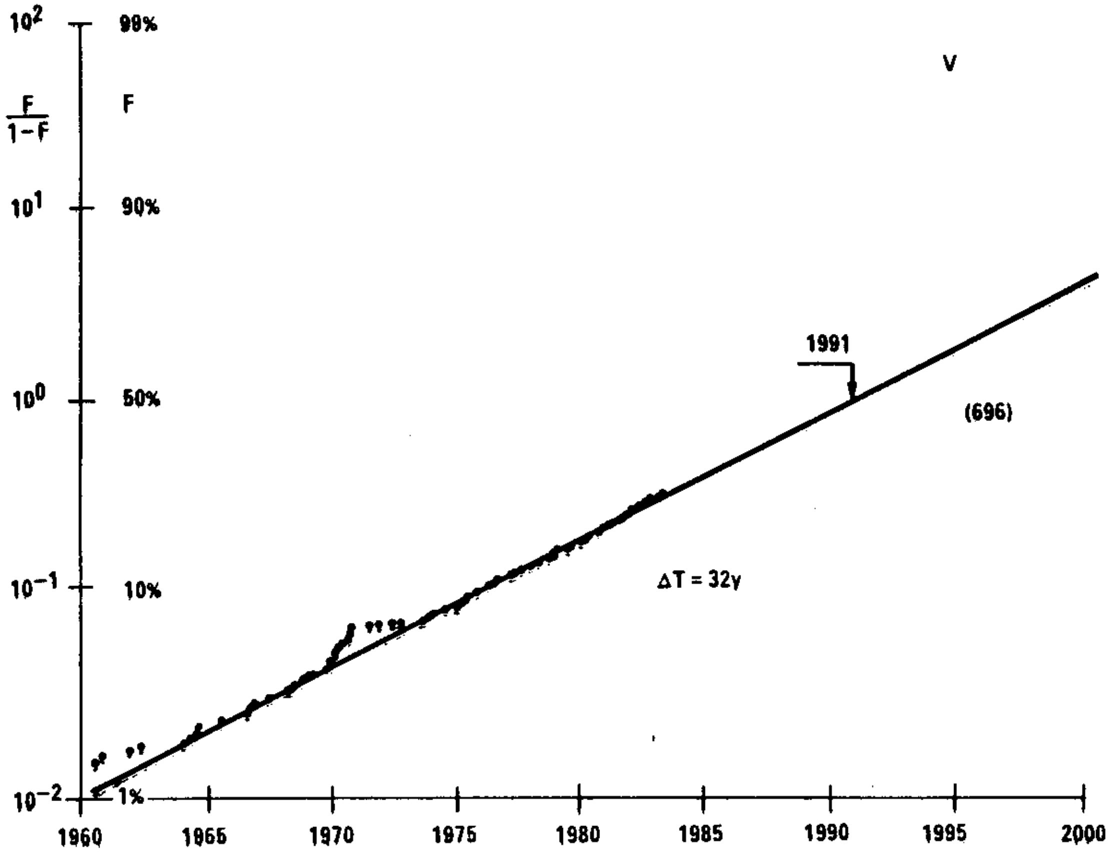


FIGURE 33. We can go one step further and look at the population (cumulative entries) of *computer manufacturers*. With the exception of a little over-enthusiasm in 1972-1973, the situation evolves again in a very smooth way. Dividing, however, saturation number of computer models by saturation number of computer manufacturers, we obtain the modest number of four models per manufacturer. As successful manufacturers may produce 50 to 100 models during this K-cycle, it seems that most manufacturers produce one or two models and then disappear from the market.

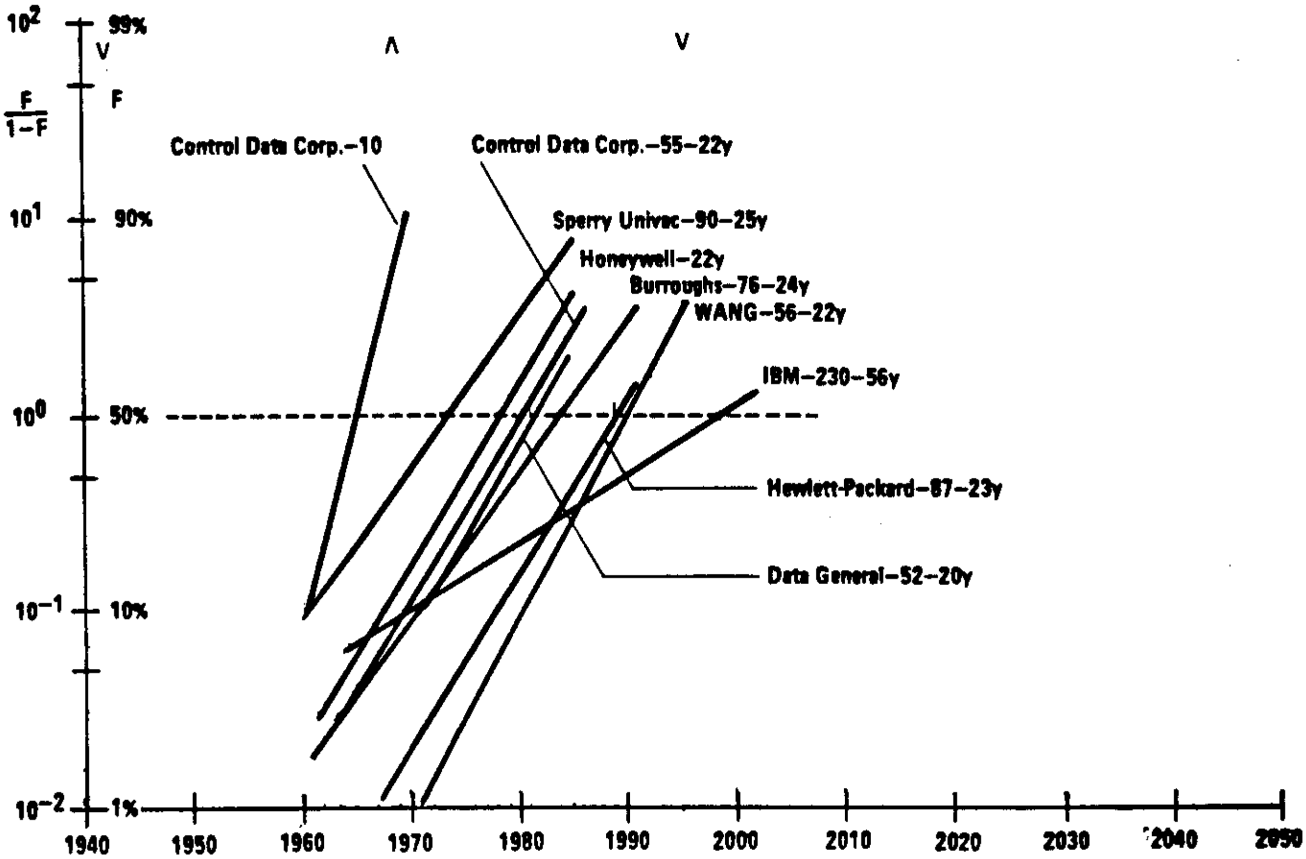


FIGURE 34. This is the equivalent of Figure 33 for single (important) manufacturers. The actual data points have been eliminated for clarity. The first number on top of the lines indicate saturation point for number of models, and the second, time constant. There is a clear convergence of behavior with the exception of IBM who seems to span two K-cycles in a single go.

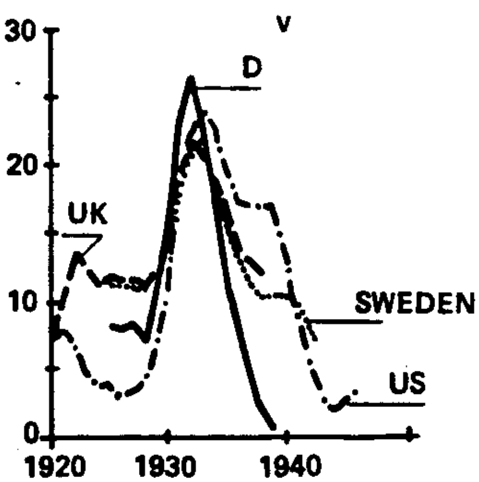


FIGURE 35. This chart shows the gliding mean (three years) of unemployment in four different economies. Saturation of markets leads to zero growth of production which works basically for substitution, e.g., of cars. Increasing productivity leads then automatically to reduced employment. Because everything as we have seen saturates around the end of a K-cycle (1940), then unemployment piles up just a few years before. Because the phenomenon is worldwide, there is no escape as the chart shows and unemployment levels are strongly synchronized.

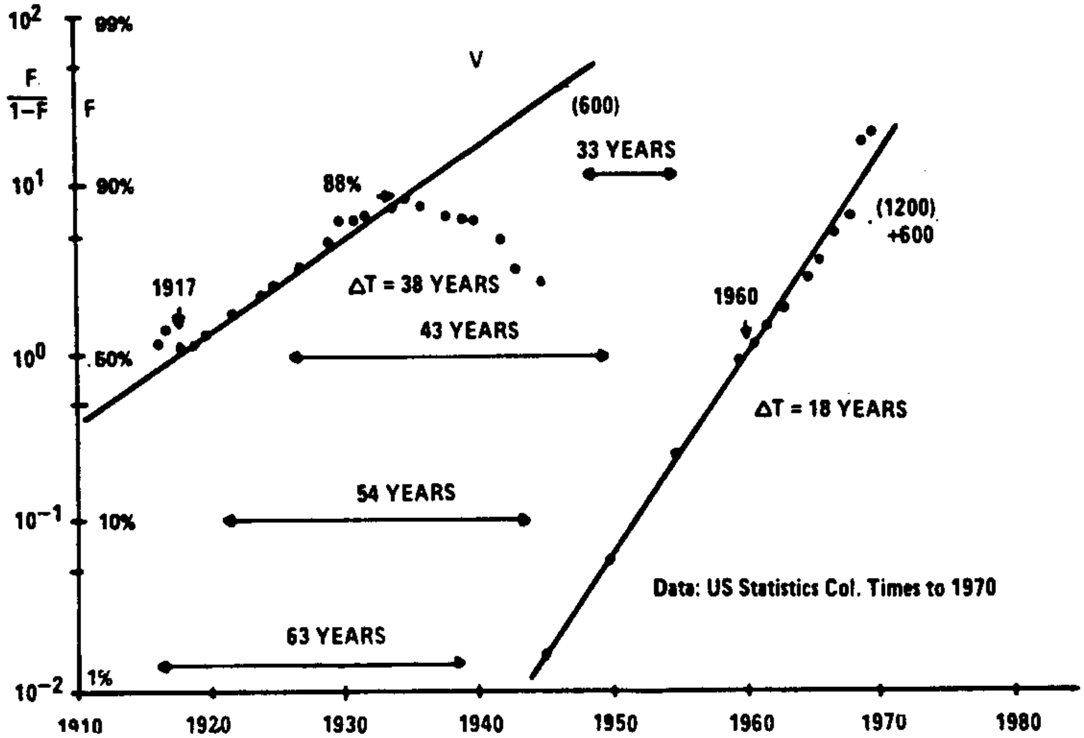


FIGURE 36. Spurts of activity are well indexed by growth in number of the activators, business companies and an analysis for the US is here reported, covering two K-cycles. The second wave has double the size (1200 vs. 600) of the first. During the period covered, US population did more than double.

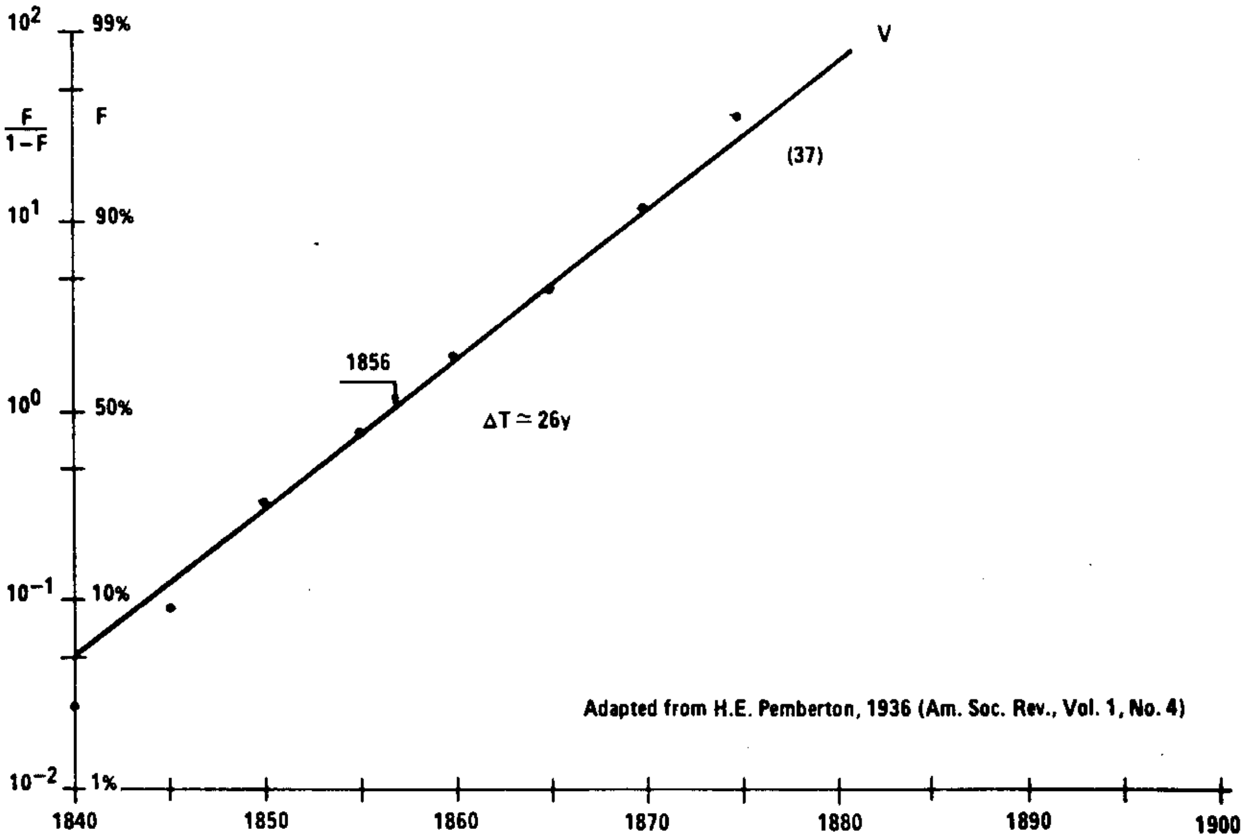


FIGURE 37. We are now moving into social customs. This one, a borderline case, deals with the technique to cash the due for transporting mails and parcels. The chart depicts the diffusing of the postal stamp, measured through the cumulative number of states who did adopt it. The process is concluded inside a K-cycle, like the starting of railway net-

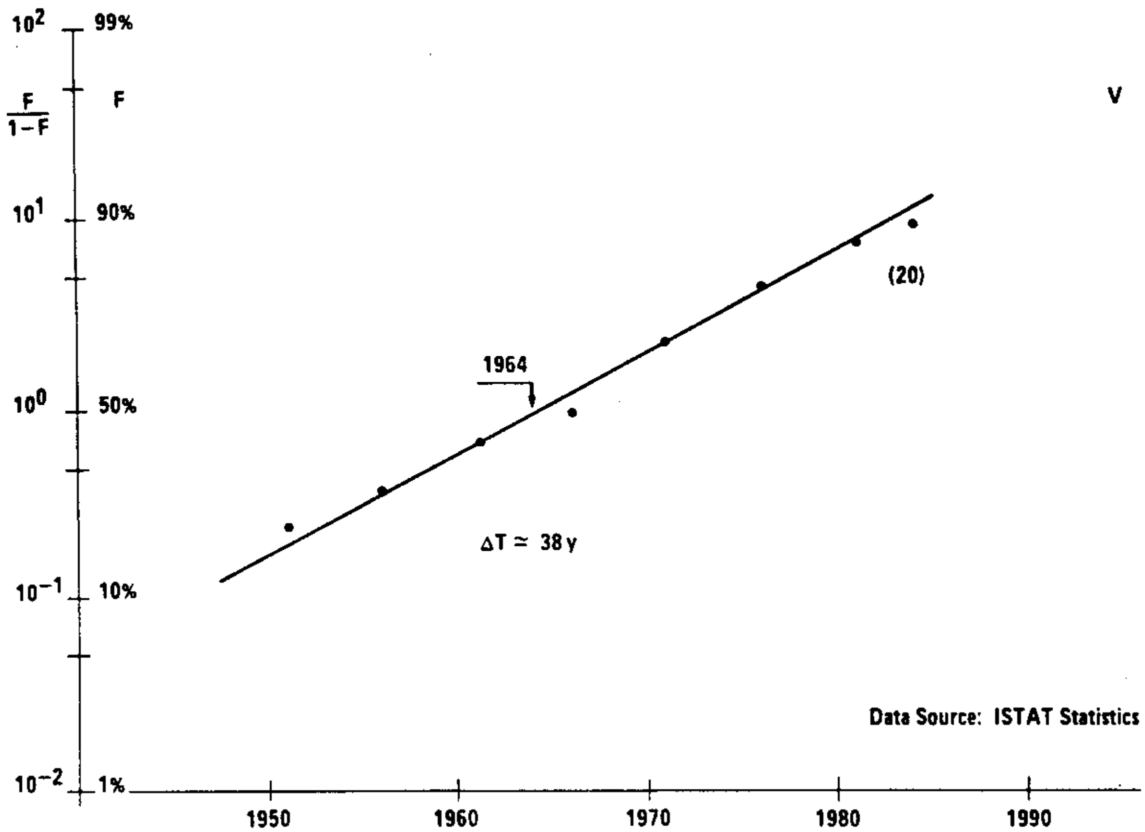
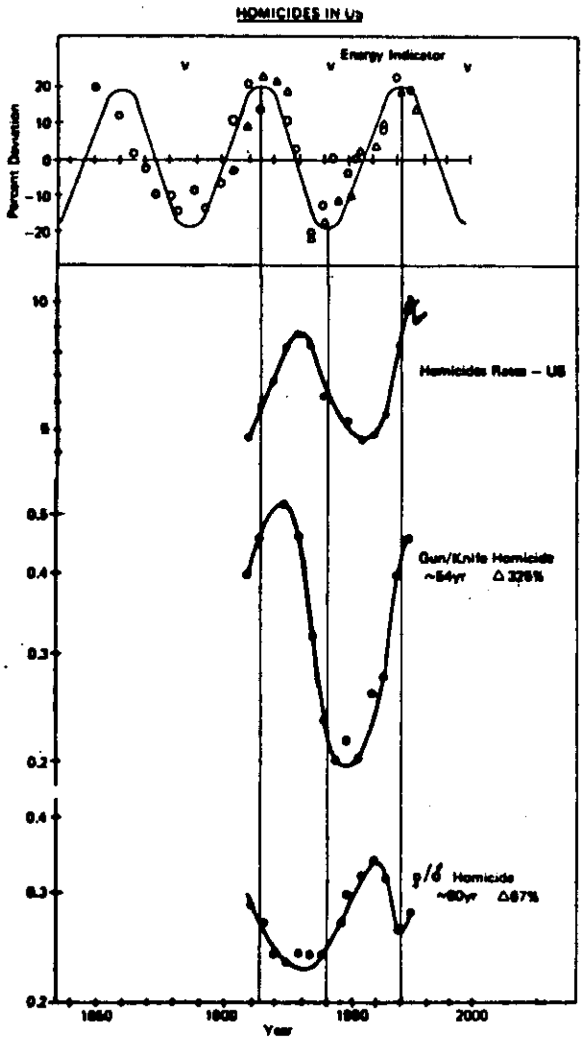
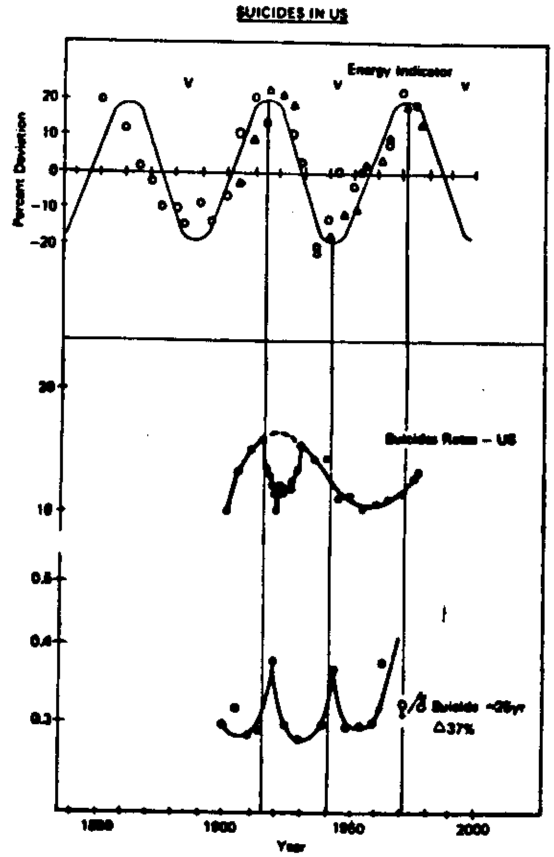


FIGURE 38. Another typical socioeconomic process is that of granting pensions. Their number will saturate to 20 million in Italy, with a total population of 56 million. There is probably no room for a second pulse of growth, also considering that the Italian population is stationary now and will probably decline during the next K-cycle.





FIGURES 39-40. We are here fully into sociology, measuring crime rates in an area where statistics are fairly credible: death rates by homicide and suicide. The link with the K-cycles depicted on top of the chart, using the Stuart curve as a clock, is very clear. It would be very interesting to try to interpret the difference in phase. Most remarkable is the fact that, e.g., type of weapons (shoot or stab) have a similar period and very high modulation (factor of three!). It seems obvious that people act under the influence of deep social moods, flowing and ebbing with a 55 year cycle.