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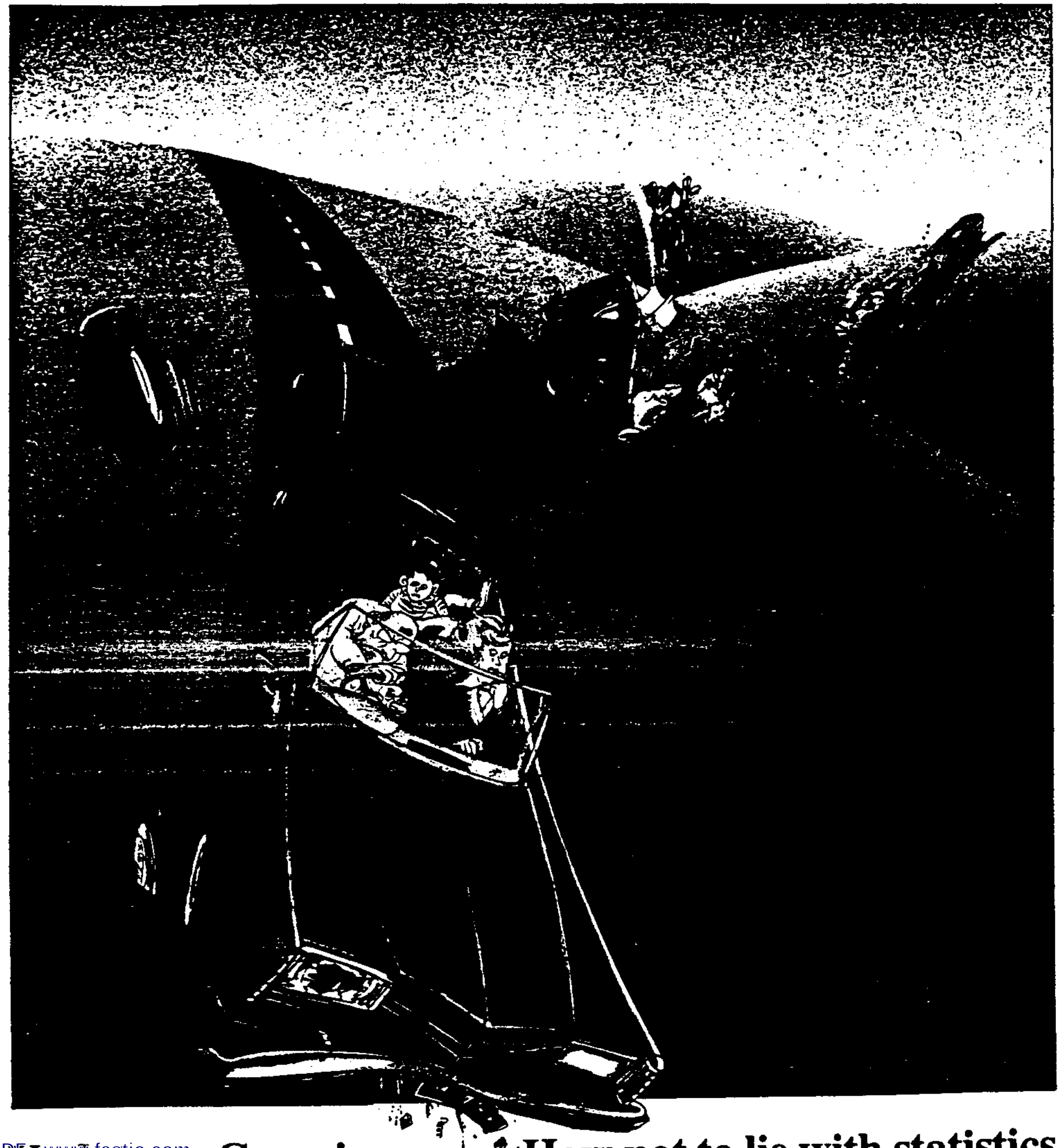
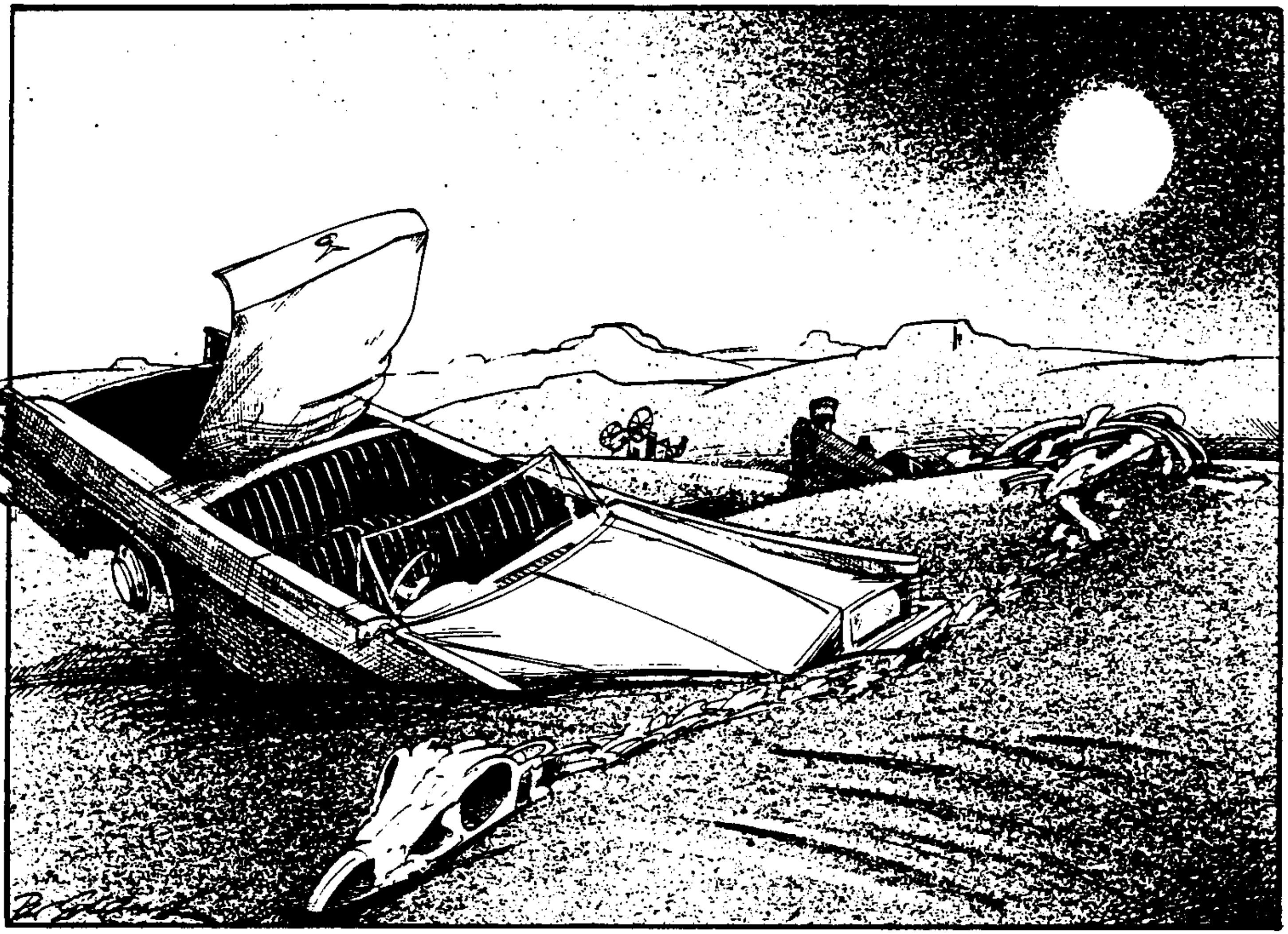
THE ECOLOGY OF ECONOMIC RECESSION



Update on Genesis

How not to lie with statistics



Swings, cycles and the global economy

Economists have so far failed to explain satisfactorily the continuing global recession. A mathematical model derived from ecology not only explains how we got into this state, it forecasts how long it will last

Cesare Marchetti

THE PRESENT world economic recession has lasted so long that not only optimistic forecasts about its duration have gone wrong, but also the pessimistic ones.

Even the priests of zero growth might begin having qualms that their prayers have been answered too well. But the international social and economic "system" is not really sensitive to prayers. As I will show, it is hard, determined and disciplined like a sergeant of the Queen. And that means that it is predictable. This statement condenses what I think is the most important result of a series of analyses, almost a thousand, that I have carried out on the dynamics of all sorts of social and economic structures in Western societies of the past couple of centuries.

The technique is formally very simple and of high pedigree. Competition, as Darwin explained, is the creative and regulatory agent of the living world. Vito Volterra (who lived from 1860 to 1940), Professor of Mathematics at the University of Pisa, and Alfred Lottke, Professor of Physics at Johns Hopkins University, developed a set of equations in the 1920s to describe the interactions of populations of predators and their prey. They not only gave Darwin's theory a formal dress, but showed that the dynamics of this competition can be extraordinarily well approximated by very rudimentary equations.

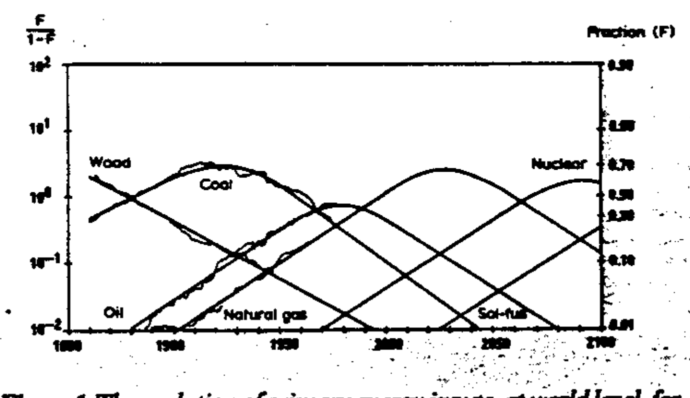


Figure 1 *The evolution of primary energy inputs, at world level, for the past 100 years. The inputs are given in calories, and expressed as fractions F of the total energy market. They appear in the figure as the wriggling lines. The smooth lines are a best fit with a system of logistics, a solution of the predator-prey equation. They are extrapolated to the future, in a predictive mode. "Sol-fus" leaves open the alternative solar or fusion power. The next 50 years seem to be dominated by natural gas*

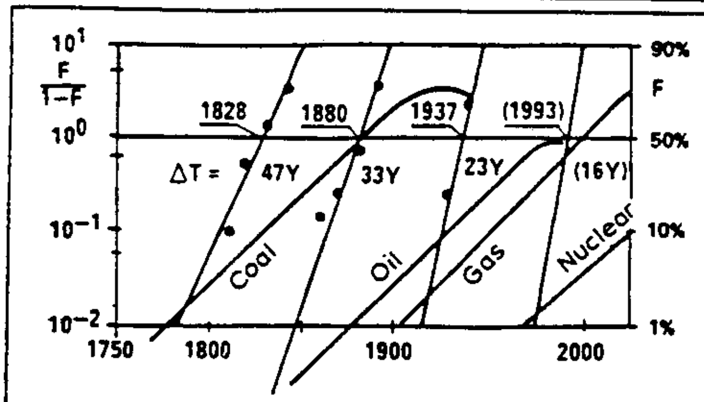


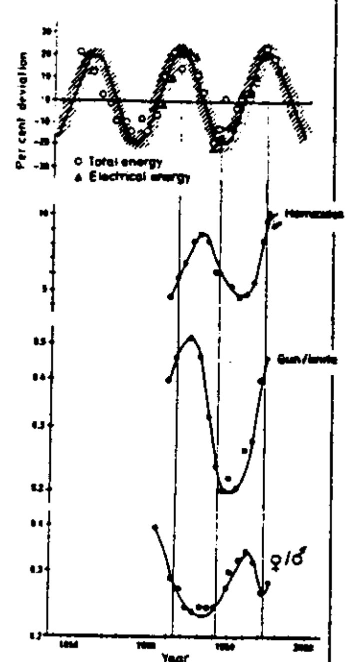
Figure 2 *The almost vertical lines represent the logistic fit of the cumulative number of innovations in three innovation waves as quantified by G. Mensch. They are expressed as a fraction (F) of the total number of innovations in the wave.*

This is equivalent to assuming that innovations are just "products" chasing for a market and filling it as it comes. The date when half the innovations in the bunch have entered the market is given.

The increasing steepness shows a "focusing" of the waves, the innovations being launched inside shorter and shorter periods of time. The last wave is calculated from the regularities of the first three

Figure 3 *The upper sinusoid, calculated by H. B. Stewart, represents the deviations of total energy and electricity consumption in the United States from a logistic best fit. They are taken as global indicators of the pulsation in socio-economic activity.*

The lower lines depict the evolution of the murder index (per population) and the ratios for mode and sex. The maximum of murders is at the centre of the period of recession, just passed at present, and the minimum at the centre of the boom. The weapons used are more in phase with the activity indicator. So when economy is going well, people shoot, when it is in the doldrums, they stab



in spite of the great complexity of the players and of the boundary conditions.

I am more of an engineer than a scientist and I was drawn into the game about ten years ago, when I was trying to solve the desperate problem of finding a single rationale to the long-term dynamics of the energy markets. I shunned the modelling techniques very popular at that time (so popular in fact that no major institution could escape them). I felt they were leading nowhere. They were, and are, complex and too arbitrary to catch the essence.

When stuck for an idea, I often try biology for paradigms. After all, biological systems spent three billion years tramping into all sorts of problems and finding solutions for them. Their library of solutions is immense. My hunch was that I could visualise primary sources of energy as species competing for a niche, the energy market. And so I attempted to analyse the changing pattern of energy use in those terms.

The result was striking. A set of logistic solutions of the Volterra-Lottke equations fits perfectly the evolution of that competition for more than a hundred years (Figure 1) at world level. And it is not the consequence of a one-in-a-billion chance. With the help of a Volkswagen Foundation grant, a team at the International Institute for Applied Systems Analysis (IIASA) near Vienna studied about three hundred energy subsystems: countries; industries; economic sectors; and we got results of consistently high quality. The rudimentary equations were obviously catching an essence.

I like this chart on energy competition for its Keplerian flavour. But I had problems digesting the messages it carries. It says in fact the "system" behaves *as if* it had a *program*, a *will* and a *clock*. A dogged will, if one reflects on all that happened during these hundred years. And a good clock too, if one looks at the straightness of the lines. It was hard to swallow, but it implied a potential for *hard modelling* human affairs, to a point where hard (as opposed to soft) forecasts might be made.

I have since added hundreds of cases taken from all sorts of human activities spread in space and time. I am now analysing the diffusion of the printing industry during the Renaissance. The mental image and its arithmetic seem to work in essence.

The development in this approach was in fact dedicated to ... raised by the initial successes. The

displace the old ones and finally replace them in the market. But each equation has two parameters which have to be calculated by fitting a string of data. There is no way of telling when a new primary source of energy will be introduced, and this is obviously a weakness if we want to use the model predictively.

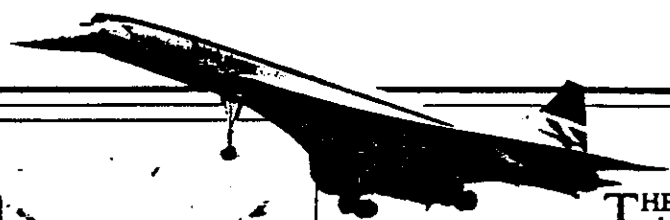
To solve this second problem I had to make a jump in abstraction. A new energy source can be seen as a *new technology* in the broad sense, enveloping a set of subtechnologies in search, transport, processing and use. In order to understand the rules that mesh the introduction of a new source of primary energy to general regularities in a predictable way, one has, therefore, to explore the world of innovations.

The result of this analysis is reported in Figure 2. What I did was to take the innovation "waves" detected by G. Mensch, then of the Berlin International Institute of Management, and put them into the logistic straitjacket. The total number of innovations in a wave is assumed as the size of the "niche" and the cumulative number of them at a certain date, is the "population" trying to fill it.

The chart shows a good match. It also shows that the start of each wave of innovation seems to coincide with that of a new primary energy source. Well, it might be coincidence. Take it or leave it. But the internal regularities of the sequence of waves make the next one predictable, if this is more than a coincidence. I have used this predictability to construct the last line in the chart, without data points. If the prediction is correct, then nuclear energy started at the "right" point in time. It has also penetrated at the leisurely pace of its predecessors, which implies a market share of six to seven per cent for the year 2000. At world level.

The chart also shows another interesting feature. The beast pulsates! It has a period of 55 years, if we take the central points of the waves. This pulsation turns up in all sorts of data and I give a glimpse of the range in Figures 3 and 4. It brings us one step nearer to solving our problem of the long recession and its evolution.

The upper part of Figure 3 was prepared by H. B. Stewart, of Nutevco, a computing firm in San Diego, California. It represents the deviations of primary and electric energy consumption in the US from the secular trend, best fitted with a logistic. Because energy is a pervasive input in social and economic activity, it is a good proxy to measure. Because



P. Davey/Bruce Coleman

Natural cycles

THE predator-prey relationship is described by the Volterra-Lottke equations. When both are scarce, the population of the prey species can increase rapidly by reproduction. The predator population then also increases, until there are so many predators that the prey population declines. This in turn causes the population of predators to fall, and with both populations low in numbers the cycle starts again.

The classic example in biology is the pattern of lynx and hare populations in northern forests. Populations of both species fluctuate with a cycle of roughly ten years, and the predator (lynx) population curve follows behind the prey (hare) curve. The relation between prey population and predator population is well established in this case.

But although mathematical analyses suggest regular oscillations, these are found only rarely in nature, because of other factors. The equations work even better for economics. JG

and there, that society as a whole is subject to a cyclical process with that period. The reason for choosing murders is that they dig deep into social moods. Still moodier is the ratio of guns to knives reported on the third line. And they are not ripples; the modulation is by a factor of two or three.

Figure 4, on the other hand, tells the happier story of the recursive enthusiasms in building transport infrastructures in the US. After the canal mania at the end of the 18th century, came the rail mania, and then paved roads and finally the airplane. The chart depicts the development of these infrastructures in terms of actual length, using three parameter logistics for the fit. The third parameter is the "perceived" maximum length, used to normalise the plot to the previous two parameter logistics.

Although the data are not always first class, and the processes complex and dispersed, the general picture comes out fairly crisply. The construction waves have consistently a time constant (10 per cent to 90 per cent) of about 50 years, and a spacing in time of the same order. So we have detected another artery showing the same pulse. But why recessions? To answer that, I have to take still another step.

Saturating the car's niche

The innovations reported in Figure 2 actually show the dates of first commercialisation. They are the "buds" of the industries that expand and flourish later on. To look at this part of the process, I studied the penetration of the car in the world market. The reason for this choice was the availability of very good statistical time series in a single place, and the supposition that one product is as good as another at this level of analysis.

This study shows an extreme regularity in the way *populations* of cars fill their geographical niches. Like bacteria or rabbits, these populations grow with perfect logistics to a saturation point which we can calculate fairly precisely many years before it is reached. Furthermore, latecomers like Japan grow faster, so that finally they all saturate more or less at the same time: the decade around 1980. It must be clear that the oil shock of 1973-74 has nothing to do with it, as *the rates were already established in the 1960s*. This is shown in Figure 5. A further consequence is that this saturation of the market cannot be due to the recession.

At this point, the problems of the car industry become suddenly clear. If the car population saturates, the industry can provide replacements only, an intrinsically rigid market. Productivity has to increase because workers expect regular increases in pay, because of competition, and by tradition. Constant production with increasing productivity means shedding employees. The industry has consistently followed this pattern, throughout the world. A modest 2-per-cent increase in productivity means a reduction in the necessary

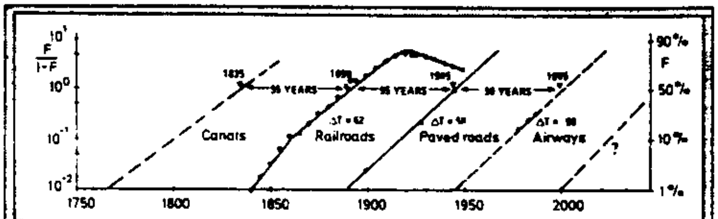


Figure 4 *Evolution of the length of transport infrastructures in the US fitted with three parameter logistic equations of the type log* $[L(t)/\bar{L}-L(t)] = at + b$ *where* L(t) *is the length of the infrastructure at time t. The asymptotic length is* $\bar{L}$, a *(spread in time of the construction of the infrastructure) and* b *(a time positioning cursor) are calculated by fitting the data.*
The spread in time is given as a ΔT, *or the time to go from 10 per cent to 90 per cent of* $\bar{L}$. L *is given under the title*

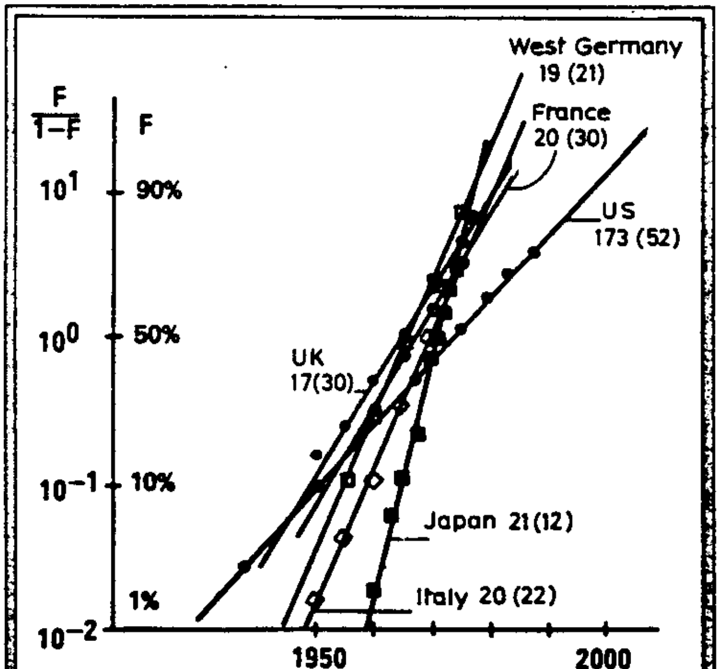


Figure 5 *Three parameter logistic fit of car populations (registered cars) for the major countries. The number in parenthesis indicates the time constant for the population to go from 10 per cent to 90 per cent of the saturation level as expressed by the number on the left*

If it were only the car industry that was in trouble, the increase in productivity means a reduction in the necessary

If it were only the car industry that was in trouble, the problems could easily be mopped up. But, alas, all the technological buds I have studied grow to saturation more or less at the same time. To come out from hardware, I have investigated another example. It is the tonne-km transported by the world's scheduled airlines. It is a service on the grand scale and it also will saturate during the next decade. The chart also shows that no dent was inflicted by the two oil shocks! The homeostasis of these large systems is truly remarkable.

At this point, a consistent interpretation of the present period of recession emerges. Innovations are born in bunches. They grow to fill their niches worldwide, with time constants in the same range. So they saturate in bunches, generating progressive reduction in employment and basically a zero growth in national product. The restart comes through a fresh bunch of innovations. This is certainly what happened in the past, as shown in Figure 2. If the next wave calculated there performs as expected, we are now in the innovative upswing—but this does not mean the economic upswing: all these activities are born small, and have to grow substantially to reabsorb unemployment and restart growth in real GNP. If we take our energy clock for reference (Figure 3), recession may well last roughly another decade.

Prospects for employment

At this point, I cannot escape the duty of offering some practical advice, even if I know I am putting my hand in a wasps' nest. If forced to choose, one should better reduce the oxygen to grandfather in order to procure the vitamins for the baby. Dismantling spent institutions (as long as we have the appropriate social safety nets) is not only cheaper than keeping them, but it liberates a human potential that will express itself into a flurry of new initiatives.

The classical cure for unemployment is public works. It was largely used even before Keynes wrapped it into a fashionable theory. But what kind of public works? The logistic analysis shows that motorways, for example, have reached the intrinsic saturation level. In other words, the system has got enough of them. But underground railways are in great demand. Perhaps instead of digging tunnels to produce unwanted coal, miners should dig them to host badly needed urban transportation systems. A logistic analysis of coal production from 1700 to present, which I did for Britain, shows that coal mining *should* disappear there before the end of this century.

At the individual level, people are beginning to realise, once again, that "jobs" are not stainless steel pigeon holes, but social configurations, with intrinsic lifetimes. So they come and go and must be continuously reinvented. This invention mostly occurs at the individual level, and every measure that helps individual experimenting may help the process. Typically, part-time employment or the mobility that may come from wiser housing laws provide the scope for new variations to emerge. Natural selection does the rest.

The message I am trying to convey with the help of short peeps into my background material, is that "the system" has a well-defined grain and it is better not to go against it. All the cases I studied, being *a posteriori*, are the expression of a success. The fact that they fit precise equations means the way to success is a narrow one. Optimisation, it is well known, freezes degrees of freedom. The real freedom seems to be that of making mistakes, but it should be used with temperance. The technique I have shown may strongly help to abort the unwanted ones. □

Dr Cesare Marchetti works in the Energy Group at the International Institute for Applied Systems Analysis, at Laxenburg in Austria. His background is in physics, which he studied at the University of Pisa, and he worked during the 1950s on the technology of heavy water separation. He spent two years as the representative of EURATOM in Canada (1959-61), and worked during the 1960s on problems of nuclear reactor design and nuclear waste disposal. Marchetti joined IIA[illegible]tigate energy systems and geoengineering.