Stable Rules in Social and Economic Behavior*

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MARCHETTI-066

*Lecture held at the Brasilian Academy of Sciences in Rio de Janeiro on November 11, 1986. This event was sponsored by IBM Brasil.

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I can tell you and foresee
what side will win and what will lose
Sun Zu - The Art of War (1,14)

Cesare Marchetti

It is an old intuition that human behavior has rules, and all sorts of efforts have been made to rationalize these rules and make them quantitative, just as in physics and the other hard sciences.

If we look historically at these attempts of the social and economic researchers, we find that systematically their starting point is anthropocentric. Man is the primary motor, *motor mobilissimus*, in the dynamics of social systems, which includes the economic ones.

Consequently, one has to rationalize first this behavior, understanding its springs and motives, and then from this "atomic" model build up the properties of molecules and macroscopic bodies. The approach makes sense, but centuries of efforts did not bring rewarding results.

Social systems and human behavior were most vitally studied by Dostojewsky, who never touched academia, and the theory of economic equilibria, which drained for a century the wits of thousands of clever professors, never touched ground to interpret and *forecast* economic phenomena.

These failures were obviously of methodological origin. The large number of people involved in these activities means a large number of top quality individuals. So any attempt to come out of the stalemate has to rely on a *radical methodological innovation*.

The results I will present today descend from a working hypothesis of Keplerian character: let us look at the *actions* of man and society and see if they are orderable. This is a sort of back-to-square-one exercise, as all observations and rationalizations of nature should start that way.

Ordering usually begins with a mental model, the working hypothesis, which is tested on the facts observed. The model I will use is lent from biology and describes the dynamics of populations of living objects, in a frame of Darwinian competition. The description of the model is given in the Mathematical Appendix in a very simplified form.

It says that a successful contrivance, be it a bacterium in its broth or a car in the transportation system, will grow logistically to fill the potential of the environment: the nutrients in the broth, or the capacity of the market to sustain cars.

So we have the external resource, the ecological *niche*, the *population* measured by the number of individuals, and *time*. The Malthusian growth of the population of bacteria to fill the niche of broth is very precisely described by a logistic equation (Figure 1), a fact already discovered by Verhulst (1845) more than a century ago.

The logistic equation provides a relation between the sizes of the population, moving toward a saturation point: the size of the niche. Moving implies a dynamic in time. Rates will be usually expressed in an intuitive form: the time for the population to go from 10% to 90% of the saturation point. This will be called the time constant and is indicated in the charts by ΔT.

The concept of the niche can be easily translated into the economy, and can be found already in the current language of practitioners who speak of market niche. Taking population size and dynamics as the visible expression of a niche, let us look into the concept quantitatively.

Car "population" in Italy is reported in Figure 2. The chart gives the number of registered cars in circulation in Italy in the period 1950-1980. The fitting logistic provides a superb description of the evolution in time of this peculiar "population". Fitting permits the calculation of the saturation point or the final size of the market, a precious indication for practitioners.

One may think that the case of car population in Italy is an isolated curiosity. However, all car populations in all developed countries analyzed this way (Marchetti, 1983) can be perfectly fitted with logistic equations. The fact is general, and I give here another example which could be of interest for IBM who did sponsor this seminar.

The case of the population of main frame computers in Japan is reported in Figure 3. It shows a saturation point of 140,000. *The niche*. The analysis also assumes the niche is stable, at least during a period corresponding to the time constant or more.

This is obviously a hard statement, as so many people think the market is plyable and act in consequence. The high quality fit, e.g., for cars in Italy, could not be possible if the saturation point, i.e., the niche, were not stable for more than 30 years. And the car market is one where unquestionably everybody tries clever manipulations.

A bit of information that may be interesting for practitioners, e.g., in the area of main frame computers, is that these niches are stable inside time blocks of about 55 years which neatly correspond to a Kondratiev cycle. This information is extracted from the historical analysis of hundreds of cases. Incidentally, our portfolio of "objects" analyzed is now well over thousand cases. Kepler could not exist without the thousands of precise measurements by Ticho Brahe.

The concept of niche can be abstracted to many levels. The number of objects to be discovered can be considered a niche, and the cumulative number of objects discovered, through a search, the population of objects discovered. We may apply this idea to the discovery of the chemical elements, and make an historical check (Figure 4). Also here the mechanism is general and permits unexpected insights, quantitative, into the internal dynamics of science as we will see later on.

In the specific case the three niches were determined by the search technologies: chemical, physical, and nuclear. Also bacteria may have multiple surges of growth, if the "invention" of new enzymes (a new processing technology!) permits the use of fractions of broth previously inaccessible to digestion.

We can now move to the next step. If a niche is already filled up, and an efficient competitor comes in, what happens? The situation is clear in biology and was quantified by Haldane (1924). The efficient competitor can be a mutant with superior mimetic properties and consequently more protected from predators. In this case the newcomer will progressively substitute the less efficient version and finally fill the niche. As Haldane did show, the substitution process is precisely described by a logistic function. To be punctilious, this is the general case. Also the bacteria substitute the "chemical species" of the broth through their superior organization and activity.

Jumping into our economic world we can look at the substitution of steam locomotives with diesel locomotives in the niche of the British railways as Figure 5 shows, the actual process fits very well the model. The chart reports the fraction of the niche taken by diesel. Steam locomotives would be represented by a perfectly symmetrical downward line, not drawn for simplicity. Other examples can be taken from coal mining technology (Figure 6) or from transportation, with cars substituting for horses in personal transport (Figure 7).

During the substitution, a third competitor may appear in the niche, e.g., electric locomotives. In most situations this is actually the case, and numerous competitors elbow for survival. The quantitative side was treated by Nakicenovic and myself in the 1970s and can be found in Marchetti and Nakicenovic (1979).

Basically, the rules are very simple. The successful newcomer penetrates logistically, i.e., takes increasing shares of the niche, following a logistic equation. Old losers phase out logistically. One competitor in between takes what is left from these rigid courses.

The first example of multiple competition is reported in Figure 8. It deals with primary energies competing for the world market. The analysis spans about 125 years and during this time coal, oil, gas, and nuclear penetrated a niche originally taken by wood and hay.

All of them are still present, if with different market shares and dynamics, upward or downward. The fitting equations are basically two parameter logistics (with interactive switches), and it is miraculous that such light mathematical equipment can encompass so precisely such a complex phenomenon over so long a period of time. When we found it, I must confess, we did not believe our eyes after so many disillusions with complex and sophisticated models (we collected and analyzed a few hundred, see, for example, Charpentier, 1974; Charpentier, 1975a; Charpentier, 1975b; Beaujean and Charpentier, 1976; and Beaujean and Charpentier, 1978).

The result is not the effect of the high aggregation. We can look at the US, with natural gas taken together with oil when associated and as a separate entity when dry (Figure 9). Or we can look at the FRG, where coal and lignite are separated, lignite being very important and primary hydroelectric energy appears above the 1% cut off line (Figure 10).

The world appears ordered even if we zoom into the small details. And, as one can suspect, primary energies have nothing special to make them a special case. We can look, e.g., at the substitution of propulsion technology in ships (Figure 11). Or at the substitutions in the chemistry of making steel in the UK (Figure 12). Or the substitution of transport infrastructures in the US (Figure 13).

A very interesting principle was discovered in biological taxonomy by Willis (1922). He observed that the same rules are valid when moving up in the taxonomical scale. A population generates individuals. A species generates populations. Genera litter species and families genera. The statistical structure is always the same, so one has a "population" of species competing and growing to fill the "niche" of the genera and so on.

These *abstract niches*, as I called them before, permit a quantitative analysis of extremely complex patterns of activity, like invention and innovation in our Western societies. Mensch (1975) made an interesting classification of them, beginning from 1800, and defining the start up of an innovation, as the date when the first machine (or service) was sold. The relevant invention is dated by the first working prototype.

Using these homogeneous definitions, he found that invention and innovations appear in lumps, in waves, and do not grow in number progressively, as it is currently thought. I took the set of dates, identifying the start ups of the items in the waves, and treated them as populations of objects, filling a niche, a *market demand*. So in a sense, an innovation was assimilated to a single object, like a car, filling the niche of car demand.

The result is reported in Figure 14, where the even numbers on top of the chart indicate innovation waves, and the odd numbers invention waves. The chart reports their cumulative numbers, expressed using the Fisher Pry (1970) transform of a logistic as usual. The regularities in the sequence are sufficient to calculate the following wave, number seven for inventions and number eight for innovations, into the period in which we live now. They will *determine the future of Western economies.*

Figure 14 condenses two hundred years of inventions and innovations in a very simple and quantitative time pattern. The case illustrates in a striking way *the very high level of self-organization of our societies.* The distance between the center points (50% of items) of innovation waves is about 55 years, which as we will see, is the length in time of a "pulsation" of the activity, economic and social, of Western world. A finer analysis of a single wave is given in Figure 15.

We can see the pulsation in smoother form, e.g., by fitting with an exponential (or better with logistic) the time series of total energy and electricity consumption in the US (Stewart, 1982). That done, we can look at the residuals by respect to the secular fitted trend. The result is reported in Figure 16 and it is clear that the residuals, both for electricity and total primary energy, are reasonably well fitted by a sinusoid with a 55 year period. Energy consumption is the most aggregated of activity indicators, including industrial, commercial, and private consumption. On this *inspiration and expiration* of the big system, as Trotsky did call it, we have indicated the center points of innovation waves, and discovered they are always located toward the lowest part of the wave, were activity has the maximum downward deviation from the secular trend: *the end of a recession period.*

Kondratiev did study in a systematic form these economic cycles, and published a set of noteworthy papers in the late 1920s. His analysis was mostly based on financial indicators which made it vulnerable to later critics by the economic establishment. We will reopen the case using only *physical indicators* to carry out our analysis, and the first one is reported in Figure 17. The upward branches of the sinusoid are taken as indicators of booms, and the downward ones of recession. The lowest points are taken as the ending date of a cycle, 1830, 1885, 1940, and 1995.

I found that the time segments, or *time boxes*, defined by these dates are in a sense separate worlds or seasonal cycles inside which many things conclude their lifecycle, or one of their lifecycles. Particularly the *niche*, the saturation level of a certain market, stays fixed during a cycle and saturation occurs toward the end of it, independently from the date when all started. The case of car populations penetrating different markets of the world, as reported in Figure 18, is typical.

The case of the US, reported in Figure 19, shows car population growing in two pulses, one saturating around 1940 and the second around 1995 with time constants of 15 and 38 years, indicating the first pulse was born late in the cycle. For Japan, which has had only one pulse in the 1940-1995 cycle and started very late, the time constant is only 12 years. Again, saturation is around 1995 (Figure 18).

The examples can be multiplied without end, and I will show only a couple of cases covering the whole life of a certain industry, where it is clear that the Kondratiev cycle modulates growth, maturity, and decay, spanning centuries (Figures 20 and 21). Even agricultural production or services do not beat the rules (Figures 22 and 23).

The fact that so many activities finally come to a standstill toward the end of a cycle provides a very simple interpretation of recessive phenomena and of the unemployment and financial unrest connected with it.

Let us take the case of automobiles to hold a concrete example. When car populations saturate, as indicated in Figure 2, production will basically cover substitution of dismissed vehicles. Because vehicle life is fairly stable around a dozen years for cars, production will stay constant. But productivity will keep growing, typically 3% per year in our case, for a number of reasons – competition, salary pressure, and mostly habit. This means the automobile industry as a whole will dismiss 3% of its employment *per year*. This does not seem much, but it makes 30% in ten years. Worse still, almost everybody is saturating his market, and consequently expelling employment. Managers interpreting zero growth as a transient feature due to oil shocks or consumers' moods, systematically prepare for the boom to resume speed. This led to systematic overinvestment in almost everything, steel, ships, cars, power plants, etc. etc. It took ten years to absorb the fact that zero growth is there to stay for a while.

Just to show examples of over investment, we can take the US electric system (Figure 24), where power plant and power line capacity are reported since 1900. Two pulses of growth are clearly delineated. Generation saturates at 45 GW during the first pulse, ending in 1940, and should saturate in 1995 at 600 + 45 GW.

As the data points over the line show, saturation levels are already being approached with an "overshoothing" on the order of 18%. Current literature speaks of this overcapacity although with more prudent figures. A conservative estimate of its cost is on the order of 200 billion of dollars, and this may explain prudence. Sitting on their hands, as many other investments in the same ball park.

It is interesting to note in passing that the end of a Kondratiev cycle is a kind of wall against which (almost) everybody is leaning, and that makes the situation critical for employment, because everybody expels man power. An historical analysis of the process in the 1930s, which was in a topological situation affine to ours (end of cycle in 1941), shows an astonishing synchronization of unemployment level in different economies in Europe and the US (Figure 25). In a few years we may collect data to construct a similar chart, although for political reasons unemployment is now called by many other names (e.g., early retirement!).

We can now look back at our clock in Figure 16 and observe that the center of innovation waves of Figure 14 are all located at the end of the recession period, i.e., at the bottom of the sinusoid. This means that the new wave of basic innovations starts when the innovations of the previous wave have exhausted their potential for growth. The new markets they will open will take care of the unemployment (for men and money!), although with a certain delay, which is the cause of the transient unemployment shown in Figure 25.

As one can imagine, everything will pulsate in time with such mega-breathing of the society. An example is reported in Figure 26 and shows how each innovation wave is associated with the introduction of a new primary energy, emerging just at the beginning of the wave and in a sense being a prodrome of it. Interesting to note, the last innovation wave in the chart is calculated, but the start of penetration of nuclear (1% in 1972) is real. This is the first check on the correctness of the calculated innovation line.

Going more into the soft sciences, we can observe that also homicides and suicides in the US are dominated by the Kondratiev cycles (Figure 27), as the Stewart clock on top of the charts shows. One could think of using a homicides clock for the same purpose! That these cycles reflect deeply into the moods of a nation is shown by a a similar pulsation in the choice of weapons to murder: guns or knives.

A company can be seen as the explicitation of a message: the message of the founding fathers (THINK!) In that sense one might very heuristically try his luck, in testing if a company grows like a population or like a tree, to fill the external niche of resources or the internal one defined by its (DNA) program. Daring sometimes helps, and in fact companies, measured by their physical output (e.g., cars) (Figure 28) or by their operating structure (e.g., airplanes) (Figure 29), grow logistically to a saturation point, just like sunflowers (Figure 30).

They grow in a similar way if we look at other indicators of company activity, e.g., progressive innovation (seen as distinct from basic innovation, where a basically new product is introduced, e.g., the steam locomotive). In Figure 31 is reported the cumulative number of main frame computer *models* put on the market by the most important manufacturers.

The analysis gives evidence to the fact that all of them are in the same ball park and saturate around the end of the present Kondratiev cycle (1995), with the one and single exception of IBM whose growth phase having double time constants will cover two cycles. One can also look at the cumulative number of main frame *models* put on the market by *all producers* (Figure 32), perfectly matching logistic growth. The same if we analyze the cumulative number of *producers* (Figure 33). The sad observation here is that the mean number of models per producer is *three*, meaning most of them have or will disappear after the first one, the large producers making 50 or 100 models.

At this point it may be clear that the idea of an informational structure, after being created (*mutation*) and tested on the outside world (*selection*), will start *diffusing*. All the dynamic of the system can be then reduced to a sequence of diffusion processes in a highly hierarchical set of niches. The fact that diffusion proceeds with great stability and that when new competitors will start diffusing the rules of the games are always the same, gives the possibility of using this methodology for precision forecasting.

An example is given in Figures 34a-c, where the primary energy competition of Figure 8 is reexamined to show its potential for forecasting. The analysis covers about a century of primary energy market shares at world level, but will take as data base only the segment 1900-1920 (Figure 34a). The competition equations are set using this data base (Figure 34b). The actual statistical data are then superposed (Figure 34c).

In 1970, 50 years after the end of the data base, the equations match with actual market levels of coal and oil by a few percent. Gas does not fare so well because the gas penetration did start in 1910 (1%) and was not yet well established at the end of the data period. Nuclear does not appear because at the time the chart was made we did not yet have the logic of the new source associated with the innovation wave. Now we can predict the next source (fusion!) by the year 2025 (1% of the market). Using the same logic we could have predicted nuclear around 1970.

We are now ready for the final step: the assumption that social systems operate basically through the elementary mechanisms of *mutation, selection, diffusion*, just like biological systems. The only difference being that in biology messages are written into DNA or RNA, and in social systems in syntactic language. If this is true, then by choosing appropriate indicators we can map any conceivable social process. In this exploratory spirit I will list now a number of cases, sometimes extravagant, all helping to support the above thesis.

Mutation and selection are difficult to observe, one has to go into intricate historical analysis, but diffusion is explicit, like rabbits populating Australia. So we may look, e.g., at the diffusion of the idea that building a Gothic cathedral was a worthwhile enterprise. It is certainly for us, but it was an unbelievable economic burden for the populations of the 14. and 15. centuries, and also a great technological challenge. The cumulative number of Gothic cathedrals, however, fits perfectly a logistic diffusion curve spanning 400 years (Figure 35).

Coming to cathedrals of modern technology, e.g., railways, we find a similar time structure in their construction. Figure 36 charts the cumulative number of start ups for railway networks, i.e., the openings of the first line of what later on will become a network. The idea appears diffusing in the world as it were an unique territory! The idea of Gothic cathedrals diffused basically into France with overflows into the neighboring countries.

Also if we look at the diffusion of a soft innovation like the adoption of the stamp to pay for the postal service, we obtain a perfect diffusion curve (Figure 37). Here the pure idea was diffusing. The investment costs for installing the procedure were obviously nil. In the same frame of mind we should look at Figure 4, where the discovery of the chemical elements was linked to the diffusion between the chemists of the idea that looking for elements was a worthwhile line of work, which determined the effort and the rate of discovery.

The process is standard, and I looked at the number of papers produced in extremely specialized sectors of biomedical research (Figure 38) or at the number of experiments (always cumulative) in an expensive branch of physics, where experiments are a public issue and can be counted (Figure 39). In these cases the content of the niches is small and can be emptied rapidly. For that reason the time constants are short in relation to the discovery of the elements. This shortening is not due to faster transmission of information. If that were true, taking a single diffusion process, the rate constant of the equation should change in time. But even for processes lasting hundred of years it does not.

Another soft process is described in Figures 40 and 41. It refers to the diffusion of the idea that burning witches is a good thing and cleans the system from bad conscience as the medieval historian L. White (1969) wittily observed. I took here the statistics from ponderous academic research that was given to the public on the occasion of an exposition last year on magic and witches in Styria (Austria) a region where a lot of them were processed and some burnt.

Examples crowd my mind, but the time limits to my presentation require to cut their number to the bone. However, I want to present another class where the diffusion seems to occur inside a pre-set program, although the program has to explicit itself into an external context. A prototype example taken from biology is given in Figure 30, depicting the growth of a sunflower plant, measured simply through its height. The logistic growth may be interpreted as if in the program there were a set point for height, and growth is proportional to size which is a very reasonable assumption, multiplied by the difference between actual size and set point. This is perhaps the simplest regulatory system we can imagine, and gives a logistic approach to the set point.

All clear, but many of you will feel it fancy, if I apply the same concepts to the creative work of a person (Figures 42-46). As the five charts show, it seems that an artist or a scientist "contains" some sort of set point in his internals and his creative work grows (cumulative number of objects!) exactly as the sunflower plant. This gives a golden opportunity to classify creative people using the three parameters defining a logistic and look for more abstract relationships.

One of these relationships can be seen in the examples. Almost all these guys (one out of the hundred cases I did examine does not work that way) *die* when they have exhausted 90-95% of what they had as a creative potential (set point), as expressed by the saturation point of the logistic. Even Mozart, who died when only 34 years old, had expressed 95% of his potential. In number of pieces actually, not in quality which is a very fleeting quantity to measure, being so dependent from context.

I am aware I am tramping into the *sancta sanctorum* of man's *ego*, but after all, the current manipulations on DNA and the explorations on the function of endorphines to set value systems into our brains, greatly facilitate my task. I may hide behind psychological gossip, saying that after all it is not strange that creativity is in some way linked to vitality. Creative old people are usually vital old people. But it is obviously a first aid bandage. The hard truth is that our internal programming goes much beyond what we feel or suspect.

To show that creativity is really a form of activity, and that my choice was actually determined by the fact high level creative people or publishing scientists can be reached through records and their statistics, I went into another case of recorded activity, that of criminals (Figures 47 and 48). The fact their actions fit so well the equations on one side makes it possible to *forecast* when they will commit their next crimes. I did it successfully in order to facilitate police forces to intercept a very dangerous killer.

However, these facts open very searching questions about the function of the juridical system in our society. The analysis of criminals who were in prison for sequences of relatively short lengths of time, as in most cases, did not change their rate of crime production, catching up, when free, for the crimes "lost" when in jail.

So finally the juridical system punishes for crimes that criminals seem unable to avoid committing, and society is not at all protected as the crimes will be committed anyway. The subject obviously merits a search on the grand scale, but I found the juridical system very protective of data, worldwide. *I suspect they know.*

Intuitive attitudes toward an organization imply it has anthropogenic behavior. A company has head, body, branches, daughters. Companies marry, are vital, aggressive or sleepy, old or young. I have a great respect for intuition, as for the nose of my dog, and as a system analyst I follow the lead. Consequently I did not have any intellectual repulsion in considering a loose organization like the Italian Red Brigades, as an abstract form of individual, and search for the appropriate characteristics. As Figure 49 shows, the cumulative number of people *killed* by the Red Brigades in Italy neatly fit a logistic, setting their life cycle in hard mathematics. Why organizations evolve precisely that way is another area open to research, where data are abundant but conventional wisdom confusing.

I will stop here. What I did present has an exploratory character. But the splendid response of the system to such simple mathematics shows we are on the right path. Mutation, selection, diffusion are modern words. But Heraclit had already seen it 2000 years before Darwin. For him, competition was the fundamental *creative* and *regulatory* system:

Πόλεμος πάντων μὲν πατήρ ἐστι, πάντων δὲ βασιλεύς

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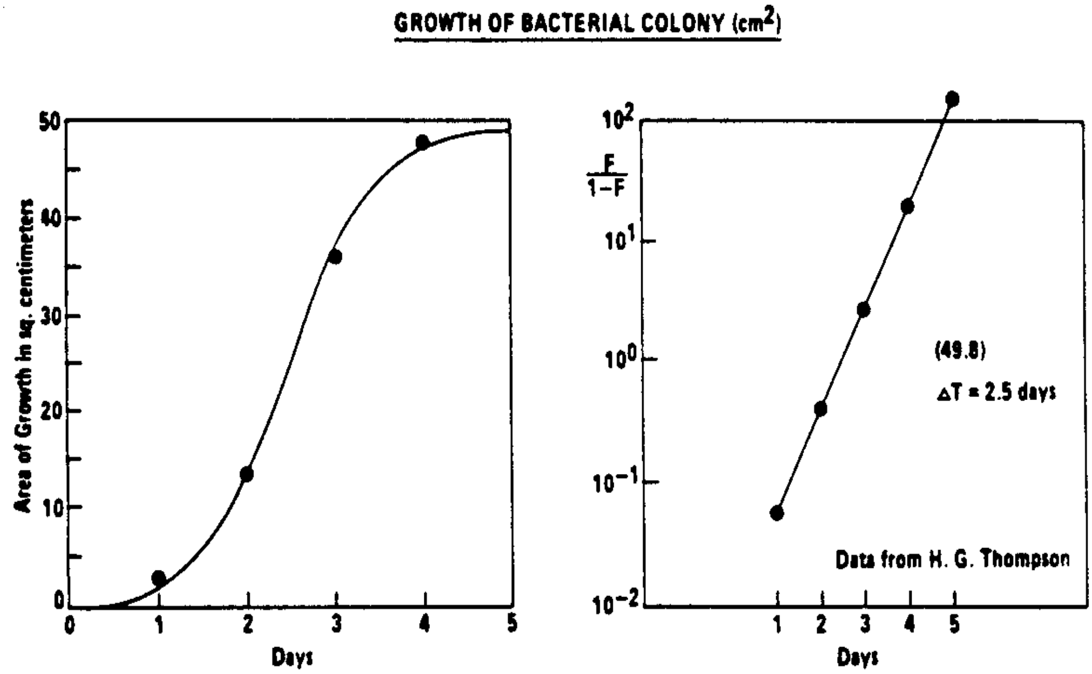
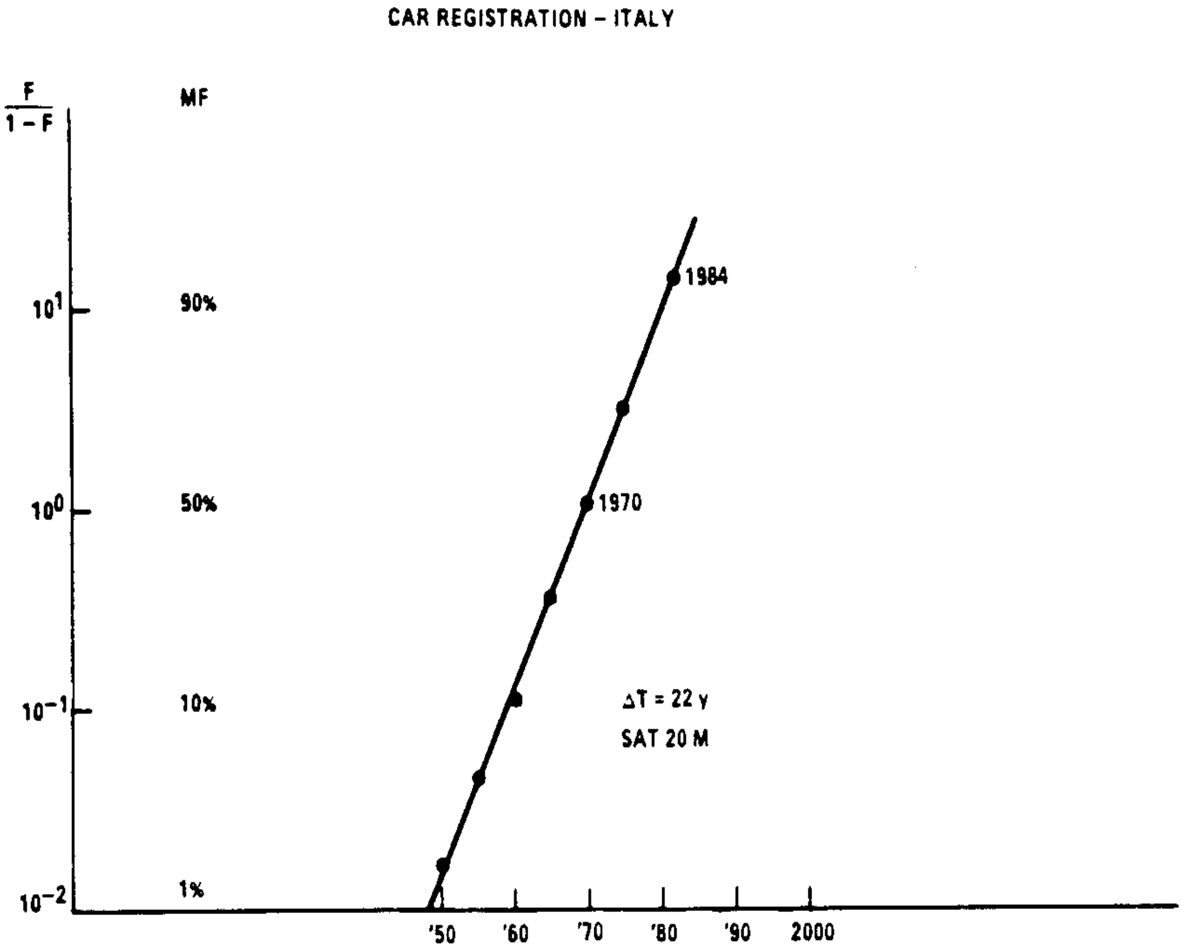


FIGURE 1. A population of bacteria in a bottle of nutrients will grow until the "resources" are exhausted. The evolution in time of the size of the population can be described, using a three parameter logistic equation (see Mathematical Appendix for definitions and Fisher-Pry transform). The amount of resources can be defined as the *niche*, which can also be measured by the final size of the bacterial population.



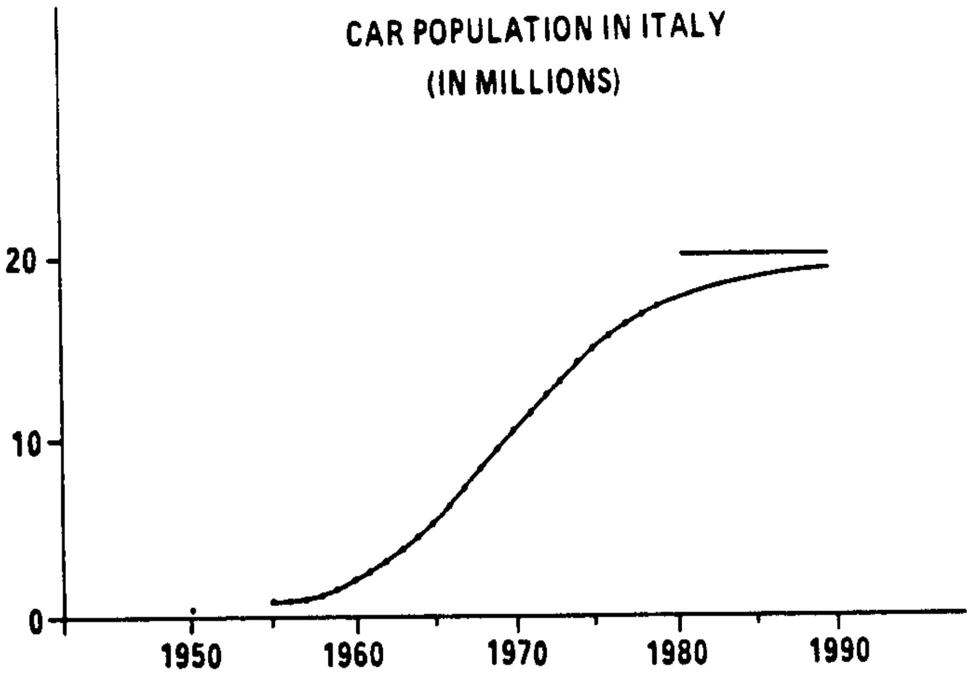


FIGURE 2. The "population" of cars in Italy grows following a logistic equation, just as the bacteria of Figure 1. The fitting is of very high quality, showing precise mechanisms at work. As explained in the text, the dynamics of the phenomenon can be interpreted as

MAINFRAME COMPUTERS JAPAN (.000)

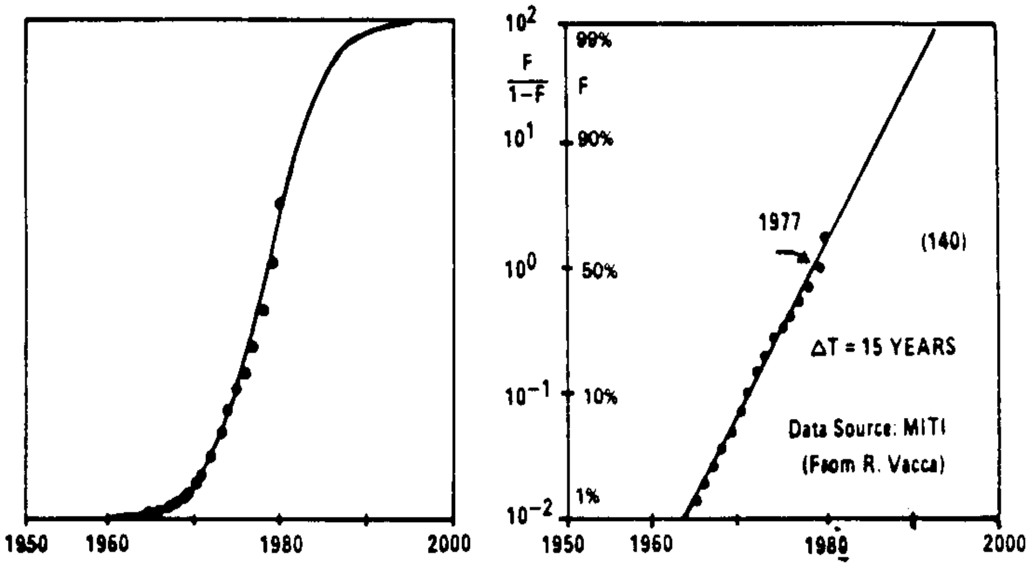


FIGURE 3. The evolution of the number of mainframe computers in operation in Japan is here analyzed in the same form as the car population in Italy. The saturation point, the niche, is here 140,000. This niche is due to stay constant until the end of the present Kondratiev cycle around 1995. Also the fitting logistic saturates around the same date.

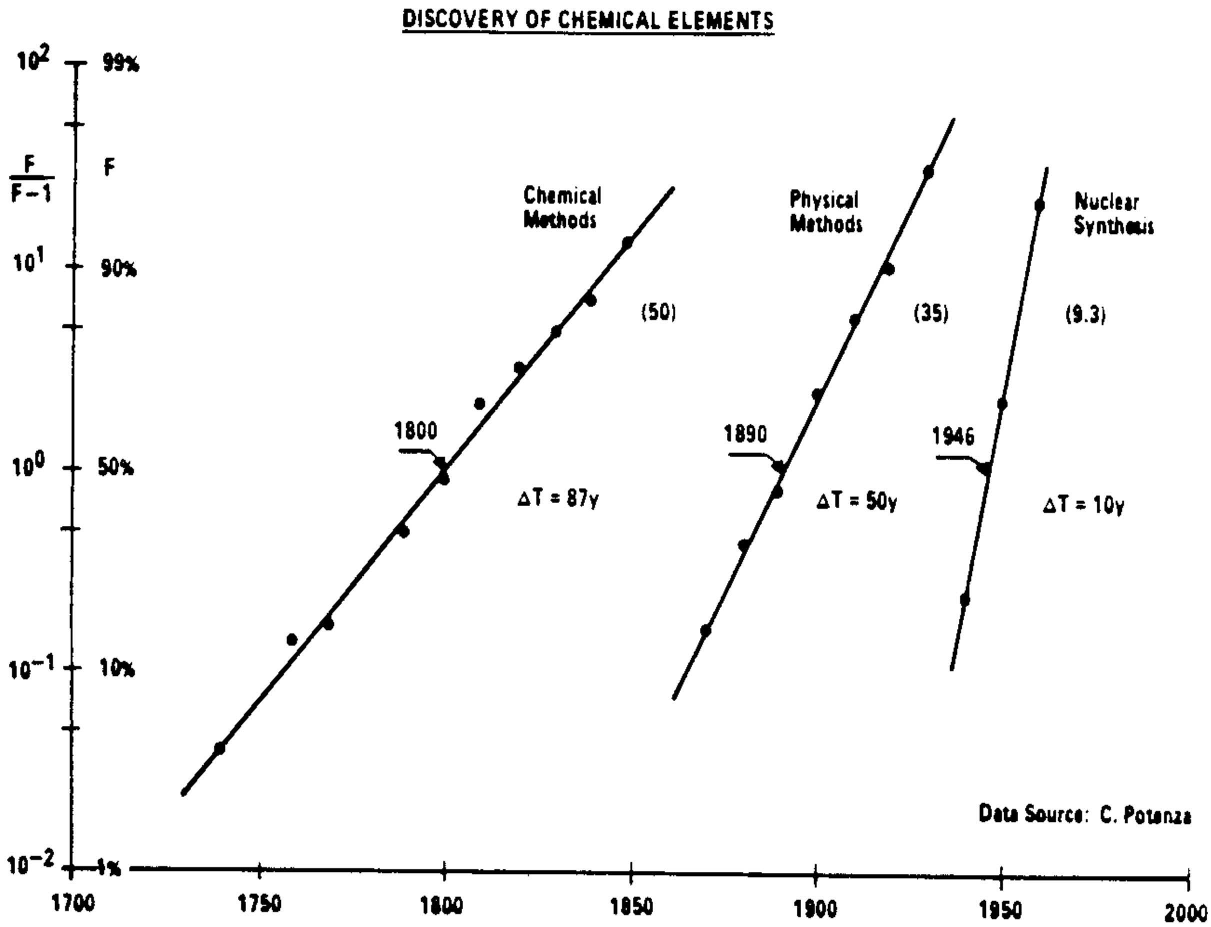


FIGURE 4. Looking at the cumulative number of chemical elements discovered during the last three hundred years, we find three "pulses" of discovery. Each of them exhausts the elements that can be discovered with a relevant technology: chemical methods; physical methods; nuclear synthesis. The example is also the first "pindaric" jump in the application of the model.

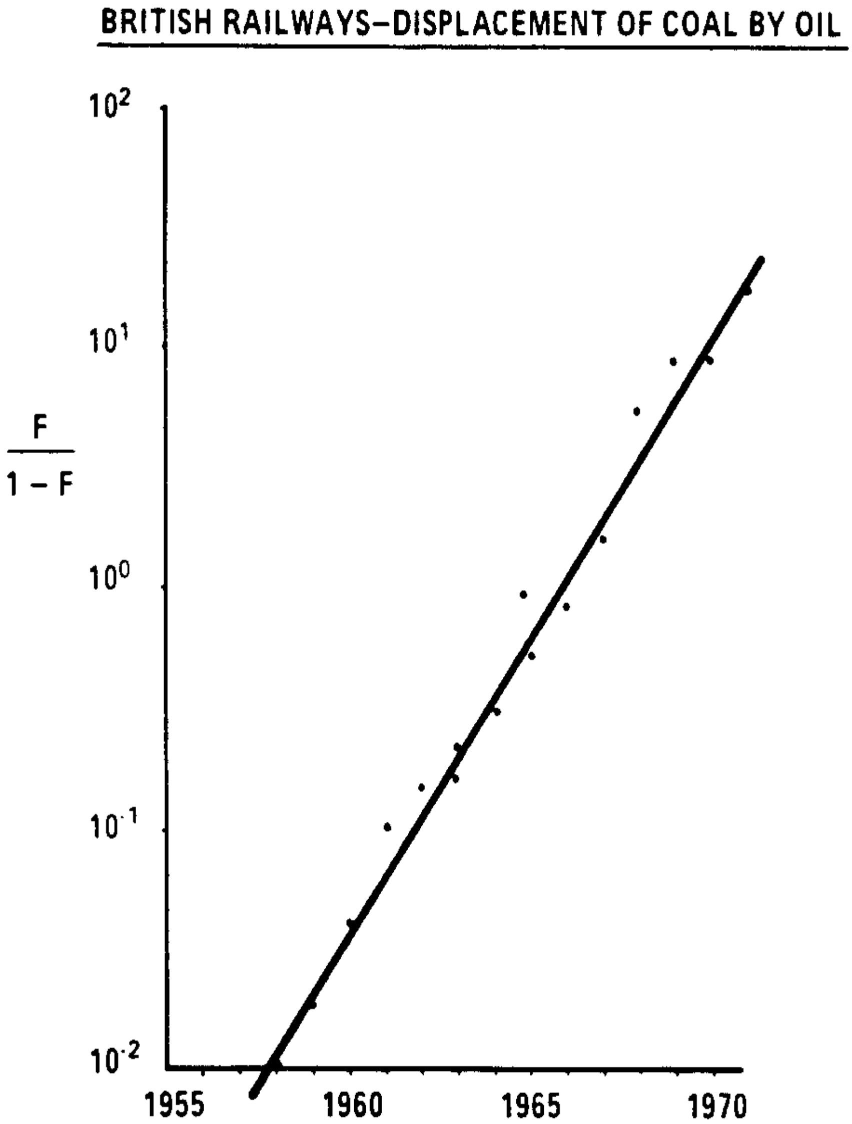


FIGURE 5. A niche can be full when a newcomer comes, but through better fitness it can displace the previous occupant. In the present case we analyze the substitution of steam locomotives with diesel in the niche of the British railways. All the process can be represented with great parsimony, using two numbers only: the *time constant* which is actually a rate constant and a *date year* locating the process in calendar time.

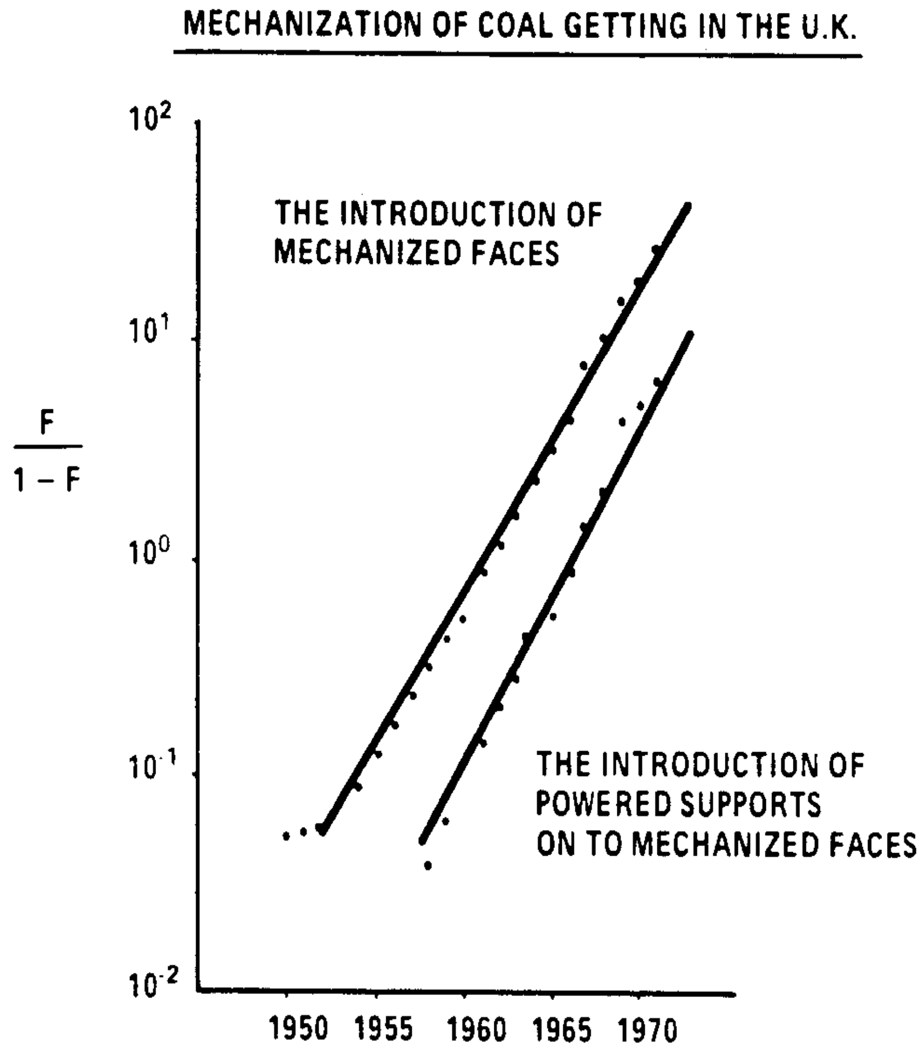


FIGURE 6. The model operates equally well zooming up and down into the system. Here two technologies relevant to deep mining are reported. As in the case of locomotives, only the progress of the winning party is reported in the chart.

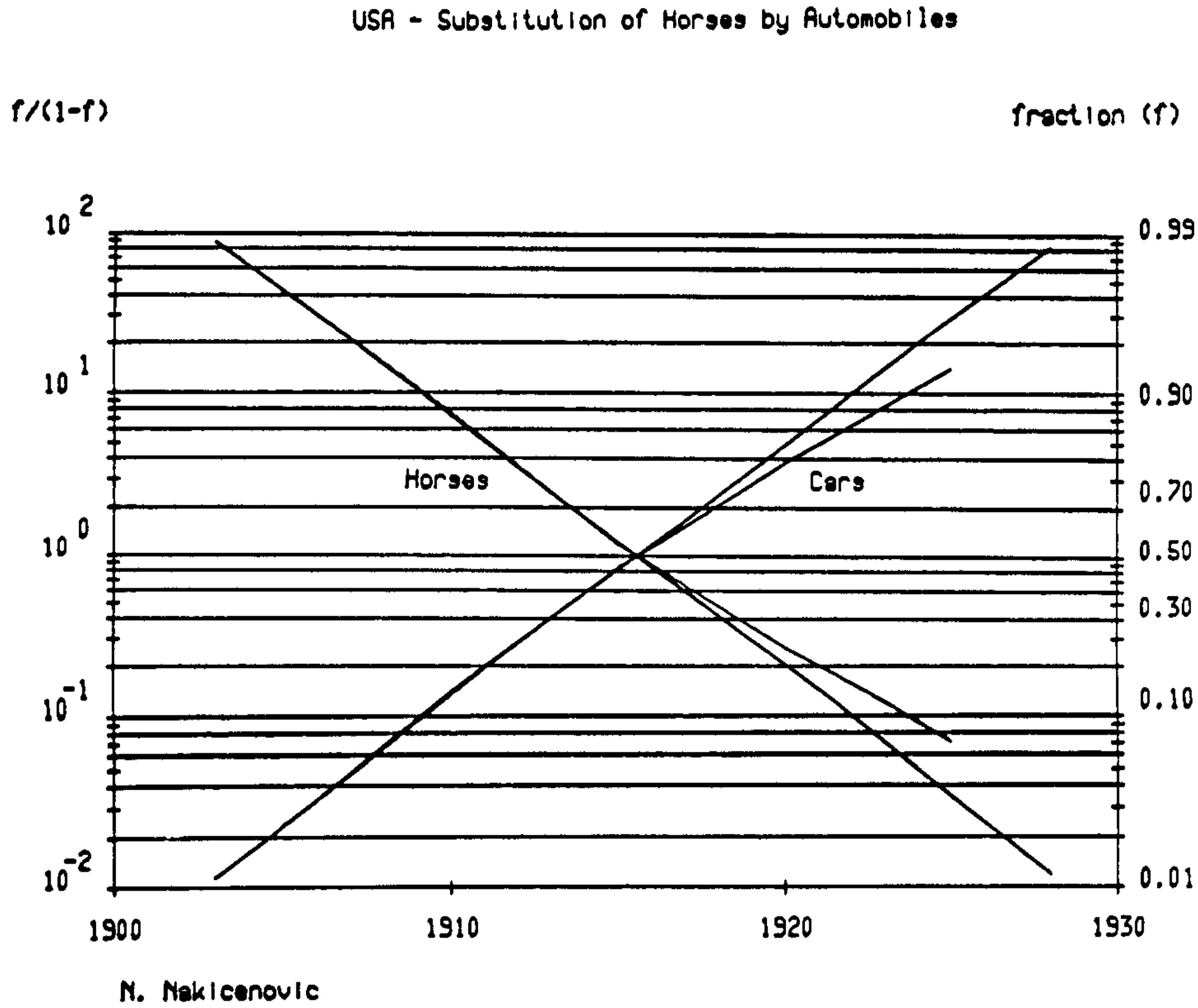


FIGURE 7. Horses and cars can be seen as two technologies competing for personal transportation. During twenty years, from 1910 to 1930, twenty million cars finally substituted roughly an equal number of horses in the US, and the evolution of the process is reported here.

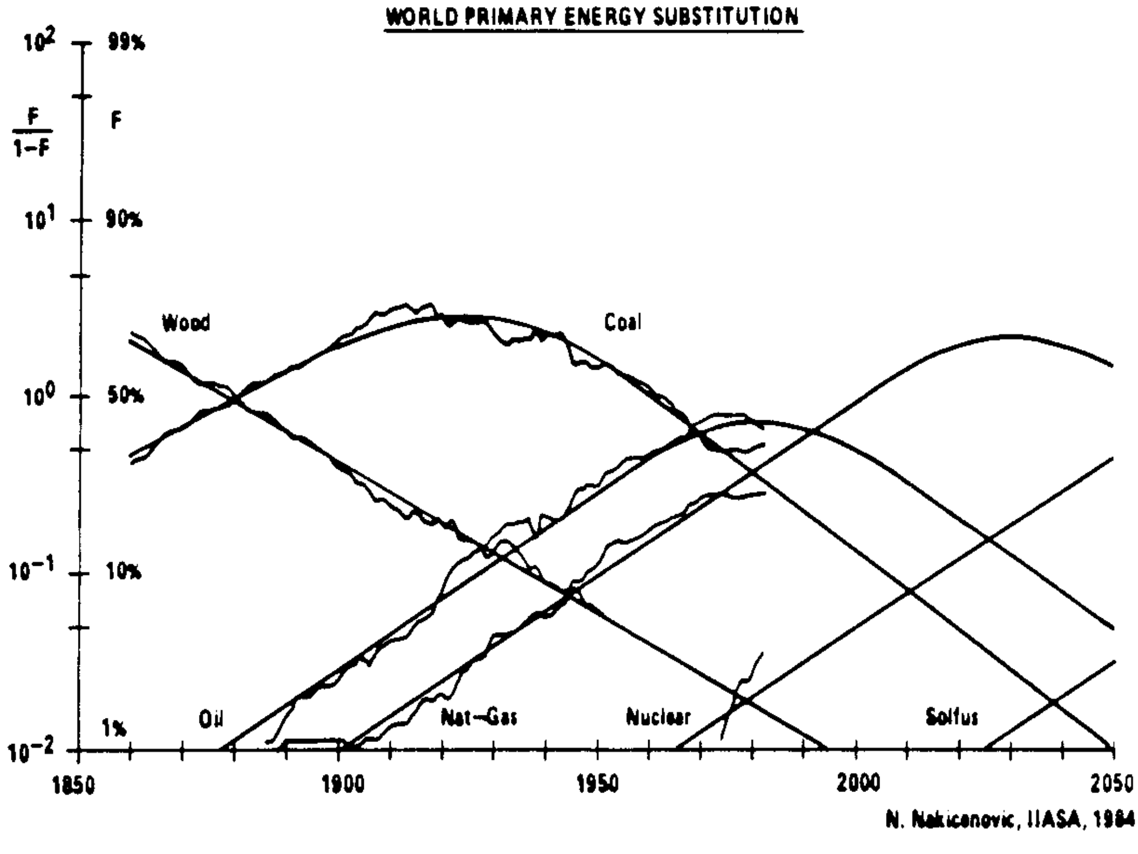


FIGURE 8. If the rate of introduction of newcomers in a niche compares with the time constants of the substitutions, we may have any number of competitors present at the same time, some phasing an and some phasing out. The great complexity of the process can be dealt with simple rules, reducing it to a one to one competition. Here the dynamics of the primary energy market at world level is represented in terms of market shares (in tons of coal equivalents!). The model fits snugly the statistics, in spite of the long time spanned and tribulated history.

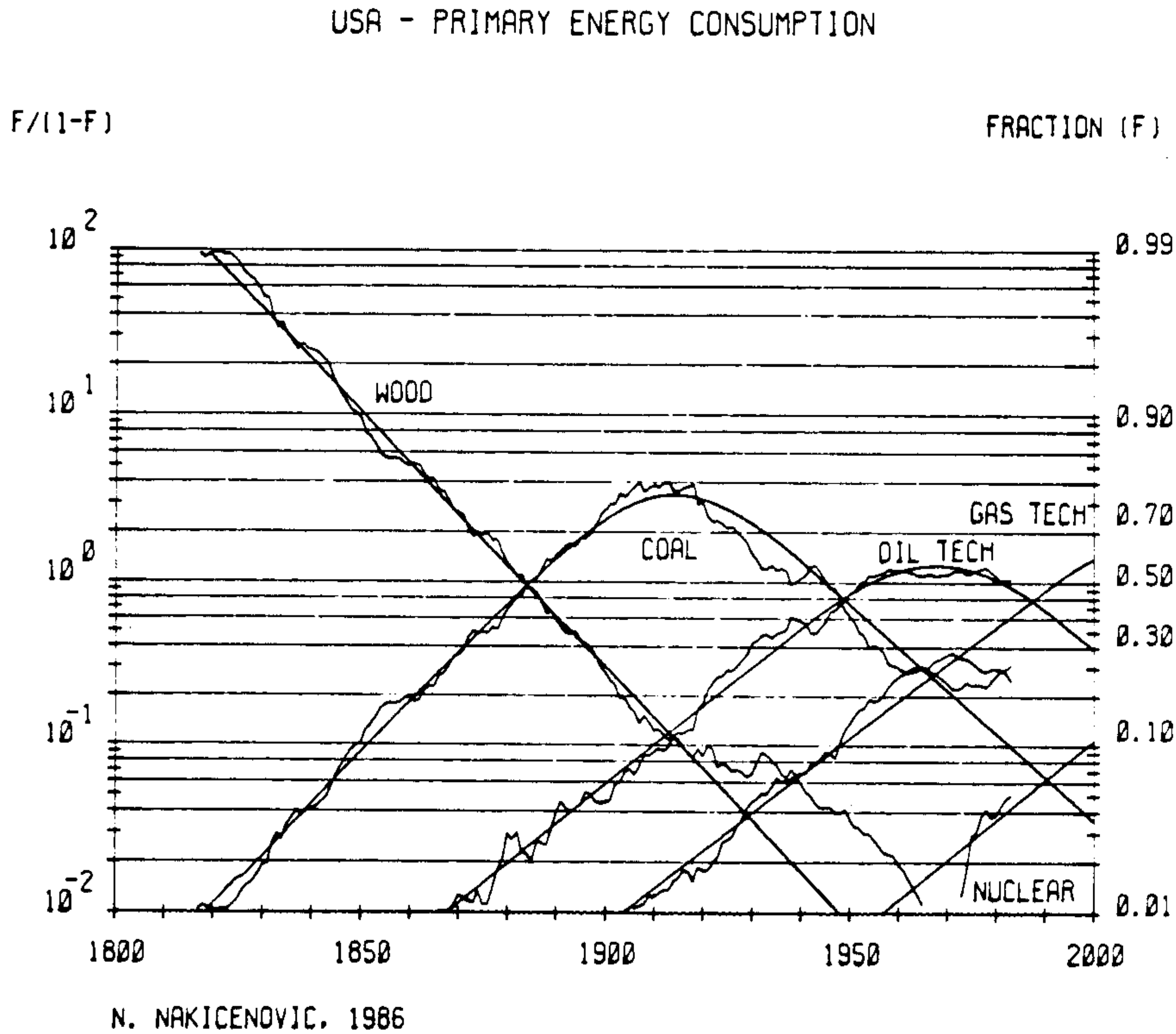


FIGURE 9. Disaggregation does not change the quality of the fitting as it is shown here, where the primary energy market is analyzed for the US. Natural gas associated with oil is counted as oil, and dry gas as gas.

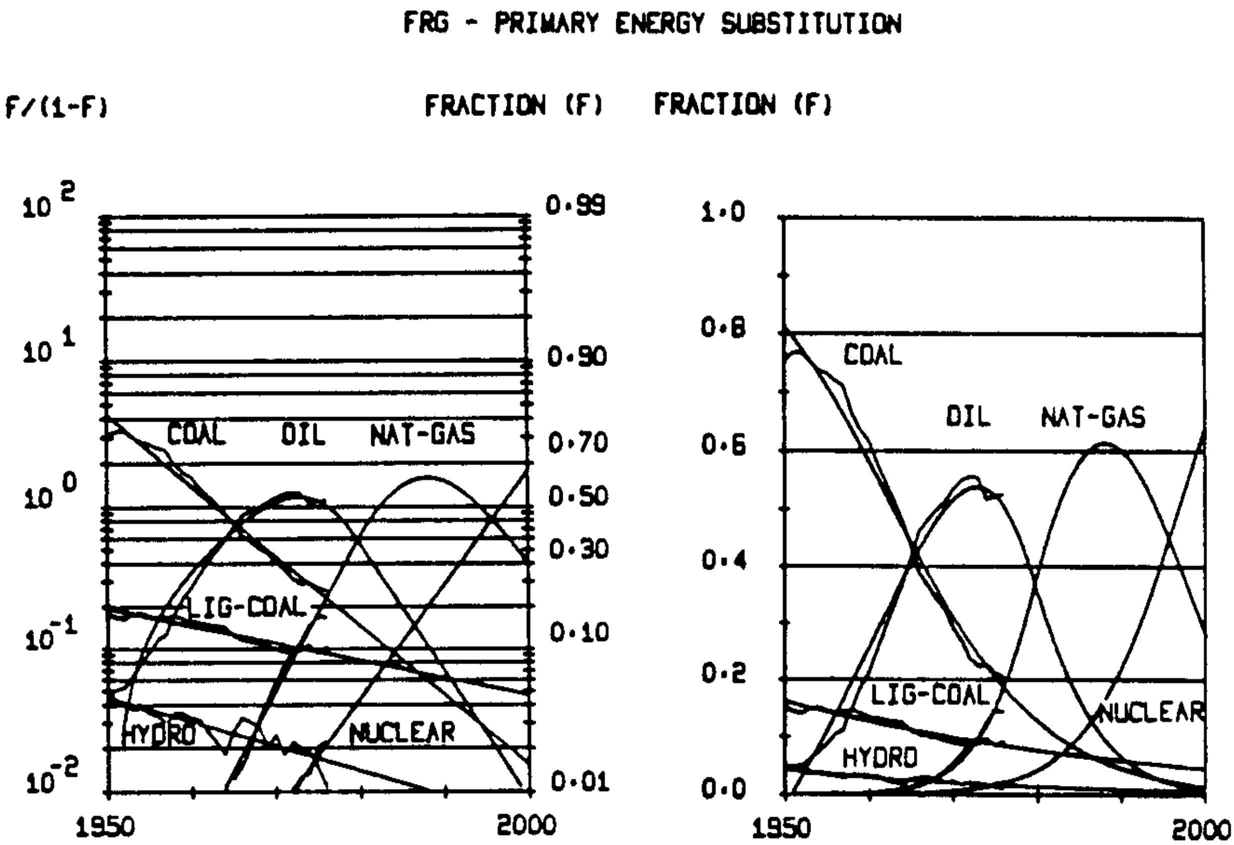


FIGURE 10. Primary energy markets for the FRG are here analyzed, separating coal from lignite, so important in the FRG. Also hydropower appears, as its share is larger than 1%, the usual lower cut off in our charts.

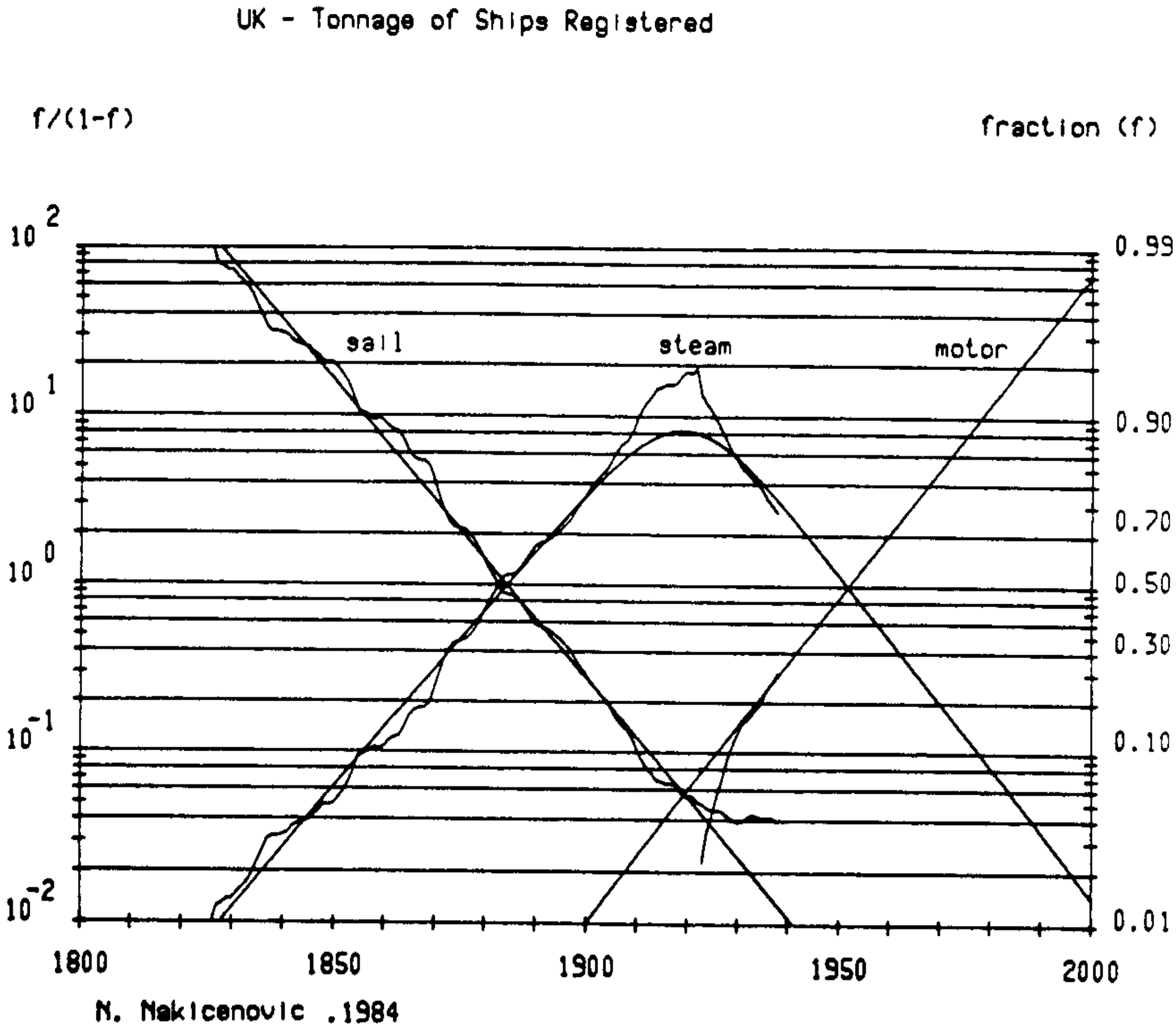


FIGURE 11. Another example of technological substitution is given by the introduction of the steam engine for ship propulsion and then of the internal combustion engine, diesel, or gas turbine, The competition is measured through tonnage operated with one or another technology. Remarkable here, as in the case of primary energies substitution, is the stability of the process. For centuries at the end.

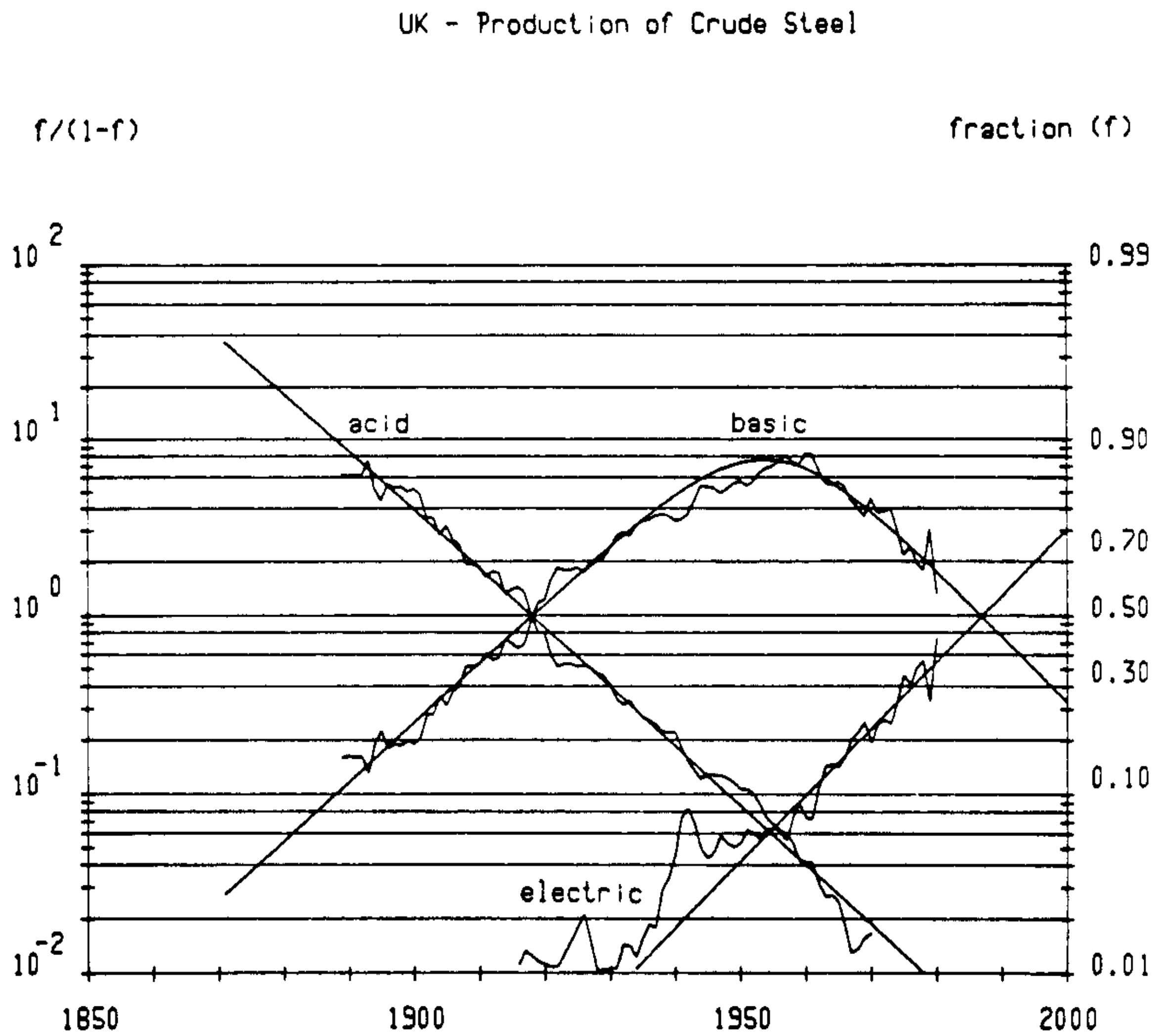


FIGURE 12. What is analyzed here is the background chemistry in steel making. It refers to the basicity or acidity of the containers, where carbon dissolved in pig iron is extracted by oxidizing it with various specific technologies (Puddle, Martins, Bessemer, LD). This substitution then is of background type, in the same sense as architecture for computing machines.

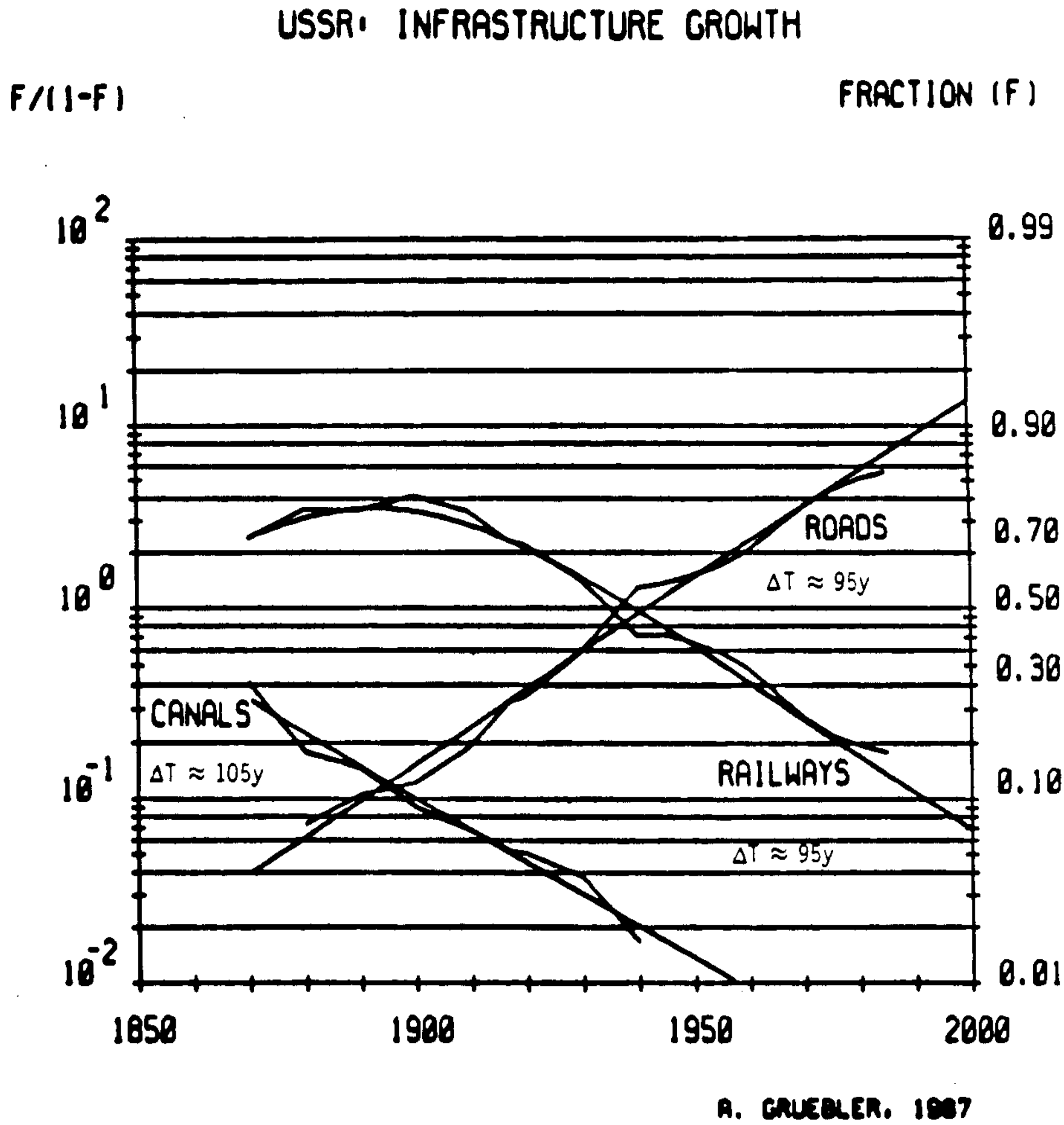


FIGURE 13. The length of a certain transport infrastructure, e.g., railway tracks, is here measured as fraction of total infrastructure length: canals, railways, roads, and air links. Substitution of infrastructures follows an extremely regular course, driven by the substitution of transportation modes.

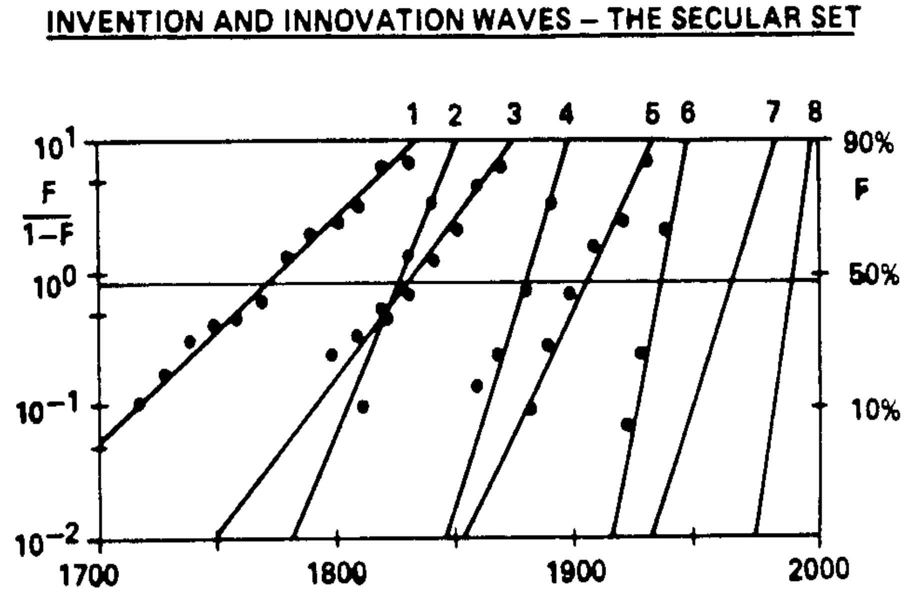


FIGURE 14. Cumulative number of inventions and innovations, in the waves identified and quantified by Mensch (1975). The "populations" in each wave are treated as in the case of objects filling a niche. The excellent fitting confirms the underlying hypothesis that innovations are not the consequence of a stochastic process, but they fill a precise market demand, a niche. In the case of inventions, only those that went into a successful innovation are counted. Invention waves are marked with odd numbers and innovation waves with even ones. The last wave, without data points, is calculated from the regularities of the previous ones (Marchetti, 1981).

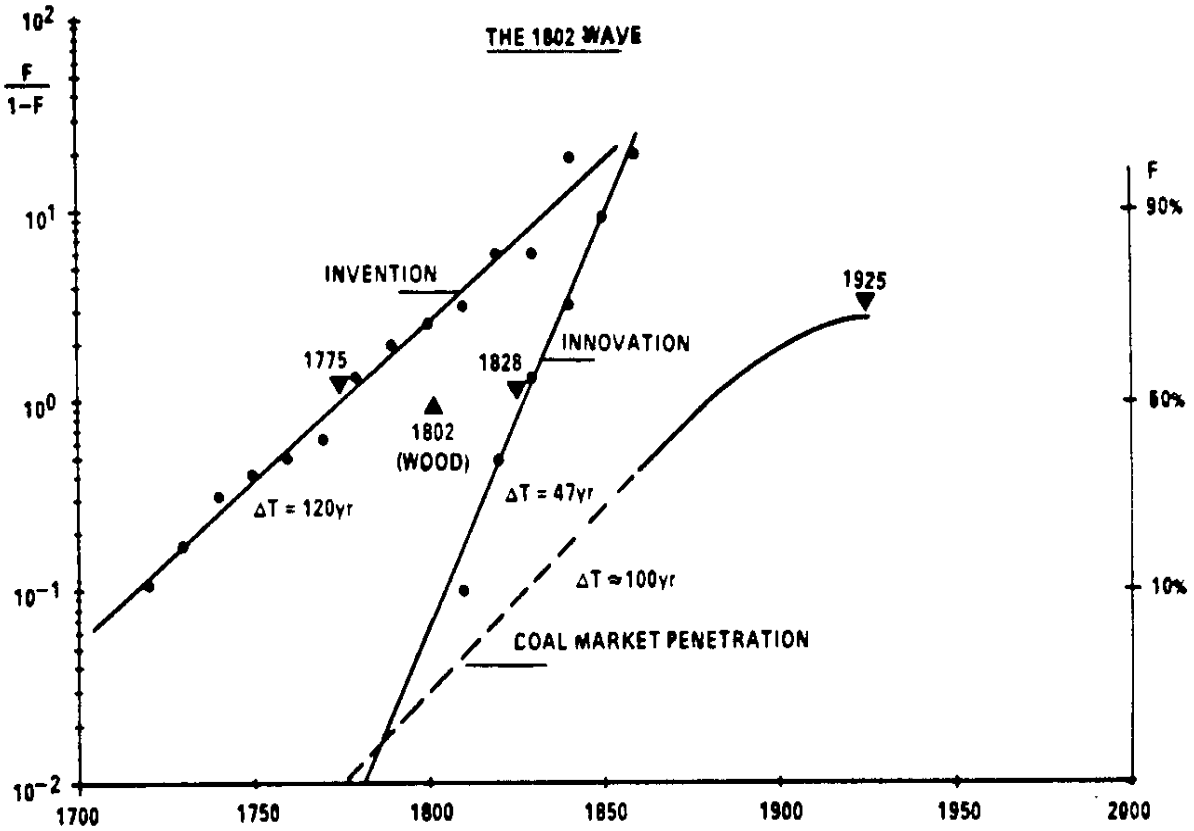


FIGURE 15. The condensed results of Figure 14 come from a detailed analysis of waves as reported here for one of them. The branch of coal penetration is extracted from Figure 8. A fact already observed by Mensch is that the sequence of innovations almost holds the time order of the inventions that preceded them (first come first served). This provides a tool for forecasting *when* a certain invention, *if* successful, will enter commercially the market as an innovation.

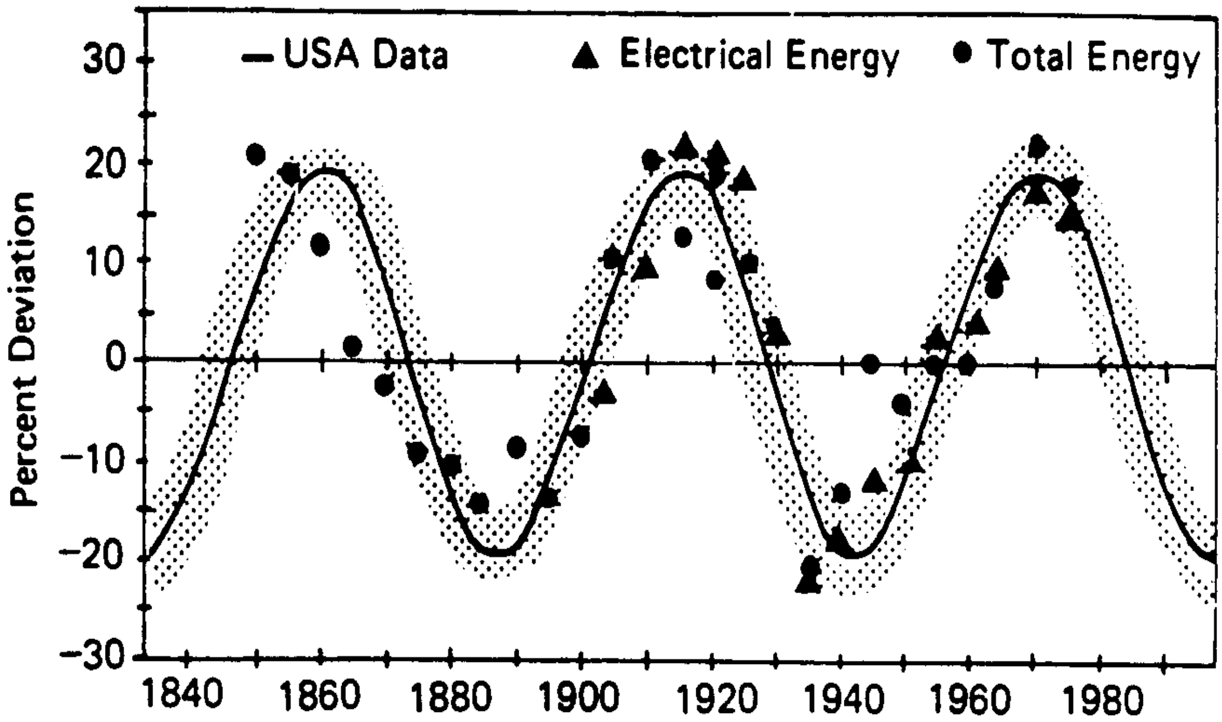
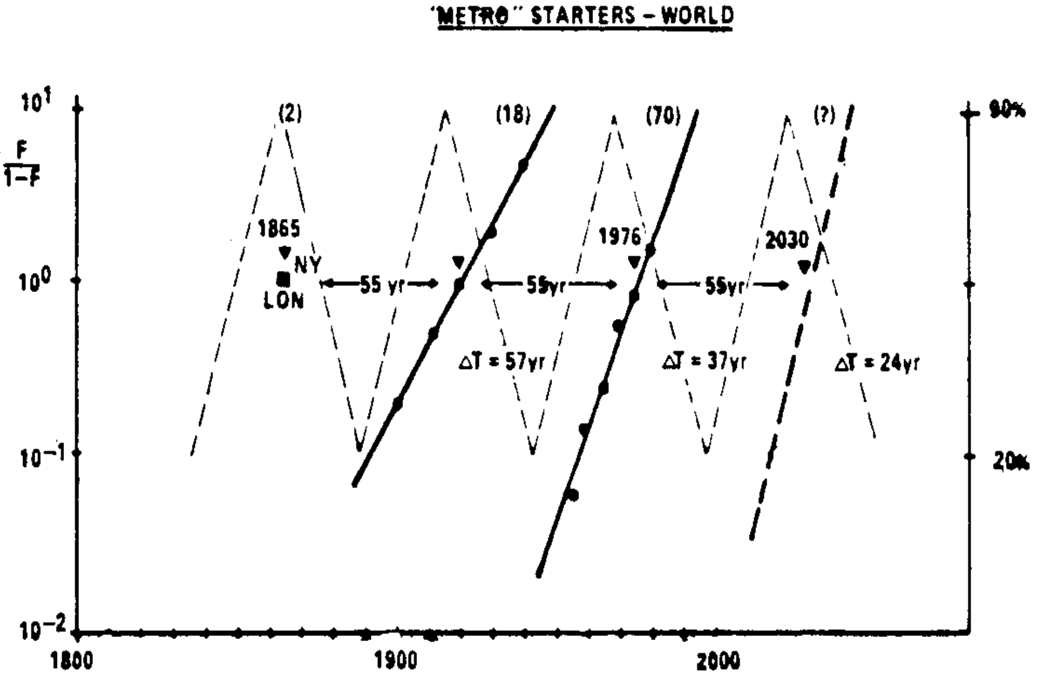


FIGURE 16. Center points (50% of the niche) of innovation waves are spaced about 55 years. This is an indicator, perhaps the most important one, of the cyclical nature of economic activity in Western world, as originally identified by Kondratiev (1926, 1928). A smoother indicator is given by a deviation from the secular trend of energy end electricity consumption, here reported for the US (Stewart, 1982). This percent deviation (up to 20%) is fairly well fitted by a sinusoid with a 54 year period.



Data Source: Int.Stat. Hbk., Urban Public Transp. (1979)

FIGURE 17. Taking the opening of the first line as the signal for the beginning of a Metro network in a city, we find these signals cluster in three waves, worldwide. Each wave contains a "population" of cities whose growth is analyzed the usual way. It is remarkable that the three waves are spaced (center points) by about 55 years, showing a strong synchronization in the background.

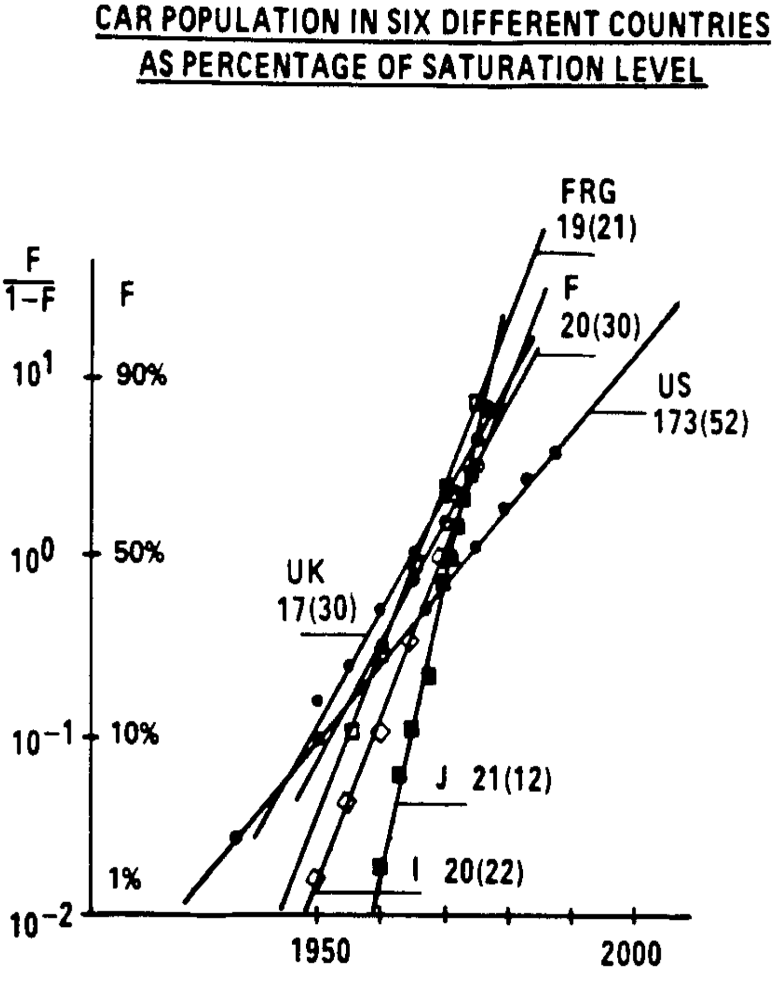


FIGURE 18. Car penetration in various Western world markets. All car populations saturate around the end of the present Kondratiev cycle due around 1995. This means the time constant, i.e., the rate of market penetration in a certain area, is linked to the date when cars did start penetrating. Japan, who came last, has a ΔT of only 12 years.

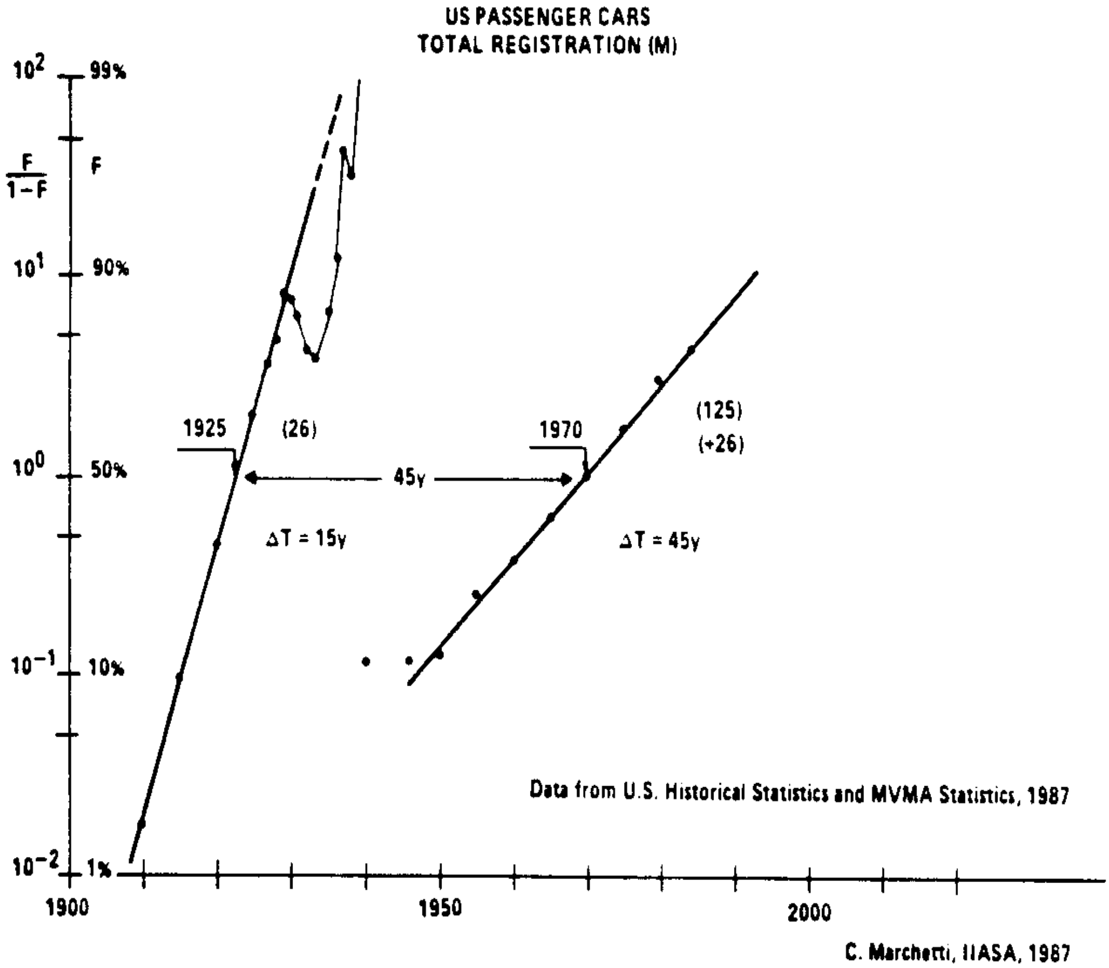


FIGURE 19. If we look over a 100 year time span, we can observe two of these waves, e.g., for car penetration in the US. The first wave having started late by respect to the Kondratiev cycle (ending 1940) had a much shorter ΔT than the second. This shows ΔT being related to timing and not to regional specificity. The second wave builds over the first one, serving as basis for its saturation level. Niches then stay constant during a Kondratiev cycle, but can vary enormously during the following one. Upwards or downwards.

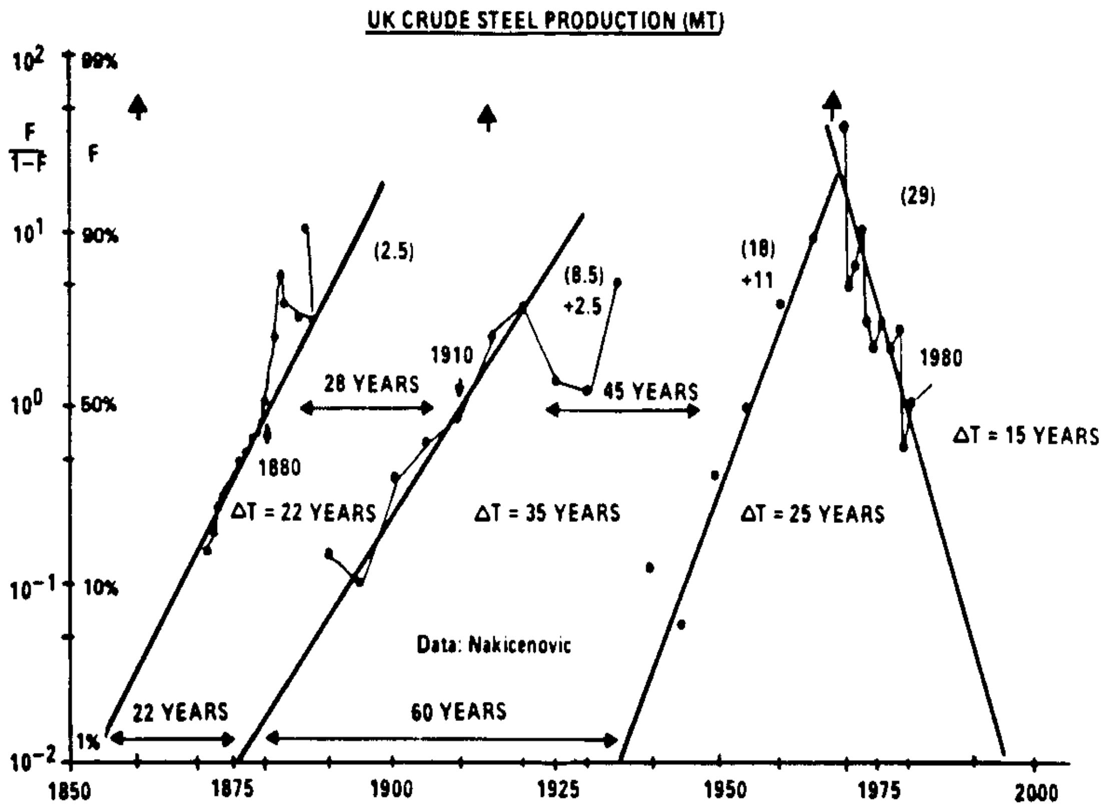


FIGURE 20. Expanding still more the time span analyzed, we can observe the whole life cycle of a major industry, e.g., the steel industry. This case refers to Britain and accounts for crude steel production. British steel industry is in a hard recession phase and presumably will continue its life only processing imported steel.

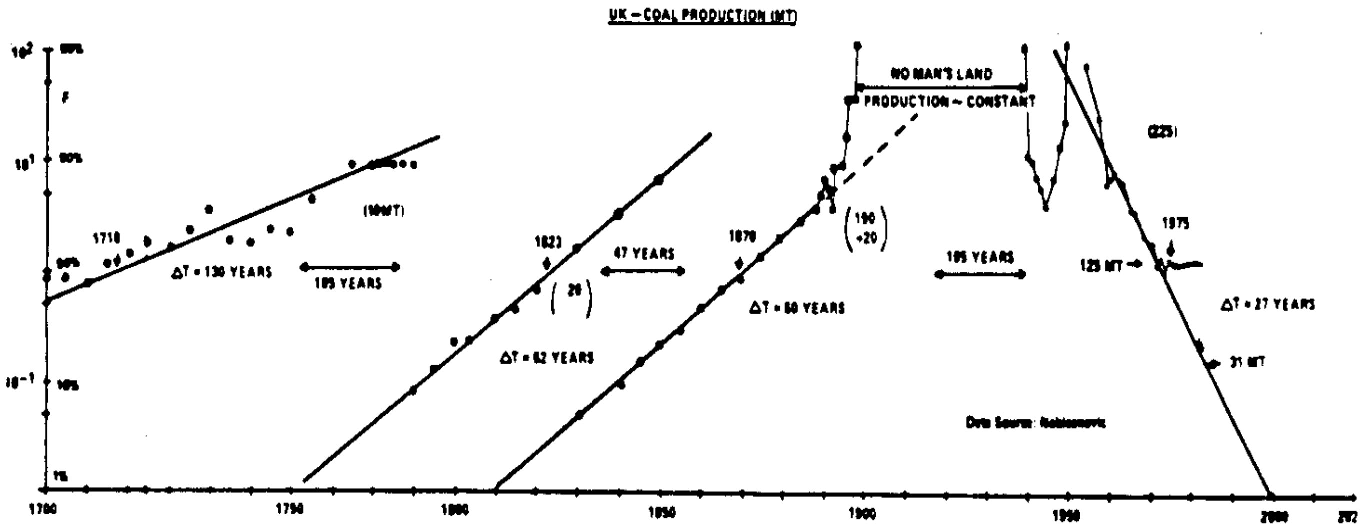


FIGURE 21. The case of coal extraction is examined in terms of logistic spurts of growth or decay during the last three hundred years. The time between world wars was characterized by more or less constant production with high instability. The logistic down in the present Kondratiev cycle has been interrupted by a legislative act fixing production at 125 MT as a protection against oil shocks. After ten years *miners*, through strikes and bickering, are bringing production down near the logistic fitting pre-1974 years.

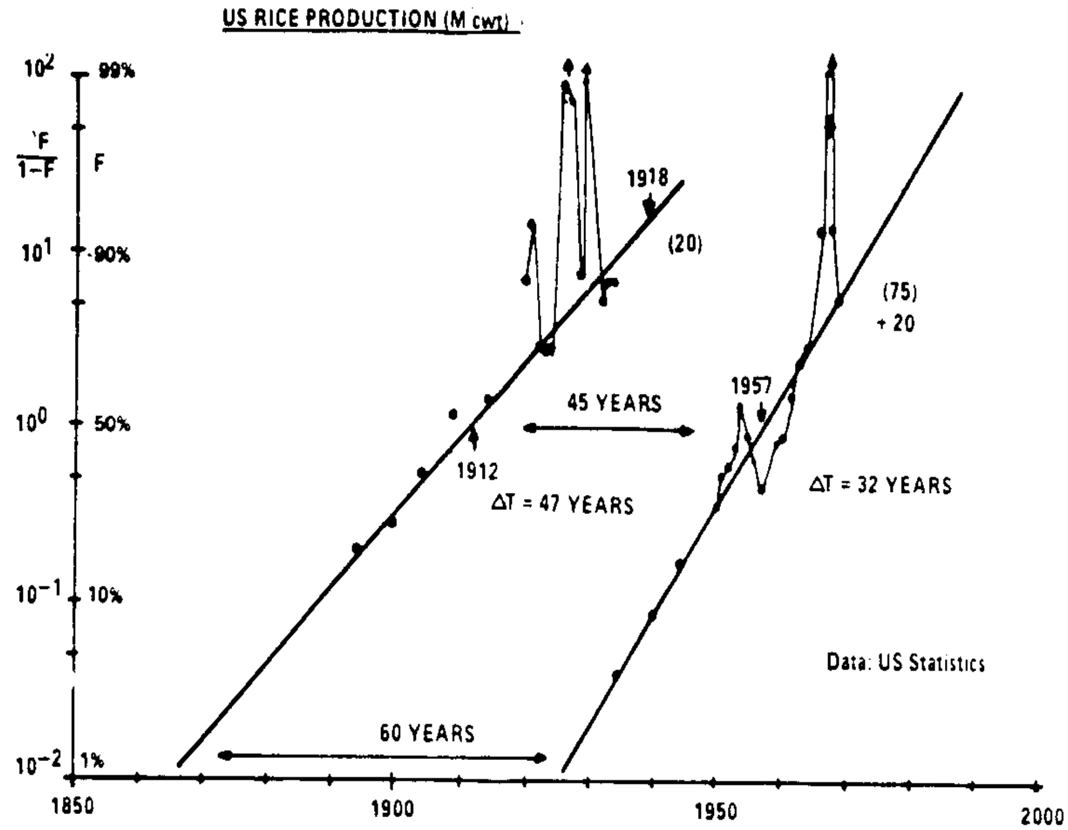


FIGURE 22. Rice production in the US is examined over a long span of time, showing two distinct waves, if highly irregular in the second half, roughly saturating with the 1940 and 1995 Kondratiev cycles ends.

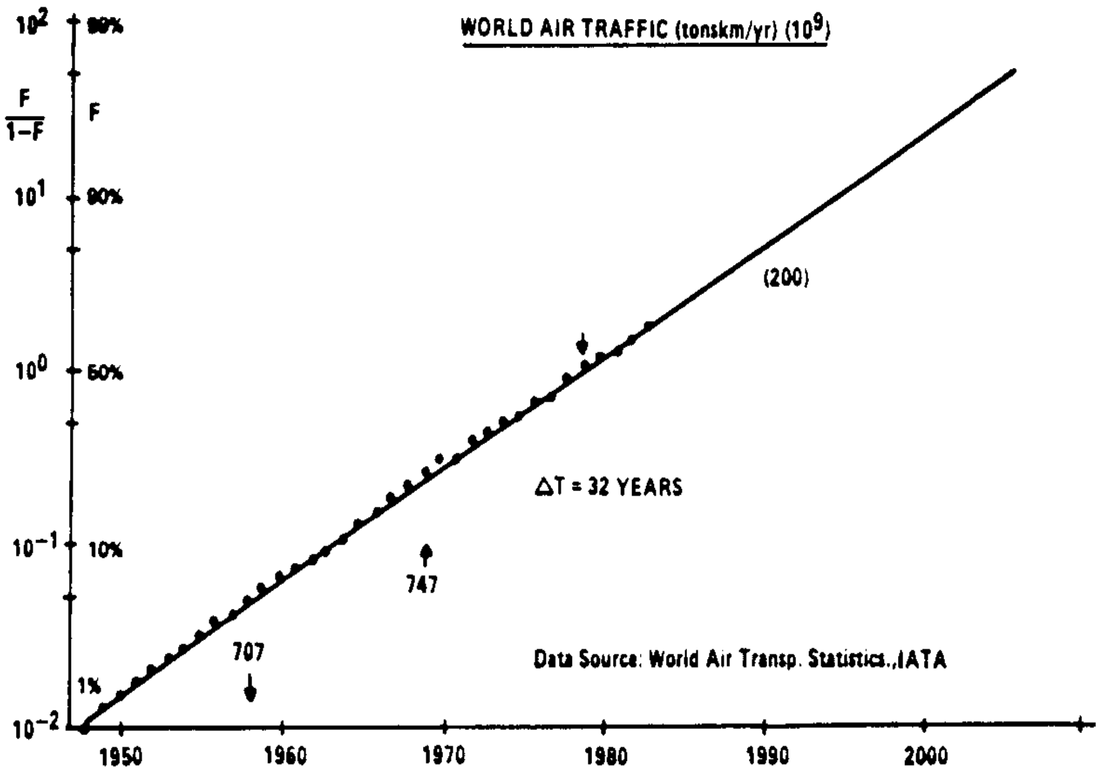


FIGURE 23. Ton km/year performed by the world commercial air system. Passengers are included. As usual, the evolution of the system appears unperturbed by external constraints. Here, to quote perhaps the most important one, a stiff increase in jet fuel price in 1974 and 1980. Internal reorganization of the air companies and of their operation, *homeostatically* compensated for the external perturbation. A new wave of expansion is expected starting 1995.

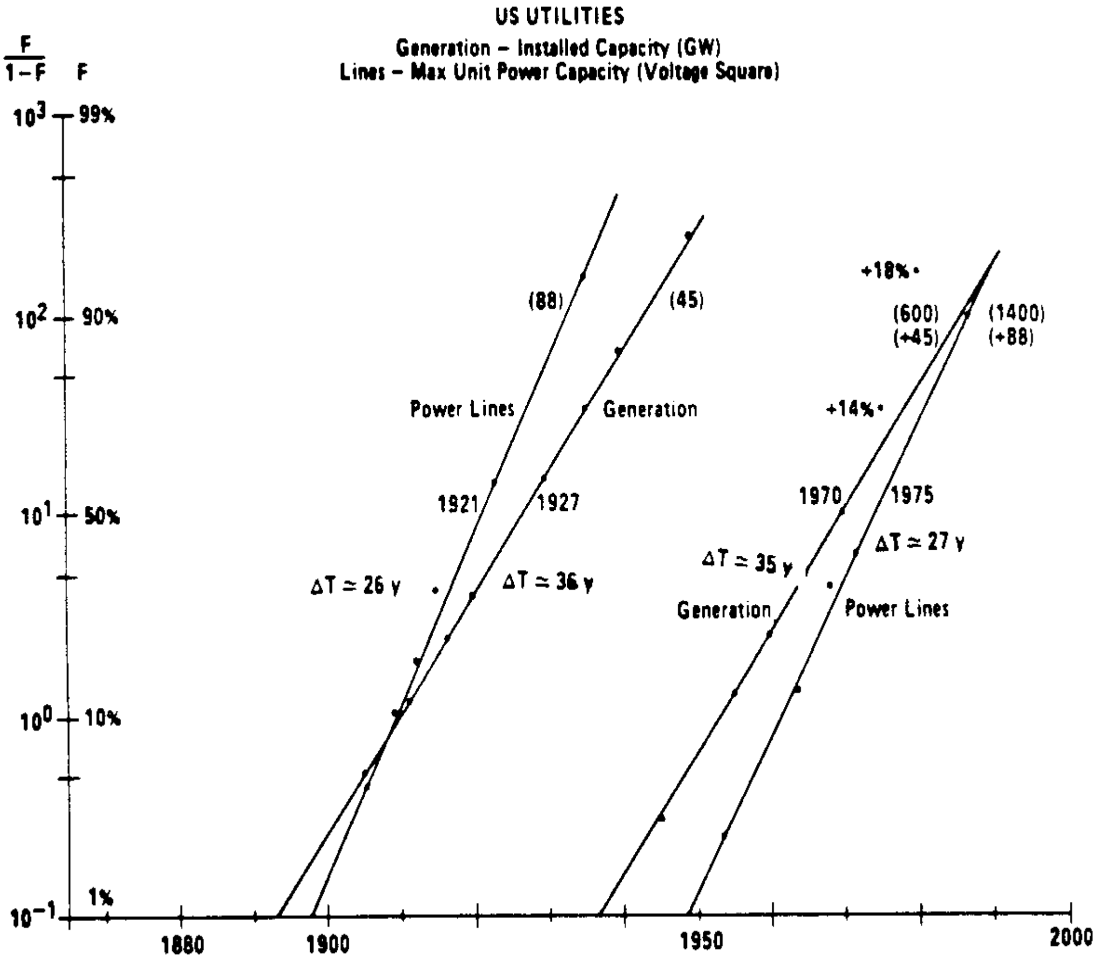


FIGURE 24. Installed electric power in the US did grow in two pulses reaching 45 GW around 1940, and due to reach 600 GW (+ 45) around 1995. Recent data points are above fitting logistic, indicating an overinvestment in this area. Capacity of the largest power lines is also reported to show the conjugation between the two systems.

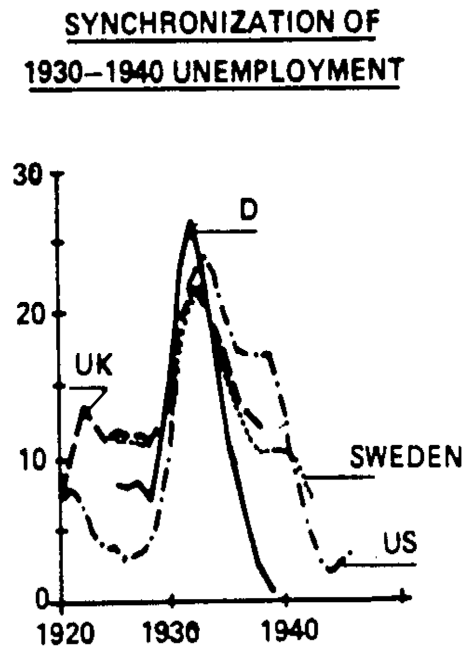


FIGURE 25. The world behaves as a single unit, and the recession at the end of the Kondratiev cycle is a global phenomenon due to markets saturation. one of the consequences of such a process of structural change is the synchronization of unemployment levels in different countries, as shown here for the US, the UK, Sweden and the FRG, toward the end of the previous Kondratiev cycle.

INNOVATION WAVES AND THE START OF NEW ENERGY SOURCES

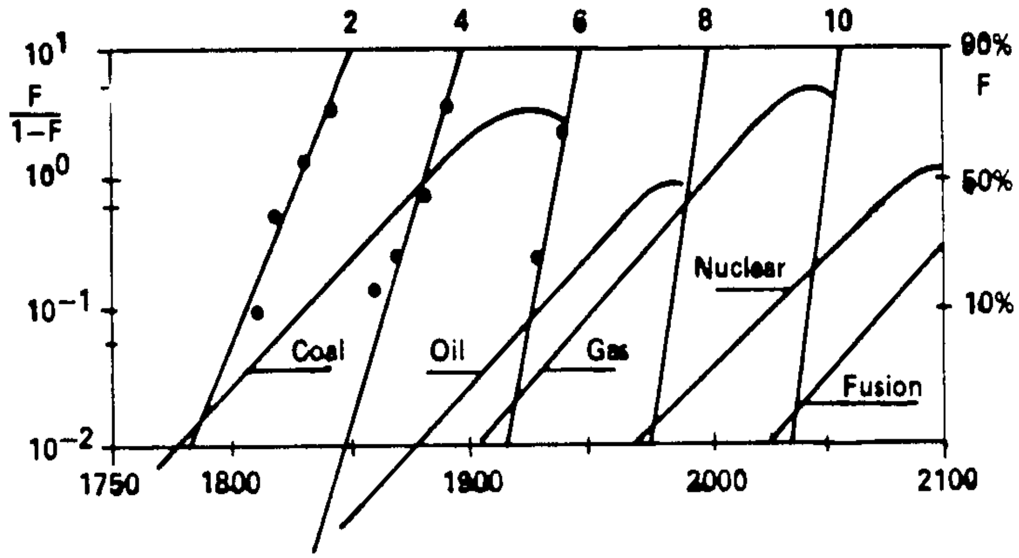


FIGURE 26. Basic innovation waves represent great reorganization processes in the economy of Western countries and windows of opportunity for trying to introduce something new. Primary energies did in fact enter the world market in tune with the beginning of a wave. This appears to be true also for nuclear energy, associated with *our* innovation wave, which for the time being can be only calculated.

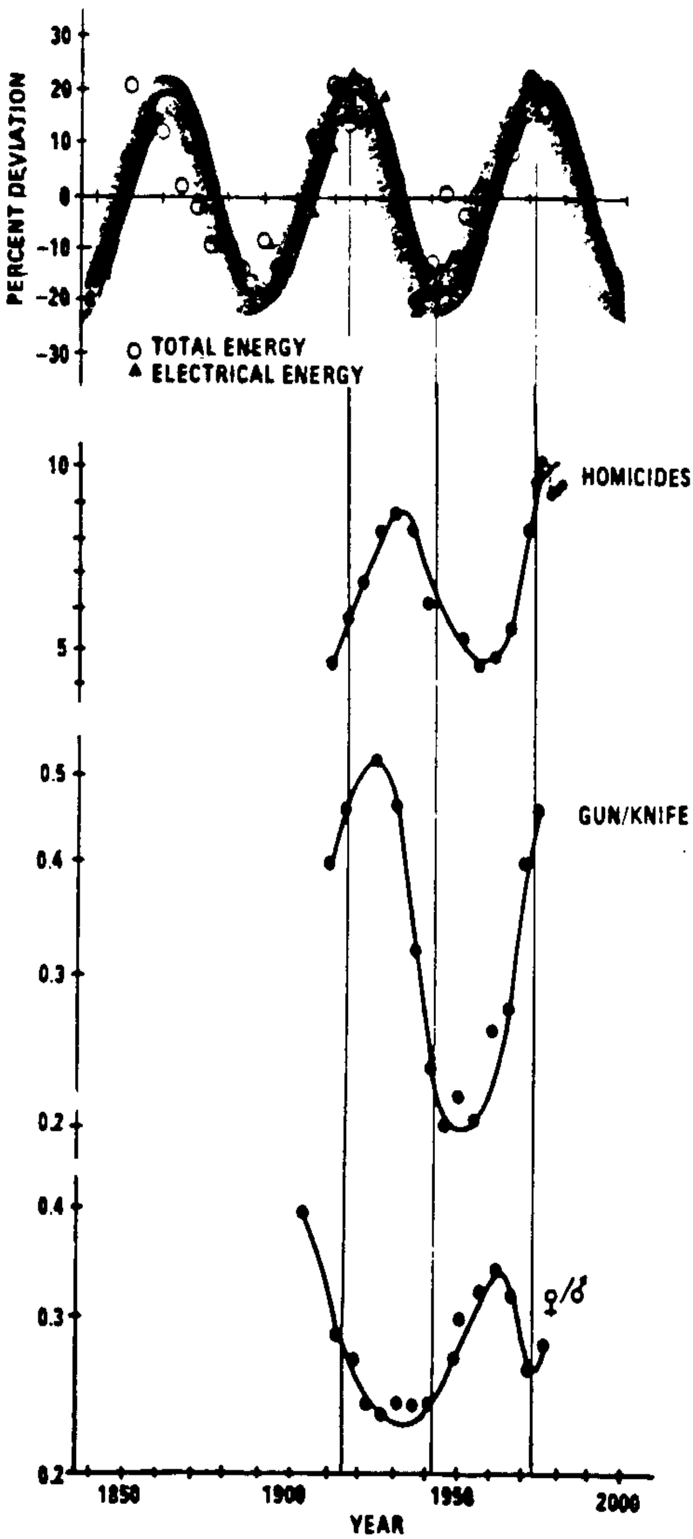


FIGURE 27. Homicides and suicides are expressions of social aggressivity but are usually related to personal aggressivity. The long term analysis of homicide and suicide *rates* in the US shows a marked synchronization with Kondratiev cycles and a high level of modulation, indicating this aggressivity may be a cooperative phenomenon at social level.

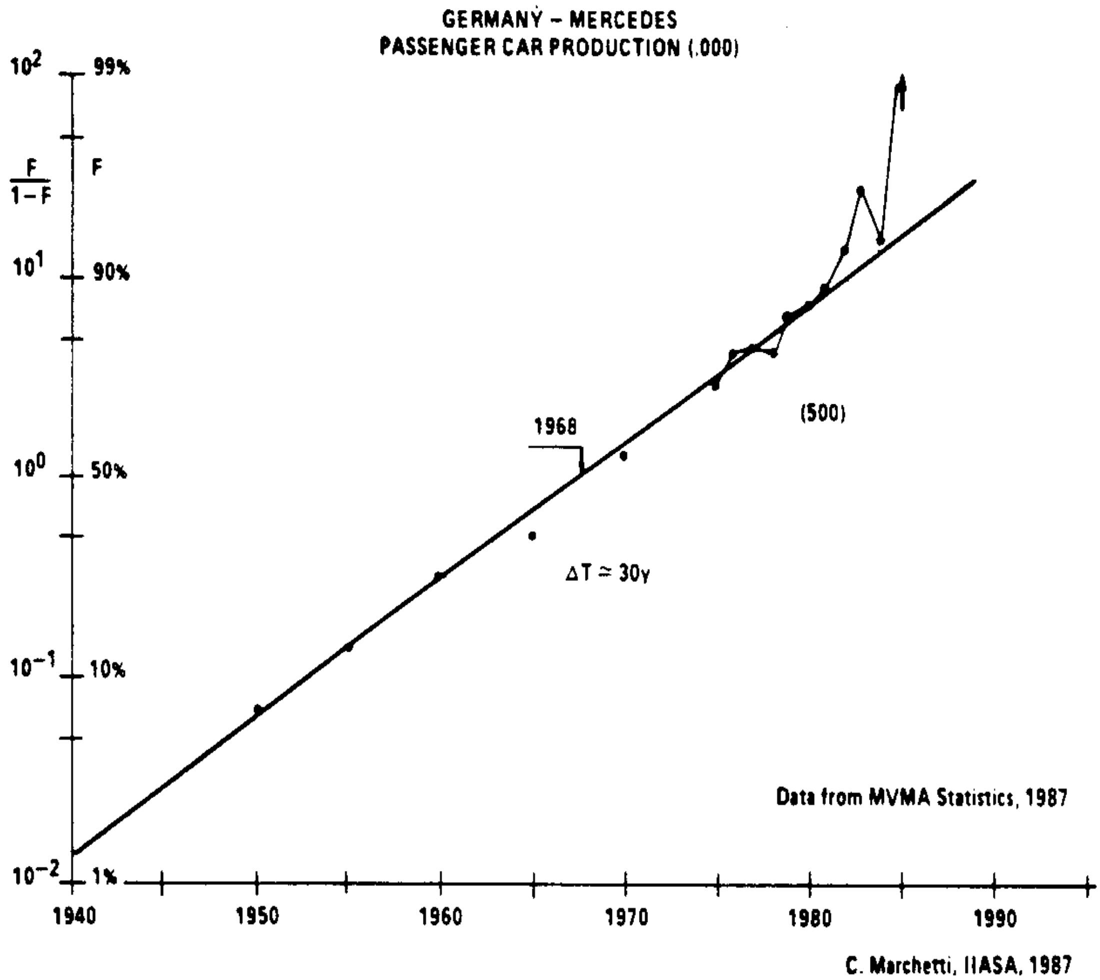


FIGURE 28. A sample of cases, especially in the car industry where statistics are reliable, show that companies, like trees, grow logistically expressing some sort of life cycle. The case of Mercedes, indexed through its passenger car production, is shown here but any other car company behaves similarly. Usually with more noise.

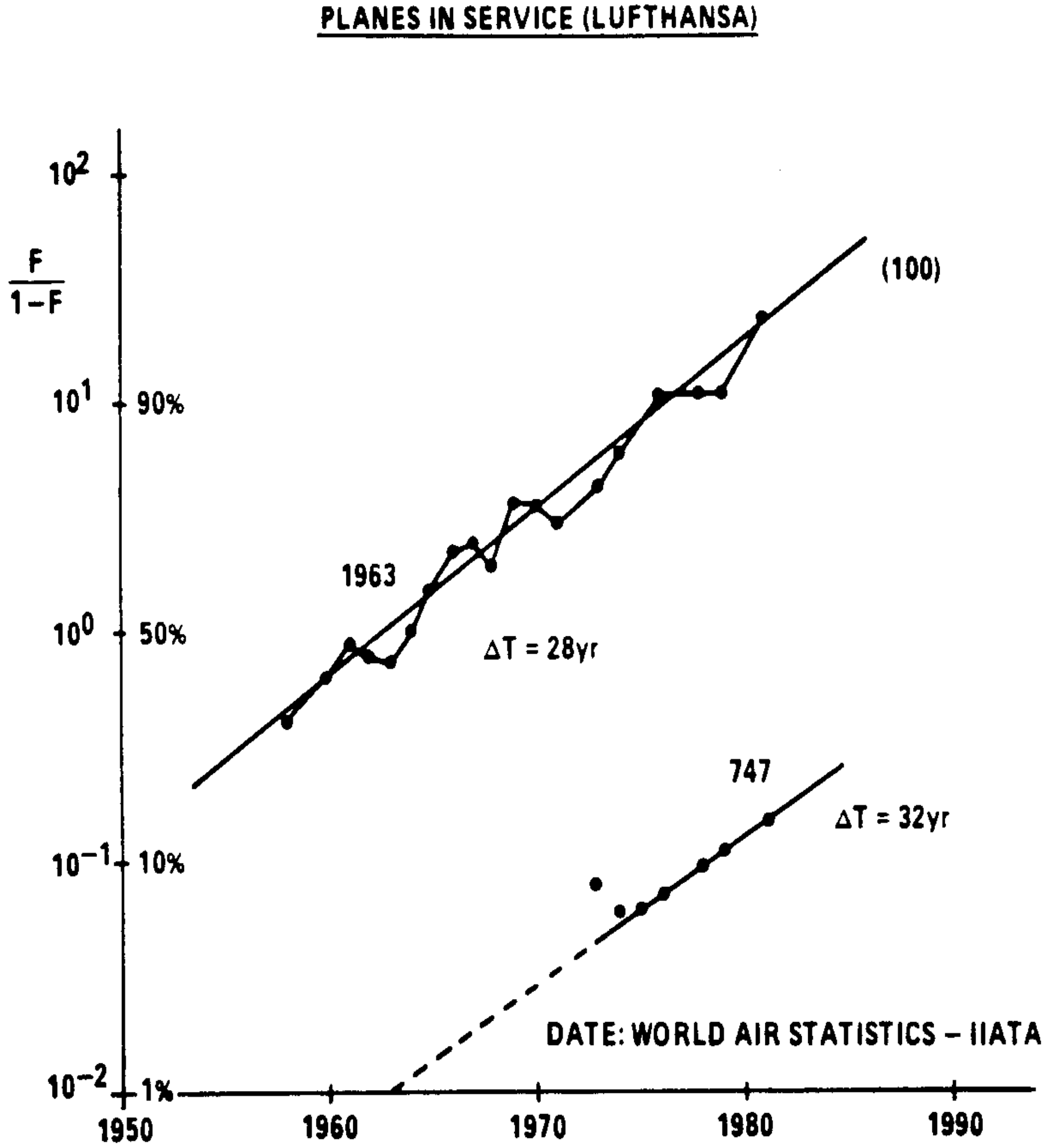


FIGURE 29. If the company has a measurable exoskeleton, we can try that. Here we take Lufthansa growth indexed by the number of planes in its fleet. We can also zoom into its structure and see what fraction of that number are Jumbos. Saturation level, here 100 planes, can be overshooted in an oscillatory mode. Incidentally, animal populations do often the same.

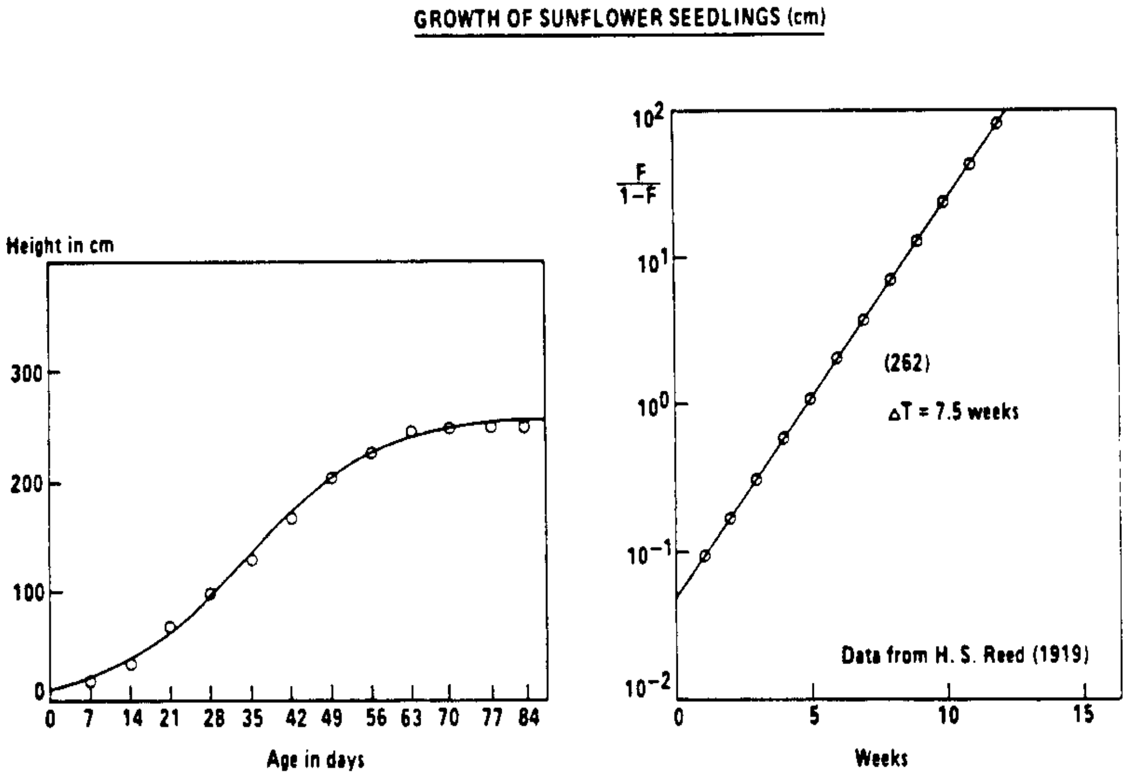


FIGURE 30. A biological archetype is here described. The growth in height of a sunflower plant. This particular behavior can be explained, assuming the plant program has a set point for height. Growth proportional to plant size per distance from set points gives a logistic growth pattern. It may be fascinating to search for the reasons of the set point of a company that can be easily calculated from its past performances.

INNOVATION IN COMPUTER INDUSTRY
MAINFRAME COMPUTER MODELS

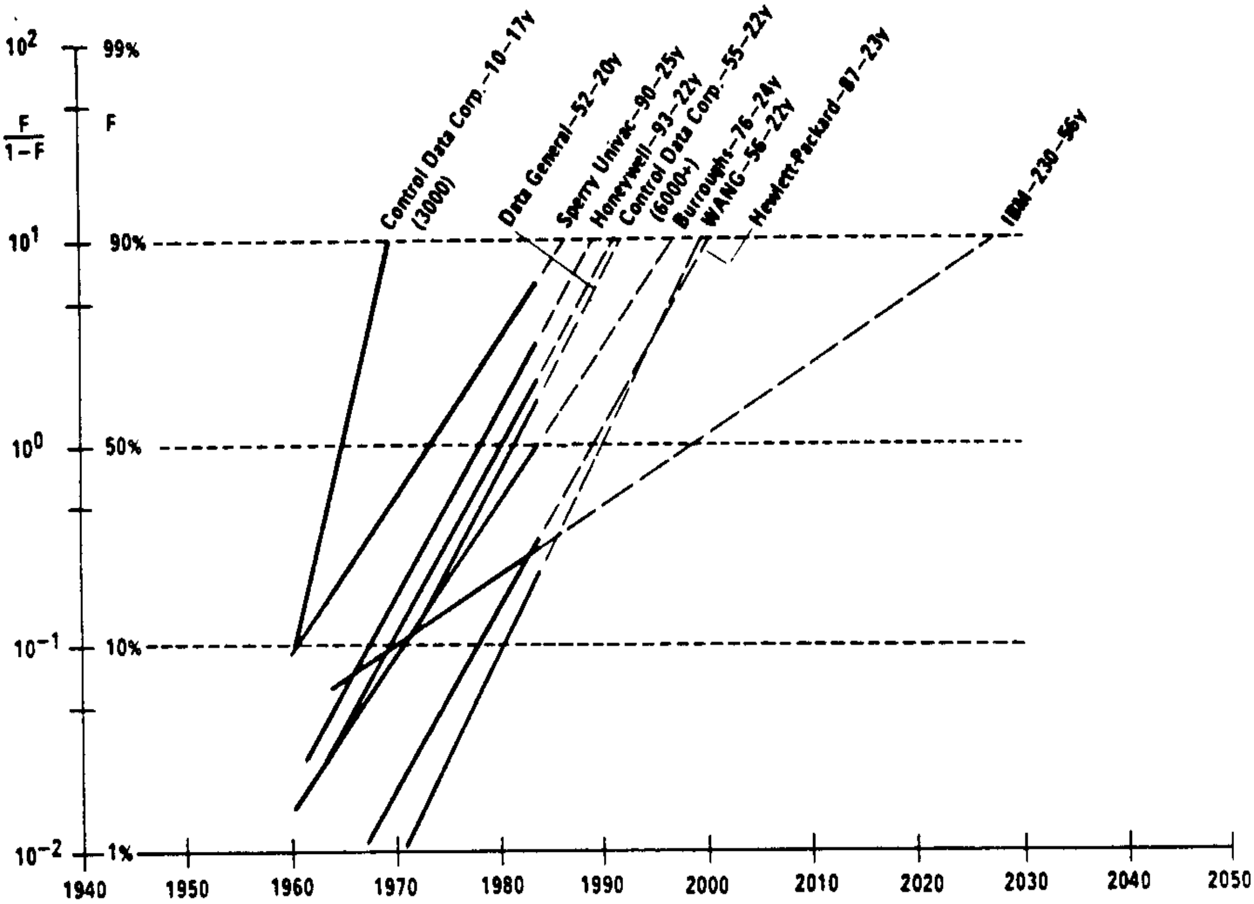
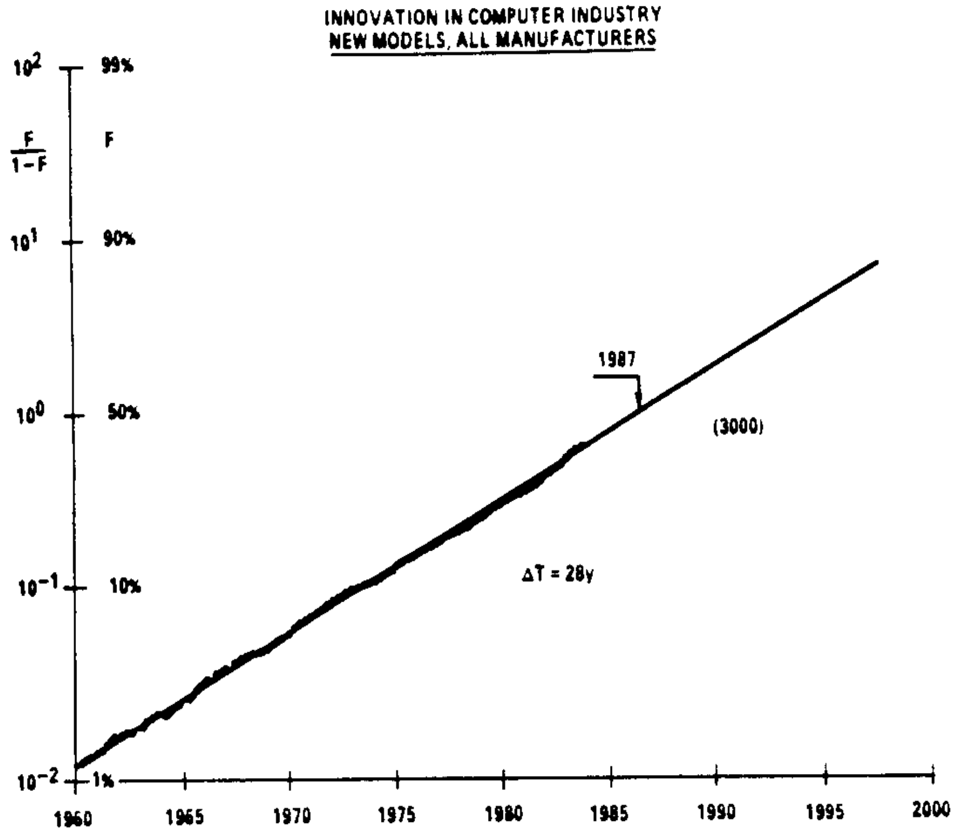
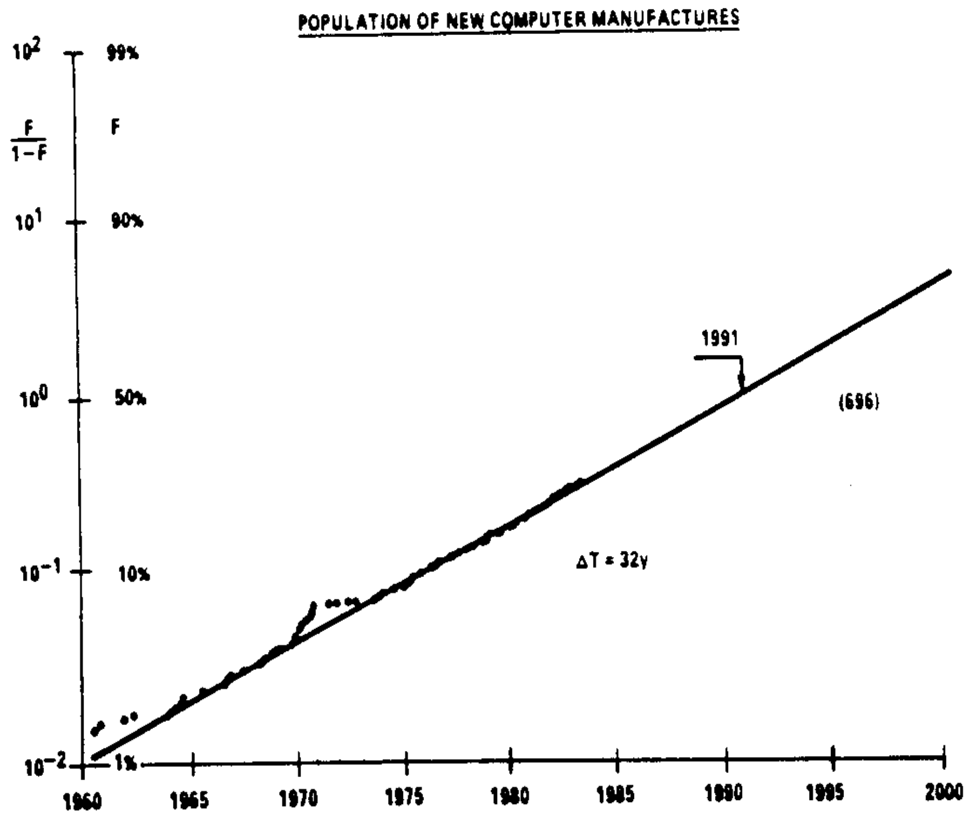
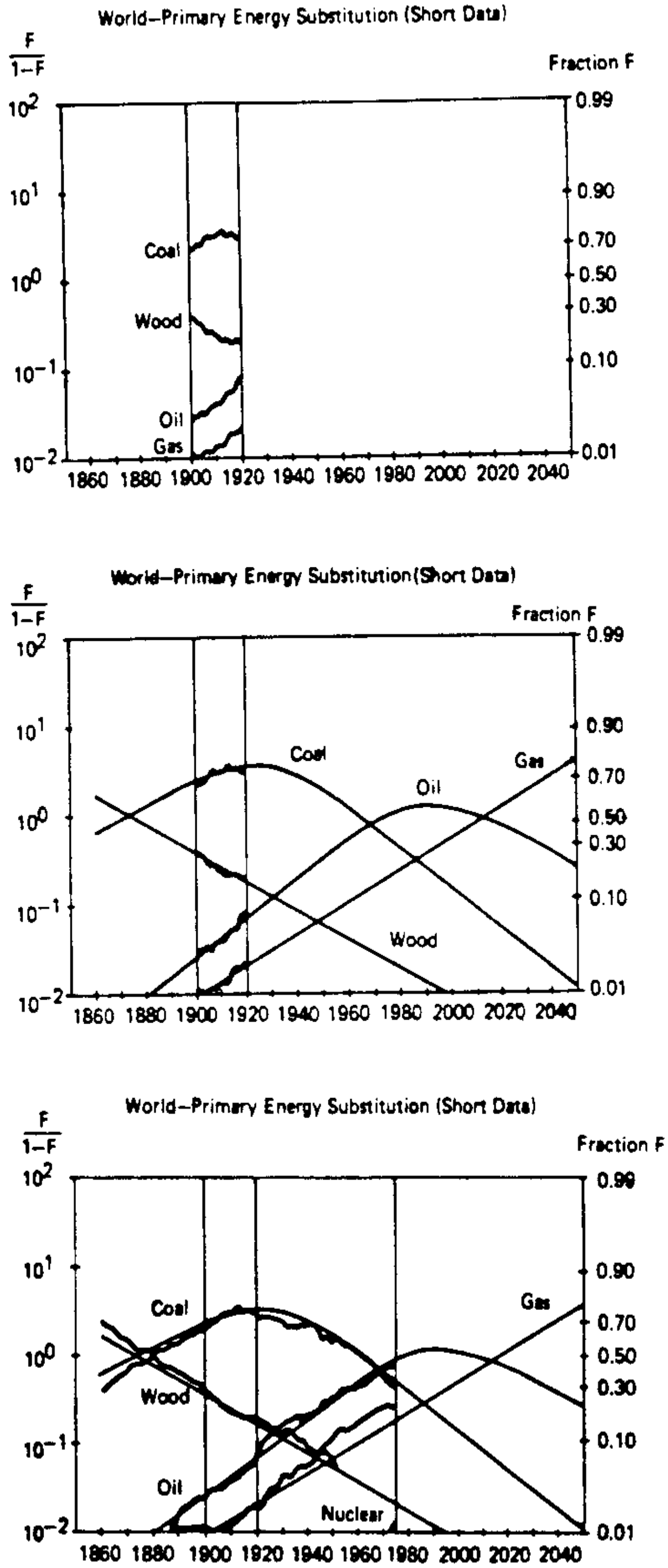


FIGURE 31. A company, as we have seen, can be represented by its production (Figure 28) or by its infrastructure (Figure 29). Its innovative capacity can also be a proxy to monitor its internal life. Here we have the cumulative number of main frame computer *models* generated by the most important companies in the field. Data points have been omitted for clarity. First number refers to the saturation point and the second to the time constant. The family look is evident with all companies having similar time constants, and to a point, similar saturation levels. The only exception is IBM which seems to span two Kondratiev cycles and has also the highest production of models, both as total and as a mean per year.





FIGURES 32 and 33. The exercise of Figure 31 is repeated for the generation of new models by *all* manufacturers taken together. This gives a bird's view of the branch and its future. An impressive number of models have already been put on the market, about 1500, and the saturation level is almost double, coming toward the end of the century. We can also analyze the branch looking at the cumulative number of producers who stepped in, e.g., since 1960. We get again a neat logistic saturation at about 700 and at present almost halfway. The wave of enthusiasm starts fading out at least from the point of view of new entry entrepreneurs. The case is understandable comparing Figure 33 with Figure 32. Every new company will produce a *mean* of three computer models. As the big ones will make 50 or 100 each, most of the small ones are left with one or two models



FIGUREW 34. The great stability of these diffusion-substitution processes can be put to work in order to obtain reliable forecasts. This can be easily checked using historical data to forecast inside historical time. One example is given here using the primary energies competition for the world market of Figure 8. A swath of data of 20 years is taken as data base (34a) and the substitution equations fitted (34b). The result is compared with the total set of data (34c). Oil, e.g., comes out with a precision of 2% (market share) after 50 years! Natural gas had not penetrated enough (2%) for a robust fitting.

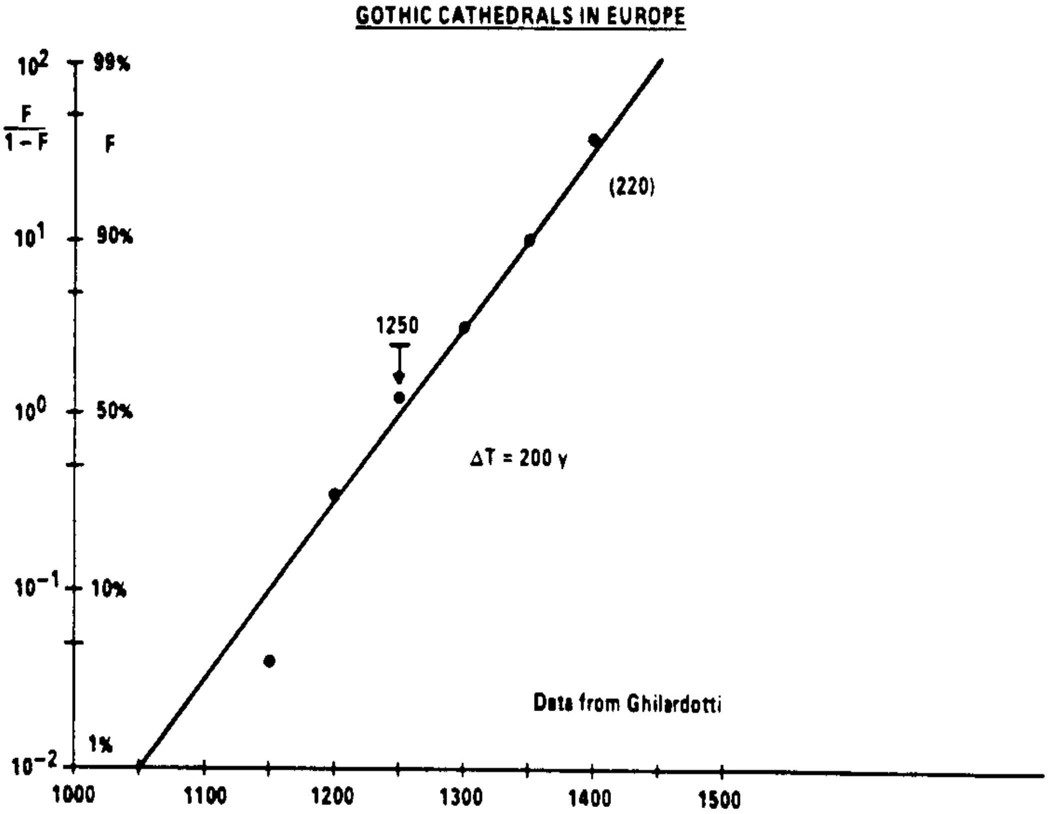


FIGURE 35. Building a Gothic cathedral seems a good idea to us, but was an incredible burden to the populations of the middle ages. So the idea took a while to diffuse, but it did it in the most orthodox way. The chart gives the cumulative number of *first stone* for what will in time become a cathedral. The dates are well documented. Taking another point in the construction, e.g., termination of the building would have been more perilous from the point of view of the statistical basis.

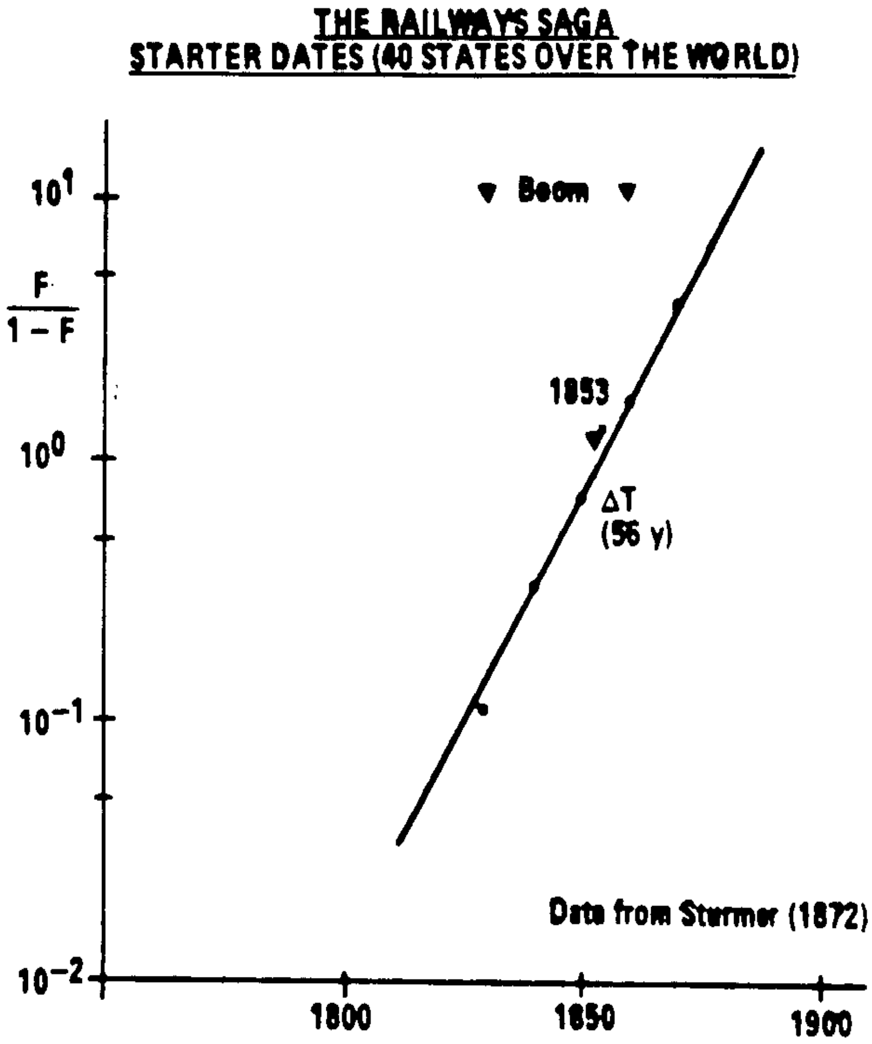


FIGURE 36. Also railway networks are in a sense cathedrals, if we look at the complexity, effort and psychological impact. The chart is constructed like that in Figure 35, this time taking the cumulative number of *first lines* openings, for first lines that finally developed into a network. In this chart the idea that railways were good things to build had to spread around the world, and the world appears to be a single unit, at least from the point of view of diffusion of ideas.

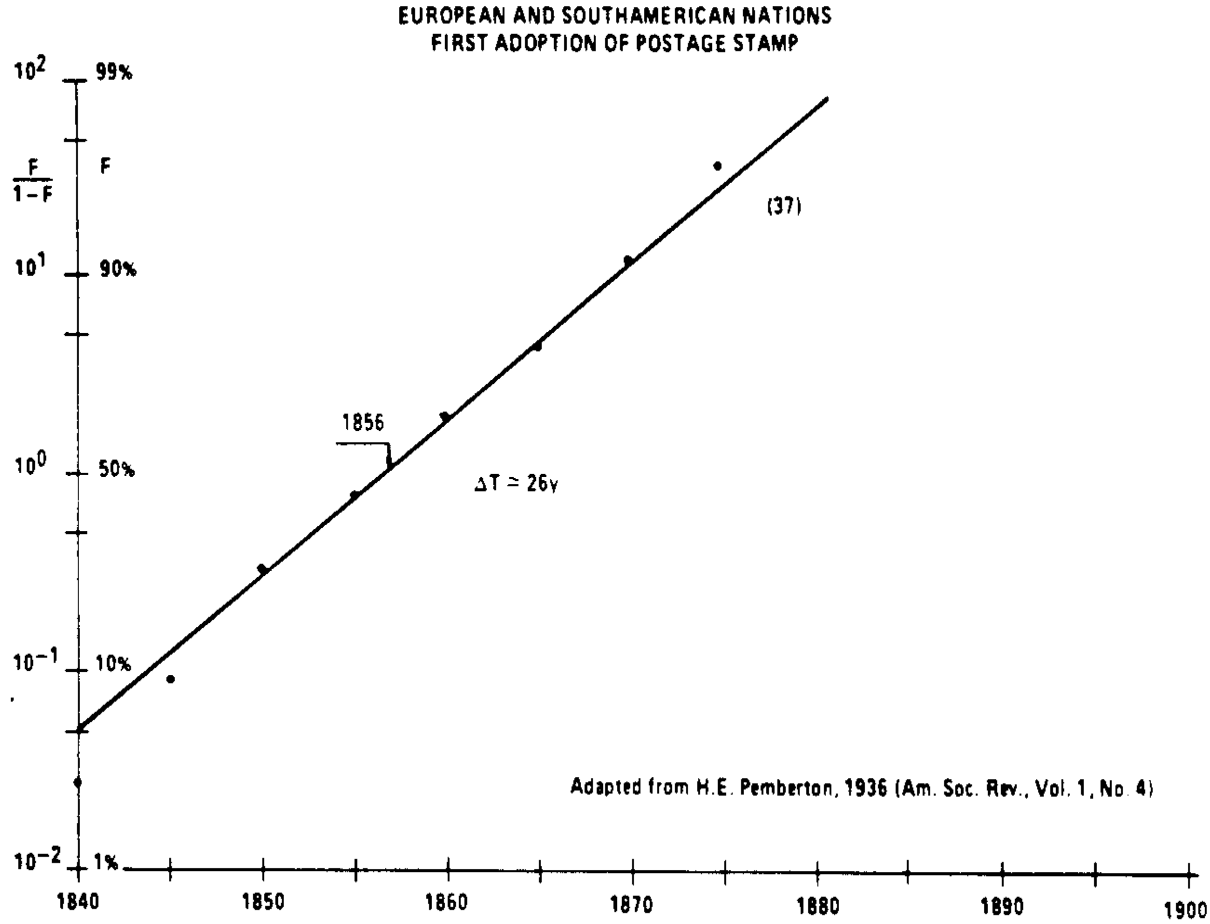


FIGURE 37. One may think the huge investments locked into cathedrals or railways were the main reason for their relatively slow diffusion. My opinion is that the obstacles are basically of cultural character. This chart maps the diffusion wave of the acceptance of a new tool of payment for postal services: the stamp. In spite of the zero investment costs, the diffusion rate is similar to that of railways, and the saturation coincides with the end of a Kondratiev wave (1885).

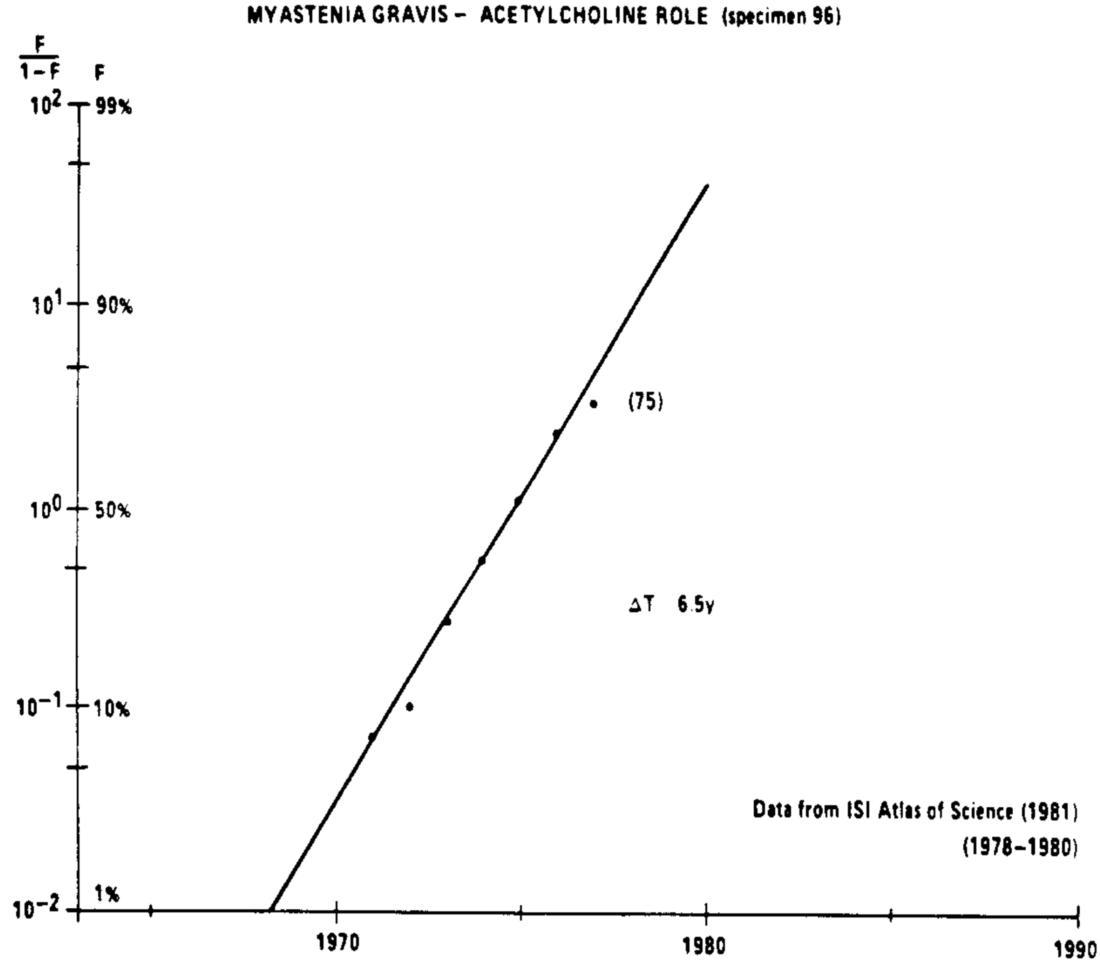


FIGURE 38. People in research operate through some sort of fashions. Somebody hits on an interesting subject and others rush. The rush can be quantified, looking at the emission of papers, and counting them cumulatively. The exercise here reported refers to a very specialized (and volatile) field of biomedical research: the effect of acetylcholine in asthenia gravis. The stable dynamics of the diffusion process makes it possible to forecast how many papers will be published on the subject and when. A boom for decision makers trying to get their best from research funds.

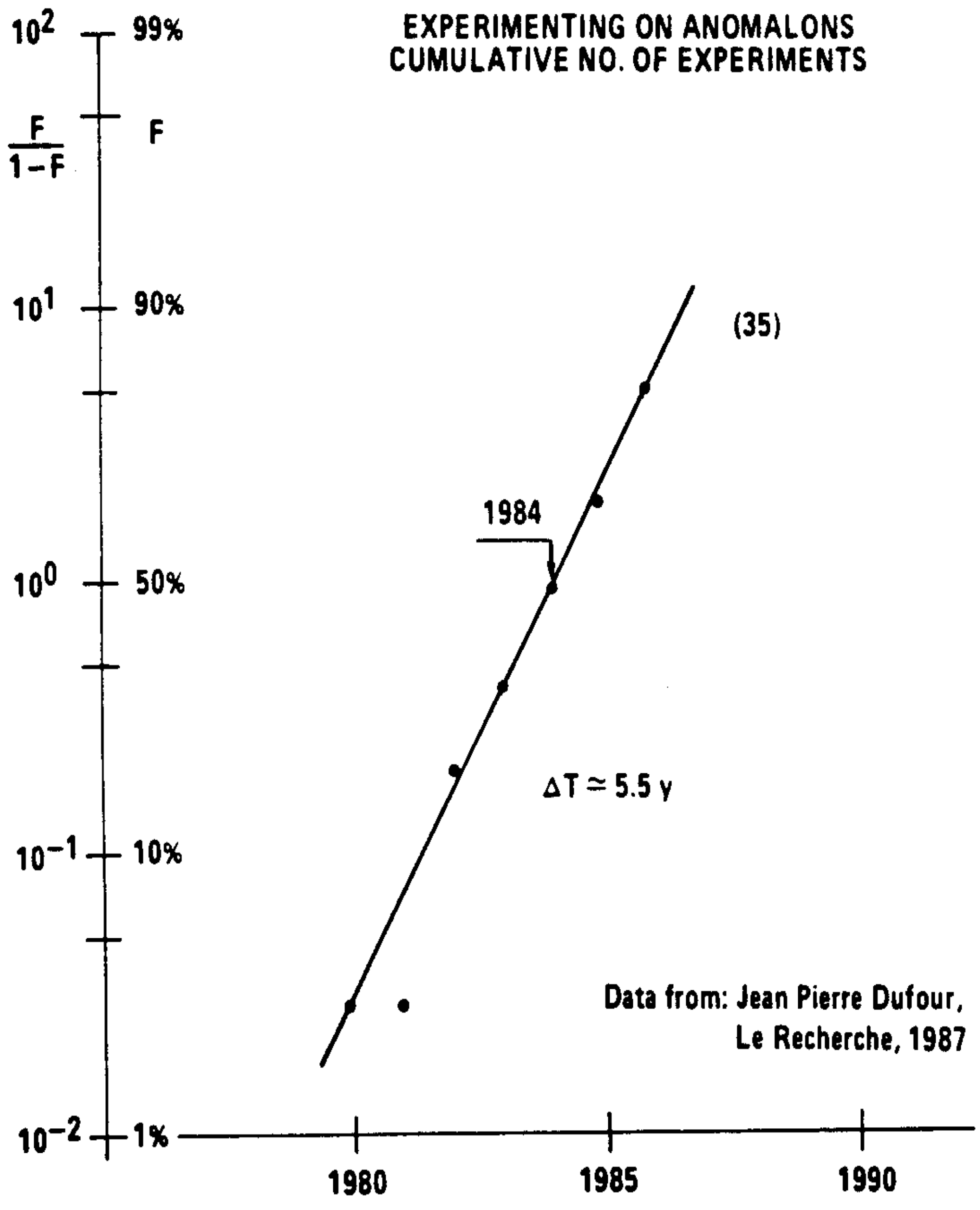
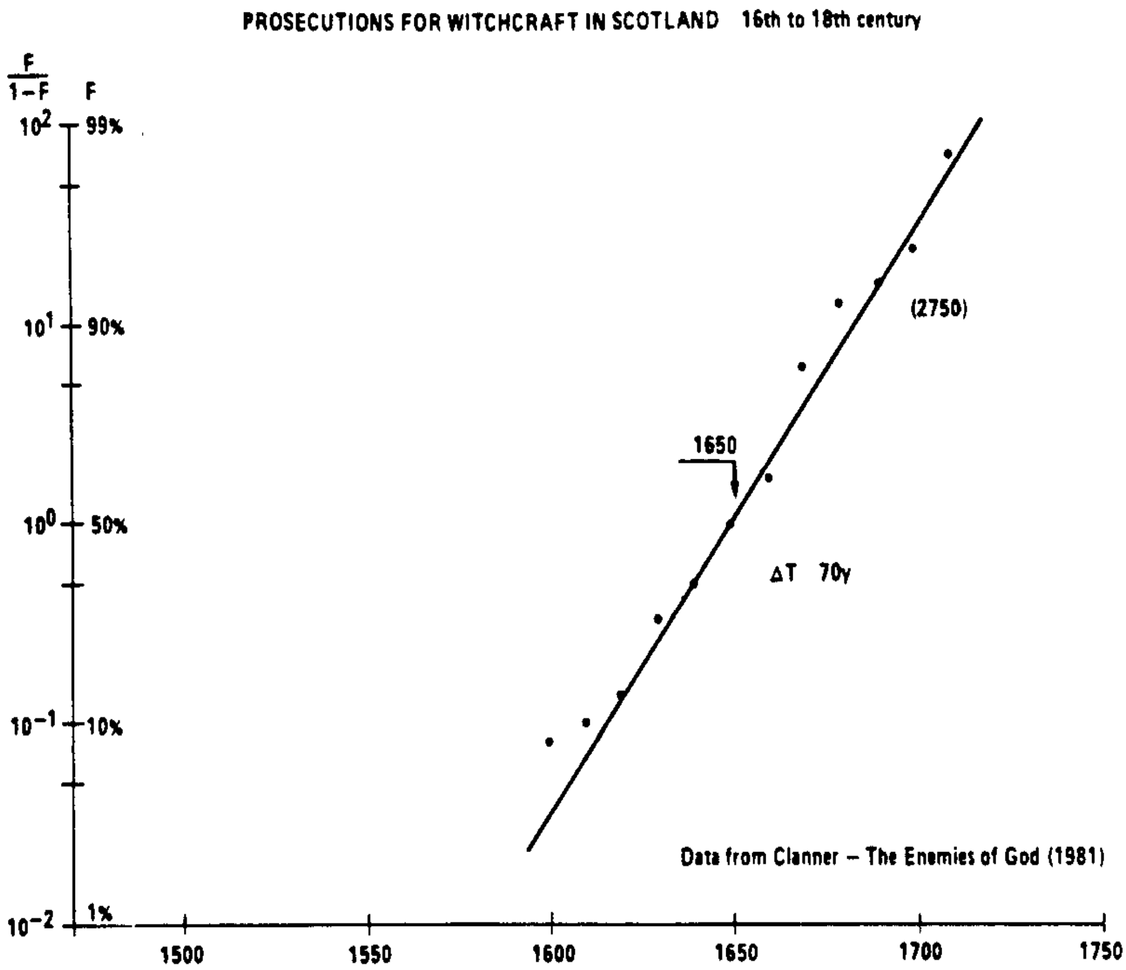
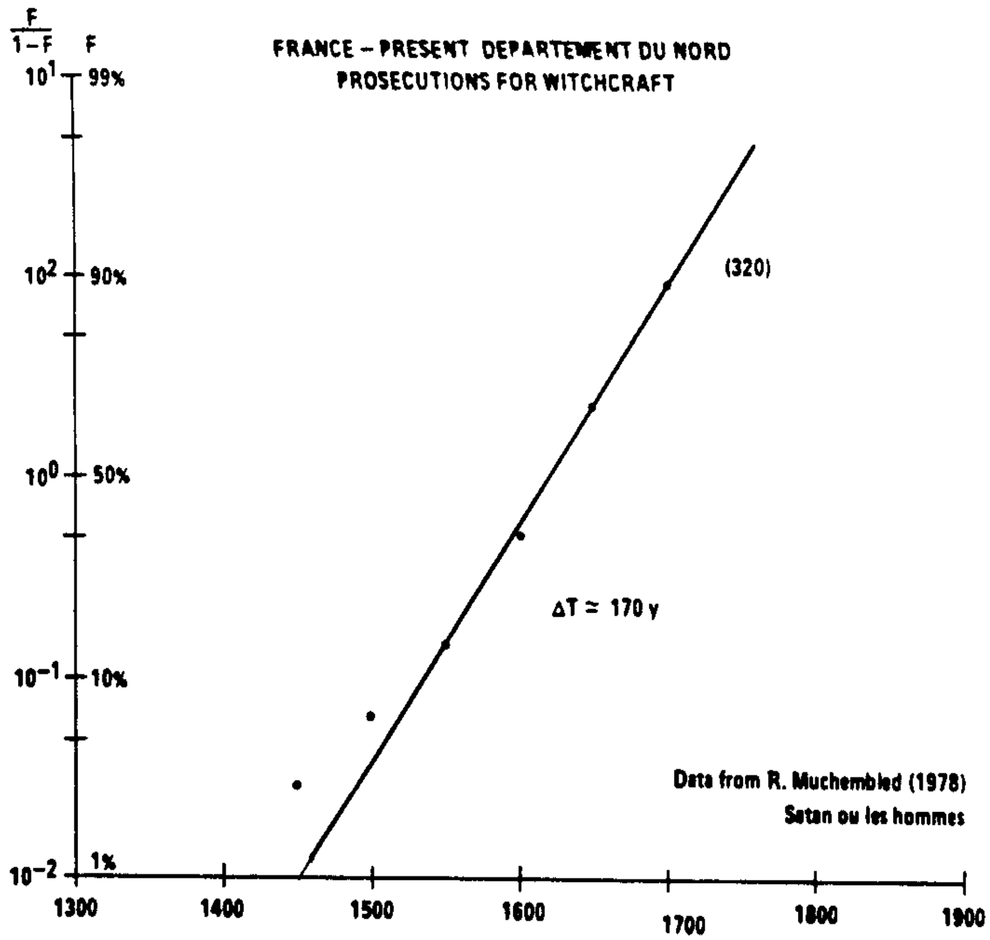
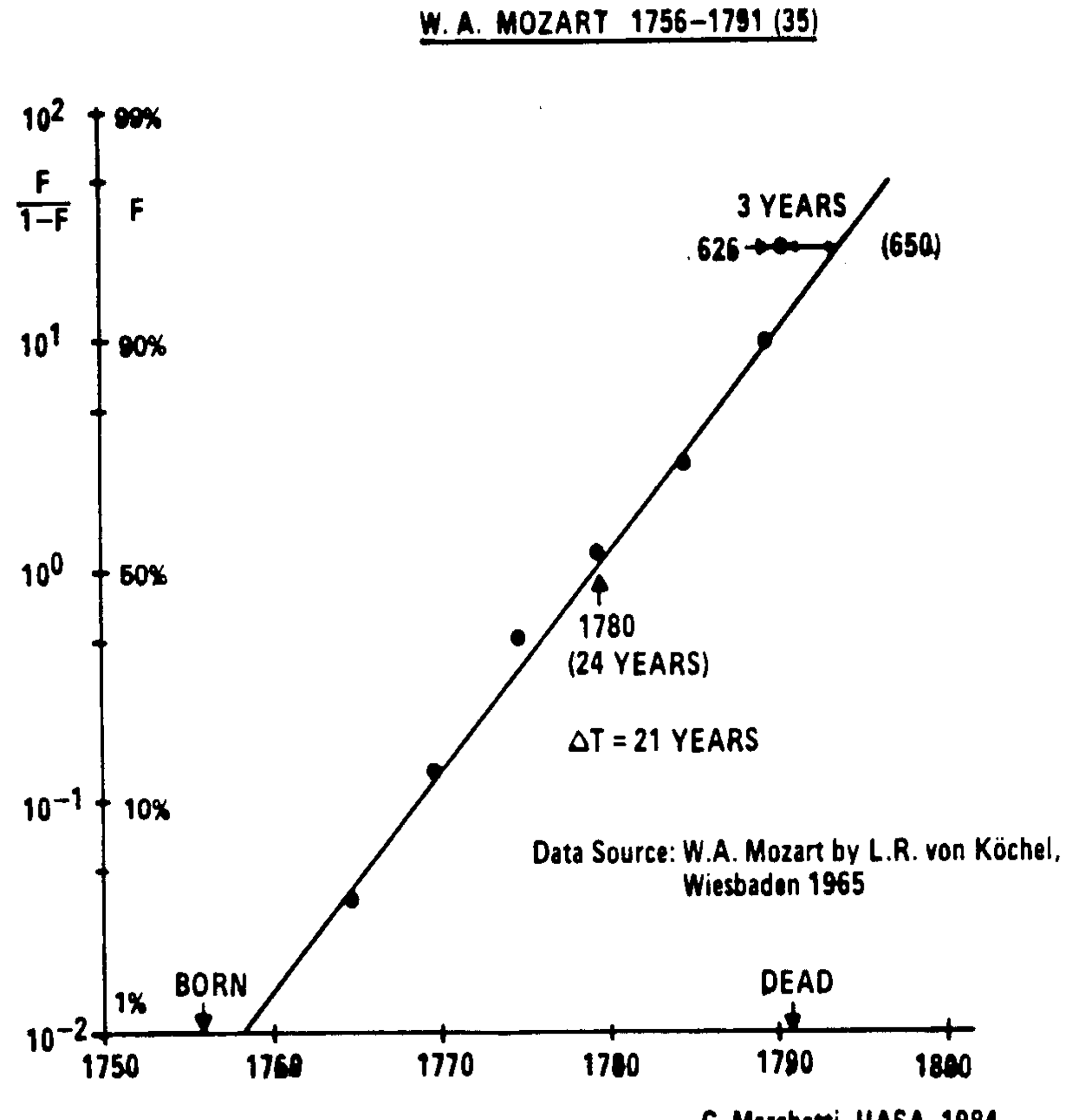


FIGURE 39. When the hardware is very expensive and goes into the headlines, it is possible to monitor the evolution of a certain field of research through the experimental set ups. The cumulative number of these set ups for searching an elusive elementary particle, the *anomalon* is here reported in logistic form. According to learned opinions the particle does not exist. Set ups, however, have already saturated.





FIGURES 40 and 41. Here two examples of diffusion of a socially centered idea are reported. Burning witches was thought as a good sport during certain periods of the Middle Ages (and more recently) because it cleans the social atmosphere. What I am trying to show here is that the content of an idea is not determining the mechanisms of its appli-



FIGURES 42-46. This set of charts penetrates into one of the most defended strongholds of human ego, that of freedom, and in particular freedom in his creative acts. The charts report cumulative production of objects of art or science (publications) by personalities eminent in their field. Two considerations emerge from the analysis of about 100 cases of this kind. First that each of us has some sort of internal program regulating his output until death. Second that the saturation point or set point is always approached, and people die when they have exhausted 90-95% of their potential.

BOTTICELLI 1445 – 1510 (65)

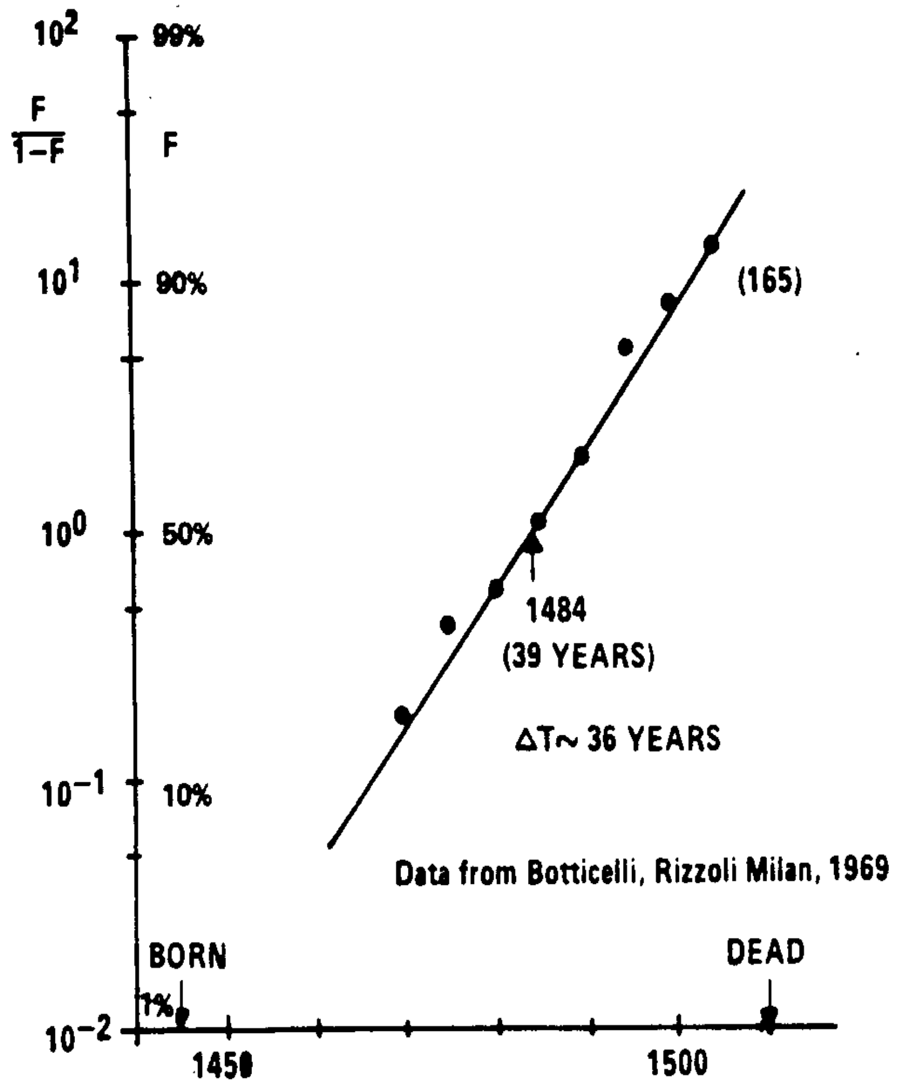
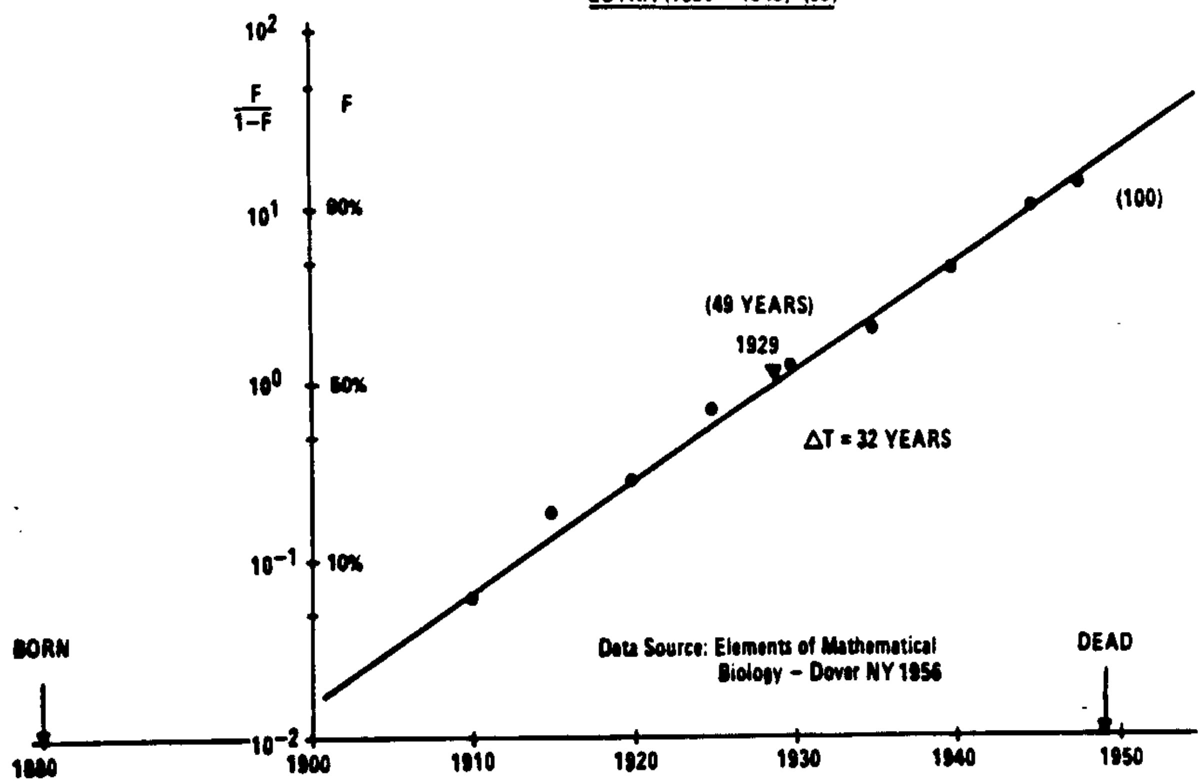


FIGURE 43

LOTKA (1880 – 1949) (69)



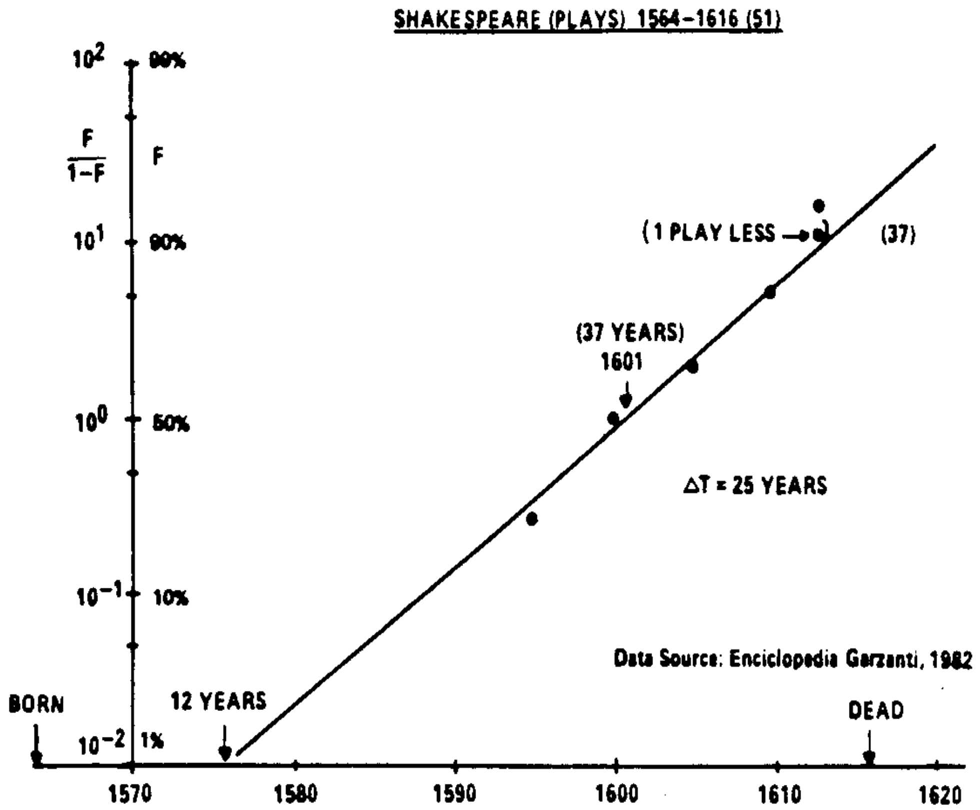


FIGURE 45

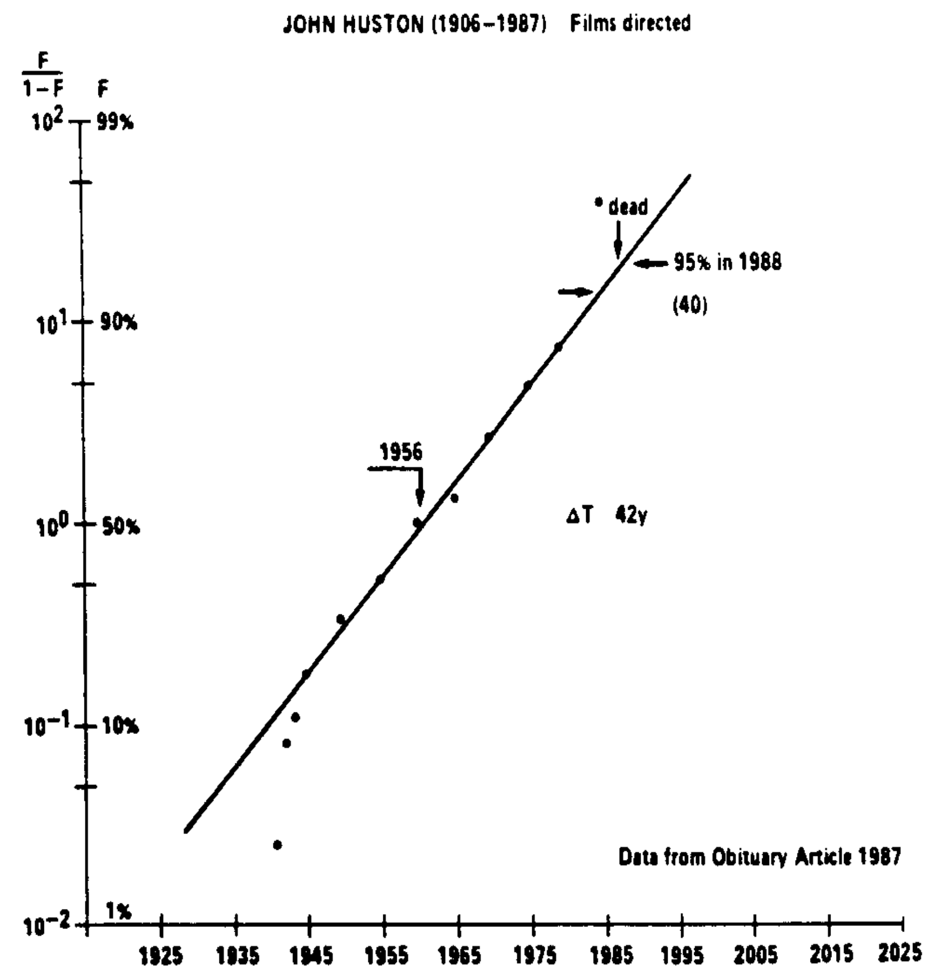
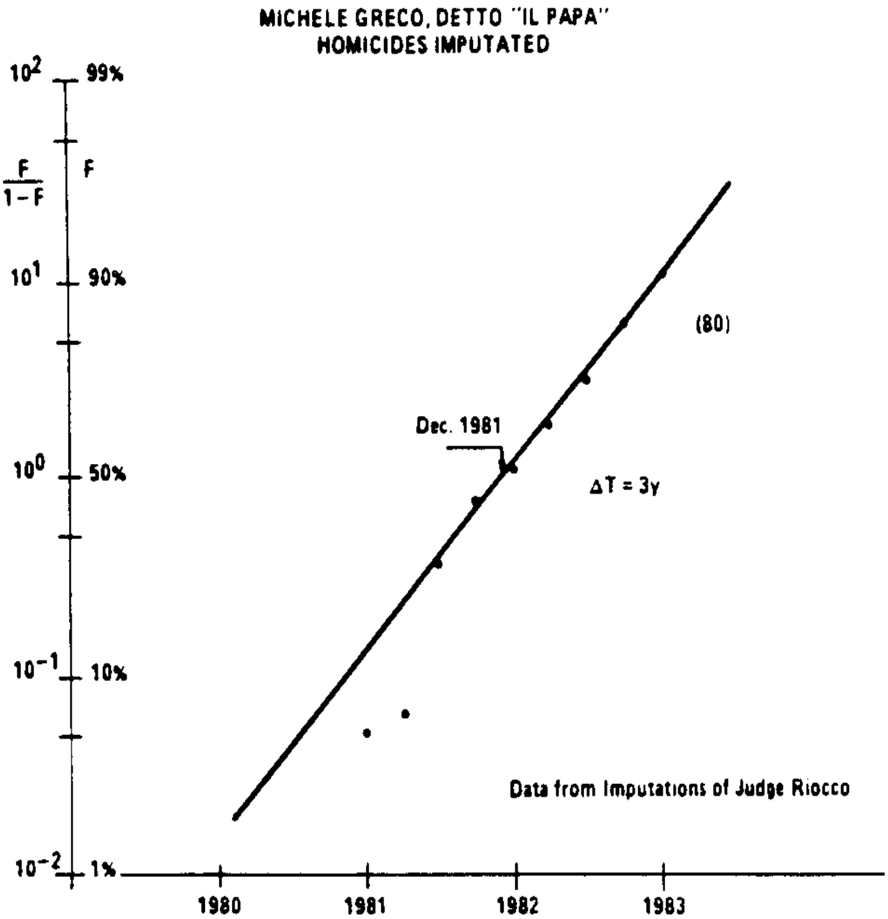
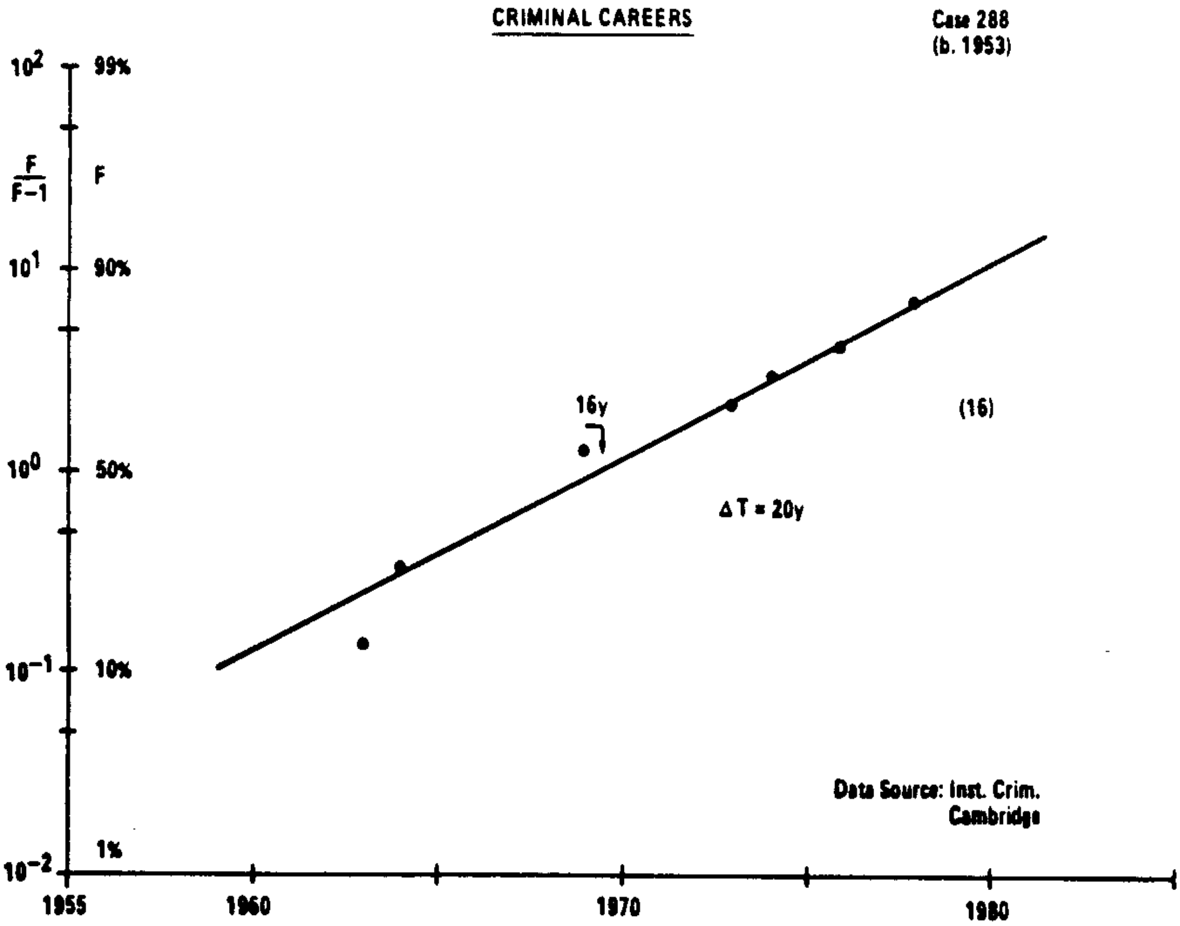


FIGURE 46





FIGURES 47 and 48. Being criminal can be seen as a creative activity. However, I did study them because they have records. Their cumulative number of crimes fits the usual logistic. The most interesting conclusion I could draw from examining a few cases is that time spent in prison does not reduce the total number of crimes. As they come out they

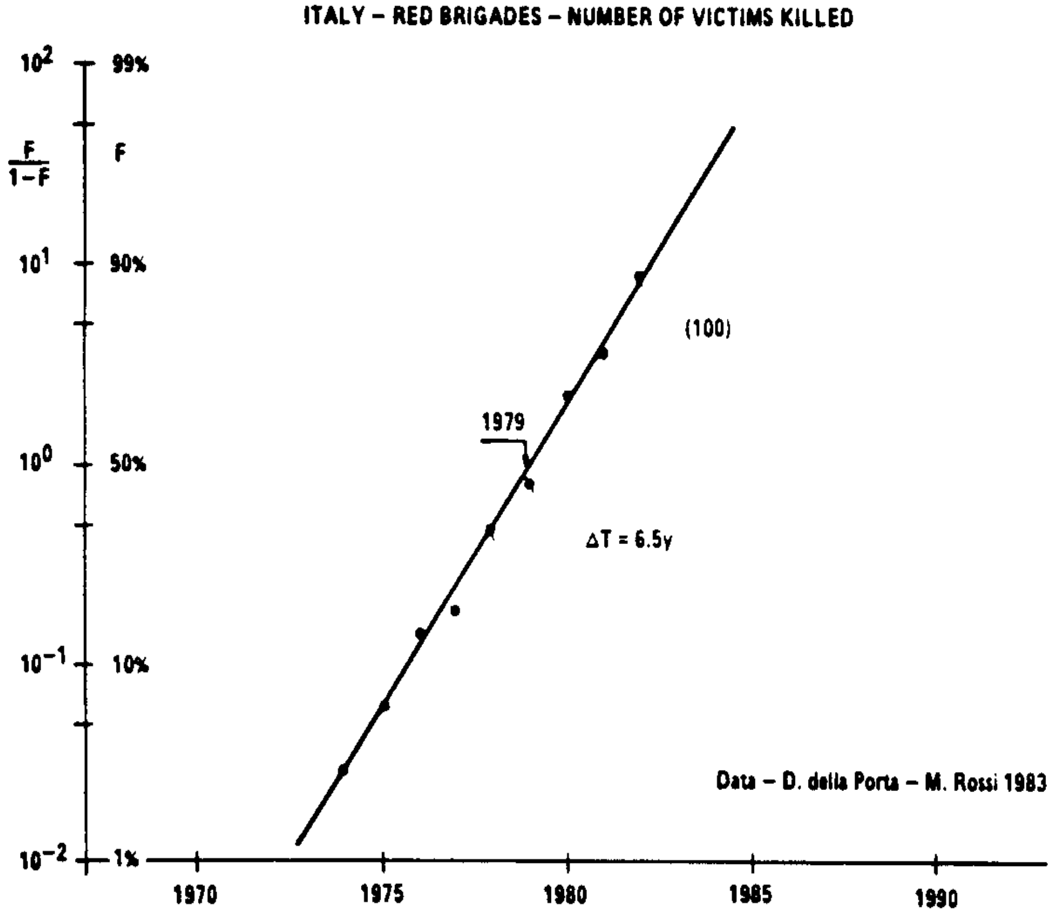


FIGURE 49. Attributing a soul, a will, and a program to a loose terroristic organization like the Italian Red Brigades may be going a little too far. Anyhow, if we look at the cumulative number of their hard actions, i.e., people killed, we find the usual logistic. The only real difference from that of Mozart is the much shorter time constant.