Looking Forward – Looking Backward

A Very Simple Mathematical Model for Very Complex Social Systems

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Historians work on plausible reconstructions of happenings, mostly war or politics. Economists work on plausible reconstructions of economic events. Both *post facto*. Historians usually do not have mathematical models. Economists have many models, but basically they never use them. I mean to describe, forecast, and backcast. For them the construction of models is an activity *per se*, to show mathematical ability and logical subtlety.

These statements stem from my personal encounters with economists and historians, from low to top level, and may suggest presumption but it is just flat observation. However, exactly the same conclusions have been reached, e.g., by Nobel Prize Leontief, he himself a modeler.

Now how can I, puny David, say that all this can be done, and with the left hand? By pure luck. Twenty years ago I stumbled on the right stone and fell, face down on the right equation. Stone and equation have stood there for eons. I only provided the falling body. I must add, however, that having been educated as a physicist, I derive a special pleasure from contemplating universals and, like a truffle pig, I can smell them underground.

That said, let us come to brass tacks: *social systems* are on the last count, *informational systems*. As *biological systems*, where DNA is the book of the books and everything descends from it. Why not using the broad analogy to see if working concepts can be transferred from one area to the other. Analogy is a trick very successfully used by physicists in their mathematical physics. So I started from the central dogma of genetics: *mutation, selection, and diffusion.* Mutation and selection are crypto-processes, what we usually observe is diffusion: Red butterflies progressively displacing green ones. Because the birds of prey were daltonic and could not see them.

Diffusion processes in interconnected informational systems can be modeled very parsimoniously. The *equations* are called *epidemic* just because epidemiologists were probably the firsts ones to use them. An epidemic is a typical cultural process, where a message, e.g., a virus, jumps and reproduces in a set of cultivars, the humans. Although each jump contains its microcausality, like the bumping of two molecules, seen from outside the process appears utterly stochastic. Actually computer simulations and mathematical models of the process using stochastic moves, lead exactly to the same equations that fit the empirical epidemic data.

If we look at the guys who pick the flue, day by day, wee find a bell-shaped curve quite resembling the normal distribution (although it is not the same as the mathematics show). If we integrate, counting all people who *already got the flue, we get a logistic equation*. This equation can be constructed from the basic mechanism of epidemic diffusion

$$dN = aN(\overline{N} - N)dt\ ,$$

where $\overline{N}$ is the final number of those who picked the flue; *N(t)* are the ones who pick it at time *t*; $\overline{N}$ – N are the ones waiting still to be infected. The rate of new infections runs then as proportional (*a*) to the product of the infectious *N* by the infectable $\overline{N}$ – N ones. Simple and logical.

That is all our mathematical equipment. Transporting this simple reasoning to social systems (much simpler, by orders of magnitude, than biological systems), we find a *precise matching between equations and events*, stretching at times for centuries. In twenty years we have mapped perhaps

3000 different cases, with great diversity in subjects, going from the penetration of diesel locomotives in the United States to the killing of witches in northern France in the Middle Ages. Both require "*conceptual capsules*" like our viruses, to jump from brain to brain, l*eading* finally to *action*, whose biological parallel can be the fever, or death, or pustules on the skin.

After having analyzed a few hundred cases, we observed an *unexpected stability in the diffusion process*, with reabsorption of accidental perturbations (e.g., a war). With appropriate prudence and manipulative skill these equations can be used in fact *to predict the future and reconstruct past events*, as I have done extensively.

In our whimsical world of liars, traitors, and nuts, as often we perceive it, the stability of these processes is really puzzling. Professor Hägerstrand, a geographer of Lund University, since the time of his thesis in the 1940s, has studied diffusion processes in the field, starting from the telephone, and asking *each person* how and why he came to have it. I take him as perfect connaisseur of the micro-physiology of diffusion processes. He told me that the most important clue to stability is the stability of fiduciary diffusion clusters. Each of us has about 100 people, whom he trusts, and with whom he chats and exchanges tips. These clusters change little during the life of the individual, and also the rate of information exchange.

As one judges the pudding by eating it, the extraordinary success we had in modeling, forecasting and backcasting (for fun) means that the system works. The philosophical and practical consequences of that have not yet been perceived by the specialists, and never really negated even if commented with: "I cannot believe it", "Where is free judgment here?" Many things that people think are under their control, are in fact under the control of subtle mechanisms, the famous invisible hand, and helas, their course is very hard to de-rail. *This burns the ego*.

A first technical point is that I generally use the integrated function, the logistic, because it smoothes out fluctuations due to small anticipations or posticipations to do something, e.g., to purchase a car. The second one is that S curves as such, are bothersome to draw and to check. So I used a little mathematical trick (Fisher–Pry transform) that straightens them. Logarithms are used here in such a way that they magnify deviations from the curve.

From now on, I will proceed with examples. I took about 20 of them, because more are difficult to digest in a brief exposition like this one. The subjects are very varied to show the extension of the descriptive power, or the invariance of the system. At least half of them should be directly interesting to political scientists. It must be clear that to make an analysis using this methodology, one has to find significant measurables, which is sometimes difficult in political and social systems. One has to use ingenuity. One of the tricks that proved successful is to use the media, and count articles or television quotes or key words. The media have to fit like a glove the moods and interests of the populace, and from the glove we can make a cast of the hand.

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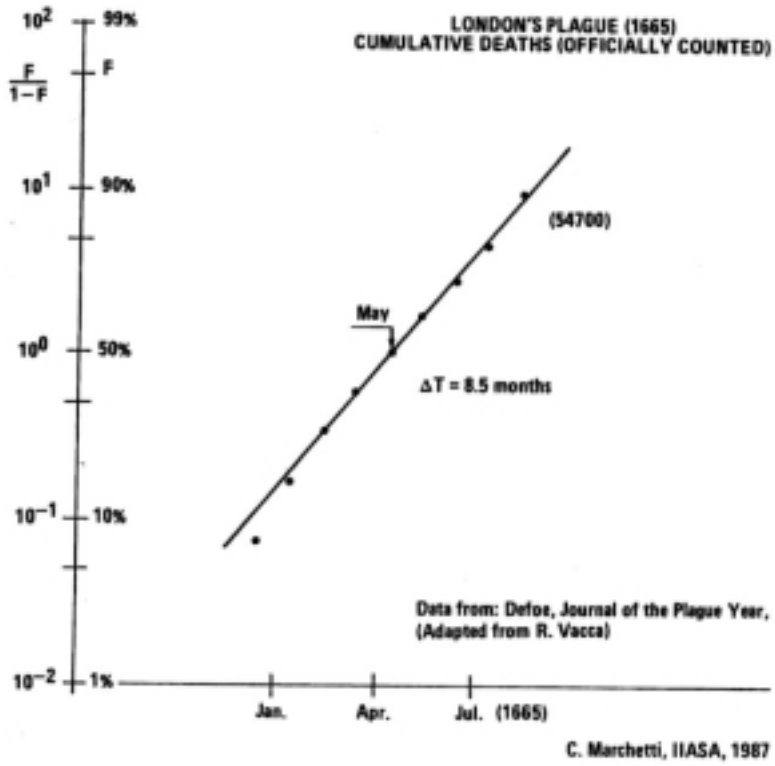
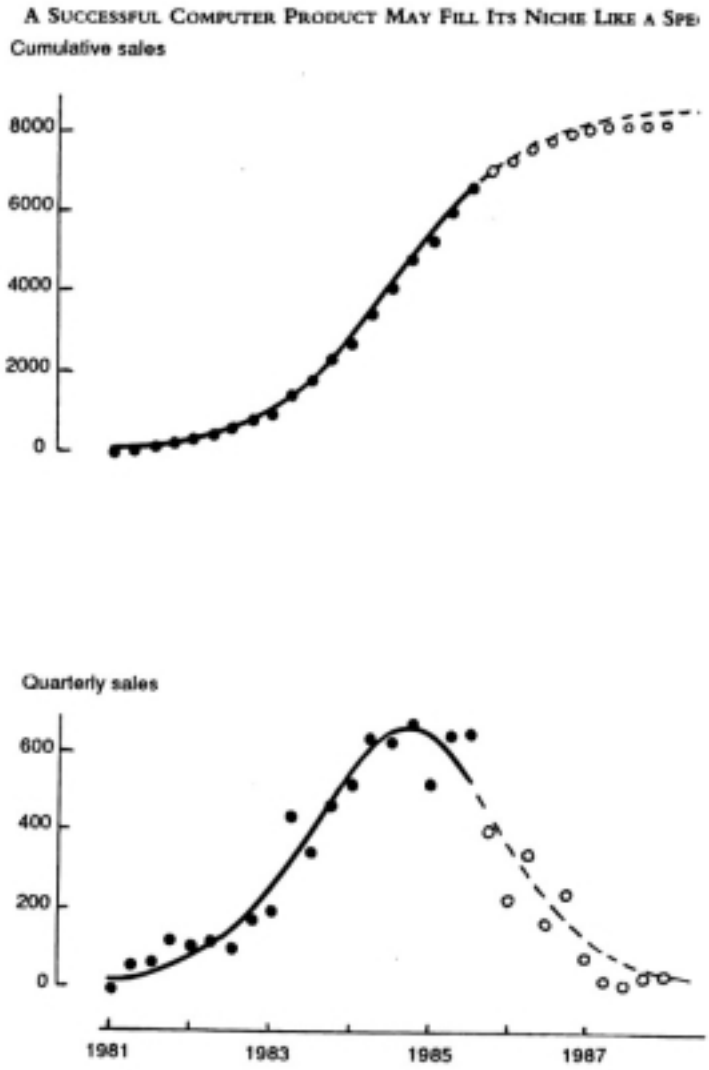
How to read the charts

- The lines represent a logistic equation fitting the statistical data: the points.
- Logistics are S-curves reaching a maximum, the saturation point. The numerical value of this maximum is reported in parenthesis.
- The S-curve can move fast or slow to its saturation. The speed is measured by the time it takes to go from 10% of the saturation value to 90% of that value. This time is called time constant and is given as $\Delta T=$ in the charts.
- Most of the charts show straight lines. To make an S-curve straight, we take $F(t)$ as the fraction of the saturation value taken at a certain calendar time t. F can go from 0 to 1, but usually we have intermediate values. The straight lines are obtained by plotting $\log(F/1–F)$ or the logarithm of the ratio of F, the level reached from $1–F$, which still has to be done.
- The point at which the S-curve is halfway (F=0.5) is signaled in the charts with the corresponding date.



London plague

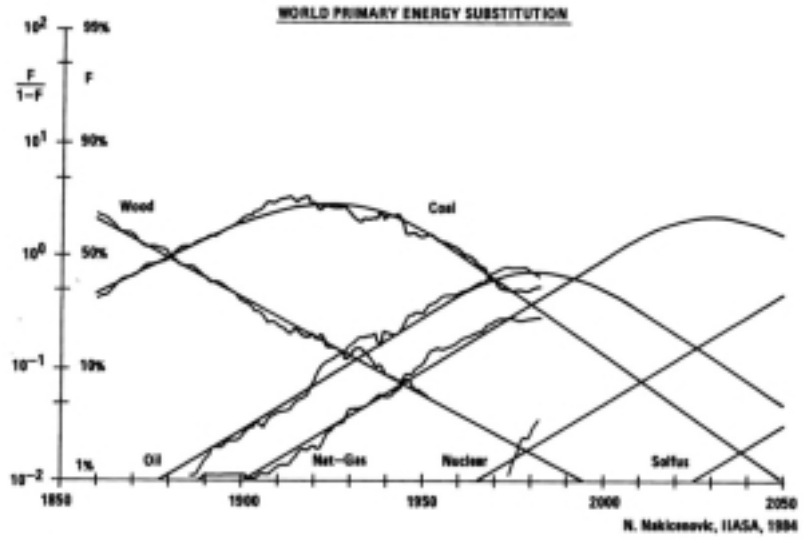
A plague is the archetype of an epidemic diffusion. As most infected people died, deaths are a good measure of the spreading of the plague. The flash of deaths was contained inside one year ($\Delta T \cong 8.5$ months) with the peak of intensity in May 1665. The spread of the plague follows with remarkable precision the logistic course defined by the straight line. Number of deaths could be forecast with precision a couple of months ahead, which could have been a bonus for the organizations of undertakers who had to manage a very fast, very large, and in their actual view, unpredictable flow of dead bodies.

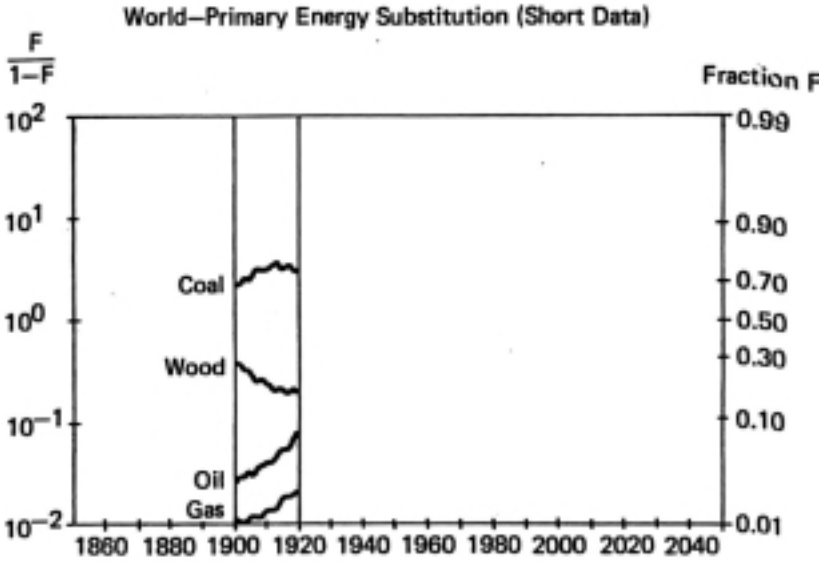


Computer products

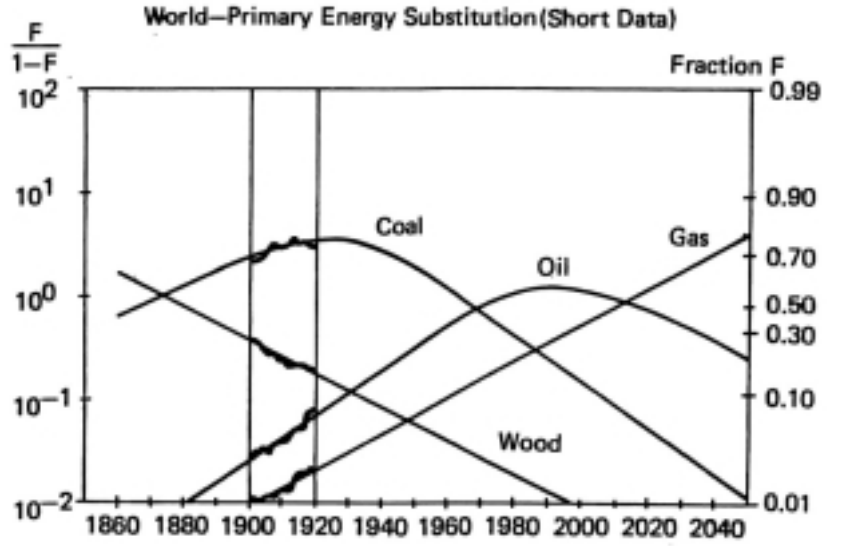
To illustrate the concept of epidemics in a socioeconomic system, I take the case of the selling of a certain computer model (by Digital) in terms of computers sold per quarter. The points are spread around the fitting curve because of little time advances or delays in purchasing. The S-curve on the contrary gives the cumulative number of computers sold. The fluctuations are reabsorbed because the integral does not see the time wriggle.

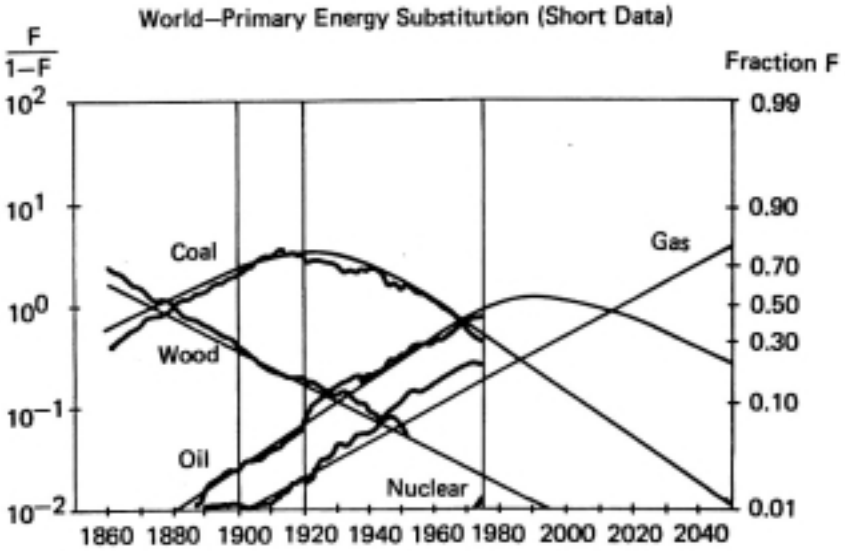
The black dots represent data and the equations have been fitted using them. The white dots represent verification of the forecasting (done in mid-1985). The working of the methodology is shown here in very simple format.





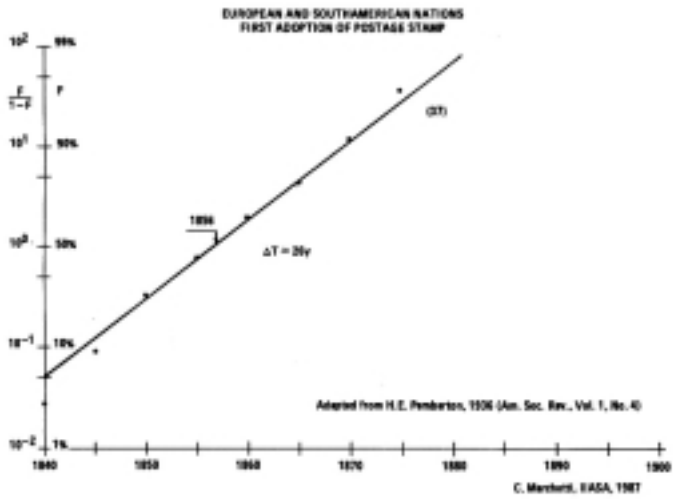
Primary energy substitution
(a) This chart represents a very complex system: the structure of the world energy market for more than 150 years. The roles of each primary energy – wood, coal, oil, and gas – are quantified by showing their *market share in terms of energy*. The twisted lines represent actual statistical data, and the smooth lines the equations that fit the data. These equations represent just a small complication by respect to the simple diffusion process and use basically the same mathematics. Diffusion, as usual, happens in a niche already occupied by competitors, and in due time, infested by new competitors. *It is remarkable here how these extremely simple equations (two parameters each) can master such complex processes over so long stretches of time*. It is this simplicity and stability that produces the context for credible forecasting. An example of what can be done, and how, is given in the following three charts. A database of 20 years is fixed, here 1900–1920 (b). The database must cover a sizable fraction of the time the process takes, here about 15%. The data base is used to fit the equations.





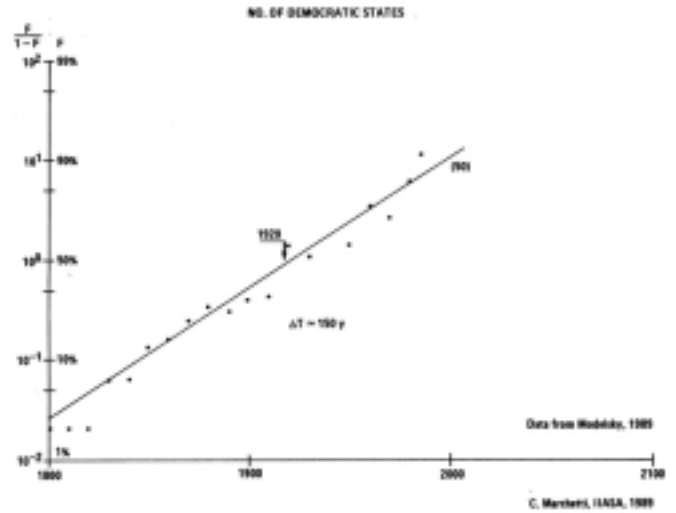
Primary energy substitution

(c). The actual data outside the data base are added to check the quality of forecasting and backcasting (d). It is clear from this example that diffusion analysis can be powerful tool for forecasting even over long periods of time. Looking at the chart (a), one could have *forecast the energy market share of oil, 50 years after* the period covered by the data base, i.e., in 1970, *with a precision of a few percent*. Diffusion analysis done at the level of the object, e.g., the energy market, can deal with a newcomer (here natural gas) only after it has penetrated somehow (the poor quality of the forecast for gas is due to that). It cannot, however, forecast the incoming of new competitors. A more sophisticated approach, operating at higher hierarchical levels, permits that. A new source of energy could have been forecast for 1970 (nuclear) and another around 2025 (fusion?). With a little patience we will check the 2025 date.



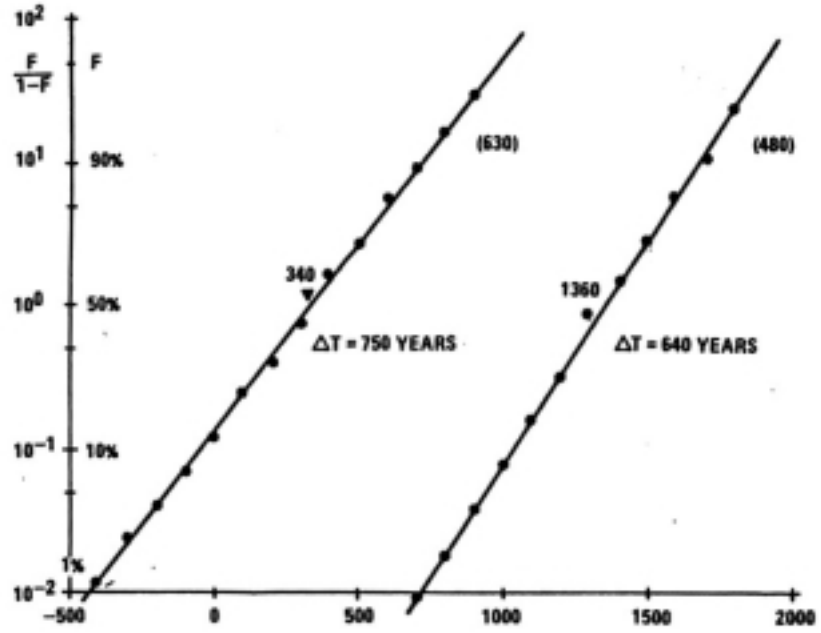
Postage stamps diffusion

The postage stamp was an important simplification in the process of extracting dues for the postal service. However, dismantling the previous very detailed system, with the inevitable context of implanted interests may not have been a very easy task. Different states adopted it in due time, but with a lot of ponderation. As usual, the practice diffused according to a logistic pattern, as reported here. The regions taken in consideration by Pemberton are Europe and South America. The centerpoint is 1856 and the time constant is 26 years. This time constant suggests a process linked to Kondratiev cycles (26 x 2 = 52). In fact, there is a cycle 1830–1885, whose centerpoint is in 1857. Societal behavior runs with a very good clockwork.



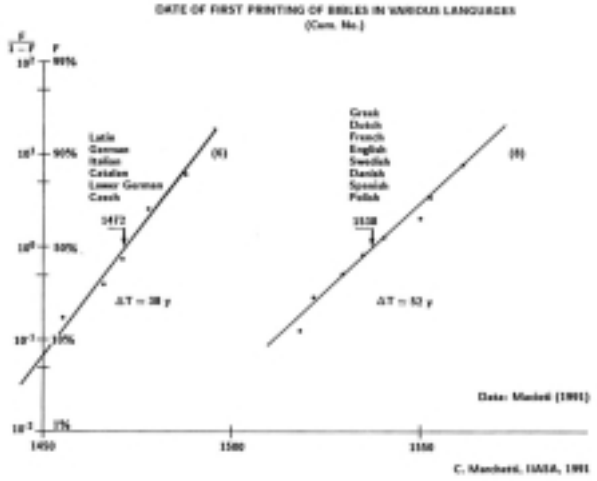
Democratic states: The diffusion of a political idea

Democracy is a state of mind and a way to implicate the body in the formation of the head. Democracy has come and gone in history, but it seems that during the last two centuries the idea did take again. Meaning that more and more states became addicted to democracy driven perhaps by the archetype winning capacity of Britain and the United States. Like for the case of adoption of postage stamps, democracy follows a diffusion process, albeit much slower. The time constant of 150 years means almost three centuries for the whole of the process to take place. We are now at around 90% of the 50 states that will become democratic according to my extrapolations and to the definition of democracy by Modelsky whose data I used. The centerpoint, when the democratization process was fastest, is in 1920. Perhaps WWI was connected to this process of switching over. Democracies had to win before democratic ideas came to be accepted.



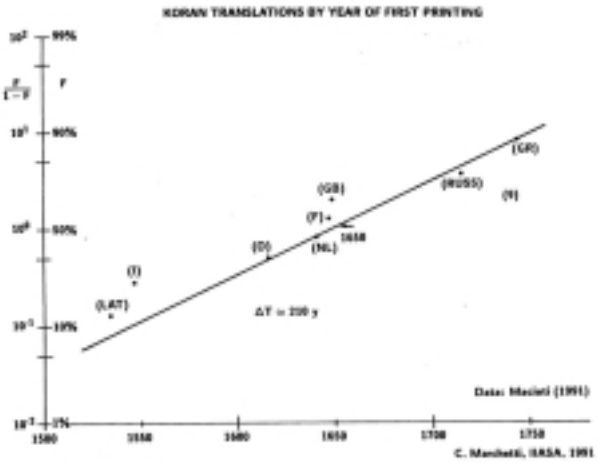
Religions: The case of the Catholic Church

Religions are a good substrate for political *evenements*. Islam, for the third time in its history, is knocking at the doors of Europe. The penetration through the Iberian bridges was stopped at Poitier in 732. The penetration through the balcanic bridge was stopped in 1683 at Vienna. It is not improbable that Italy may become the third bridge, perhaps through infiltration and takeover. After all, Moslem populations on the south of the Mediterranean will become more numerous than the European ones, up to Scandinavia, in only 10 to 20 years. If Darwin is right, the process of overtaking our system is inevitable. In this scenario a look at the Catholic church and its evolution in the millennia may be instructive, as the church has been in both cases behind European reactions. I took as an indicator of churches' vitality, the number of saints produced per century (taking death). The numbers can be plotted neatly into two logistics, showing the epidemic characteristics in the diffusion of a religion, both in terms of territory and of internal strength. The centerpoint of the growth is when the accretion rate is maximum. Maximum strength comes a little later, say +50% of the time constant (it corresponds to 90% of the final value). Now if we add 350+750:2=725, and 1350+640:2=1670, we find almost exactly the dates of the great strike-backs of Christianity against the Moslem, 732 and 1683, respectively. The sad point is that there is no third pulse in the growth of the Catholic church, because the rules of these pulsed systems require the beginning of a new pulse before the end of the previous one (in our case the third pulse should have started in 1600÷1700). Incidentally, the second pulse is practically at its end. A look at the increasing mean age and reduction in number of the Catholic clergy shows a tragic situation. A typical demographic implosion. The points in the first pulse, before year 0 are obviously constructed using the internal selfconsistency of diffusive processes. The fact that the curve goes back about 400 years before Christ may point to the “Servant of Jahve" as the sect where the Christian gospel was nurtured.



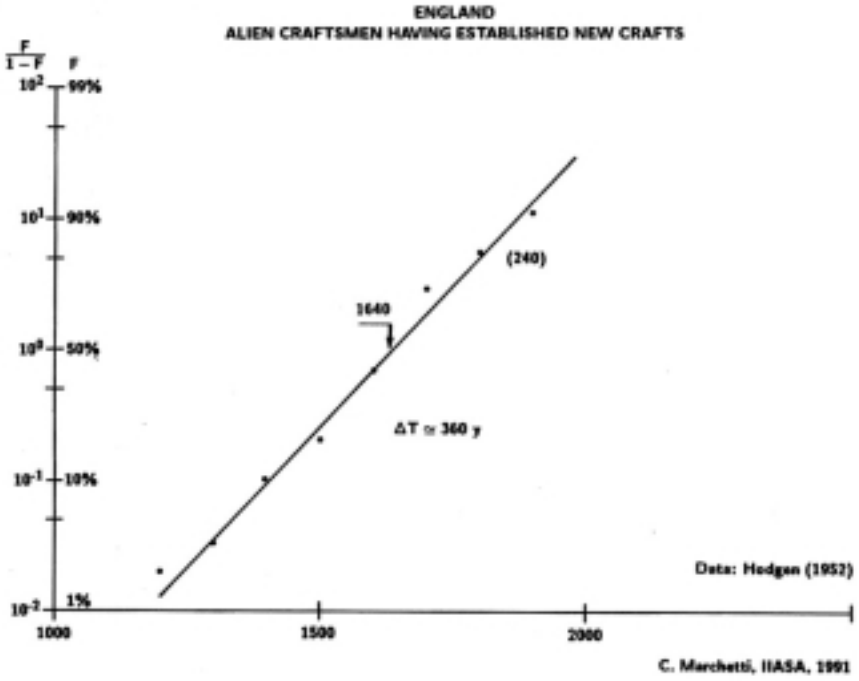
First printing of Bibles

The European version of the printing press as developed by Gutenberg, and the declining prices of rags, when the spinning wheel made it easy to produce the thread for linen, leading to cheap paper, made books a popular way to diffuse knowledge since the 16th century. The Bibles were a hot selling product and, to adapt to the popular reader, they had to be translated from the educated Latin into lay languages. Our analysis shows how the process occurred in time by monitoring when the first Bible in a given language appeared. The process curiously occurs in two waves, the first one probably radiating from the Gutenberg core in the nations sitting nearby. A second wave for “fringe" nations followed. The centers of the two pulses have a distance in time of about 66 years, which shows how bad it is to sit in the periphery. Otherwise the two pulses are well shaped in terms of “epidemic" diffusion, showing again the grip of the model even on shadowy processes like this one.



Coran translations

As the moslemic world is breathing again on the neck of Christianity, it may be interesting to see when the Coran was printed first in the various languages of the infidels. Latin came first, reasonably, as the Coran was foremost a curiosity for intellectuals, but very very slowly, in the course of three centuries, the “vulgata" in the principal European languages finally appeared. The process, however, was very slow, taking about 200 years to cover 9 languages. The maximum rate of translation–printing was around 1650. A curious notation is that Corans in arabic were first printed in Venice, which in the renaissance became a world center for printing these books, sending shiploads of them to the Orient.

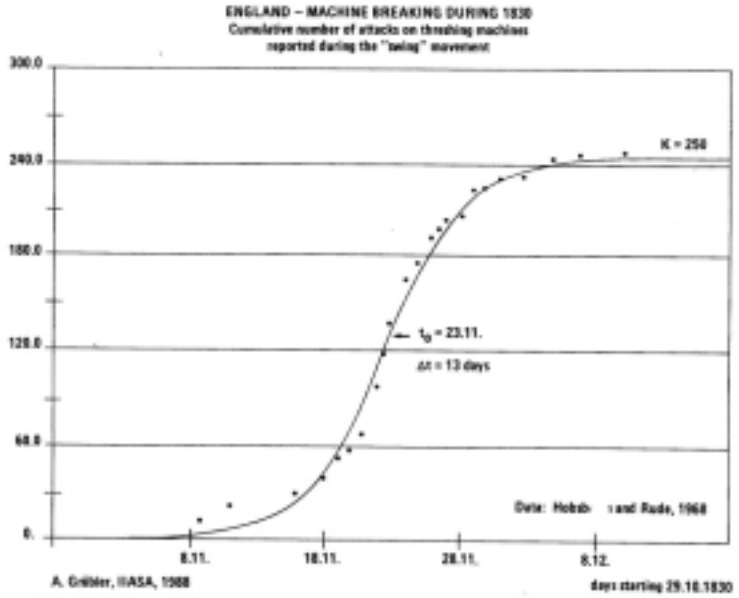


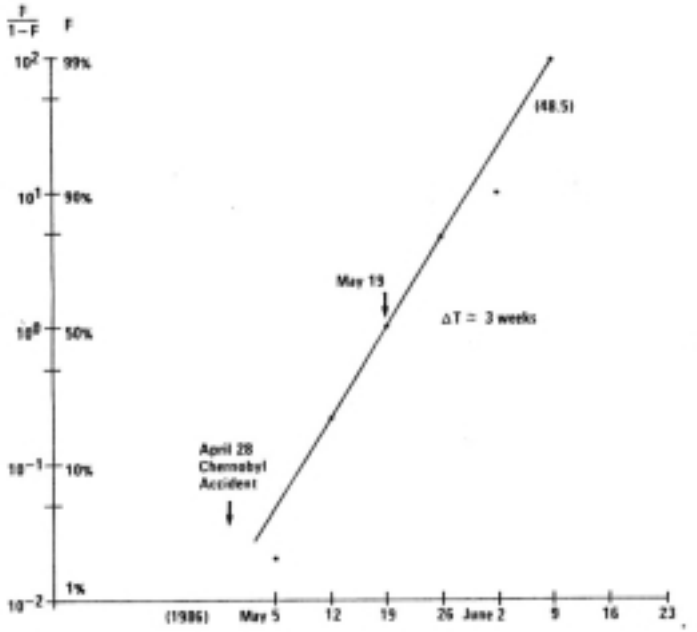
England: Immigration of artisans in the 17th century

Displacement of technically learned persons, due to economic, religious, or political changes have always been a strong mechanism for the diffusion of crafts and the economic flourishing of regions. The historian may well read time tables of facts, e.g., of emigrated craftsmen having opened up a fresh activity, but lacks the tools to describe the process in a mathematical expression, synthetic and quantitative, that can help making comparison and *hierarchical integrations*.

Here the system of importing know-how is analyzed for England. It shows an extraordinary selfconsistency over a time span of about four centuries. At least this self-consistency would certainly have escaped visual perusal of the tables.

The process reached its peak rate around 1640. Finally, 240.000 shops were opened by aliens if we sum up all the starts. (Not subtracting the closures.) The analysis has to be intended as a modeling of entrepreneurship.



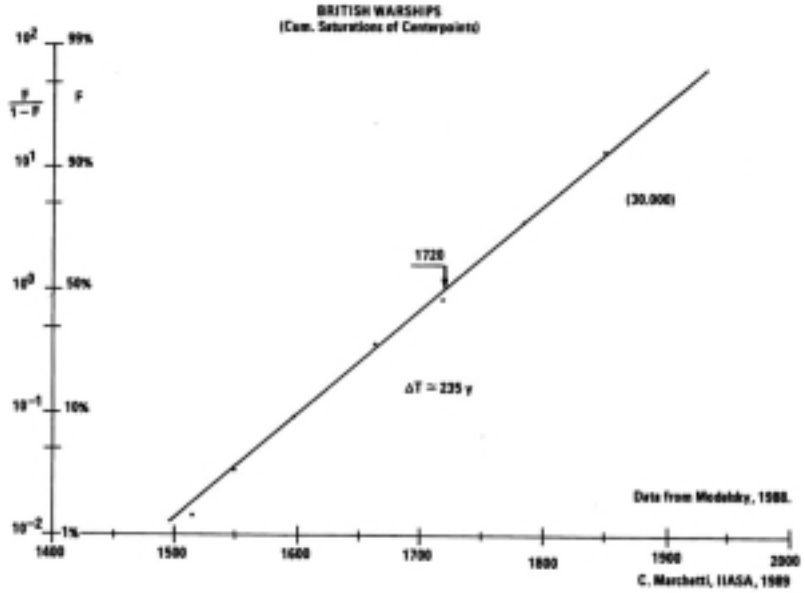


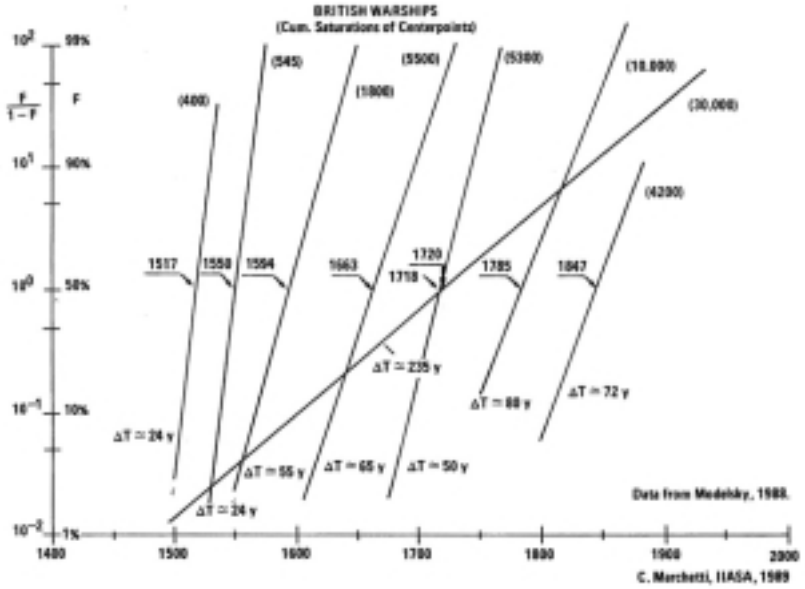
. . The Chernobyl Attention Pulse in US Periodical Literature. Cumulative Number of Articles.
DATA SOURCE: *Reader's Guide to Periodical Literature* (1986).

England: Thresher's breaking

This is a Luddite flare of farm hands rebelling against the threshing machine that menaced their winter petty income. The example is reported to show that the same pattern holds for phenomena lasting thousands of years as for others lasting a couple of weeks like this one.

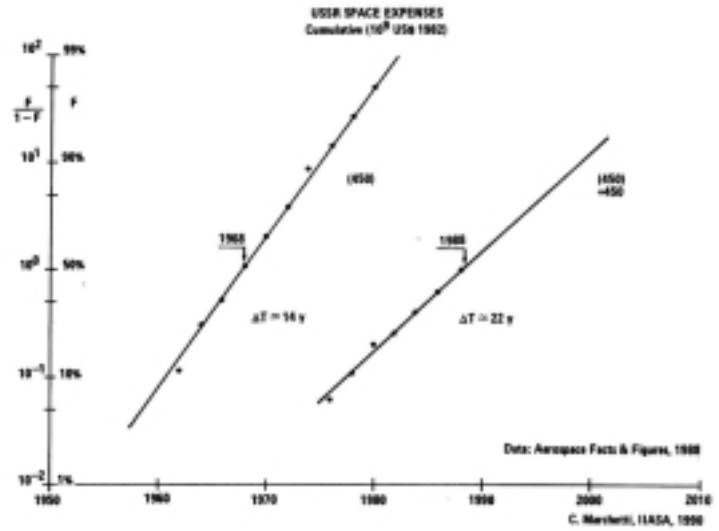
A fast phenomenon that may be interesting for investigators of political matters is for how long can people “hold" attention on an important and shocking issue like, e.g., the Chernobyl accident. The answer is: for a couple of weeks. I did the analysis by counting, day by day, the articles appearing in newspapers and periodicals in Europe and the United States.

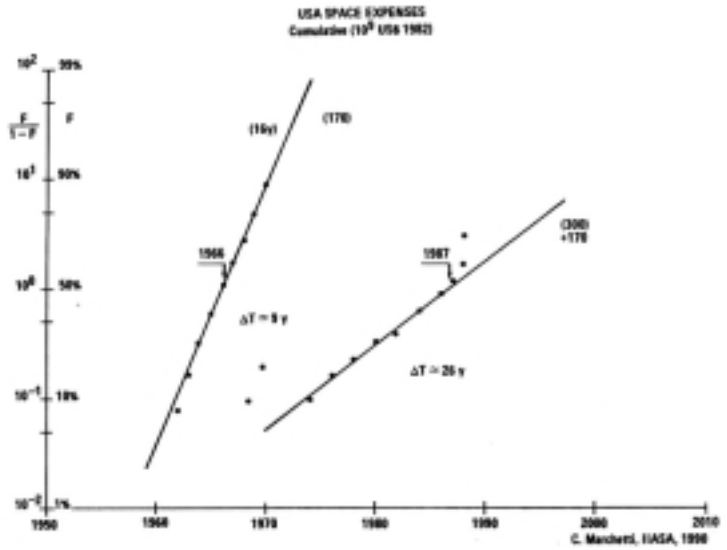




British sea force

For the ones who enjoy a deep breath into history, this is the chart to ponder. Modelsky painfully collected the data on the force of the British Navy, in terms of ships operational, since 1470. I thought the expenses to maintain this navy, measured in warship-years, and *cumulated*, could give a measure of the aggressive *elan* of Britain. Actually, after much labor, I could splice this sum into a set of logistics, seven of them, pretty well delineated, and with centerpoints that Modelsky himself has found historically very significant. So the big naval battles are embedded into long-range processes starting much before, and fading out after them. The mean length of these action pulses is about 55 years, strongly reminiscent of our Kondratiev cycles. To take the breathtaking look at the secular evolution of British sea power (400 years!) I used the trick of concentrating on the centerpoint of a pulse the total intensity of the pulse (integrated warship-years). Using the dates and the values so obtained I constructed a superlogistic, centered in 1720 and *ending* around 1950. The end in 1950 could have been predicted with fair precision one hundred years before.

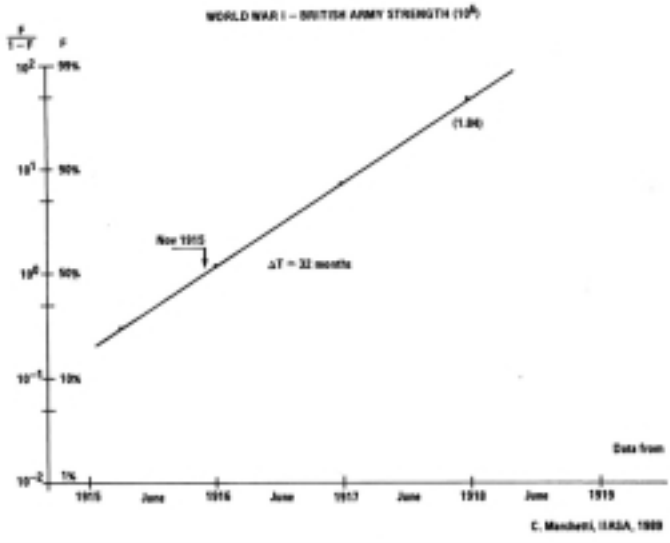




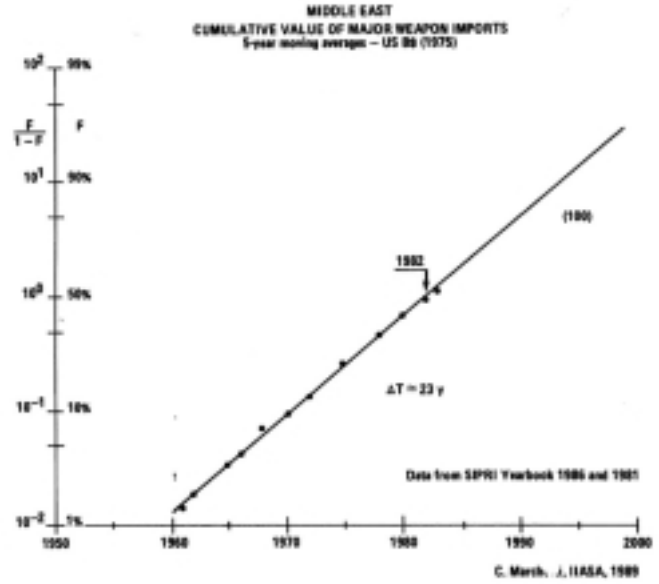
USSR and USA space expenses

During the various phases of the postwar grit and of the cold war, space expenses were considered as a sensitive indicator of the actual moods and intentions of the antagonists. My personal impression, which I basically got from the press, was that one considered the decisions about space expenses as something that had to be pondered *year by year* in order to match, to menace, to impress the counterpart. If this is true, then it may come as a surprise that for both the USSR and the USA these programs developed according to a rigorous, *long-term*, internal logic. It might mean that real decisions were taken by the subliminals of both systems, at least in this respect operating according to the same rules. For the USA the first wave of expenses was centered in 1966 and a flash of activity with only 7 years of time constant. For the USSR the centerpoint was in 1968, very near if slightly later than in the USA, and a more leisury time constant of 14 years. The total expenses were much larger, by a factor of three although the purchasing power of the ruble was difficult to assess. The second wave comes in the USA, centered in 1987, time constant of 26 years, and for the USSR in 1988, with a time constant of 22 years. So the second pulses were much similar in shape, but the Russians spent again about 50% more.

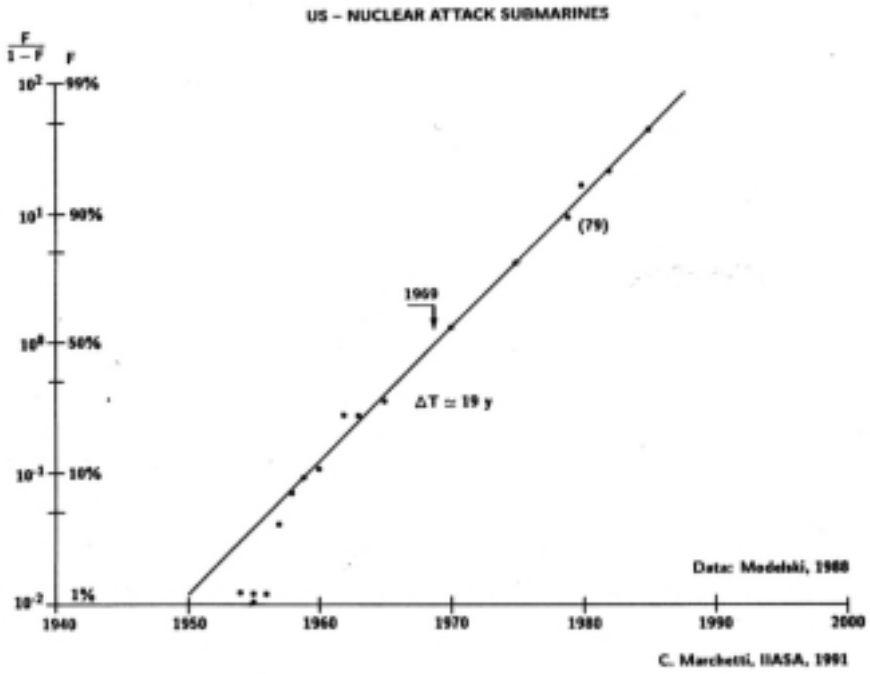
The two pulses may be justified or explained on various grounds. I obtained them in a very formal way, by discovering that the data for both, the USA and the USSR, could be fitted by the sum of two simple logistics. This “splicing" can be done in only one way.



British army strength
British army strength, measured in terms of number of men, kept increasing during all of WWI. A growing army, like a growing tree, required a lot of organizing activity, internal, to provide the drill, and external to provide equipment and infrastructure. These selfbuilding organizations tend to grow logistically, like trees. Actually the logistic equation fits perfectly the growth of the British army during the whole war period, and could obviously be used for forecasting its size at any time during the war (by German intelligence?).

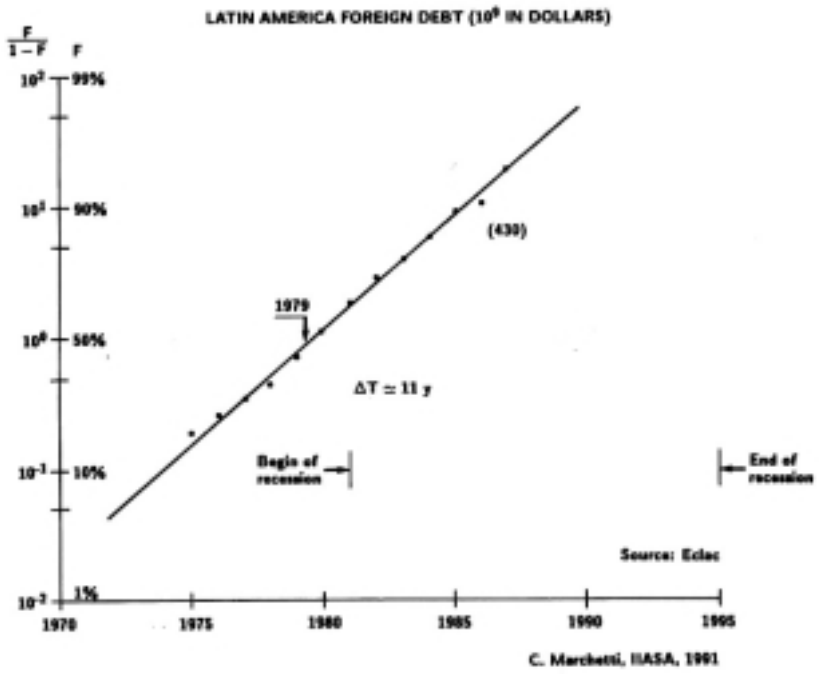


Weapon imports
Weapon buying and selling is an obvious indicator of instability and of dependence. Contrary to current opinion weapons are not bought on the whim of the moment, even if sometimes it looks so to journalistic observers. In fact, these purchases follow precise long-term trends, coming presumably much more from the way the system works than from rationalized planning. Twenty years of Middle East weapon imports, measured in constant (1975) dollars, smoothed with 5 years moving averages to iron out the inevitable peaks when large orders are placed, show a very selfconsistent signal. The cumulative value moves logistically from a very low rate of acquisition in 1960, to a maximum around 1980 to come down up to the present. The fact that it dwindles down in tune with the Kondratiev cycle leaves the suspicion of a possible restart at the beginning of next century.



US nuclear attack submarines

In this chart the evolution of the actual number of US nuclear attack submarines is reported and fitted *post mortem*, i.e., after the end of the construction pulse. The exercise shows that the build-up of the striking force followed precisely the canons, like the build-up of the British army during WWI. This leads to a couple of comments: 1. The intelligence services who try to snatch each other bits of information to guess what may happen during the next six months, could more profitably extract such information from past statistics. Modern computer-weapon systems can now very precisely determine the position of the shooter and that of the target, just by briefly observing a projectile in flight. 2. Decisions taken during the explicitation of a project, e.g., the deployment of a nuclear submarine attack force, do not introduce any modification to the time course of this deployment. They are homeostatic in nature, even if the timing was not precisely incorporated in the planning. Incidentally 1969 was the year of the maximum rate of growth of US (and world) economy.

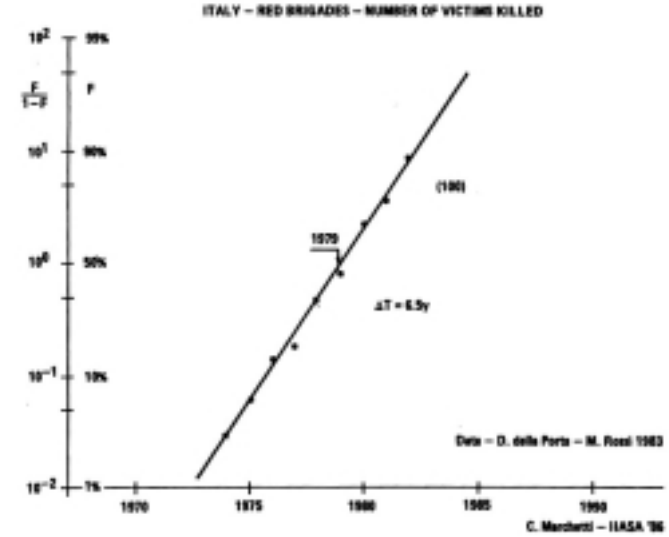


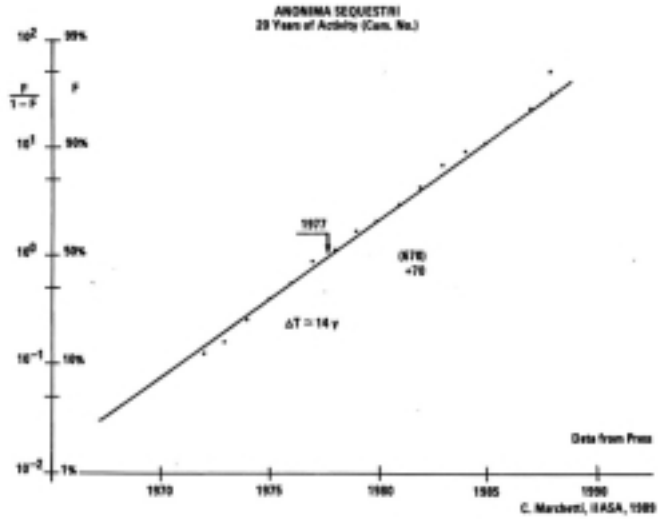
Foreign debt for Latin America

Foreign debt is a fairly important element in determining policies between lender states and receiver states, first. But also contributes in creating political attitudes from third parties. Foreign debt is usually well-known *a posteriori* because these transactions are usually done in the open. Obviously, it would be very interesting for the politician to have a forecast on how these debts will develop in the future.

We have observed that these debts have “diffusional" characteristics. Perhaps poor hands “diffuse" into well provided pockets. Anyway, one case is here reported on the evolution of foreign debt by Latin America, basically since WWII.

It appears that the lending spree is fairly short (11 years from 10% to 90% of the final level) and centered in 1979. The recessive phase of the Kondratiev cycle begins in 1969 (to end in 1996), but recession is harder in the second half of this period, 1982–1996. Incidentally, projecting the curve backward, we see that lending started around 1967 (1972–11x2) if at very low levels. 1967 is exactly the beginning of Kondratiev's recessive period. I have done various analyses of foreign debt seen from the lender or the receiver side, and they normally fit the equation, i.e., one can forecast (and backcast) them.



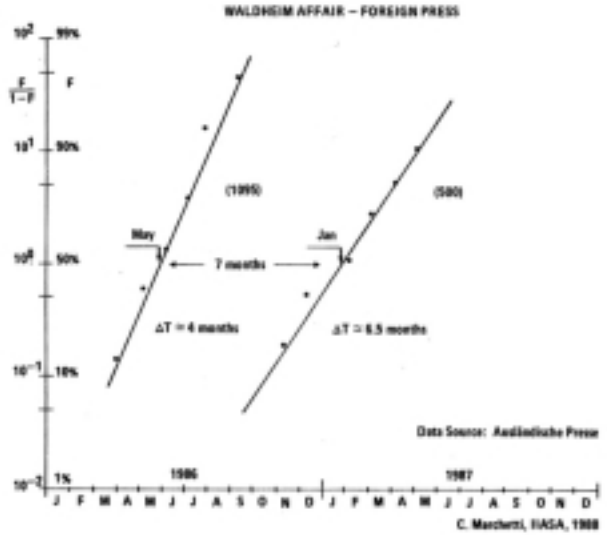


Red Brigades and Anonima Sequestri

Red Brigades were a purely political entity whose contours are still blurred. Anonima Sequestri can be seen as a criminal organization profiting of a political context. I do not want to bring them together here to show any kind of connection, except, maybe, that very generic one of political and social atmosphere, but to show that criminal organizations operate according to *fixed patterns*. Which means that they can be predicted, with great embarrassment for the carabinieri brass for which I did one of these analyses.

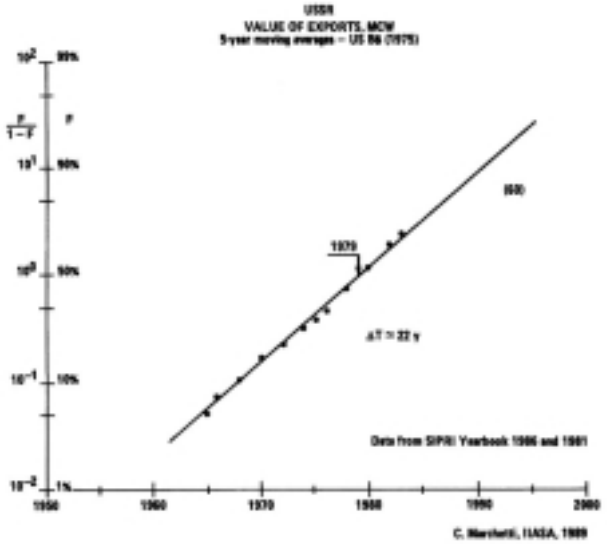
The Red Brigades with a time constant of 6.5 years were a flash in the pan. The point of maximum activity was in 1979, incidentally when Moro was kidnapped and killed. As the equation shows it was the year of their maximum activity.

The Anonima Sequestri is a little more leisury in the deployment of its professional bite. The logistic wave of kidnapping shown here is centered in 1977, has a time constant of 14 years (i.e., it spreads over almost 30 years). The number of kidnappings amounts to 670. The +70 shown in the chart belong to a previous wave.



Waldheim affair

The attack on Waldheim based on his Nazi past, at a precise point in his political career, was a quintessentially political operation. His past was well-known to his *grands electeurs*, when he was named UN secretary. In 1987, with the help of his porte-parole, I filtered and analyzed all press clippings referring to the case. Here is one of the results, concerning the coverage by the foreign press. It was clear that attacks first increased and then faded out. So the simplest way to survive was to resist. The chart shows how things moved in fine time details.



USSR major conventional weapons (MCW) exports

A detailed picture of the market is obtained by observing the behavior of buyers and sellers. Although they operate interactively, their behavior can be considered and described in isolation. Here the smoothed average of major weapon sales by USSR (then) are plotted cumulatively in constant 1975$ and fitted with a logistic equation. The period of maximum sales is around 1980. Although I suppose the Middle East was only one of the markets, however, it is interesting to note some parallelisms. The periods of maximum activity coincides for the two in the 1980s. And so the time spread, or the time constant ΔT, which is practically identical. Perhaps the political minds can detect the mechanisms operating behind. It must be clear that they are clockwork mechanisms, keeping a precise course for tens of years. Something not really taken into account in the *ad hoc* and *à peu près* vision of human facts that historians and politicians seem to prefer.