THE CAR IN A SYSTEM CONTEXT. THE LAST 80 YEARS, AND THE NEXT 20.

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FOREWORD

This work of Dr. Marchetti was performed within the scope of the Innovation Management Task in order to test the relevance of market penetration studies developed at IIASA prior to this task. The idea was to chose the so-called "declining" sector and the final choice fell on car industry because of the relatively good data available.

The result of this attempt is a set of interesting facts, some of which can be fully explained, others leave some doubt, and some cannot be easily explained at all. Most of them are interesting enough, contrary to traditional views expressed elsewhere. This method, even if it does not always give clear ideas about the cause and effect relations of the studied object, detects properties of homeostatic character. To find the process causing all this seems to be a reasonable topic for further research.

In relation to innovation management this work is another prove that it is very difficult to make generalizations concerning innovation.

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ABSTRACT

The car is examined as a world system, concentrating on numbers and behavior and abstracting from most of technical details. Three parameter logistics appear to fit well the penetration of cars in various areas, and show a remarkable relationship between time of introduction and rate of penetration.

Innovation and publicity do not show as tools for aggressive behavior, but more as homeostatic channels. Also safety appears under societal control.

The position of Japan in the game is sketched, with medium term forecasts.

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INTRODUCTION

This study was originally started in order to try to evaluate the effect of innovation and promotion efforts on the acceptance and market dynamics of cars. It somehow expanded around the original task, and came to show some unexpected and anti-intuitive aspects of the car system. In particular a very high level of determinisms, most probably due to strong and efficient social feedback loops. I will usually refer to them when speaking of homeostasis, a term borrowed from physiology.

Much of my analysis in fact is borrowed from biological thinking and methodology, as I am fairly convinced that the equations Volterra developed for ecological systems are very good descriptors of human affairs.

In a nutshell, I supposed that the social system can be decomposed into structures that compete in a Darwinian way, their flow and ebb being described by the Volterra equations.

FILLING THE NICHE

I examined the evolution of the car population, i.e. the number of cars on the road, in nine different countries. Because the population of a new species fills its eco-niche following a logistic trajectory, I tried to fit the evolution in time of the car stock in the nine countries using three parameter logistic equations. Of these parameters, one localizes the process in time, the second gives the rate of the process, and the third the saturation point, or the capacity of the niche. The result is given in Figs. 1 to 9.

As can be seen, the fitting to a logistic curve is perfect, so that the third parameter--the saturation point, or in biological terminology, the perceived size of the niche which would correspond to the total volume of the market--can be calculated with fair precision. The values for each nation are reported in parenthesis for each of the figures, together with the time constants and central point dates which serve to characterize the logistic.

It is well known that fitting three parameter logistics is a slightly fishy process because the trajectory of the function is fairly insensitive to the position of the maximum, at least up to the flex. Consequently the slight differences in twist are easily masked by the noise in the data.

Contrary to expectation, the data are exceptionally free from noise, as one can verify by inspecting Fig. 10, reporting car population for Italy in linear scale. Furthermore, I interpolated by eye on the transforms, where logistics appear as straight lines and where the eye is more sophisticated in my opinion than most computer programs. The most important point, however, is the fact that--as shown in Fig. 13--there is a further internal link between the various logistics, which eliminates large errors through a check of internal consistency.

That said, most of the conclusions I will draw are not finely sensitive to the level of saturation, so that bickering about one million cars more or less in that level makes really no sense. One thing I cannot answer, however, is if, in analogy with the biological case, a subtle and progressive matching to the econiche does not progressively enlarge its size. In other words if the saturation level has a secular drift.

SHUNNING THE MEDIA

The first comment on Figs. 1 to 9 could be that the effect of launching new models, introducing new tricks, and slashing prices, is of no consequence on the determination of owning a car, which seems to follow a perfect path, controlled perhaps by use values of the car which are little influenced by new shape or new bumpers.

The fact that whatever one does things go their way, is hard to swallow. But there is a path out of the stalemate, if we think that there is a pool of good ideas in manufacturing, product design and advertising which lie around and are picked up and used when there is the menace of falling behind the perceived path. This is more or less what happens in biological systems where mutants are usually kept in a recessive state till the change in environment draws them into the limelight.

In this rationalization, innovation and brain softening through the media, usually seen as basically aggressive operations, acquire the much softer connotation of purely defensive acts which may also change the rationalization for selling them to the management.

In other words, innovation and promotion are basically seen as homeostatic processes, in the same sense as sweating and shivering which protect our body temperature from changes in the boundary conditions. The fact that this temperature keeps its set point does not certainly mean sweating and shivering are unimportant.

A typical reaction, when I presented these results, was that if car ownership is a pre-set goal, companies certainly compete to get larger shares of this market, using inter alia innovation and promotion as aggressive weapons. To see the dynamics of this struggle, I plotted market shares for the dominant companies in the US and Japan. As Figs. 11 and 12 show, these shares keep fluctuating but remain basically constant in the long run. As the Red Queen said to Alice: "Now here you see, it takes all the running you can do to keep in the same place." Actually there is some life at the lower levels and smaller companies come and go. Much of the penetration of Japanese cars in the US, e.g., can be seen as a replacement of market losses by Chrysler, American Motor, and other smaller companies.

LAST COME, FIRST SERVED

Figures 1 to 10 have been ordered according to the time when car penetration reached 1% of the final saturation level. It is clear that the penetration rate, expressed by the time constant ΔT, i.e. the time to go from 1% to 50% penetration, keeps decreasing. Dr. Ed Schmidt suggested plotting ΔT vs the 1% penetration rate, and obtained Fig. 13. Not only does ΔT keep decreasing, but it did so in a very regular way.

I have no hint to explain the decrease nor the regularity. It seems, howeever, that the process should stop. If not, absurdly short penetration time will be reached in the next future. Japan has already the extraordinarily short ΔT of 12 years, and I cannot really imagine what the 2 years ΔT in the year 2000 could really mean. Can a country, poof, be motorized to saturation in four years? Improbable. Perhaps, like in the case of inventions and innovations [1] the function is a see-saw. But having no theory I cannot really say.

A further comment on Figs.1-2: Contrary to current intuition, the US and Canada appear far away from saturation, and more or less in a similar position in the penetration curve. Formally, this is happening because being early adopters of the car, the time constant is so long, but as said before, it is not clear why it should be so. Zahavi [2] has made a highly convincing "mechanical statistics" style theory linking time, money and road network to produce car usage, but I have not been able to distill from it a simple concept clarifying such behavior.

The other developed nations studied so far,on the contrary appear to be very near to saturation point; the car industry is then at the mercy of more whimsical replacement markets. Eat your neighbor practices will be then the only mechanism to keep a healthy growth. This is straight war and here innovation may play a major role in determining the victor. Although competition analysis shows that normally the youngest, <u>if</u> already successful, will be the winner (for a while). Success is sealed when a market has been penetrated by a few percent [3]. This is good news for the Japanese industry which may well finally win through a disinhibited use of innovation.

In old minds, in fact, decisional reflexes are linked to past successes and may not be efficient in strongly modified environments. Furthermore only in rapidly expanding industries the workforce has a vested interest in increasing productivity, as it favors high salaries and does not lead to a reduction of occupational levels.

The penetration of Japan in the international markets is shown in Fig. 14, and the phase-out of such historically aggressive exporters like Germany and Italy, in Fig. 15. These early exporters are also invaded by foreign cars themselves (with a measure of swapping), and a hint in that direction is given in Fig, 16 showing the progressive dilution of the car population in Italy with foreign makes. This is also a consequence of the progressive internationalization of the car market as shown in Fig. 25.

Unless new competitors, like e.g. Korea, pop up in the next few years, Japan appears to become the dominator of these international markets before the end of the century. It holds already about 50% of it.

Keeping the guidelines in mind, I also looked at competition between classes of cars. This is reported for Europe in Fig. 15. Contrary to much advertisement and newspaper theories, the market appears solid stiff, and the rush to smallish cars inexistent. In fact, the market shares for all classes of cars appear to stay constant (if with considerable noise) and the only movement is that of medium class cars eating out the market of very small cars.

THE ROBOTIZED BUYER

The central issue in the car industry is forecasting demand, for next year first, and the following five. A key element in that forecasting is the mortality rate. This rate is difficult to assess in a clean form becaue explicit statistics are generally lacking. The US have something usable, and I tried to plot vs. time the survivors of a certain cohort (year make) as shown in Fig. 17. It is a point experiment, but very encouraging. In fact, the survivor's numbers are neatly fitted again by a logistic. With a little peotry incorporated, one could say death competes with life, and finally wins. As for any other competition between "structures", progress should be described by a logistic.

Assuming that mortality rates are stable (apart from noise) or predictable from the incipient mortalities of new makes, then a logical procedure to forecast demand for new cars can be generated on a purely physical basis, i.e. without any knowledge of economics or consumer behavior.

The derivative of the car populations, as they are shown in Figs. 1 to 10, is defined as first wave. The definition can be considered as arbitrary, or perhaps linked to the concept of the first car. I will use it in a purely formal way. Applying the death function (derivative of the survivor's curve) to first wave cars one obtains the second wave, because the number of cars at saturation being constant any death produces a birth. The process is repeated to get a third wave and so on. The sum of the waves gives the demand. The results of this exercise are given in Figs. 18 and 19 for the case of Japan. It is obviously a zero approximation, but promising.

HOW SAFE IS SAFE?

Much interest and emotions are usually raised by the problem of car safety. After all, cars kill a good $2 \cdot 10^5$ people/year and maim presumably ten times as many. Many efforts are made to render cars safer in case of accident, and the driving more cautious. It may be interesting to look at the effects with a detached eye.

Speaking of risks, my opinion is that society feels them globally and tries to keep them under control. Consequently, instead of looking at accidents per mile or per car, I looked at accidents per unit of population. The very interesting result, reported for the US first, because time series are good and available down to about 1900, is shown in Fig. 20. Deaths are taken as an indicator, as they are best interpreted and recorded.

What we observe is that deaths grow with the car population, but to a saturation point of about 25 per 10^5 people/year. From then on they become independent from the number of cars. It seems obvious to me that a social homeostatic mechanism enters into action when this "set point" of 25 is reached. Why it should be 25 and not 35 is not clear to me, so I looked to other nations to see whether a similar set point exists and is culturally linked.

The case of 10 nations is reported in Fig. 21 where deaths are reported for the year 1975 (with some corrections to take into account for different methods of recording deaths after the accident). For seven cases the set point appears to be about 25, which is extraordinary if we think of all differences, physical and cultural. Three cases, however, have set points almost half of that, and the analysis of the whys may yield interesting results. Are left hand drivers less risk prone?

CARS FOR MOVING

Another curious observation (Fig. 20) is that, at least for the US, mileage per car is basically independent from the number of cars on the road and is about 15.000 km/year. This stability suggests homeostatic linkages between personal traveling time budgets, road network and disposable income, as studied in depth by Zahavi [2]. Gas consumption should not then be too difficult to forecast.

Concerning road network, Fig. 23 reports the deployment of paved roads in the US, curiously preceding, at least in relative terms, the boom of the cars. In a chicken and egg logic one could argue that the stimulus to the introduction of the car came from the development of paved roads, a slightly queer suggestion which Zahavi could support with his UMOT model [2].

Car is one of the possible means of transportation and if we look at the transportation market the various modes should darwinially compete between them. I already did this analysis in relation to a study on air transportation [4] and the result for the US is reported in Fig. 24. For homogeneity reasons the market was separated in intracity, intercity, and commuting. The graph refers to intercity traveling. As supposed the three modes under consideration, train, car and plane, fit Volterra equations for ecological competition, with car reaching maximum penetration in 1958. Curiously enough at that date cars did masquerade as airplanes with Mach .8 aerodynamics, ailerons, tails, and "cockpit" instrument panels. The competitor is the devil--in this case the airplane--and as peasants still do in the Austrian Alps, to scare the devil one has to dress like the devil.

SOME FINAL THOUGHTS

This search was exploratory and many leads we found are still left unexploited. In particular, the fact that this form of analysis is not linked to a particular type of commodity, but has a general character.

Even at this point a certain number of conclusions can be drawn:

- The deployment of car population in a certain area appears to be dominated by an internal dynamics that does not appear to be determined by decisions taken inside the industry, and vehiculated through innovation and marketing.
- Innovation and publicity do not seem even able to change the relative market positions of large manufacturers. One may perhaps interpret them as manifestations of vitality to insure territorial respect, in the sense of posturing by territorial animals.
- Concerning the future, the top down analysis I used gives an extremely simple, if simplified, picture of the state of the system and its evolutionary lines. Car industry appears to become more and more internationally oriented (Fig. 25) and Japan appears to dominate that market (Fig. 14).
- Car safety appears to be controlled by societal set points and feedbacks. Trying to increase it on purely technical grounds may be disappointing if societal homeostasis is not taken into account. Strapped drivers seem ready to release their inhibitions right to the point they can meet their allotted quota of killing.
- Car demand appears predictable on "physical" grounds: penetration rate and death rate. A reference curve based on that could in any case greatly help to separate the superimpsed noise

and try to spot its causes. For car types, the much talked whims of the public do not appear in hindsight. For Europe at least (Fig. 26), all boiled down to a substitution of medium for very small cars, all the rest keeping solid their market shares. With hindsight wisdom one gets the impression that the famous statement of Ford about his model T: "They can have it in any color, provided it is black", may not be a pure witticism, and styling might be, at least in part, a selfpreserving game.

I hope that hindsight may help insight and wise planning for the troubled years ahead.

AND AFTERTHOUGHTS

One of the objections almost inevitably popping up when presenting these results to learned societies or to interested bodies, is that the excessive determinism is unpalatable to a voluntaristic society like ours.

My first line of defense is that what I am showing are basically facts, if in a different light and perspective. My second line is that this determinism is behavioral and intrinsically generated, having nothing to do with external and metaphysical "fate".

However, to break a little the lucent carapace and start a new line of research (evolutionary potential is of necessity linked to imperfection), I will describe here two cases where I zoomed into details in search of misbehavior.

Figure 1 describes the evolution of US car population between 1950 and 1977. I had in fact data down to 1900 from [5], but I did not use them in order to have a homogenous data base [6] for all cases under study.

With the data from [5] one gets the result shown in Fig. 27. The curve is good, but has a funny kink with twists in the '20s. My question then was whether during the first rush of expansion the car system did not "perceive" a different saturation point and behaved accordingly. An analysis of this period taken in isolation (Fig, 28) shows that the hypothesis is worth a further exploration. My friends in the car industry actually pray for a multilayer niche that could accommodate their brand new dreams, e.g. a car that parks in 2 m^2 by sitting on its back.

Another objecton was that the saturation number of 19 M, which I had given for Western Germany, had already been overtaken. This is not unexpected. As Fig. 29 shows for three cases taken from the mining industry in the US, these logistics or quasi-logistics can become oscillatory when approaching saturation (a possible solution of Volterra equations often appearing in ecological contexts). However I was very curious, and examined in detail the last four years, separating them from the rest (Fig.30). It appears here too that the overshooting can be interpreted as a change in maximum level perception and rate of approach, the functional relationship being held. So the castle has back doors. And trap doors too, as any serious castle must have to make life a little challenging. If at the perception level.

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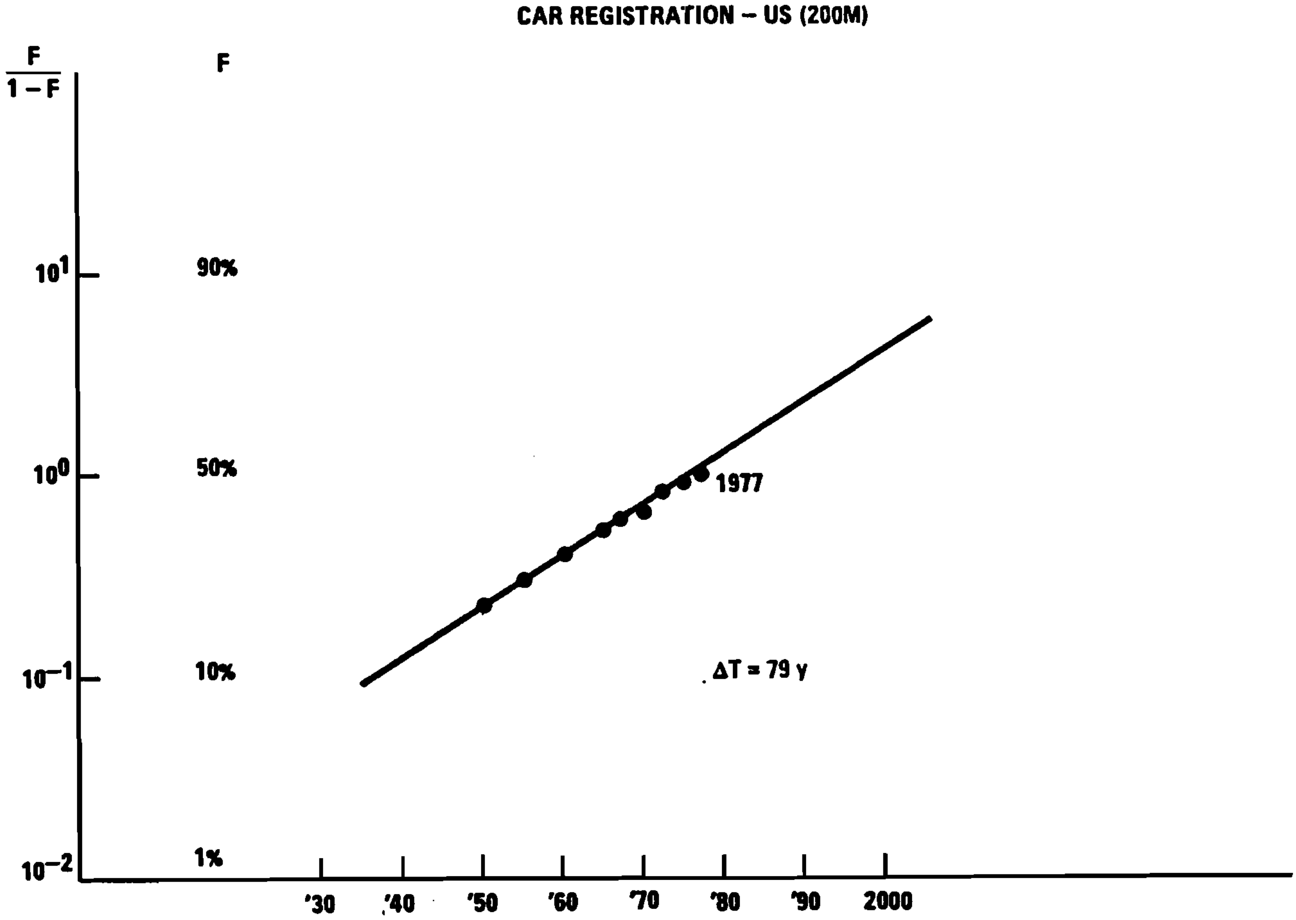

Figure 1.

Cars registered in the US are reported as fractions F of the "perceived" maximum (200 Millions). The perceived maximum is calculated best fitting the data with a three parameter logistic. I actually did it by trial and error and by hand using the above transform. The flex, or the 50% penetration point is indicated with a date, and ΔT represents the time constant, or the time to go from 10% to 90%.

To facilitate reading of the curve, fractions F are reported for the levels indicated.

Perceived maximum can be considered as the size of the econiche for the car species. If other modes compete, the niche may never be filled, as multiple competition between primary energies clearly shows. It can also be "overshot", the approach to the asymptotic level becoming then oscillatory.

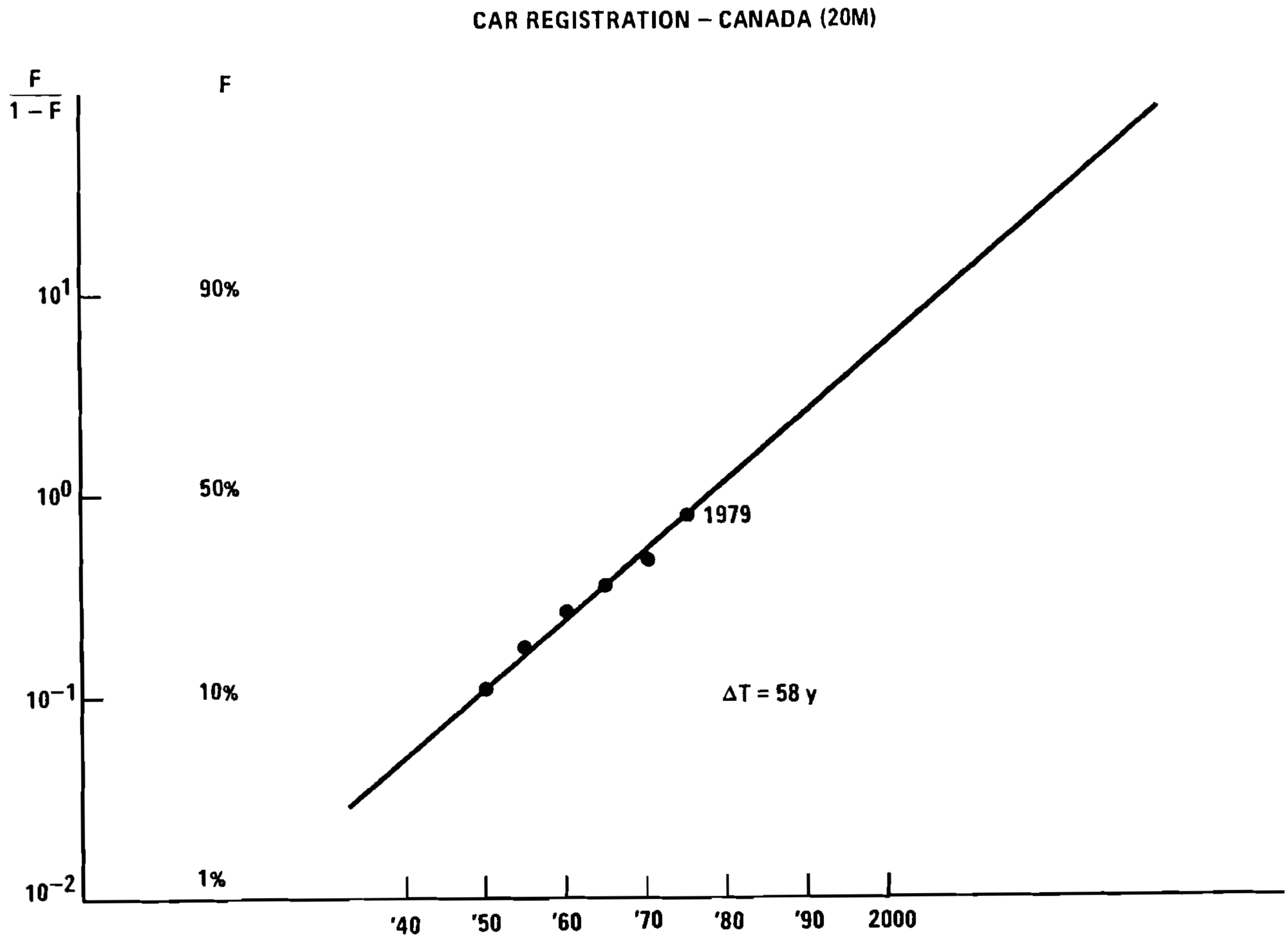

Figure 2. (For explanation see Figure 1.)

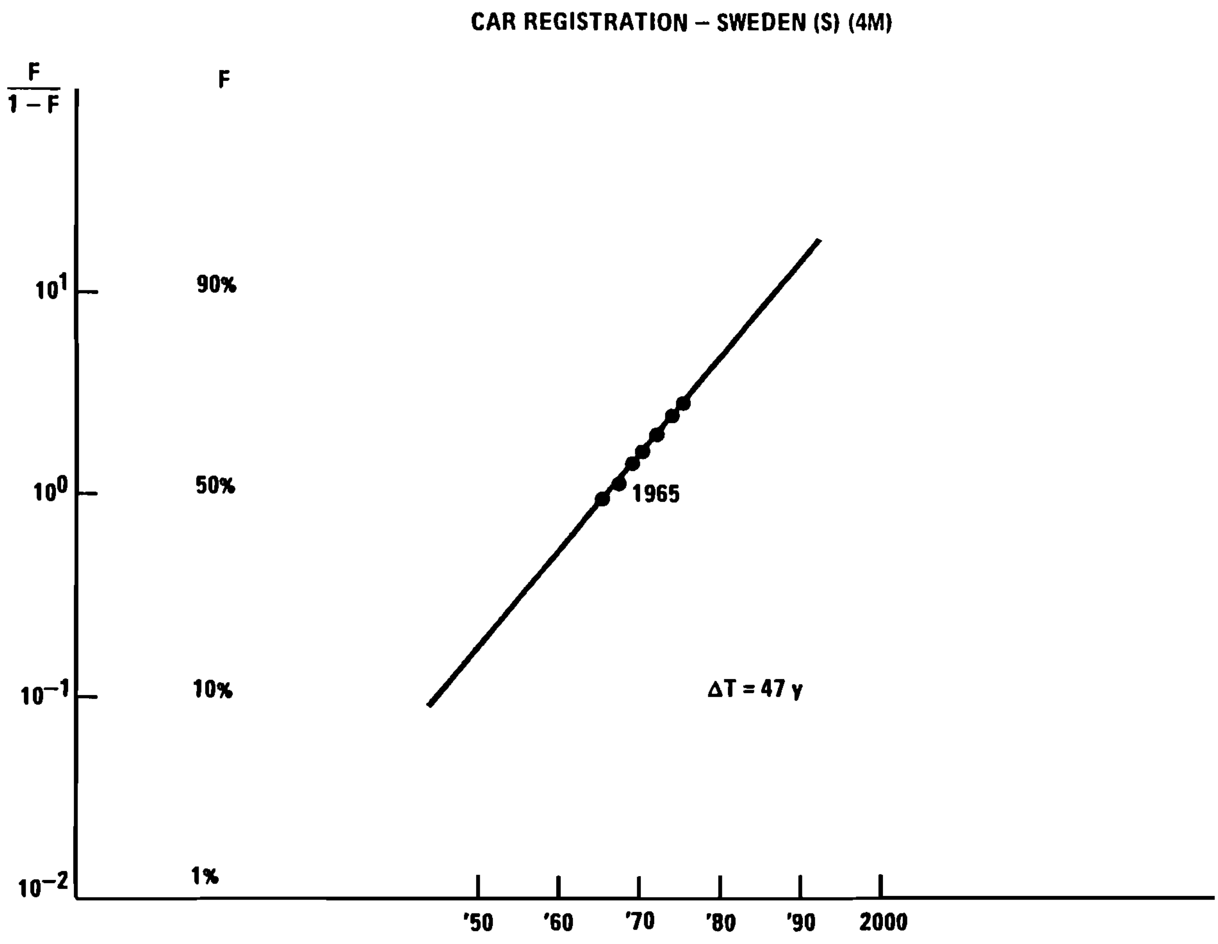

Figure 3. (For explanation see Figure 1.)

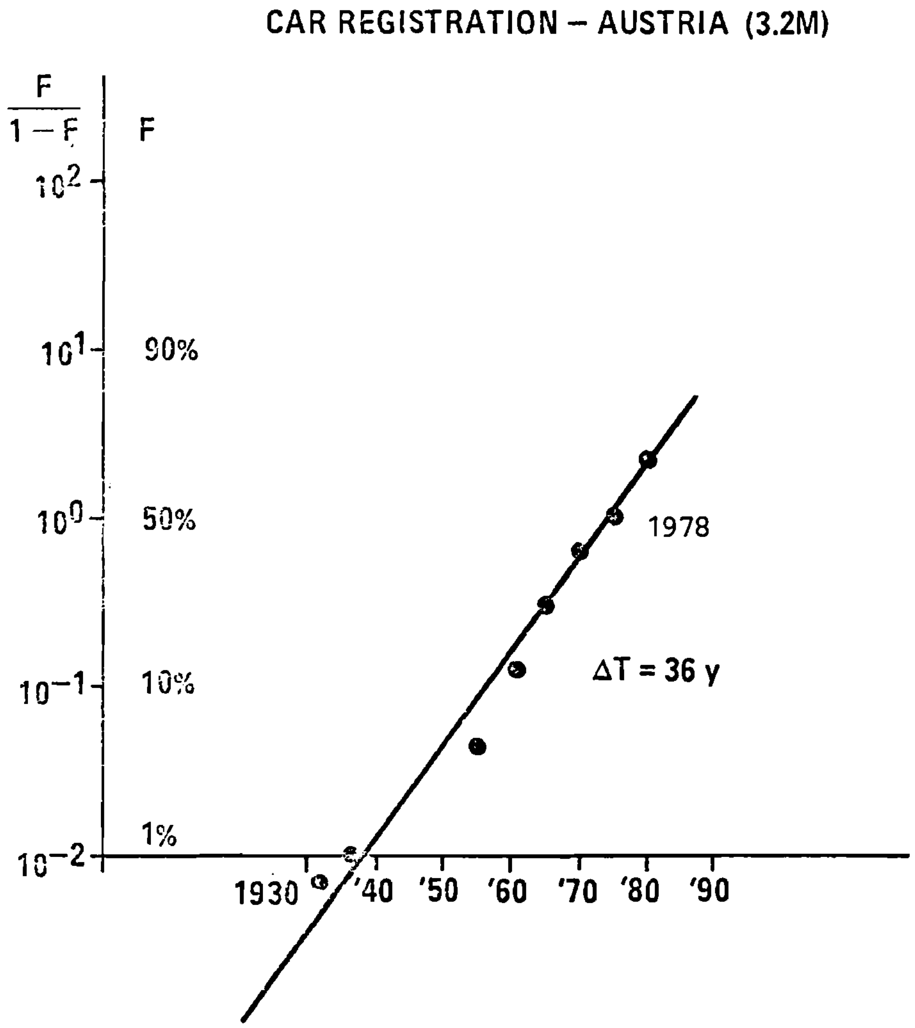

Figure 4. (For explanation see Figure 1.)

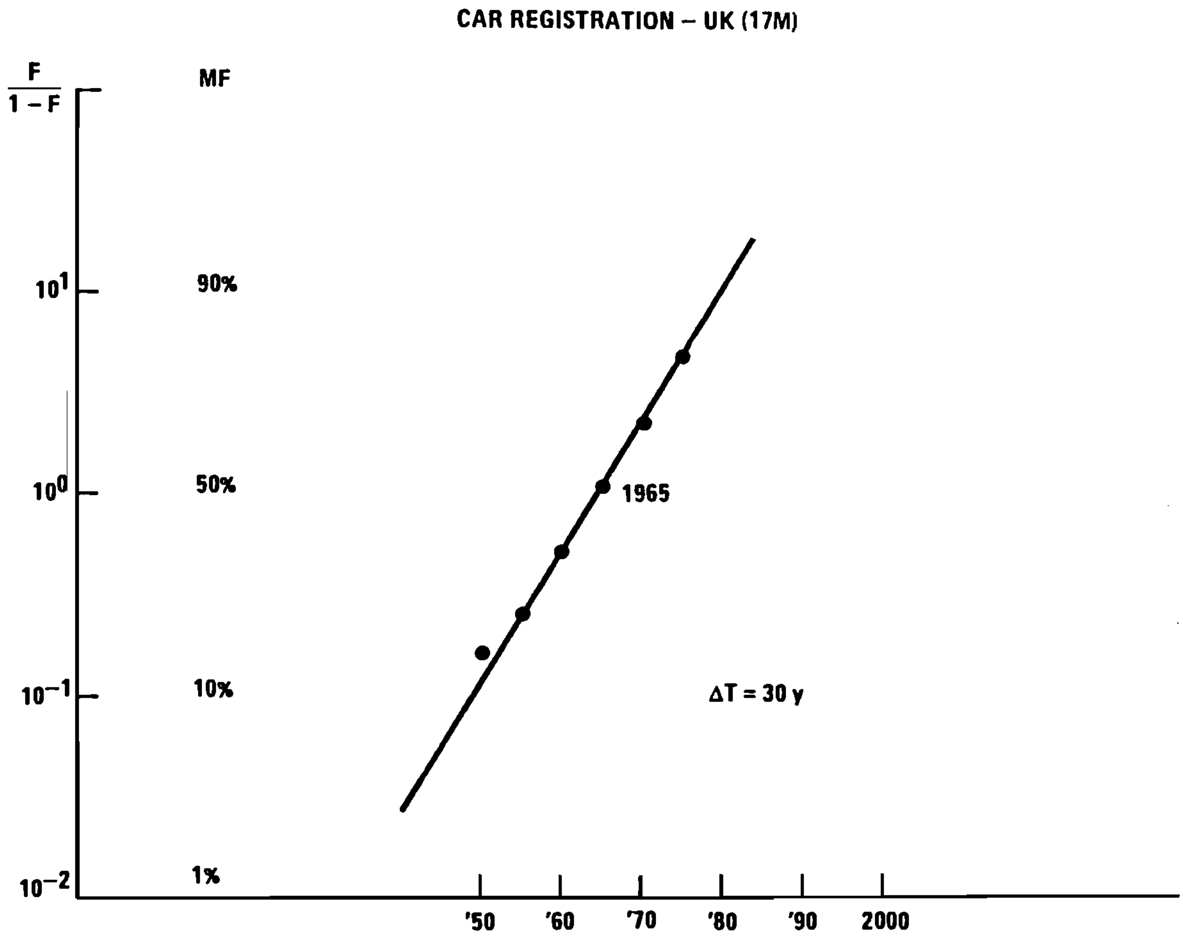

Figure 5. (For explanation see Figure 1.)

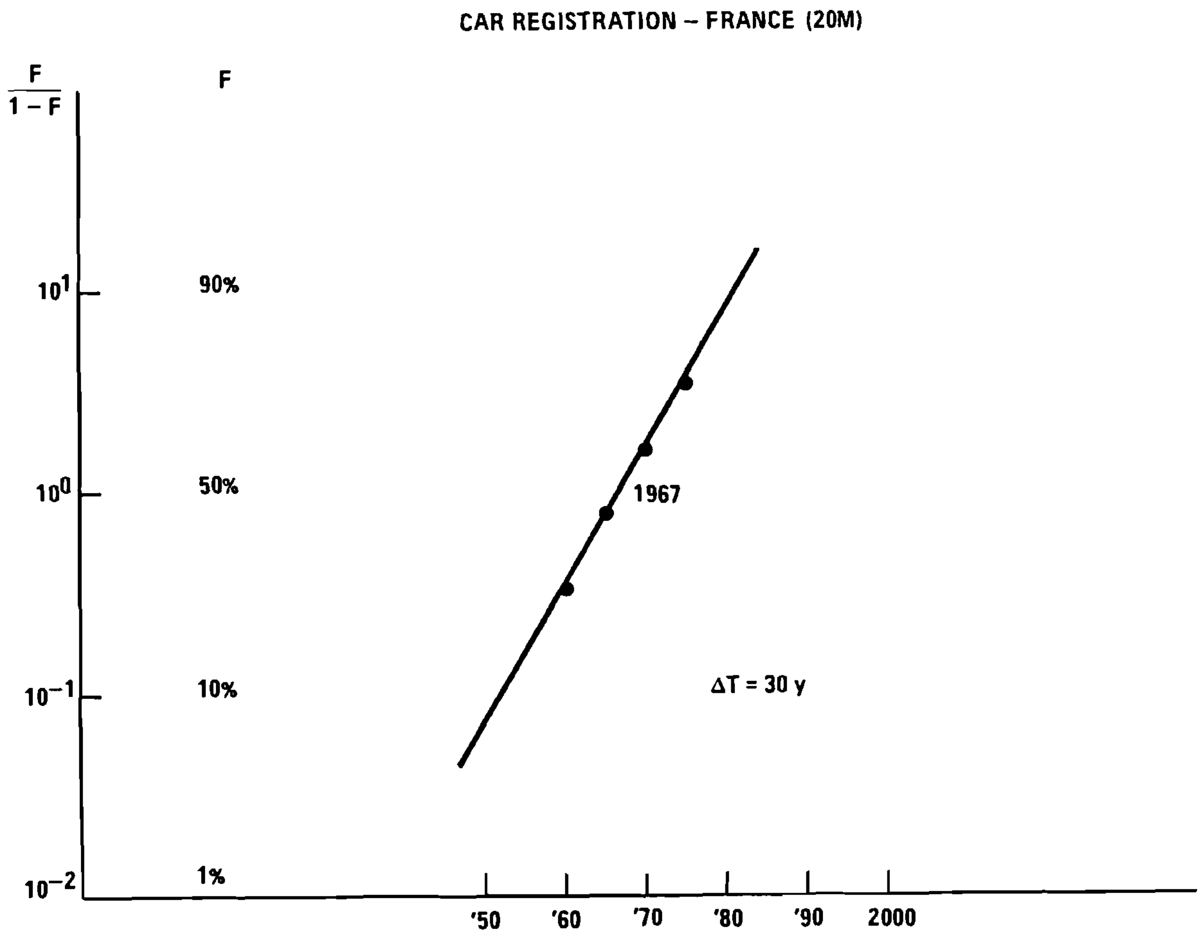

Figure 6. (For explanation see Figure 1.)

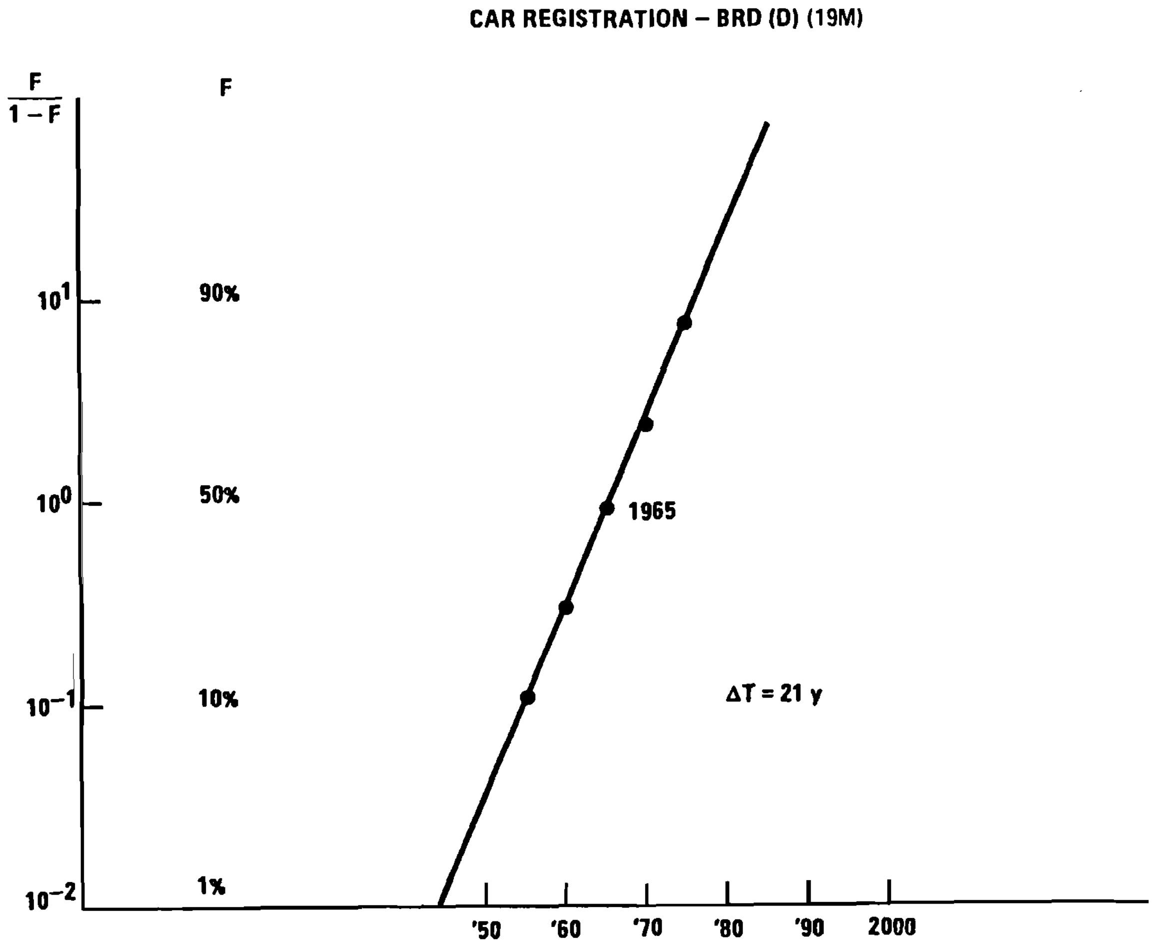

Figure 7. (For explanation see Figure 1).

CAR REGISTRATION – ITALY (I) (20M)

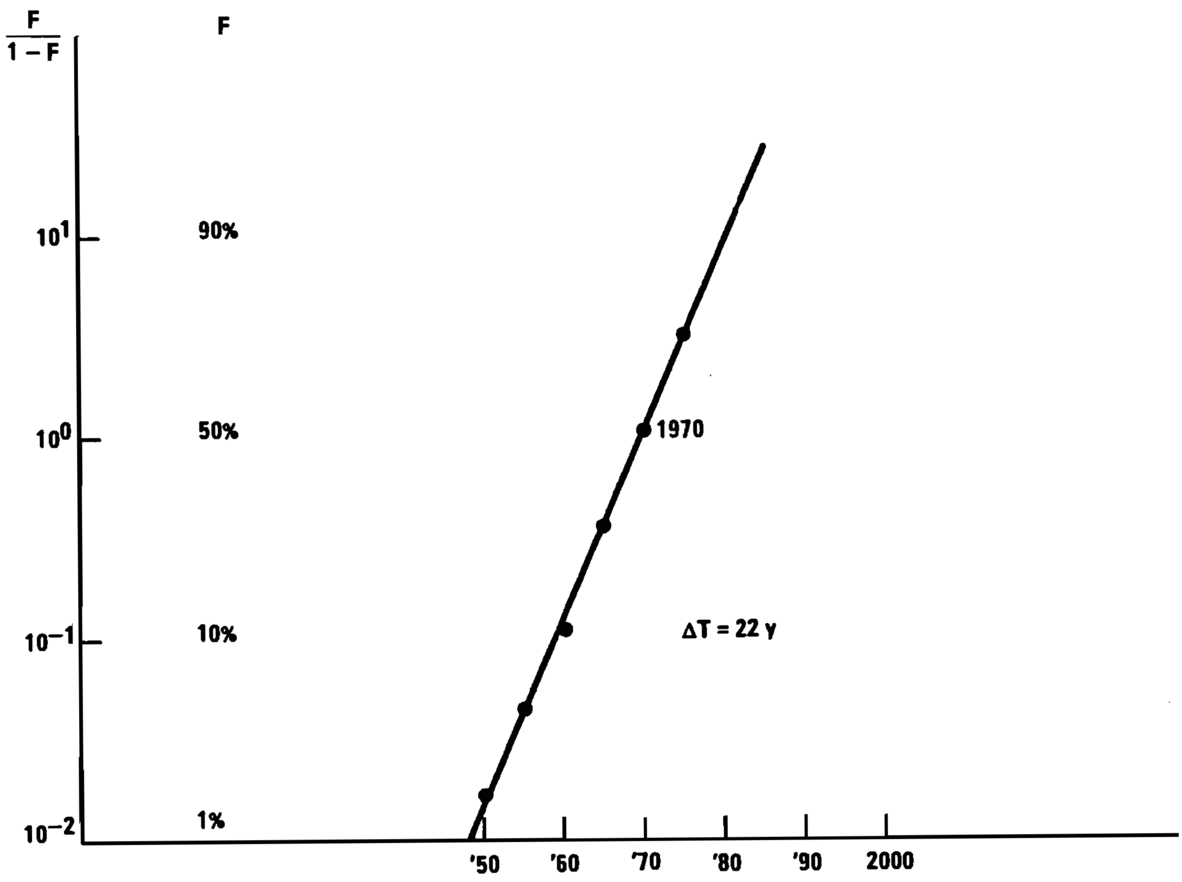

Figure 8. (For explanation see Figure 1.)

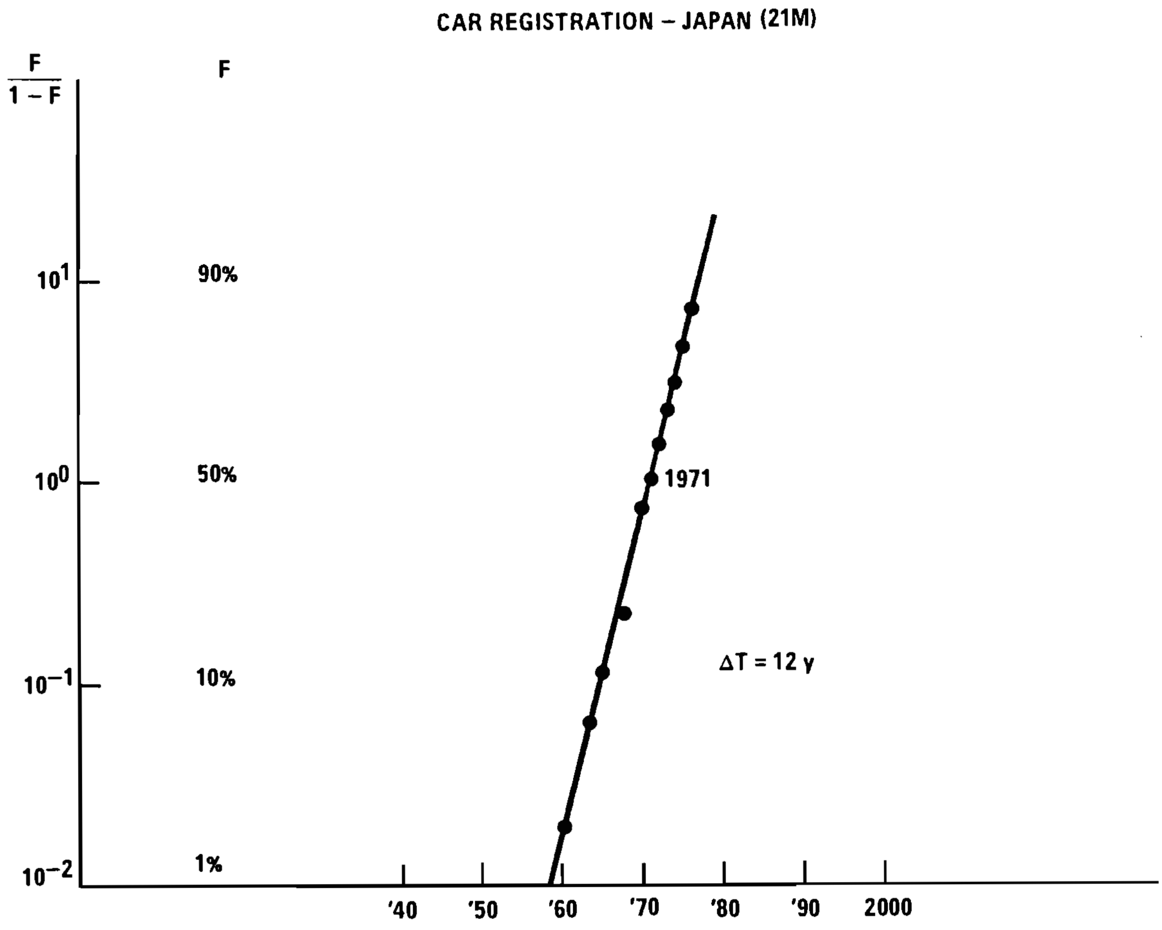

Figure 9. (For explanation see Figure 1.)

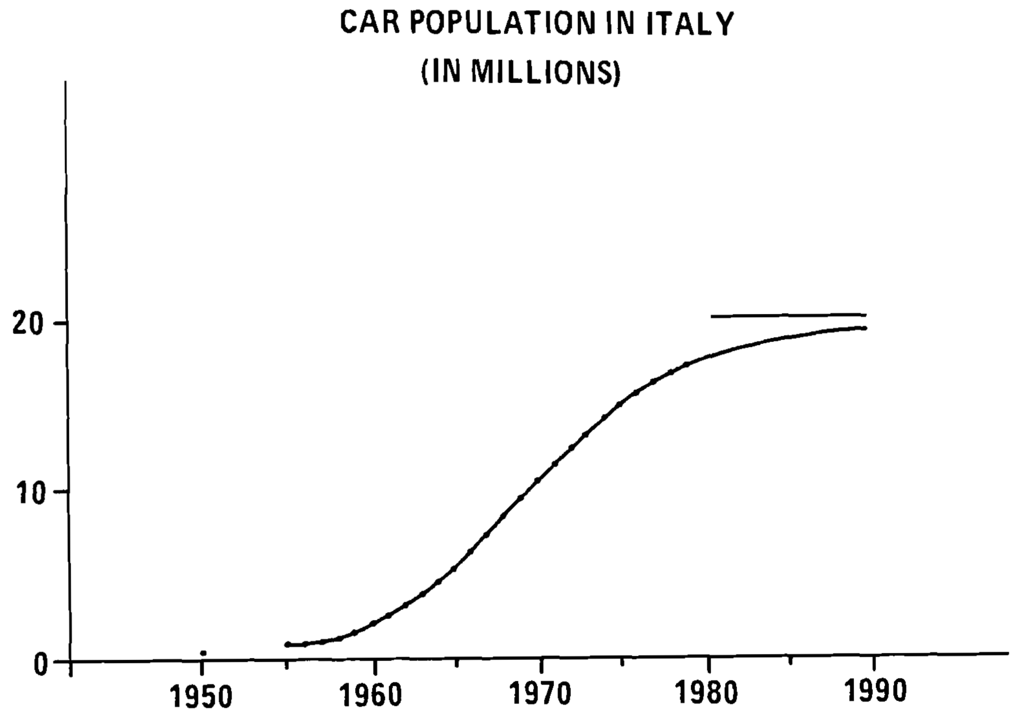

Figure 10.

To show the extremely low level of noise, data for the Italian car population are reported in linear terms.

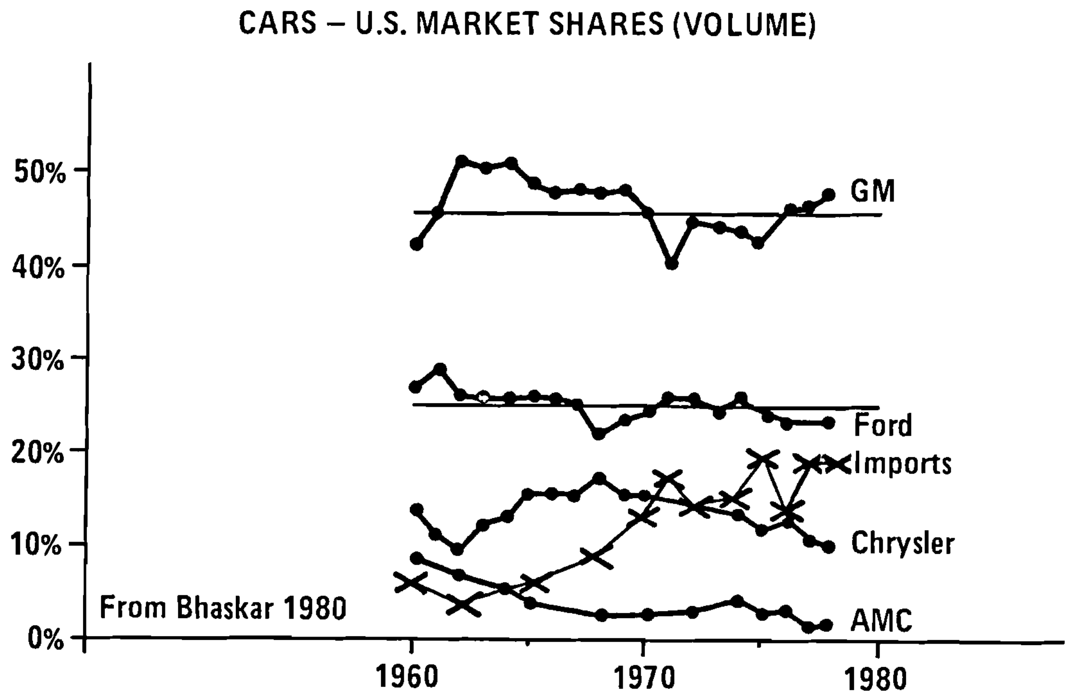

Figure 11.

Analysis of market share of major firms shows a great stability in time. Innovation and promotion do not seem to provide an edge, but they are probably part of the elbowing mechanisms.

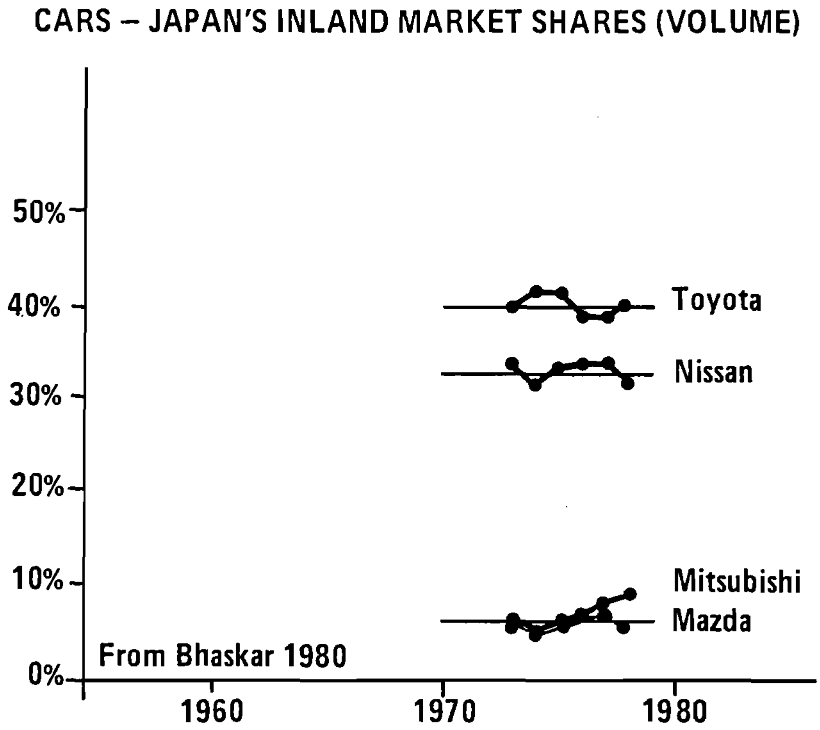

Figure 12. (For explanation see Figure 11.)

RELATION BETWEEN ΔT AND TIME WHEN CAR POPULATION WAS 1% OF SATURATION

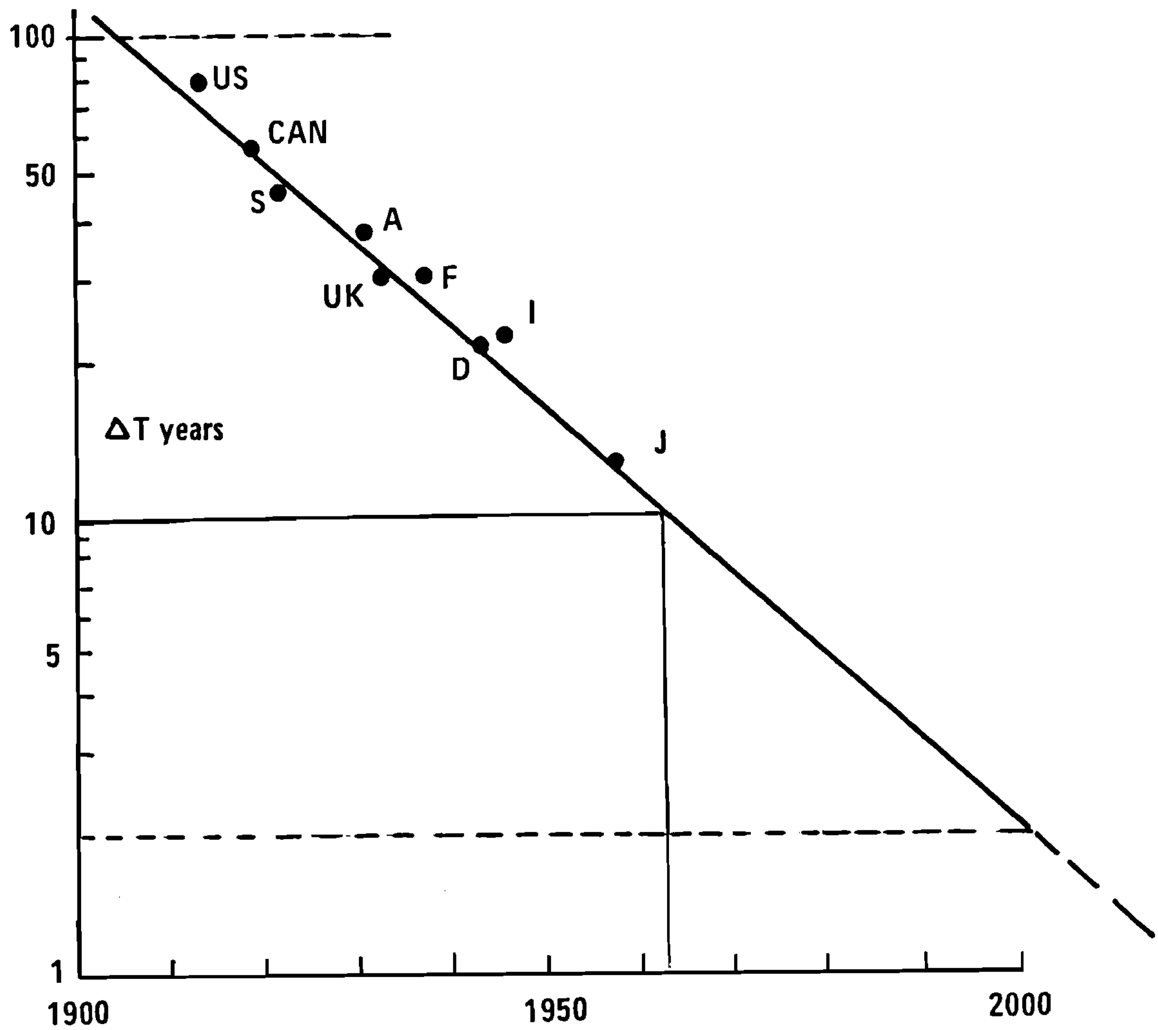

Figure 13.

The time constant of car penetration in various countries is here reported vs the date when car population reached 1% of saturation level, which is considered as the starting point of massive penetration. The precise time trend log ΔT = at+b appears to be well matched. No explanation is available.

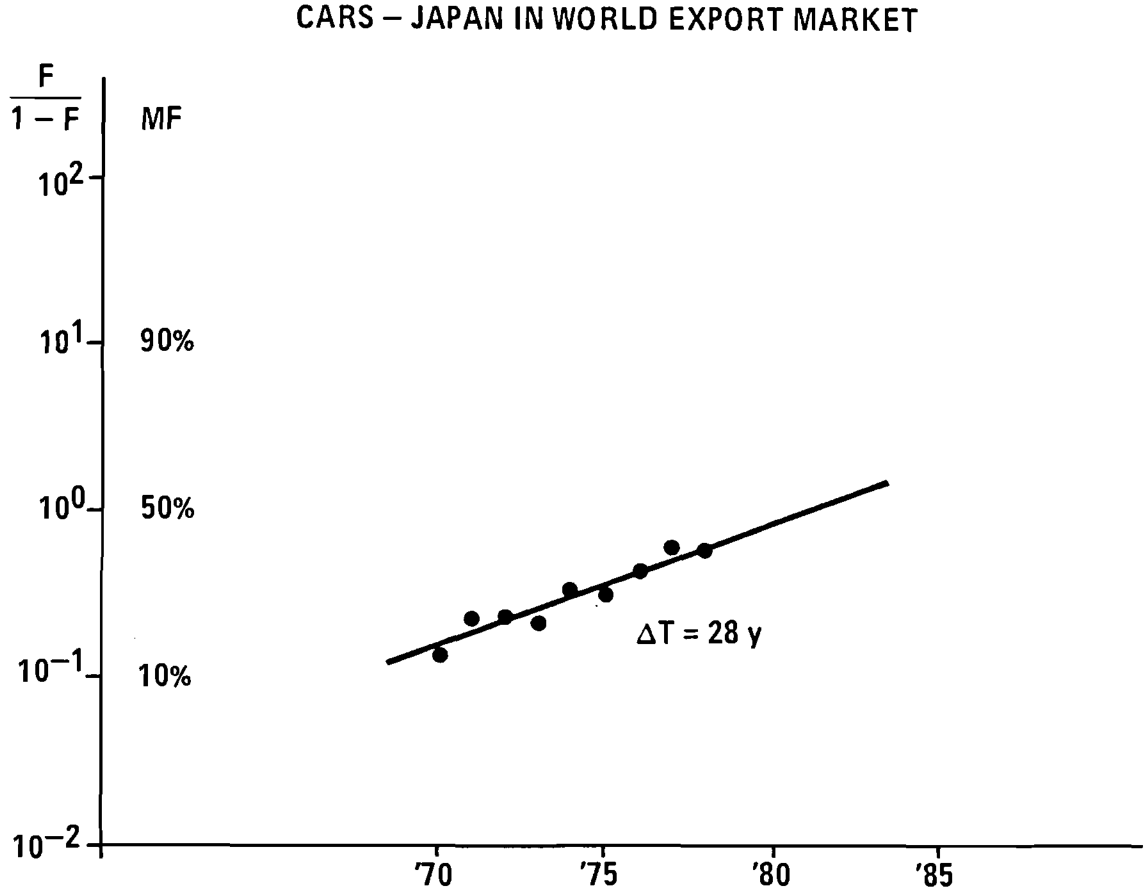

Figure 14.

Japan appears steadily progressing in the penetration of the world export market, about half of it should already have in 1982 and 90% in 1996 if no newcomers will challenge her progress.

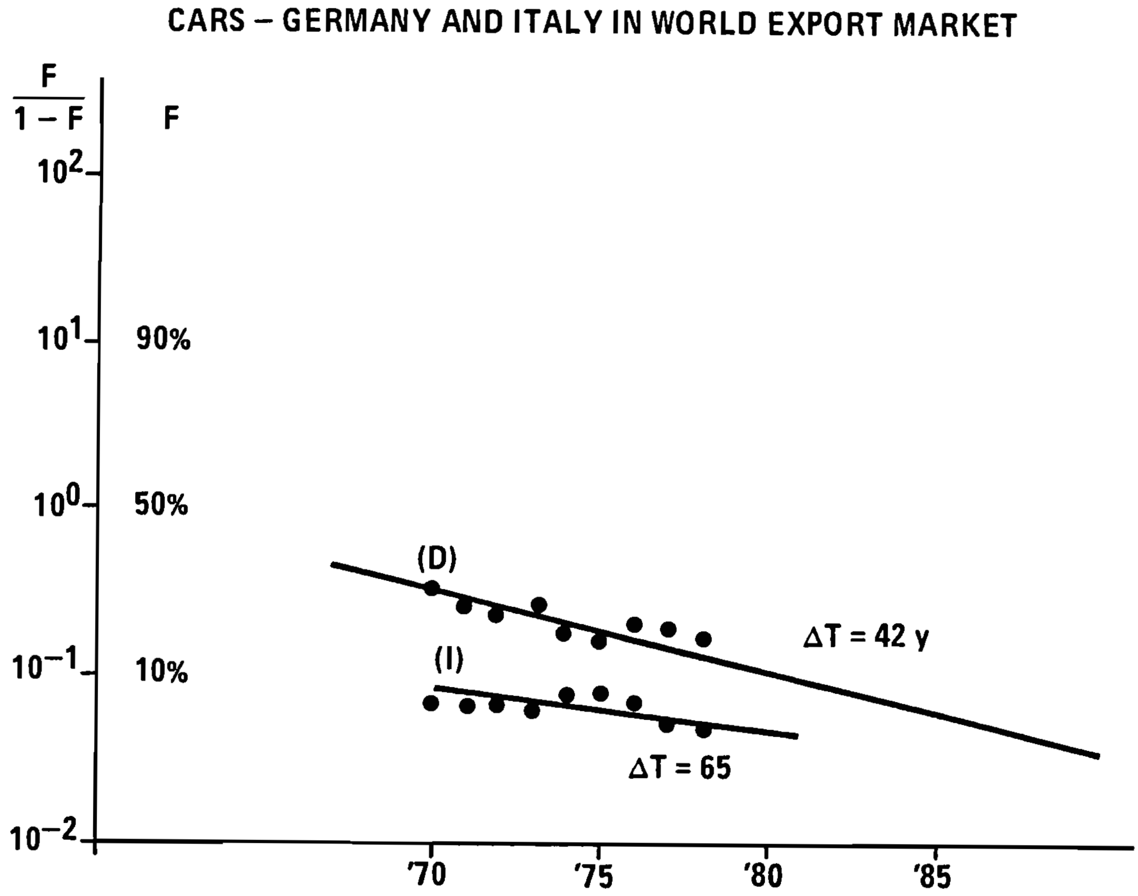

Figure 15.

Two aggressive exporters, Germany and Italy, see their positions in the international market slowly but progressively eroded.

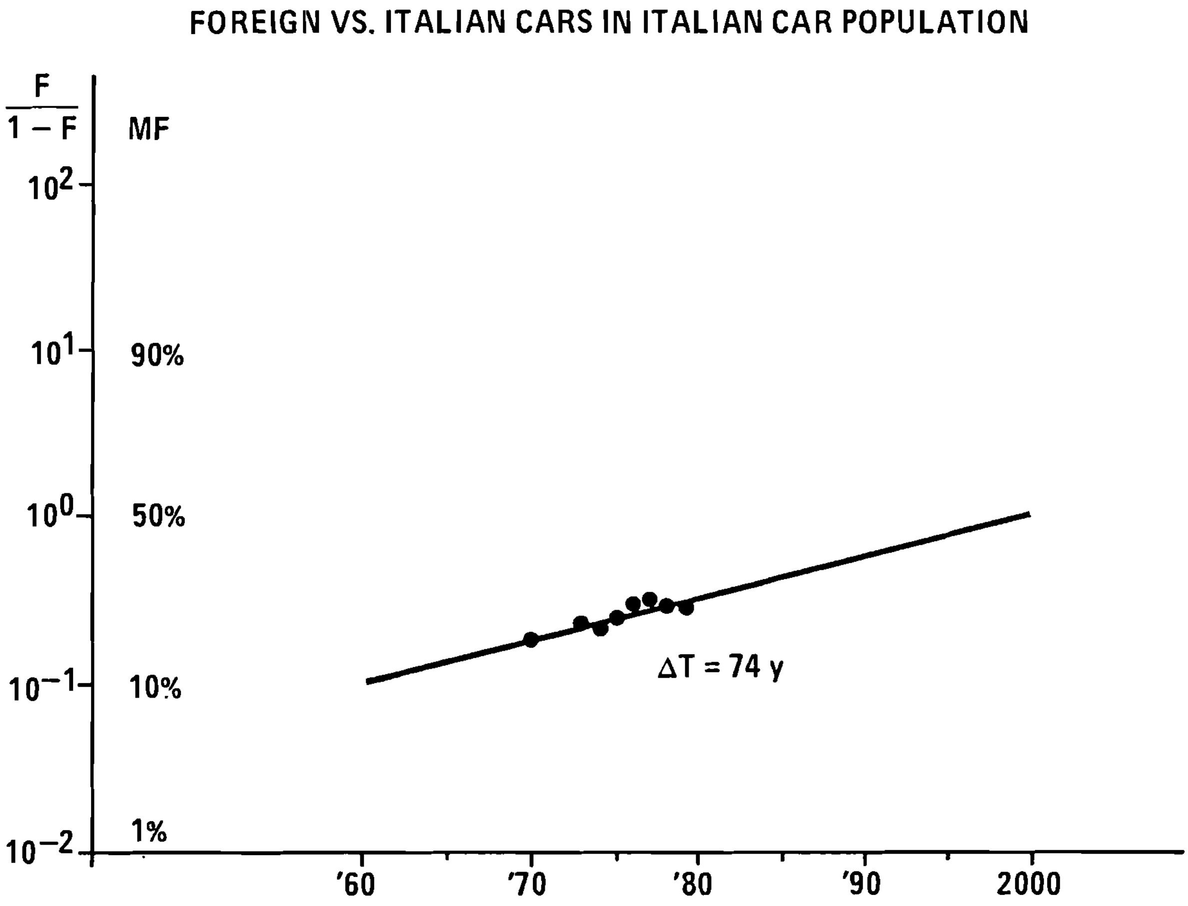

Figure 16.

The analysis of car population mix in a certain country shows spreading of foreign "genes".

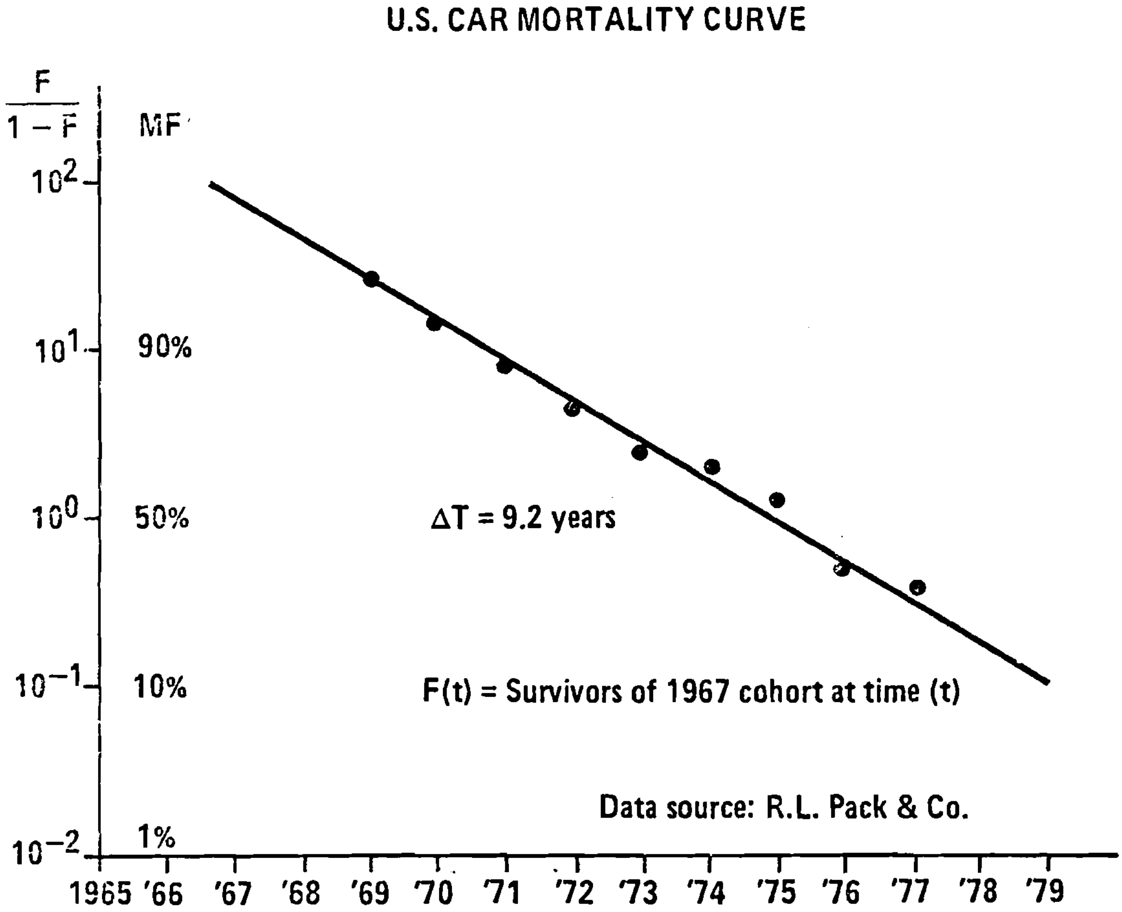

Figure 17.

Survivors curve appears to fit neatly a logistic trend. Curiously death curves and birth curves have the same functional expression pointing perhaps to a deep symmetry in the two processes.

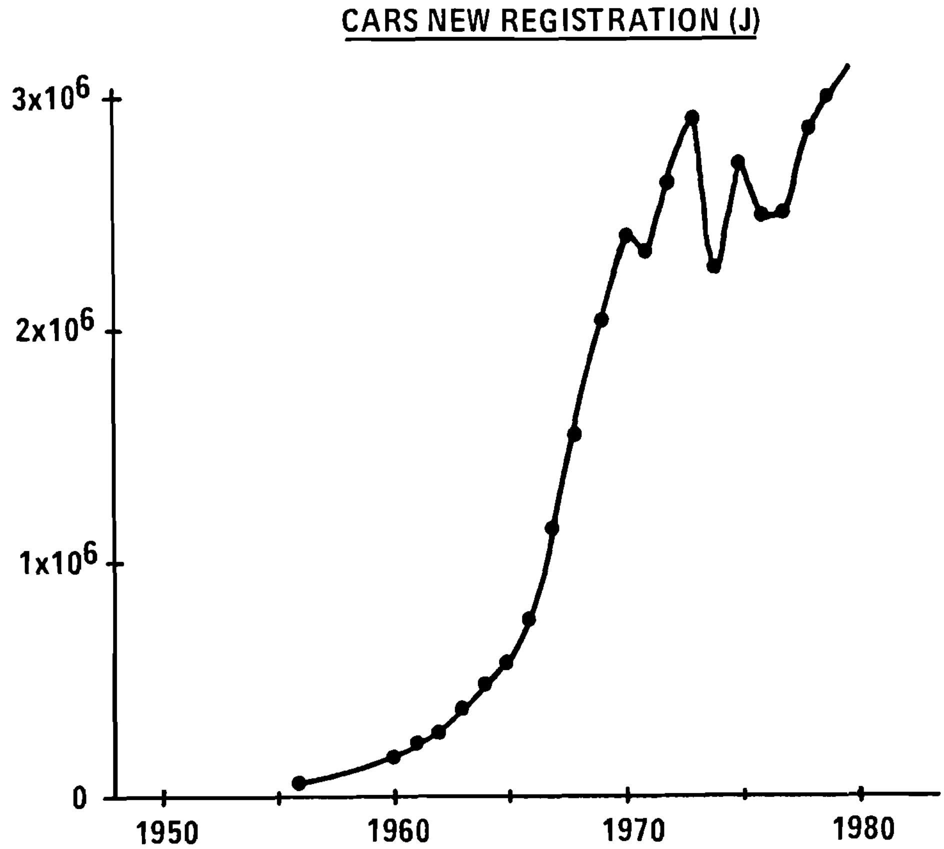

Figure 18.

New registrations in Japan are reported here. Figure 19 will show an attempt to calculate them using birth and death functions.

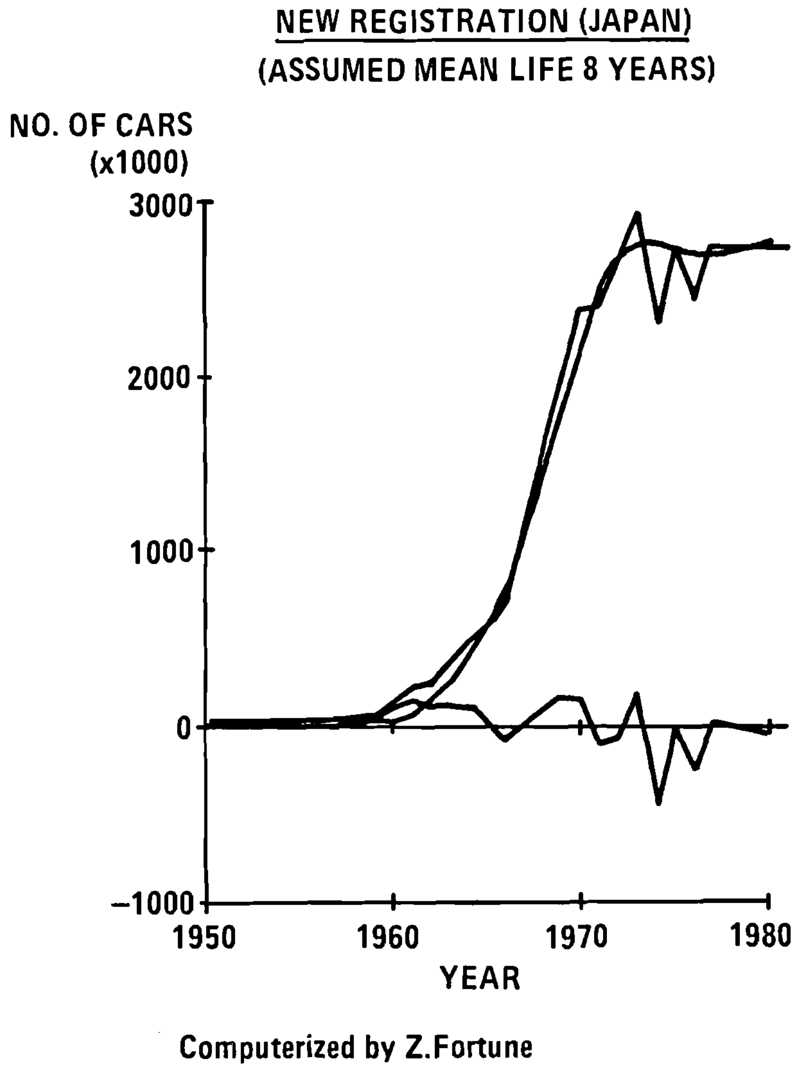

Figure 19.

"Synthetic" demand reconstruction using only "physical" principles: birth and death functions, calculated for a car mean life of eight years. The difference between calculated values and actual ones is given at the bottom of the figure.

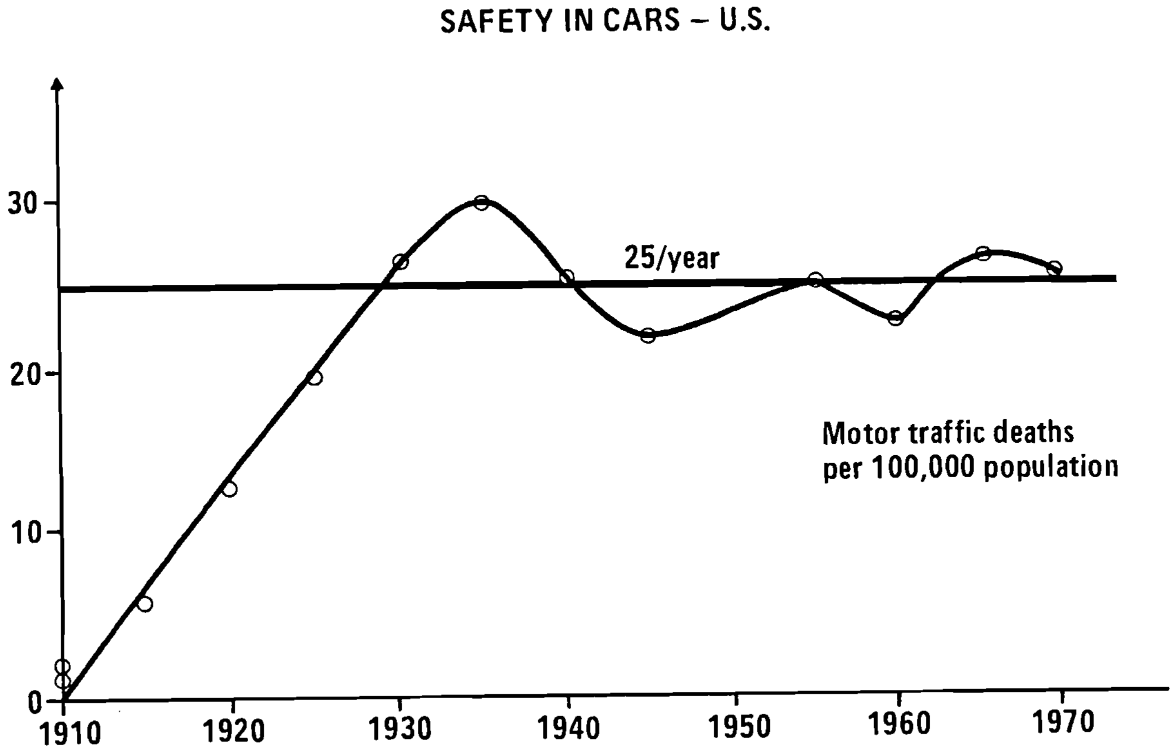

Figure 20.

Traffic deaths expressed in terms of population grow first with the number of cars (but at a lower rate) and finally stabilize around a "set point" of about 25/year per 100.000 population. This suggests a very strong societal homeostasis imposing restrictions when deaths go above the set point. What is almost incredible is the stability of the set point over time and the strength of the hold.

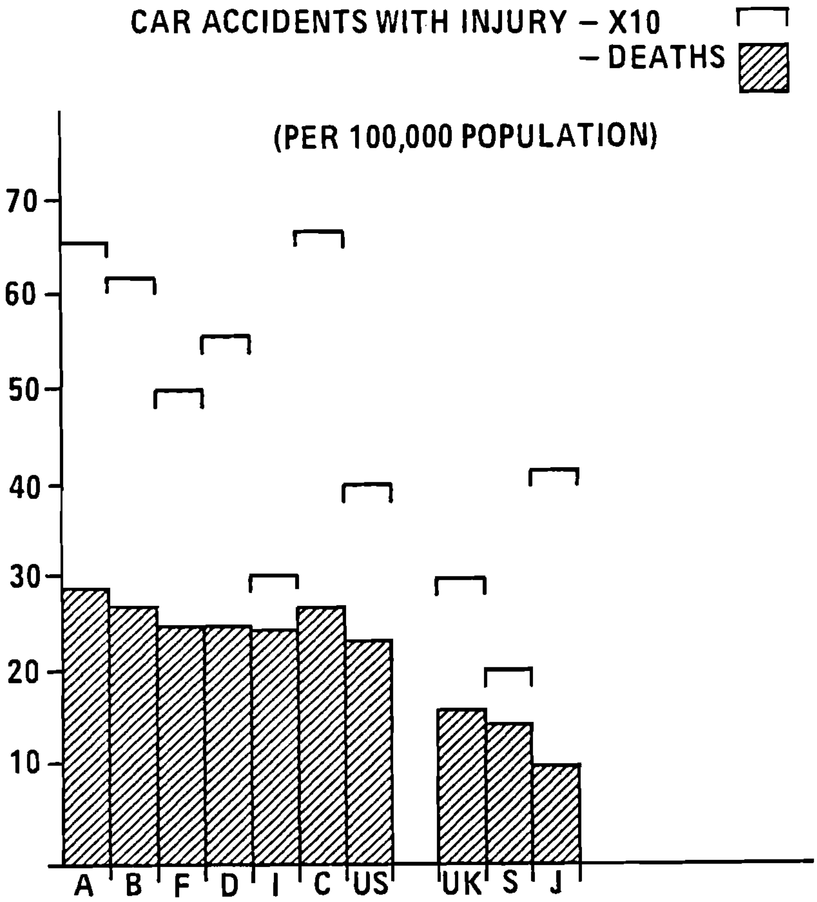

Figure 21.

Set points are given for 1975, and for a number of countries. Most of them seem to be locked to the magic figure of 25. UK, Sweden and Japan are a curious and unexplained exception.

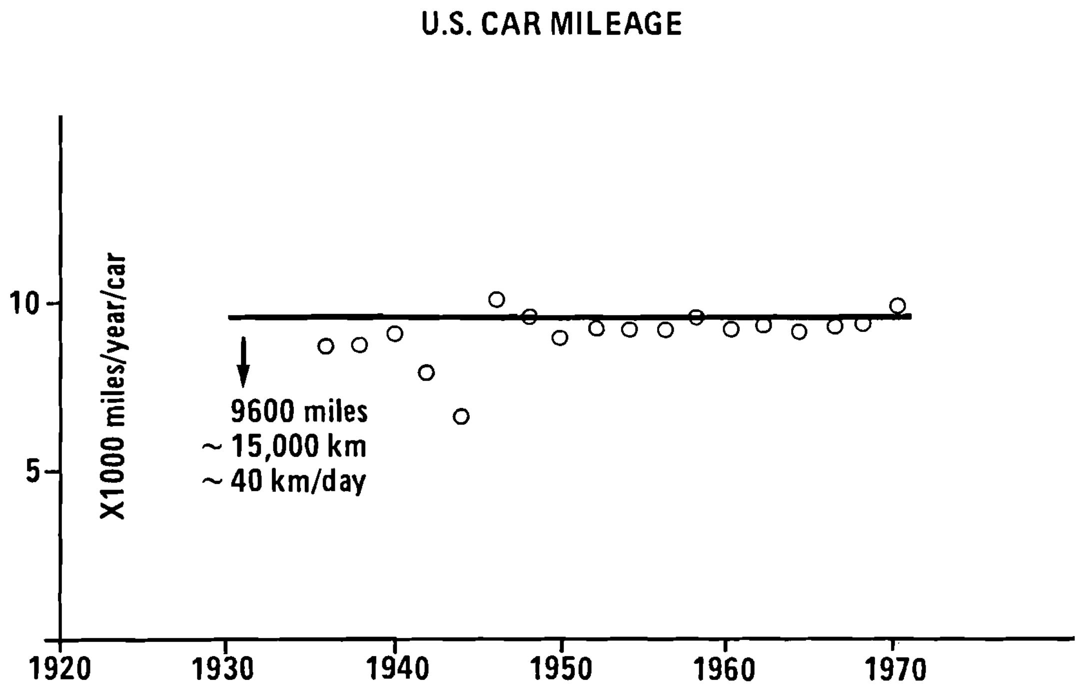

Figure 22.

Mileage per car remains remarkably independent of time and car number pointing to complex relationships between the car and the transportation system. Data for other countries are not much different.

US SURFACED ROADS (SATURATION POINT 3.4×10^6 MILES)

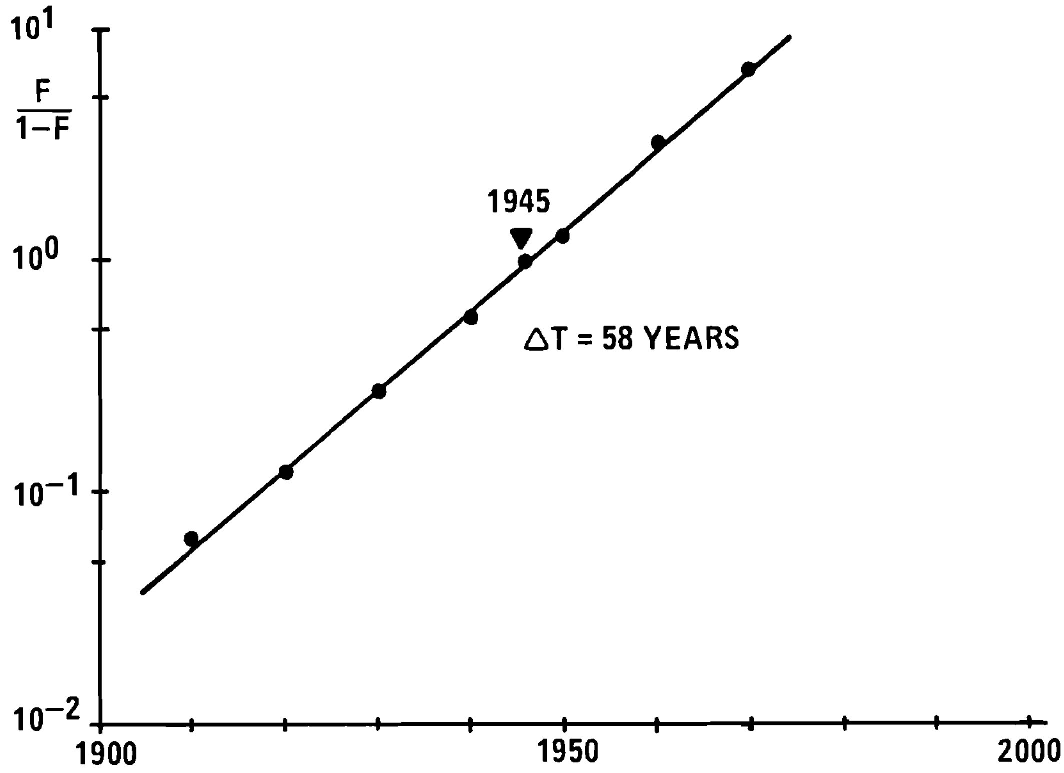

Figure 23.

A common statement in the literature, that the development of the paved road net is a consequence of the introduction of the car, should be taken with caution. Certainly cars and paved roads show a symbiotic relationship, but the fact that paved roads preceded by a good 30 years the introduction of the car in the US, and the fact that their rate of deployment was not modified when the car appeared, strongly points to a reverse causality.

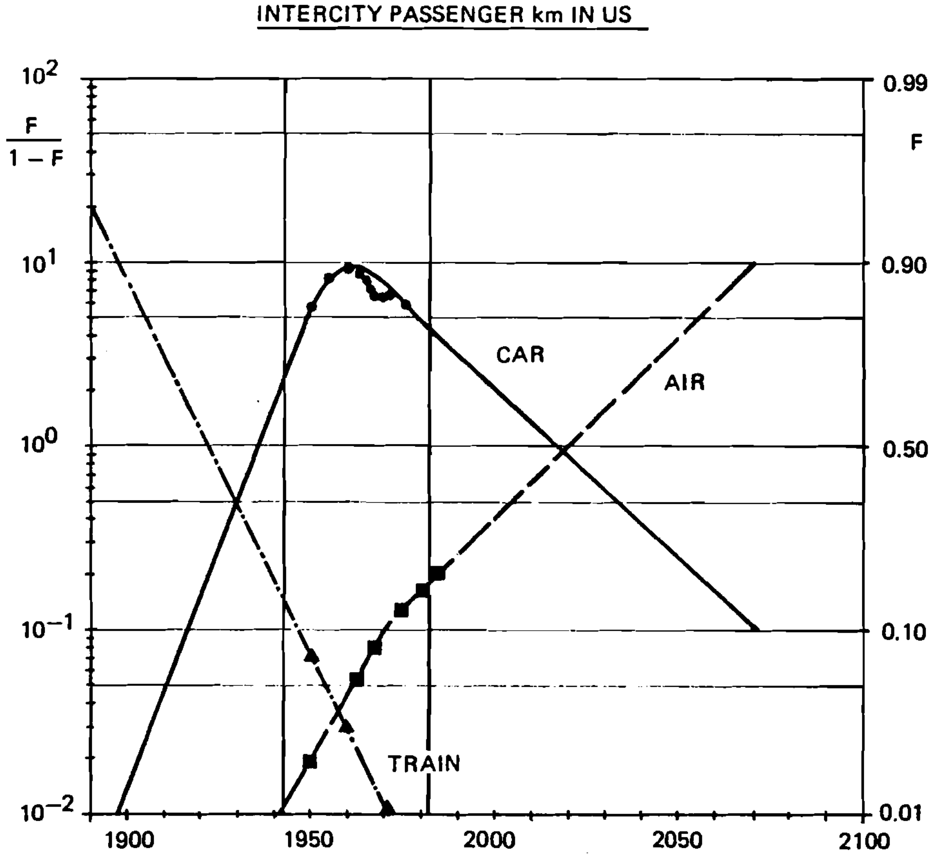

Figure 24.

Train, car and plane compete for passenger-km in a neatly darwinian way. Curiously, US cars displayed airplane secondary characteristics when reaching, in 1959, the top of their penetration, and initiated the inexorable fall. Mimicry of the fight?

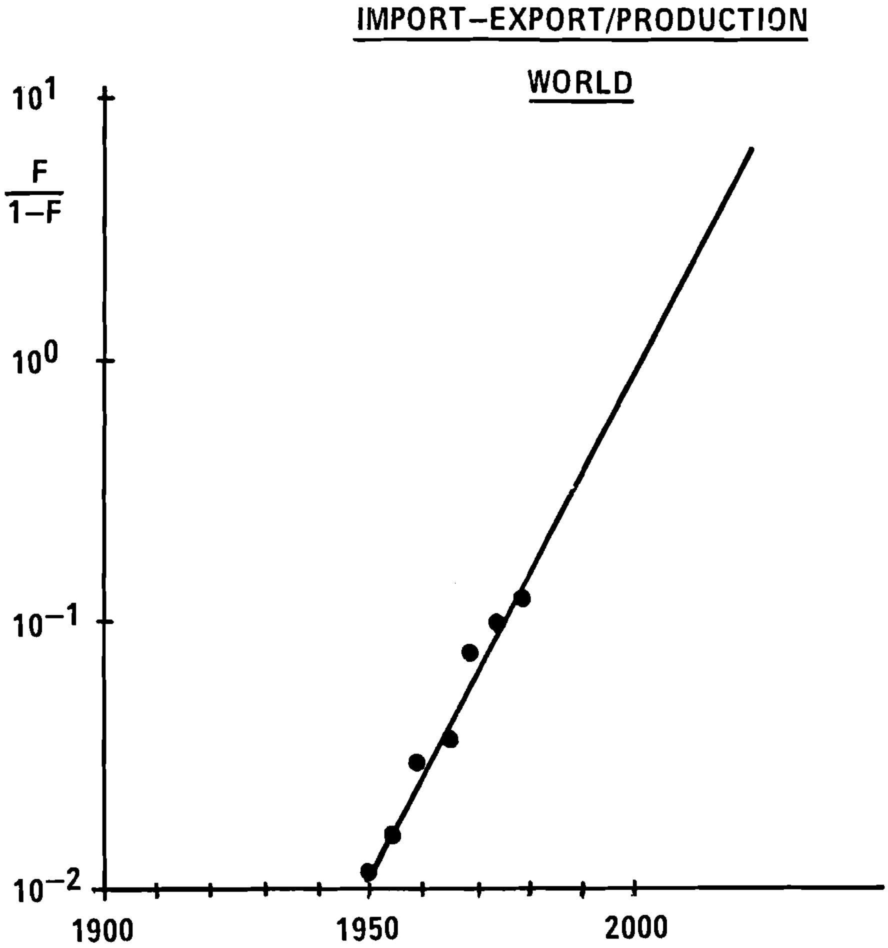

Figure 25.

The car industry is rapidly going international as the data show. Only the US appear actually to be nationally contained, but this may only be an optical effect, as the international operation is taken by overseas daughter companies.

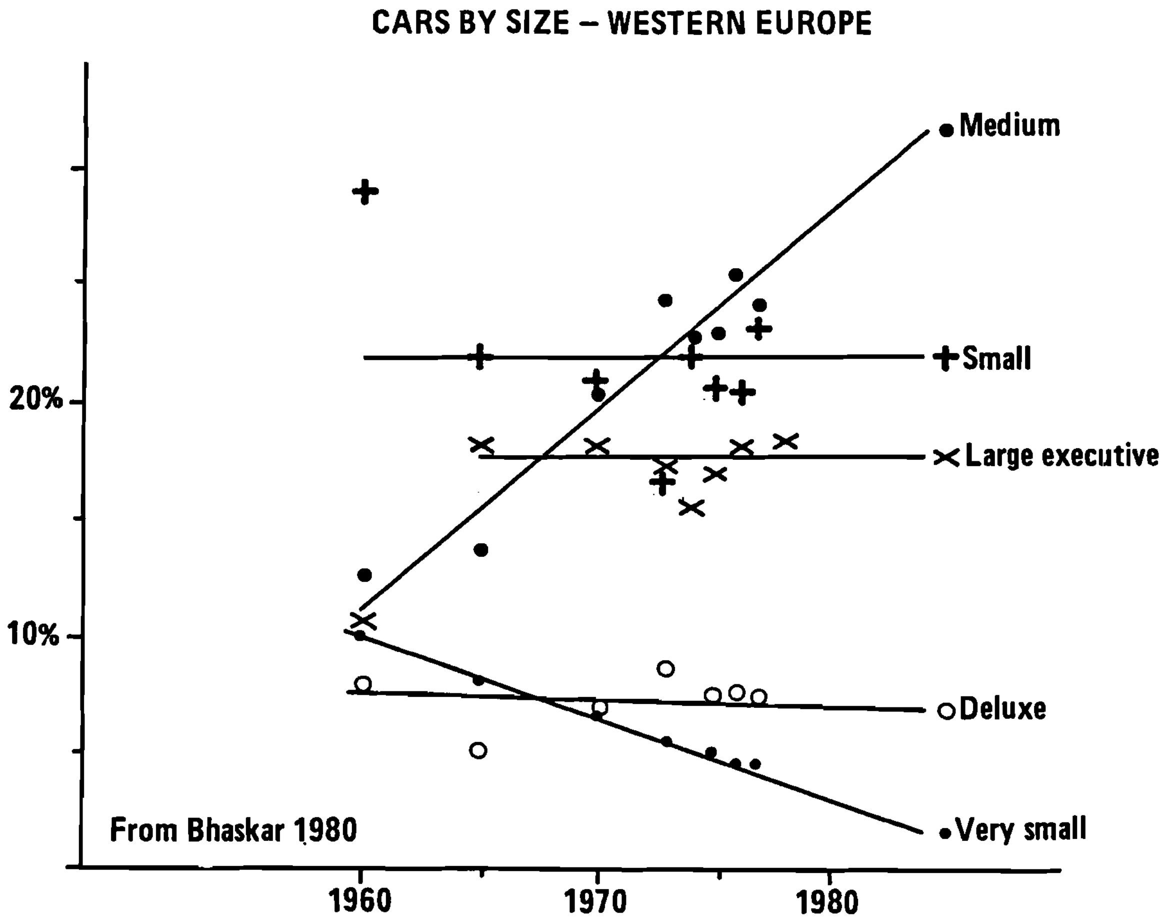

Figure 26.

With ups and downs most car categorizations seem to hold their market share in time with the exception of "medium" cars eating out the niche of the very small ones, and nibbling that of the others.

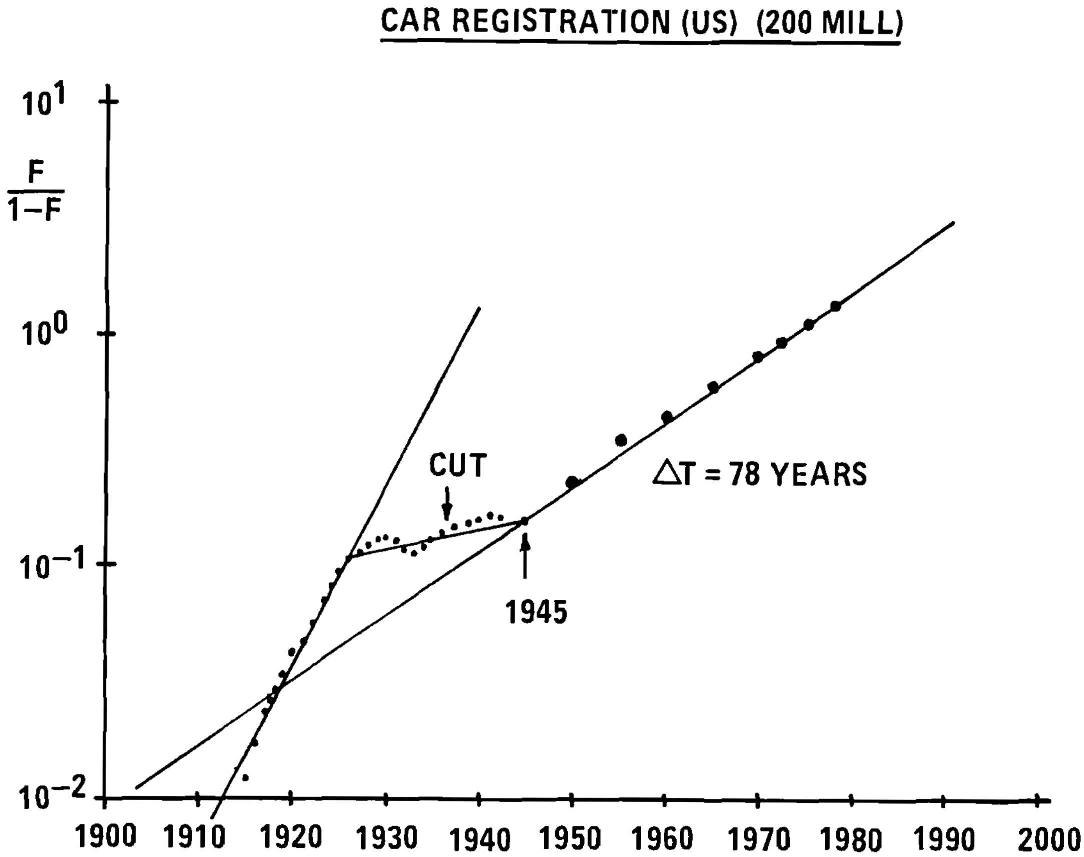

Figure 27.

Total car registrations in the US from the beginning of car introduction. The dash at the start to the point indicated by CUT has been analyzed independently in Figure 28.

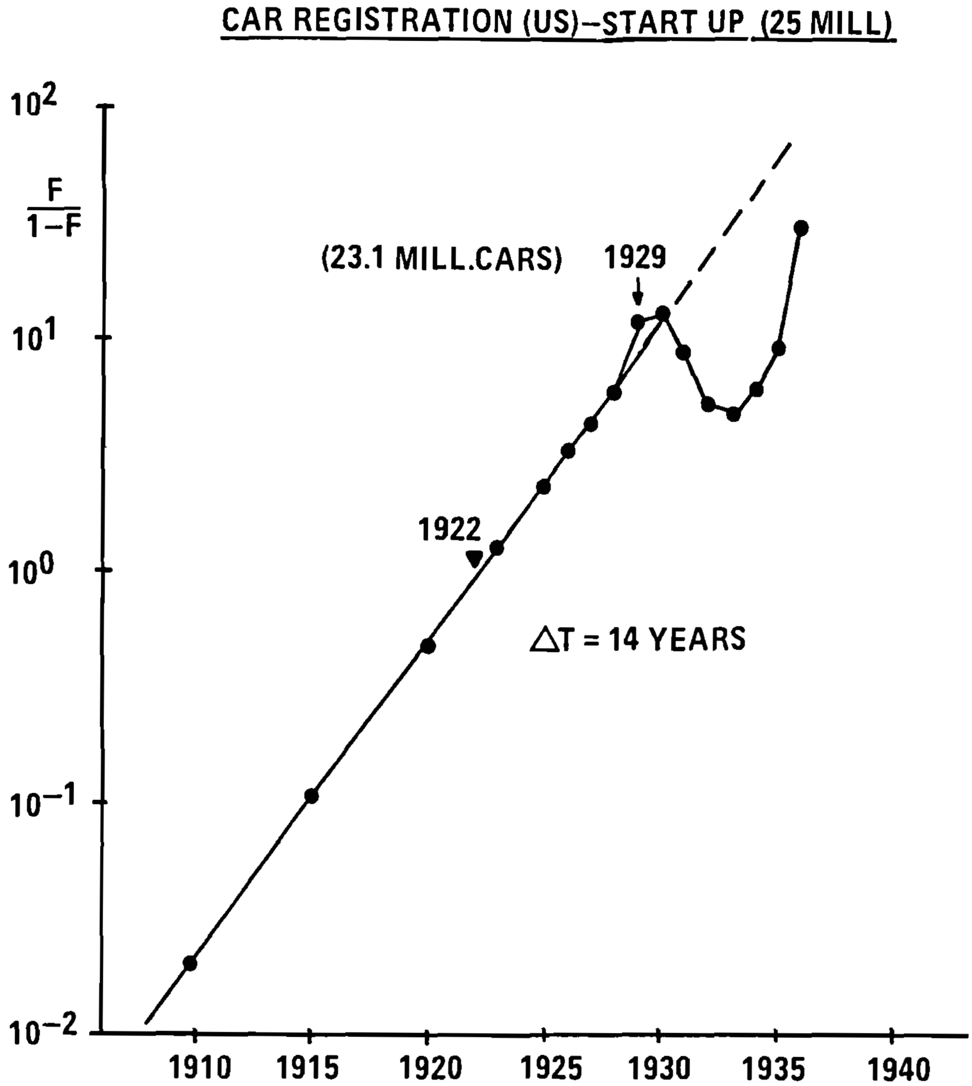

Figure 28.

If I had analyzed car penetration in the US in 1930, the result would have been this one, with 25 M cars as the perceived saturation point and ΔT = 14 years, a situation not much different from that of Japan today.

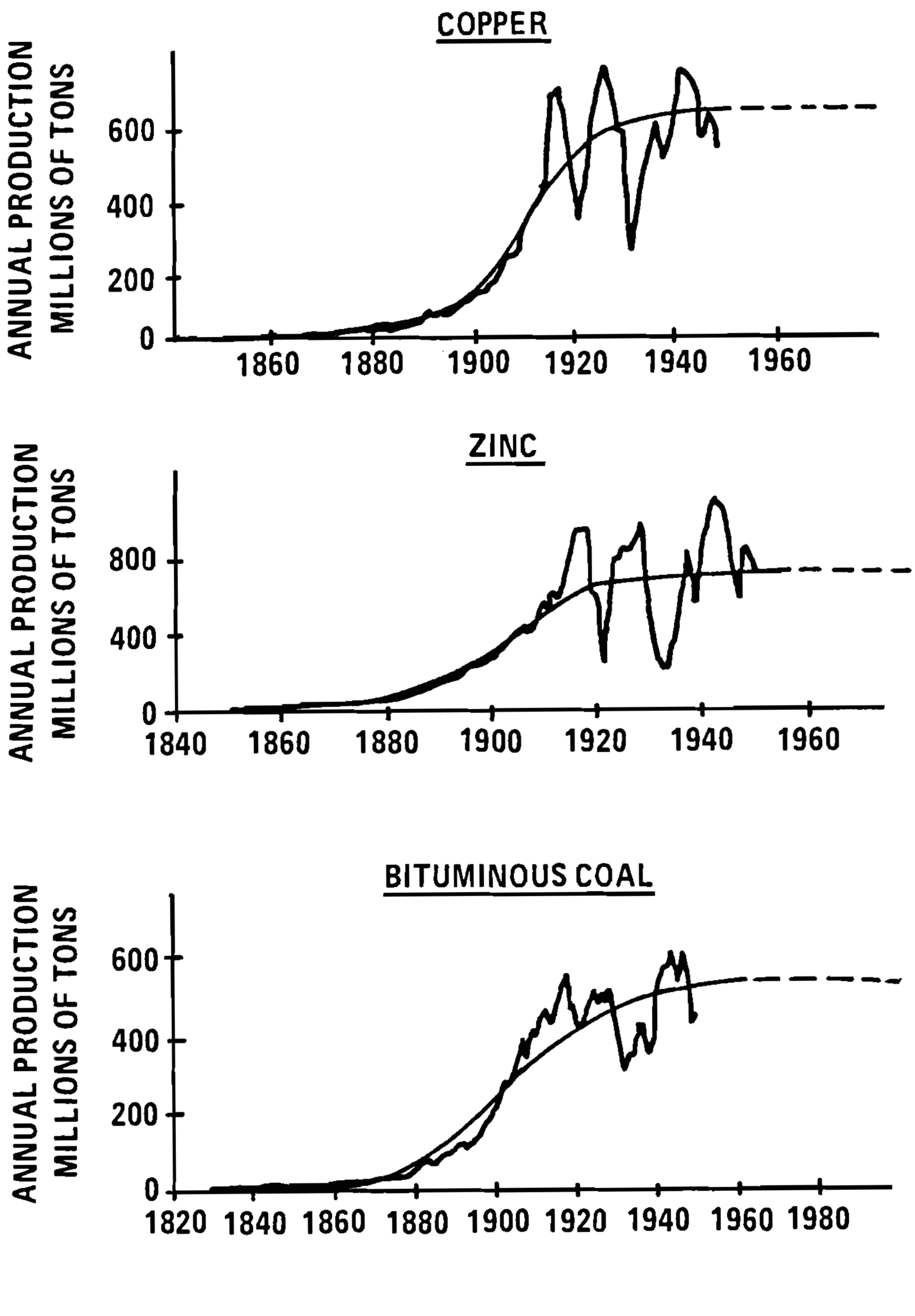

Figure 29.

These three examples from the mining industry in the US show how a very regular logistic progression can develop instabilities when the saturation point is approached.

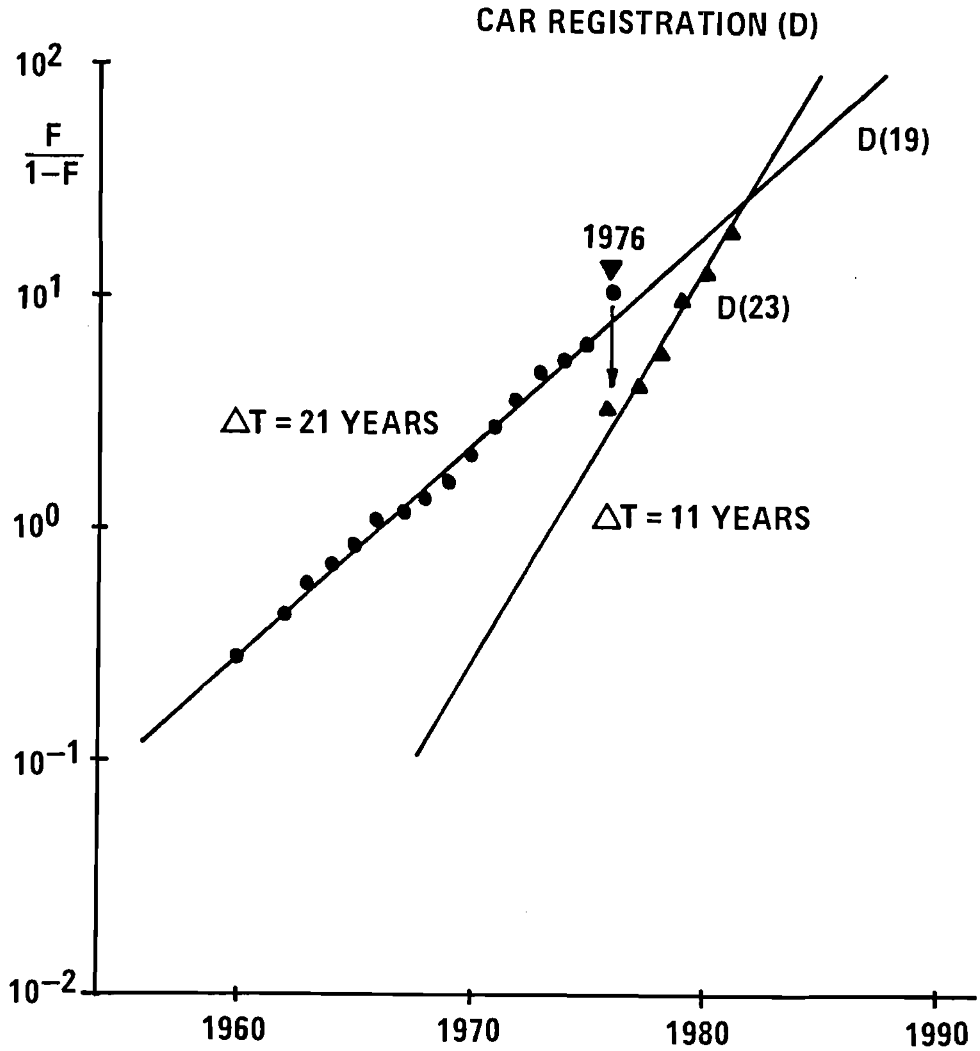

Figure 30.

The instability occurring with the West German car park has been analyzed separately, reaching for the new perceived saturation point (23 M), and time constant. I cannot say at this point whether this instability will resolve in an oscillatory behavior as in the three cases presented in Fig. 29, although I think it very probable.