ON TIME AND CRIME
A Quantitative Analysis of the Time Pattern of Social and Criminal Activities

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November 1985
WP-85-84

Invited paper. Annual Interpol Meeting, Messina, Italy, October 1985.

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Resume

Volterra analysis of economic and social behavior reveals a striking uniformity in the way structures behave. Including man, socially a single unit but intrinsically already a complex structure.

In this paper the analysis is focused on "deviant" behavior, showing that technically it is not different from "normal" behavior. The labeling seems to be basically determined by the dominant value system. The paper should be seen as an exploratory exercise to determine the limits of application of the Volterra-Lotka equations and paradigm.

ON TIME AND CRIME

A Quantitative Analysis of the Time Pattern of Social and Criminal Activities

Criminal activity has always been considered as a special case of social activity deserving a special treatment.

The criminal has been considered as the product of society, mental illness, genetics, or else, with a clear connotation of being deviant for reasons only partially under his control. Society tries to take control, and the prison can become the instrument of punishment or the tool of redemption, depending on the dominant paradigm at the time.

As I will show in the following, the criminal does not appear to behave differently from any person, except obviously for the fact the objectives of his activity being considered as criminal by the dominant part of society. So the mental illness paradigm which so strongly dominated last century's criminology, should not be considered as specific. Artists, housewives, or cadaster employees can be mentally ill, with no strict connection with their trade.

The methodology of my analysis is very simple, especially because I will not try to delve into the treacherous process of finding explanations. I will only search for "structures", for order, into the set of factual data. I will, in fact, only analyze facts, trying to see the features they contain. It is like looking through a person with x-rays. One can see bones and organs, without any hint about why these are where they are. The basic assumption is that actions are the final output of information processing in our brain, and that this processing follows some very general rules of Darwinian character, coded in a quantitative way by Volterra-Lotka equations.

These equations say, e.g., that the population dynamics of two competitors, or of one species with limited food supplies (self-competition), evolve in time according to certain very simple mathematical equations called logistics. Volterra equations can produce other solutions, but I will use only logistics for my diagnostics, first because they are very simple (see Appendix) and, second, because they cover an extremely large number of practical cases.

A case of logistic growth is reported in Figure 1. It represents a case of self-competition, like that of an animal species growing in a "niche", which provides a limited amount of food. In the case of Figure 1, the "population" of registered cars in Italy is reported. The niche in this case in the potential market for cars. Car population grows to fill it, first at a fast rate and then progressively at slower rates. Incidentally, the same curve describes the growth of a tree (height or weight), or of a person. Because these S-curves look all alike, and there is no way of visually checking they represent a logistic equation, I normally use another form of cohordinates, reported in Figure 2, where logistics appear as straight lines. As explained in the Appendix, the numbers characterizing the process are usually reported on the chart. They are:

- The saturation point, or the asymptote, i.e., the largest number of cars the market can receive, as in Figure 1. This number is usually given in parenthesis (20) in the appropriate units (millions in the case of cars in Italy).
- The time constant, which gives an idea of the speed of the process. It is the interval of time ΔT, to go from 10% to 90% of the niche. For cars in Italy it is 22 years.

- The centerpoint of the process is often referred to, in order to fix it in time.

This analysis can be applied to all sort of dynamic processes also with numerous competitors. We have, in fact, about a thousand different cases examined to date. The analysis is purely phenomenological. We try to fit the data to equations of the type described in the Appendix. A case of two competitors could be that of cars substituting horses for personal transportation, reported in Figure 3. In this case, the size of the niche is not necessary, as we are dealing with the ratios of the shares of the market. Actually, the niche keeps changing in time as shown in Figure 4. The numbers of personal vehicles grows exponentially in the U.S. during the period under examination and at the same time cars substitute for horses.

As the last example of this series I will give the case of competition between primary energies at the level of world market (Figure 5). Here we see all the energies going slowly up in market share, and finally down. The reasons for showing this particular case are:

- To get acquainted with the great slowness of social processes. Our society appears very dynamic, but the substitution of this for that takes eons.
- To make aware that these processes of acceptance and rejection are very stable in time. Wars, crises, and great inventions do not seem to change their progress.
- To show that this stability is a prerequisite to forecasting and give an example of forecasting in the long range.

Figures 6a, 6b, and 6c give the sequence of a forecasting exercise. The statistical data for the market shares of primary energies in 1900-1920 for the world are reported in Figure 6a. If we use these data to fit a set of competition equations (Figure 6b), we can extend those equations outside the 1900-1920 range. This can be considered as an attempt in forecasting, e.g., from 1920-1970, i.e., for fifty years ahead. We can then superpose the actual statistical data for that period to the equation in Figure 6c, to check how good we could have been in 1920. As the result show, the forecast would have been by all means an excellent one.

The central idea I want to support is that our society is a highly regulated and stable system. In order to show the same thing by a different process, the number of car traffic accidents in the U.S. between 1910 and 1970 is reported in Figure 7. The context of the analysis is always very important in such cases. The background idea here is that society sees the car as one of the many causes of death, and reacts in the appropriate way to keep it in check. So the appropriate measure is numbers of deaths per thousand population.

The very interesting result is that this number is 25 per hundred-thousand population and per year, *independent from the number of cars*. It shows what society is ready to take and no more. Incidentally, as Figure 8 shows, most Western countries are locked to the same level of deaths! This shows also that police action must be contextual. No measure can counterbalance the "readiness to die" of the drivers.

The high level of self-regulation of large aggregate systems has led to the question of regulation at lower levels of aggregation. Jumping through many intermediate levels, like nations and regions, we went to the formally most simple form of organization, the commercial company. The objective of that company is to sell a product or a service, and the amount sold can well be considered as a measure of its size. Figure 9 shows the case for Mercedes-Benz, were the number of cars produced is reported as a fraction of the (calculated) saturation point. The exercise has been repeated for about a hundred companies and the result has been always positive.

A company can be seen as a formally organized set of people with a definite purpose to reach. Producing cars, or organizing vacations. There is no *a priori* hindrance to treat a criminal organization in the same way. Figure 10 reports the "actions" performed by the "Red Brigades" in Italy during the period 1970-1976. The chart reports the cumulative number of actions, treated as described in the Appendix. The Red Brigade movement appears perfectly quantified by the equation. With a six-year time constant, it appears relatively ephemeral. The equation *forecasts* (in 1976!) the end of the movement (99% of actions performed) in 1985. The peak of their power was reached in 1976-77, and the decline was *built in* into the system. In other words, organizations seem to have an intrinsic aging process, which can be interesting to measure, as we have done here, in order to deal appropriately with them. At the level of the police or at the level of the stock exchange, depending on the objectives of the organization.

Just for systematic reasons, one can ask if man, so complex and composite in many ways, does not contain similar organized structures inside himself. After all, he is the prime mover on one side, and on the other his brain contains billion of interactive cells, the neurons. Obviously we have to quantify his actions through some form of output, and this is not difficult for such "public" men, like artists or scientists. Their work is carefully catalogued. So I started analyzing artists and men of science, looking at the cumulative number of their work: paintings, plays, pieces of music, or scientific publications.

A pick of the results is given in Figures 10a, 10b, 10c and 10d. What these results say is that their production is regulated according to a precise schedule. Each of them has a mechanism incorporated telling how much and when. Our equation just unravel the mechanism. And because the equation can be established on a partial set of data, it can be used, e,g, to predict how many books a famous writer *will* produce, and *when*. It is well known that we are genetically programmed in a quite rigorous form, but this long term programming of the *vis vitalis* may come as a surprise. I do not think, owever, that at this level it interferes too much with the holy cow of the "free will".

My purpose here is practical and not philosophical, and the objective is to see the applicability of the methodology to a systematic study of criminal behavior. I do not think criminals are different in the mechanisms of their behavior. Only their objectives are not orthodox. Criminality then is not intrinsic, but comes from a social definition. To use a worn out example, murder is criminal in peace but heroic in war. So the analysis should apply to criminal activity too, As Figures 11a, 11b, 11c, 11d, and 11e show, this is the case. The criminal has a potential, a bag of beans, which he will dutifully spill. Although the final proof requires a large casistic, which requires your collaboration in providing data, it appears that prison does not have an effect on the global result. The incapacitating periods appear compensated by increased activity once the bird is out of the cage. This hard will to comply with the program and the schedule makes the criminal forecastable. His past activity contains the information to map the future one, in the same sense a segment of the trajectory of a bullet can be used to calculate the previous part and the following part.

Because my analysis can be done only after a sizable chunk of the career has been explicated, I cannot make any statement why the gun was originally aimed in a "deviant" direction. It seems evident, however, that measures to really reduce criminality have to be taken *before* a person becomes a criminal.

After having brought the analysis down to the individual I will try it again on an aggregate case, not of a gang, however, but on a population. The case of criminality against the property in the U.S. is reported in Figure 12. It just counts the number of people arrested according to age. The raw sum appears to be a composite, of juvenile, young, and long-term professional activity. I tried to separate the juvenile component through the first bell-shaped curve drawn onto the chart.

This part of the criminality curve is then analyzed in Figure 13. The second part of the curve in Figure 12 is not drawn by free hand. It is calculated using the first part and the usual logistic equation. Apart from the descriptive and organizing aspect, this chart also tells that whatever is done to keep in check this criminality, the effect appears to be zero.

On the other side, I would also attract your attention on social forces and moods which on the contrary strongly influence the level and the modes of criminality. The case is reported in Figures 14 and 15. The oscillating curve of the top is a "clock" measuring social activity. The curve in fact describes the deviation from the trend of energy and electricity consumption. Loosely speaking, the upward parts of the curve represent periods of boom, and the downward parts periods of recession. The second curve down represents the *rate* of homicides. I took homicides because I think their statistic is more credible and homogeneous over the long term than the statistics referring to other crimes. The homicide curve has a period of about 54 years, like energy, but it is out of phase. In fact, the maximum of homicides is in the middle of recession and the minimum in the middle of the boom. The ratio between maximum and minimum is an incredible factor of two.

The second still moodier side of the story is reported in the third curve down, telling the ratio of guns to knives in the execution of the homicide. Also this oscillates with a period of about 55 years, and with a ratio between maximum and minimum of a factor of three! The curious point is that during the boom period, people tend to shoot, and during recession tend to stab. Also the ratio of female to male murdered has similar long-term pulsations. Analogous considerations could be done for the analysis of suicides, which I consider a special form of homicide. In this case, the most striking feature is the 26-year sharp pulsation of the ratio female to male suicides.

This zooming up and down inside our society shows an unexpected level of self-control and a very self-consistent behavior. This leads to predictable behavior of numerous intermediate structures, from man to humanity.

How to exploit these features is just a question of imagination. Predicting when a certain criminal, specialized in a certain type of crime, is "ripe" for an operation, can help preparing the appropriate reception. Or, after the fact, to restrict the rose of the possible actors.

To see inside the clockwork of a criminal band or terroristic organization may greatly help in setting up a tuned strategy. To have a way to calculate the *natural* deployment of criminal activity can serve to measure rapidly the effects of initiatives against criminality. So often in the past the effect of these initiatives could be assessed only after tens of years.

In a nutshell, I hope this may contribute to improve the rational control of the system.

References

Marchetti, C. (1980) Society as A Learning System: Discovery, Invention, and Innovation Cycles Revisited. *Technological Forecasting and Social Change 18*:267-282.

Marchetti, C. (1983) On a Fifty Year Pulsation in Human Affairs: Analysis of Some Physical Indicators. PP-83-5. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Marchetti, C. (1983) The Automobile in a System Context: The Past 80 Years and the Next 20 Years. *Technological Forecasting and Social Change 23*:3-23.

Winfree, A.T. (1980) The Geometry of Biological Time. Berlin-Hamburg-New York: Springer Verlag.

Simonton, D.K. (1984) Genius, Creativity and Leadership. Cambridge, Mass.: Harvard University Press.

Marchetti, C. (1983) On the Role of Science in the Post-Industrial Society: "Logos – The Empire Builders". *Technological Forecasting and Social Change 24*:197-206.

These references are basically limited to my connected work. Literature on the application of Volterra-Lotka equations is vast and easily retrievable. Two general references can be the following:

Goll, N.S. *et al.* (1971) On the Volterra and Other Nonlinear Models of Interacting Populations. *Rev.Mod.Physics 43*(2):231.

Gatto, M. (1985) Introduzione all'ecologia delle popolazioni. Milano: CLUP.

Appendix

The formal derivation of the equations used to fit the dynamics of competition is from the *Volterra equations*, which basically say ***big fish catch small fish*** when the opportunity comes. There is a vast literature about Volterra-Lotka differential equations, and their discussion will not be reported here. The basic growth equation ,which is used in most of the charts, is a special solution of the Volterra-Lotka equations and is actually a logistic function of the type shown in Figure 1. This equation can be written in the form

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

where N is the cumulative number of objects observed, e.g., number of crimes committed by a certain person up to time t. The curve has a maximum (asymptotic) value $\bar{N}$. It is the upper line in Figure 1. $\bar{N}$ and the constants a and b have to be calculated by best fitting the available data in form of the value of N at various times. Most of the charts are normalized by using F = N/$\bar{N}$ so measuring the process in relative terms.

Equation (1) then can be rewritten in the form

$$\log\frac{F}{1-F} = at + b \quad . \tag{2}$$

and appears in the charts as a straight line. The transformation greatly facilitates the graphic handling and use of the data.

The fitting is done by iteration, choosing $\bar{N}$ arbitrarily, and then improving the fit by changing it. The physical meaning of *a* is that of a rate, i.e., the speed at which the process occurs. In the chart it is given in the more intuitive form of a rate constant, i.e., the time for N to go from 10% to 90% of $\bar{N}$.

The constant *b* is merely a time cursor to position the process in calendar time.

The year of maximum process speed is midway when F = 1 - F or $N=\frac{1}{2}\bar{N}$. This point is often marked in the chart. The first data points are sometimes below the equation line. I usually interpret this as a "catch up". The person has the drive but not the means, e.g., when he is very young. When the means come, then the time lost is made good in a fast dash.

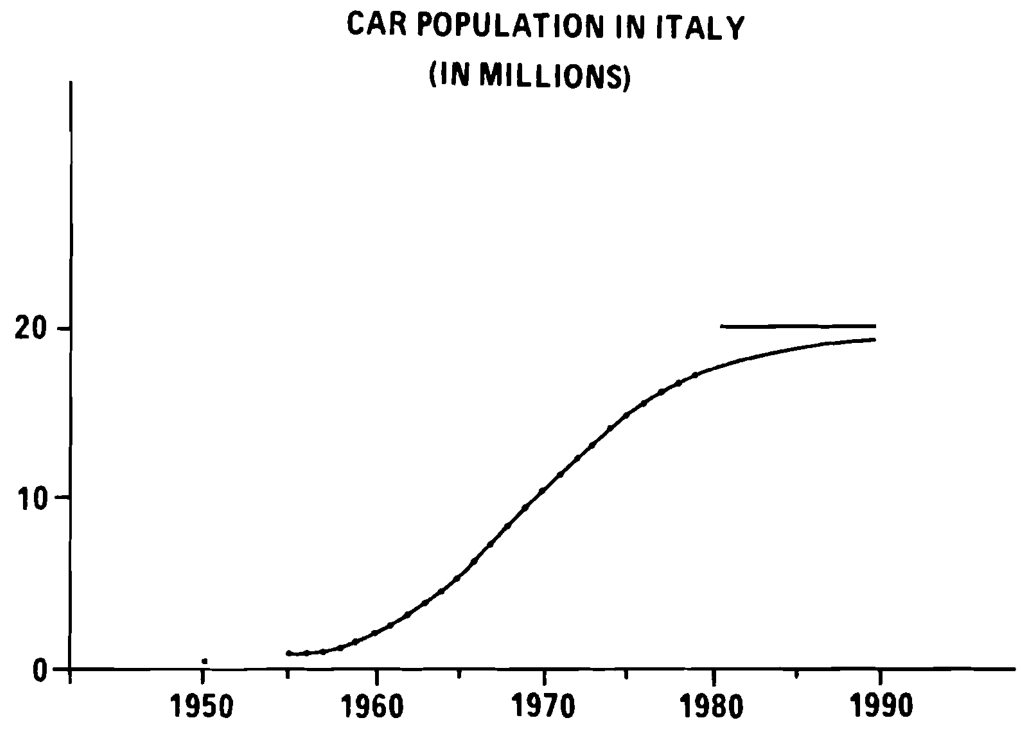

CAR POPULATION IN ITALY
(IN MILLIONS)
20
10
0
1950
1960
1970
1980
1990

Figure 1

CAR REGISTRATION – ITALY (20)

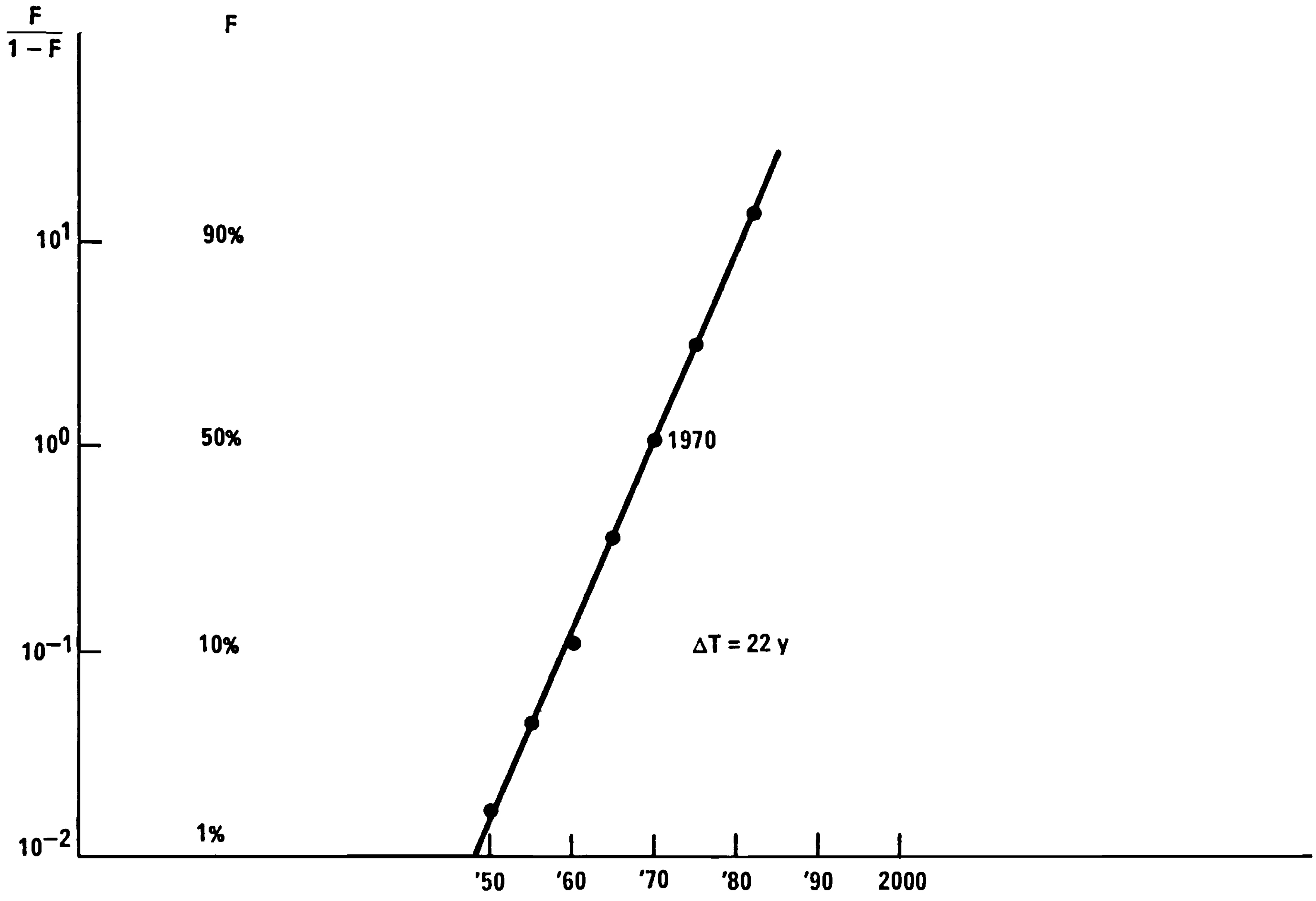
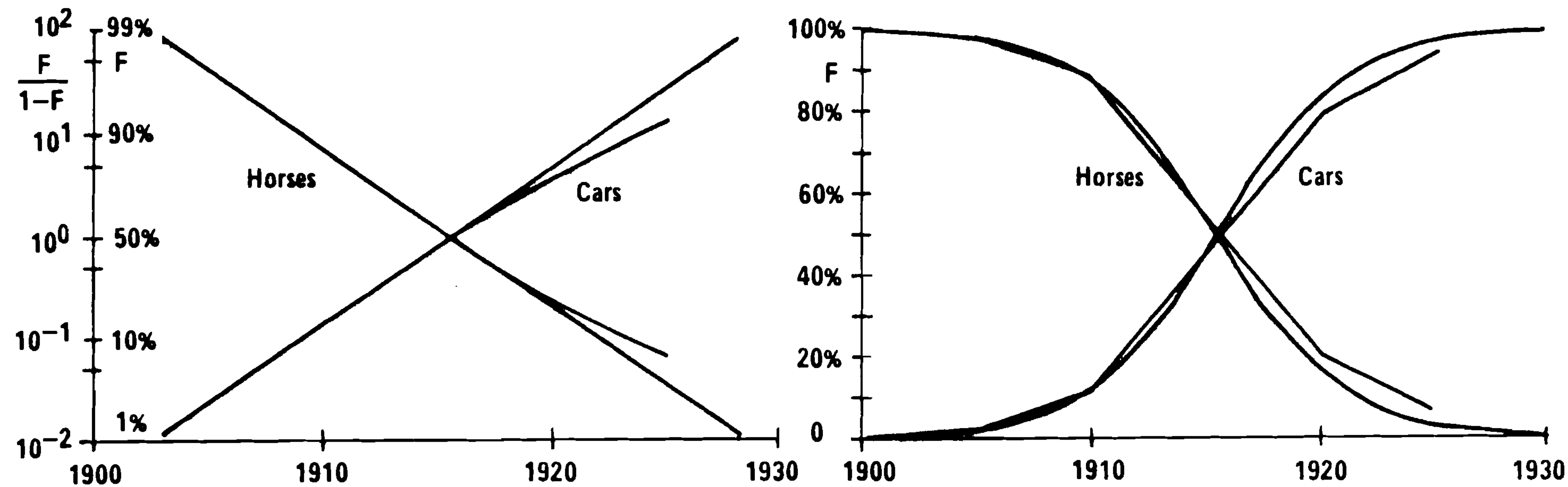


Figure 2

USA – SUBSTITUTION OF HORSES BY AUTOMOBILES



N. Nakicenovic, IIASA, 1985

Figure 3

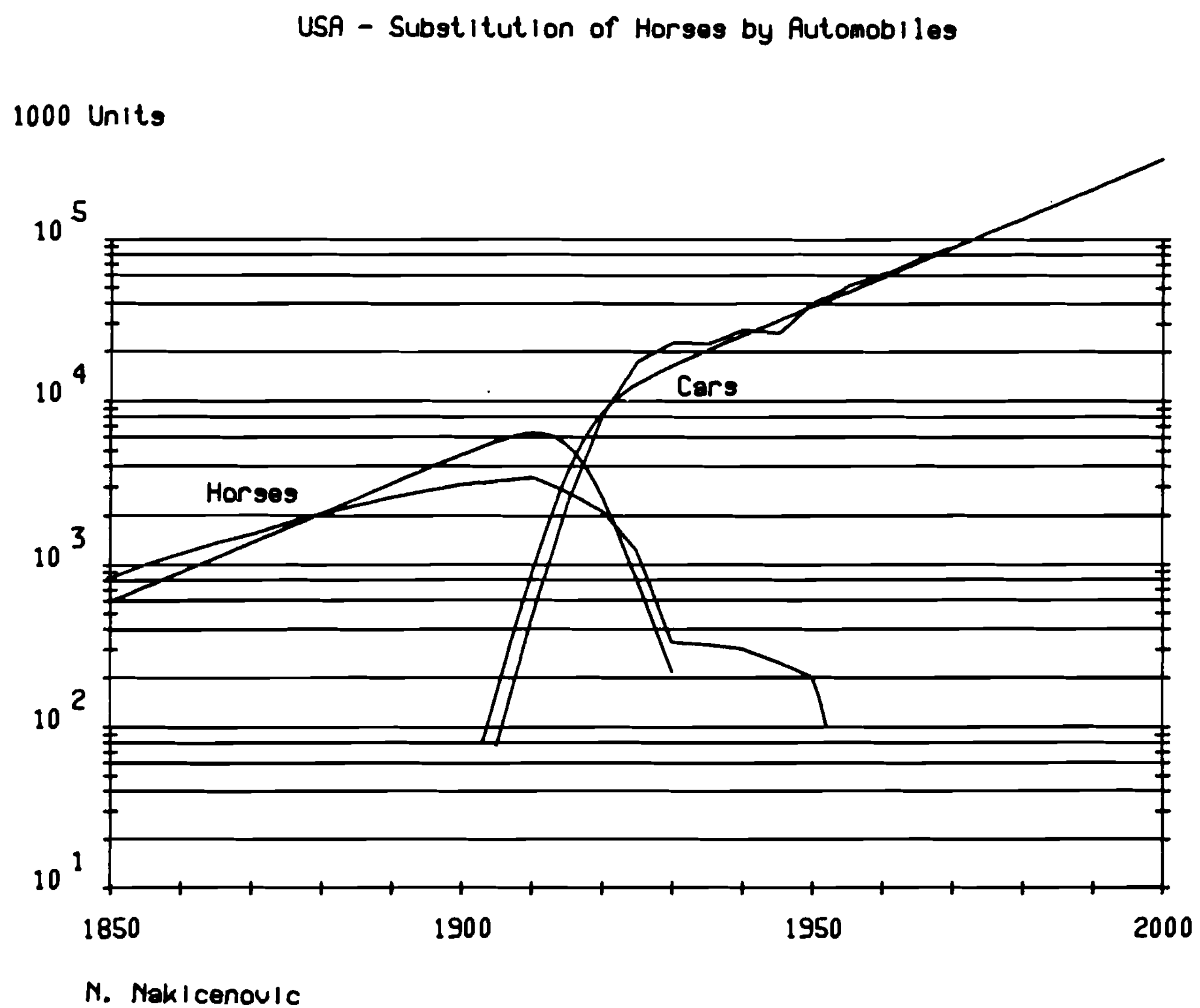

USA - Substitution of Horses by Automobiles
1000 Units
10^5
10^4
10^3
10^2
10^1
Cars
Horses
1850
1900
1950
2000
N. Nakicenovic

Figure 4

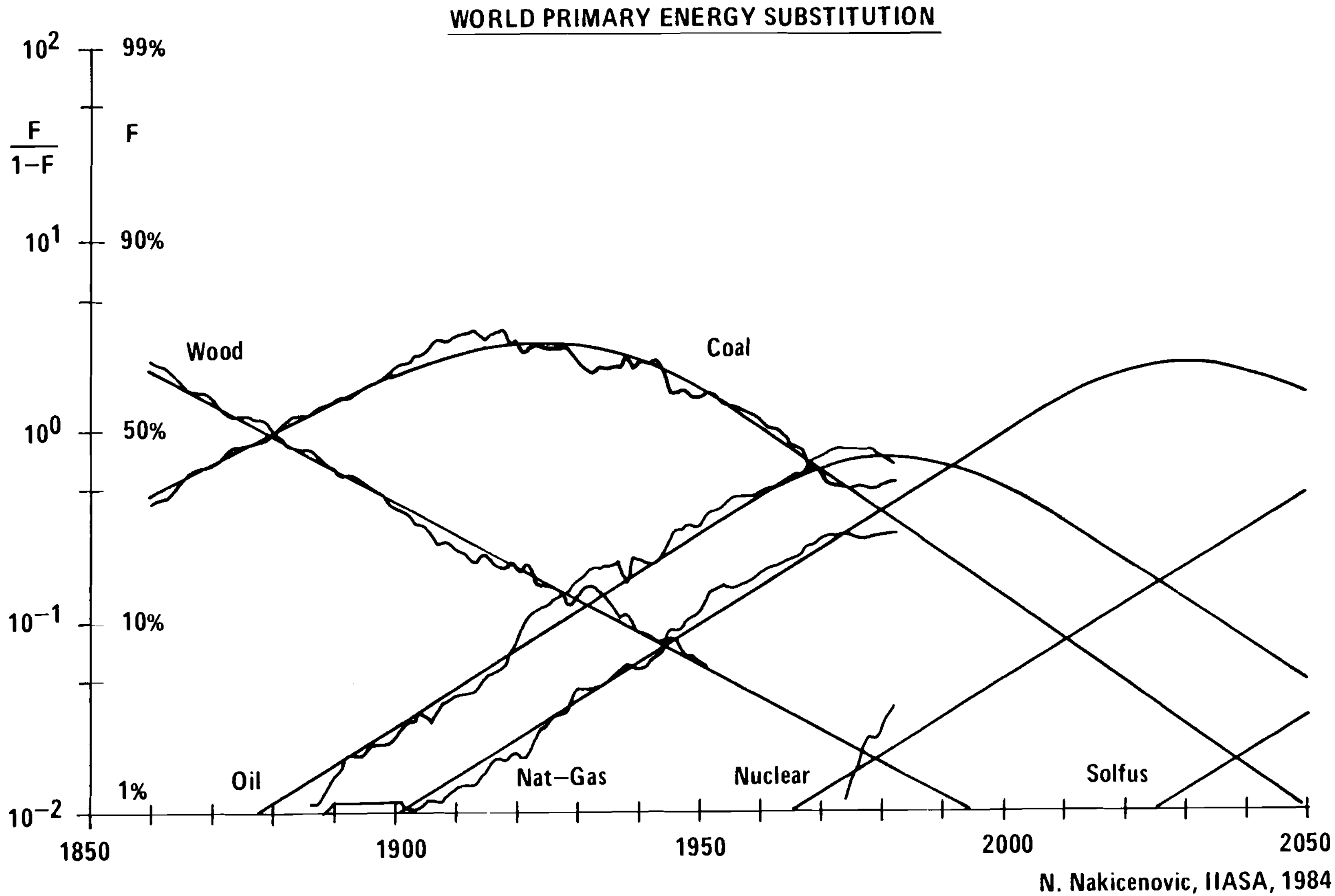
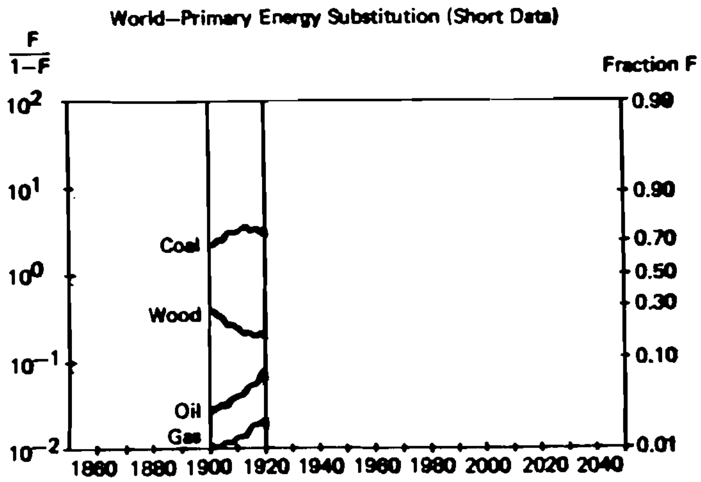
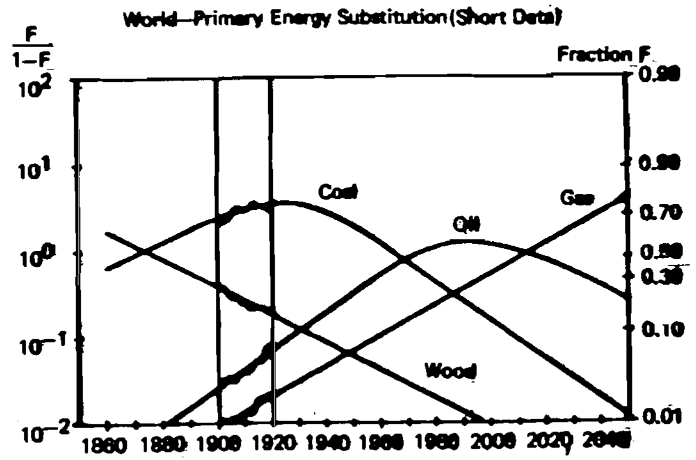
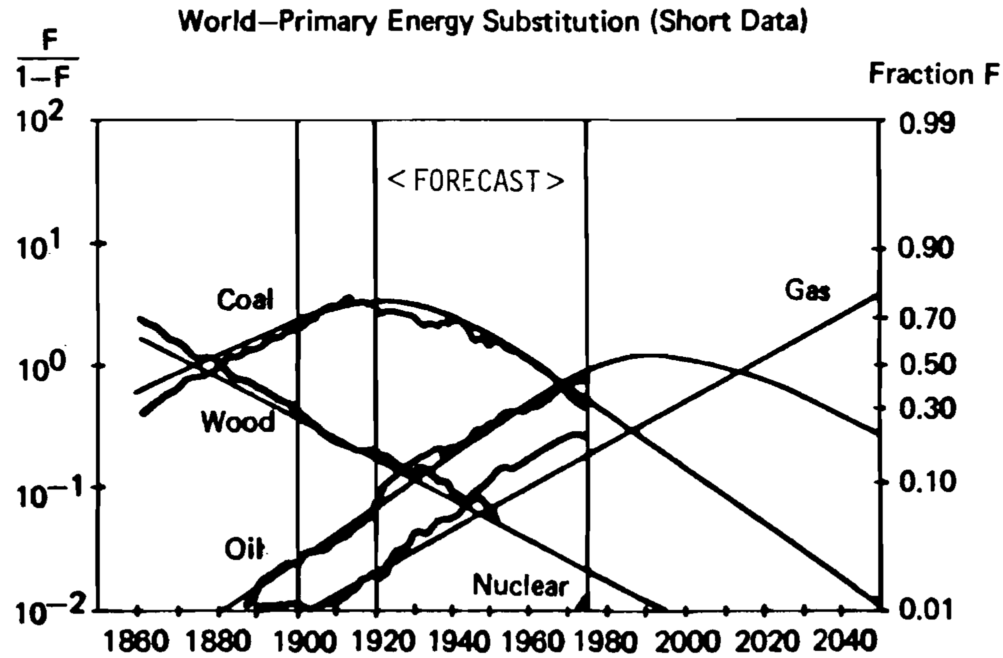

WORLD PRIMARY ENERGY SUBSTITUTION
10^2
99%
$\frac{F}{1-F}$
F
10^1
90%
10^0
50%
10^{-1}
10%
10^{-2}
1%
Wood
Coal
Oil
Nat–Gas
Nuclear
Solfus
1850
1900
1950
2000
2050
N. Nakicenovic, IIASA, 1984

Figure 5







Figures 6a, 6b, and 6c

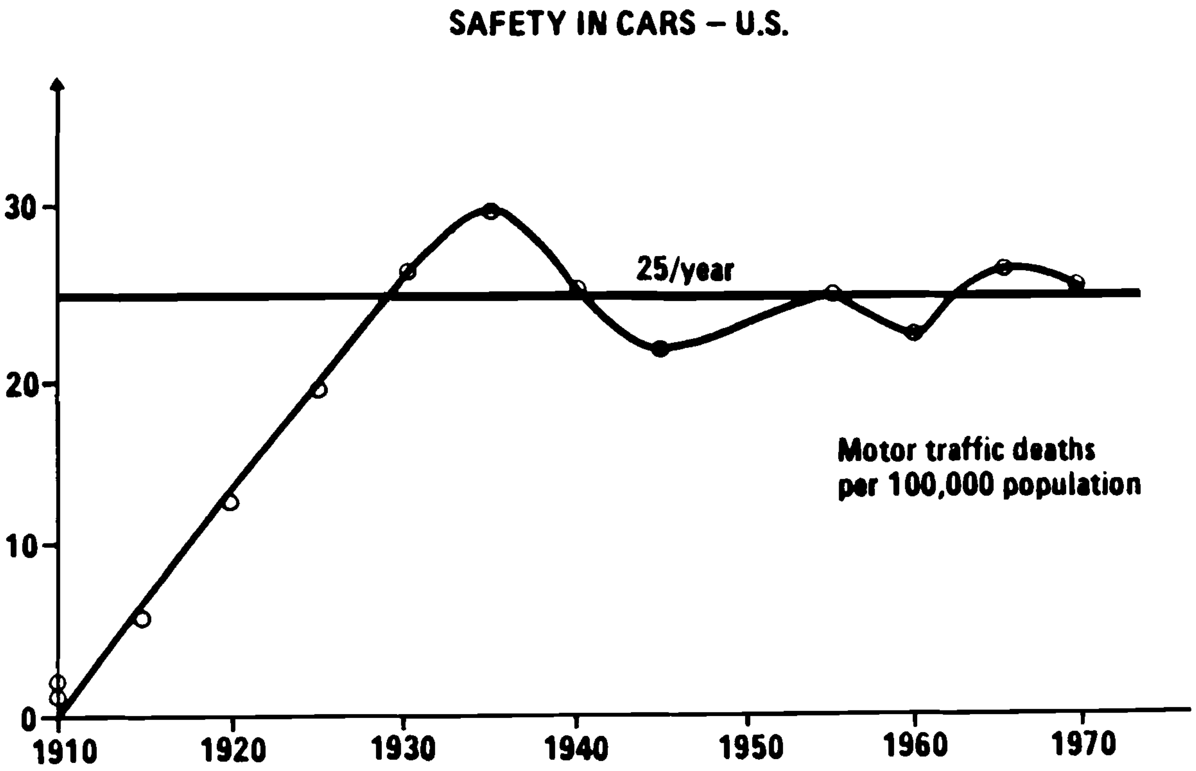

SAFETY IN CARS – U.S.
25/year
Motor traffic deaths
per 100,000 population
0
10
20
30
1910
1920
1930
1940
1950
1960
1970

Figure 7

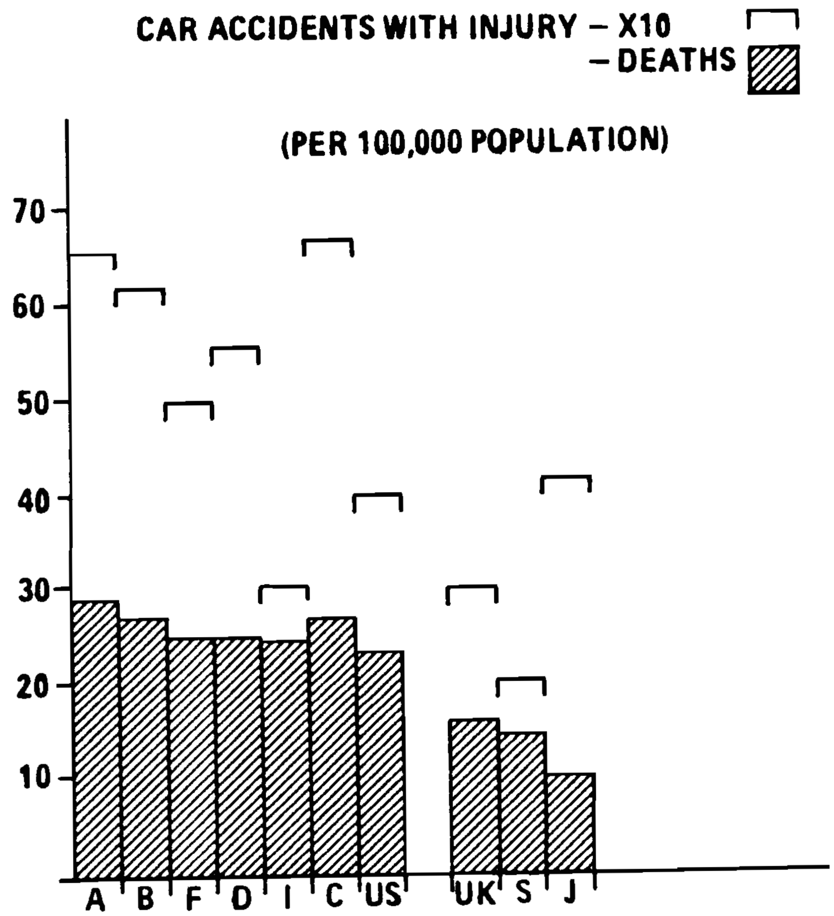

CAR ACCIDENTS WITH INJURY – X10
– DEATHS
(PER 100,000 POPULATION)
70
60
50
40
30
20
10
A
B
F
D
I
C
US
UK
S
J

Figure 8

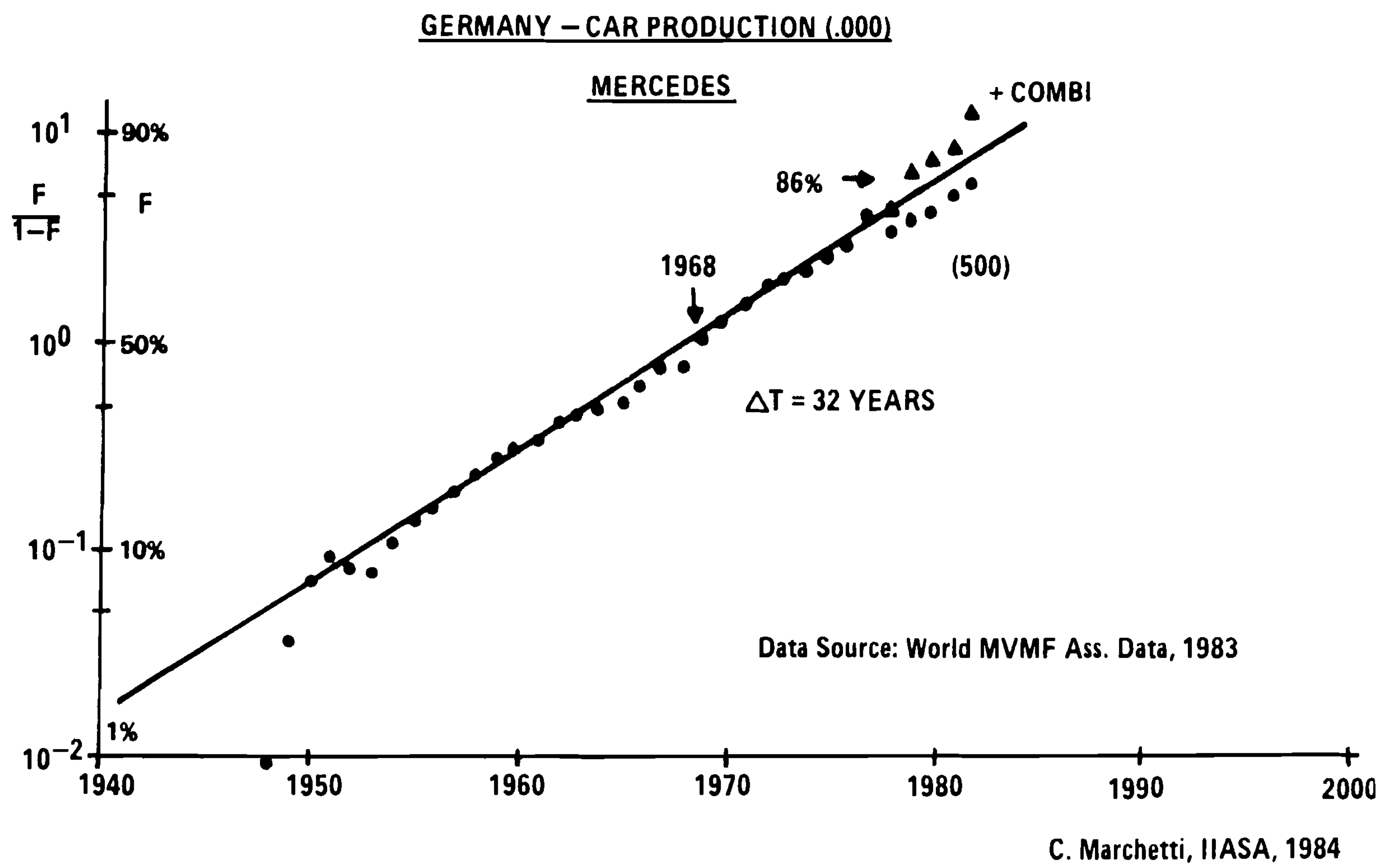

GERMANY – CAR PRODUCTION (.000)
MERCEDES
+ COMBI
86%
1968
(500)
ΔT = 32 YEARS
Data Source: World MVMF Ass. Data, 1983
10^1
10^0
10^-1
10^-2
F/(1–F)
90%
F
50%
10%
1%
1940
1950
1960
1970
1980
1990
2000
C. Marchetti, IIASA, 1984

Figure 9

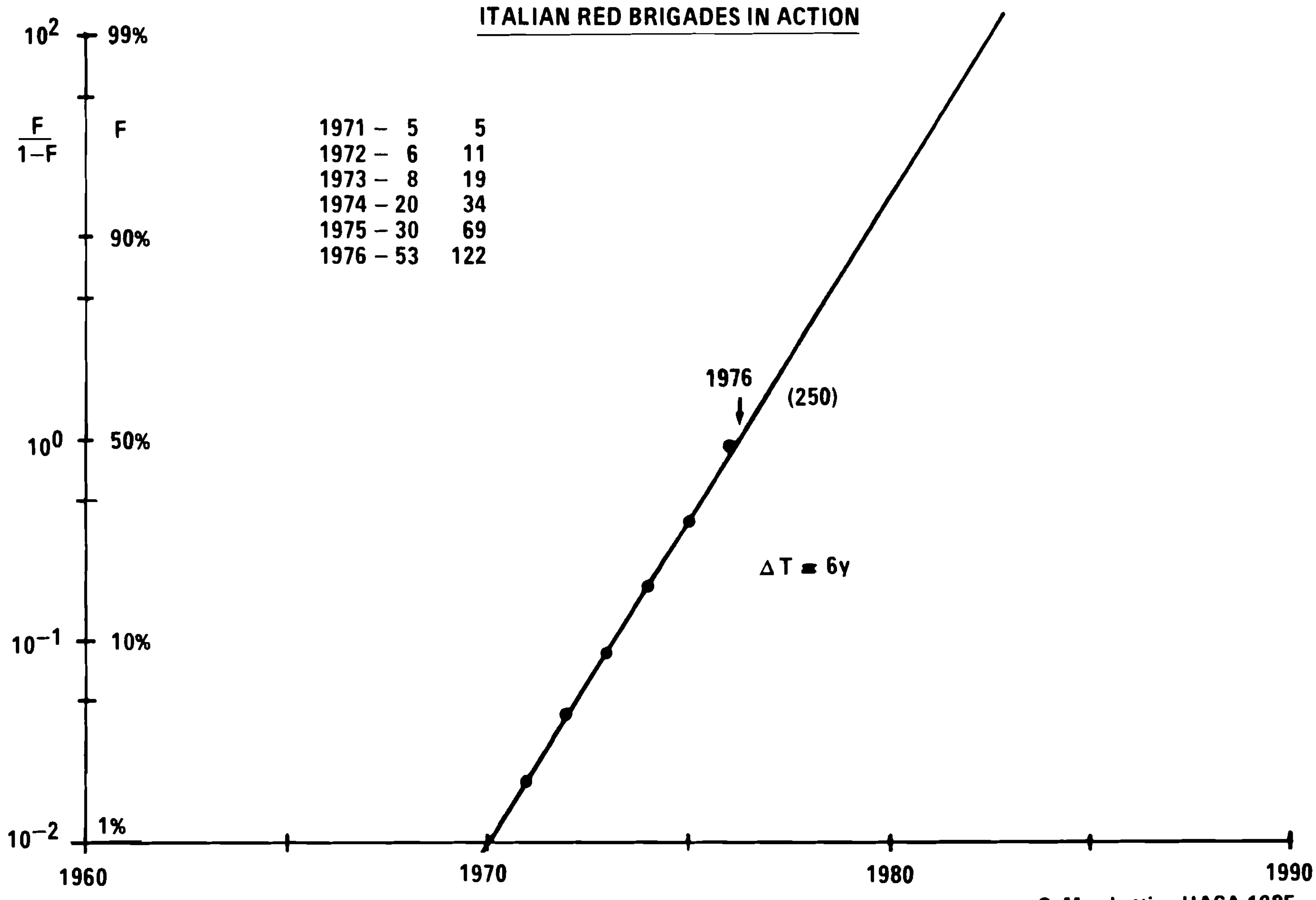
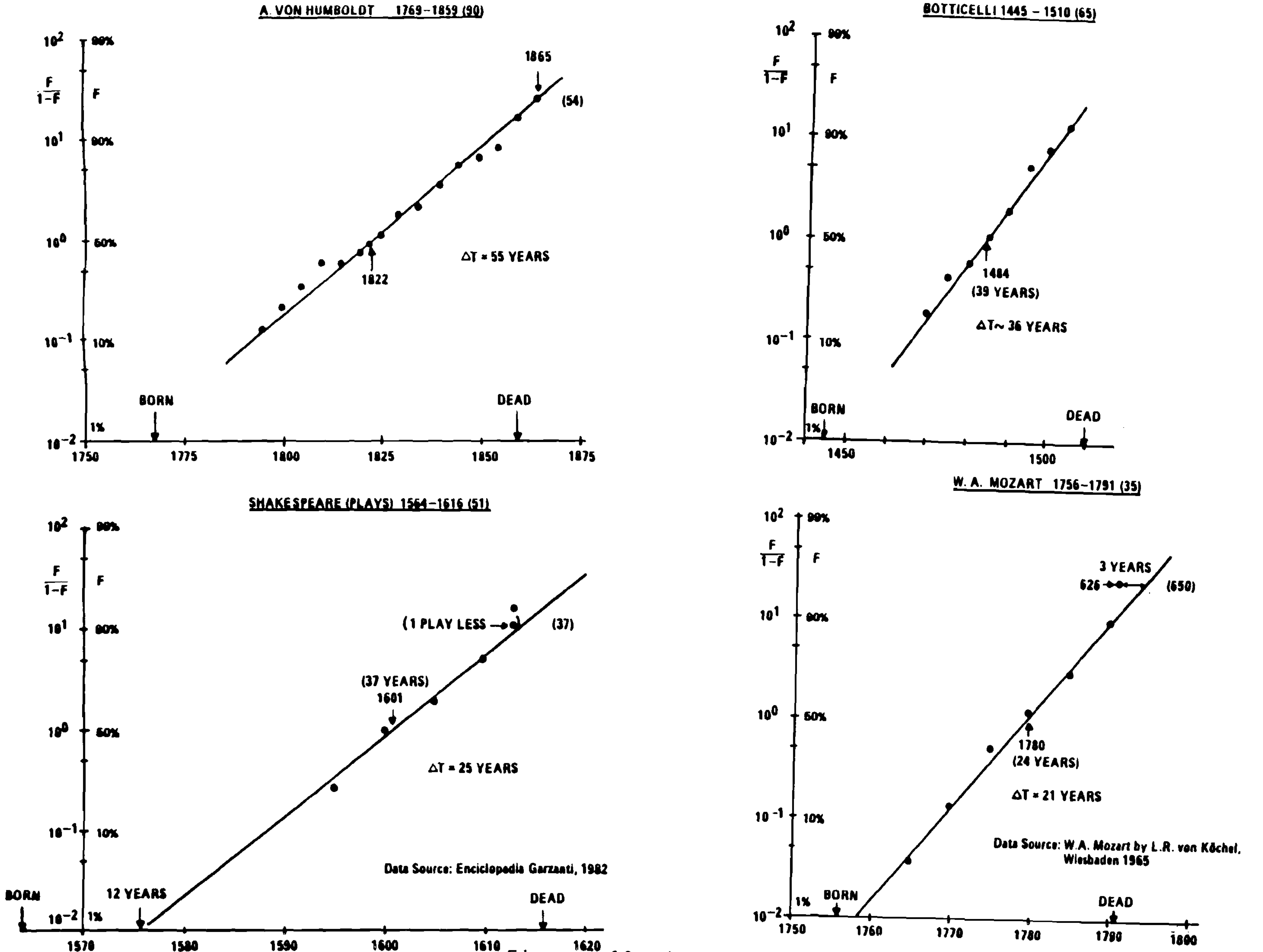
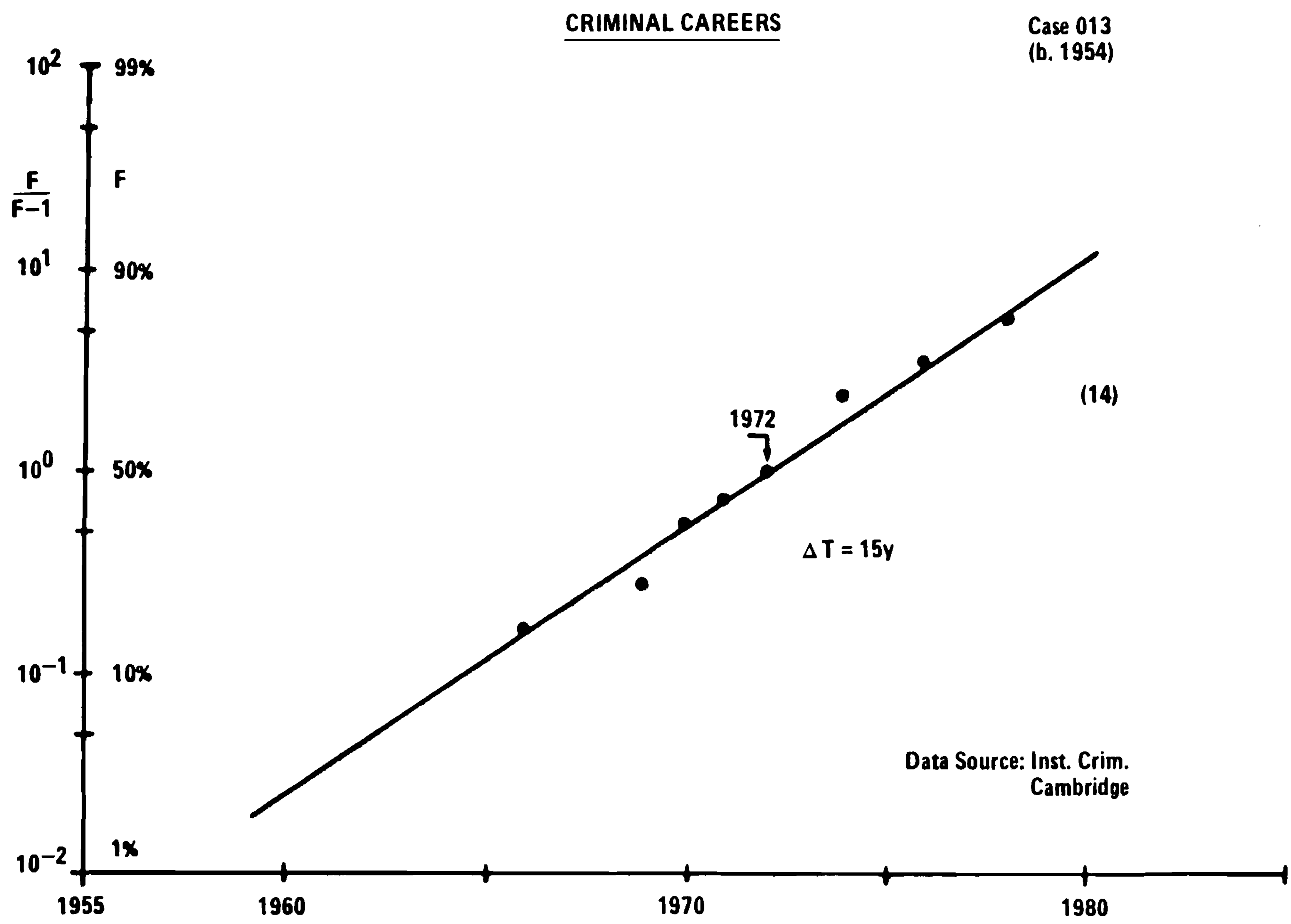

ITALIAN RED BRIGADES IN ACTION
10^2
99%
$\frac{F}{1-F}$
F
1971 – 5 5
1972 – 6 11
1973 – 8 19
1974 – 20 34
1975 – 30 69
1976 – 53 122
90%
10^0
50%
1976
(250)
$\Delta T = 6y$
10^{-1}
10%
10^{-2}
1%
1960
1970
1980
1990
C. Marchetti – IIASA 1985

Figure 10

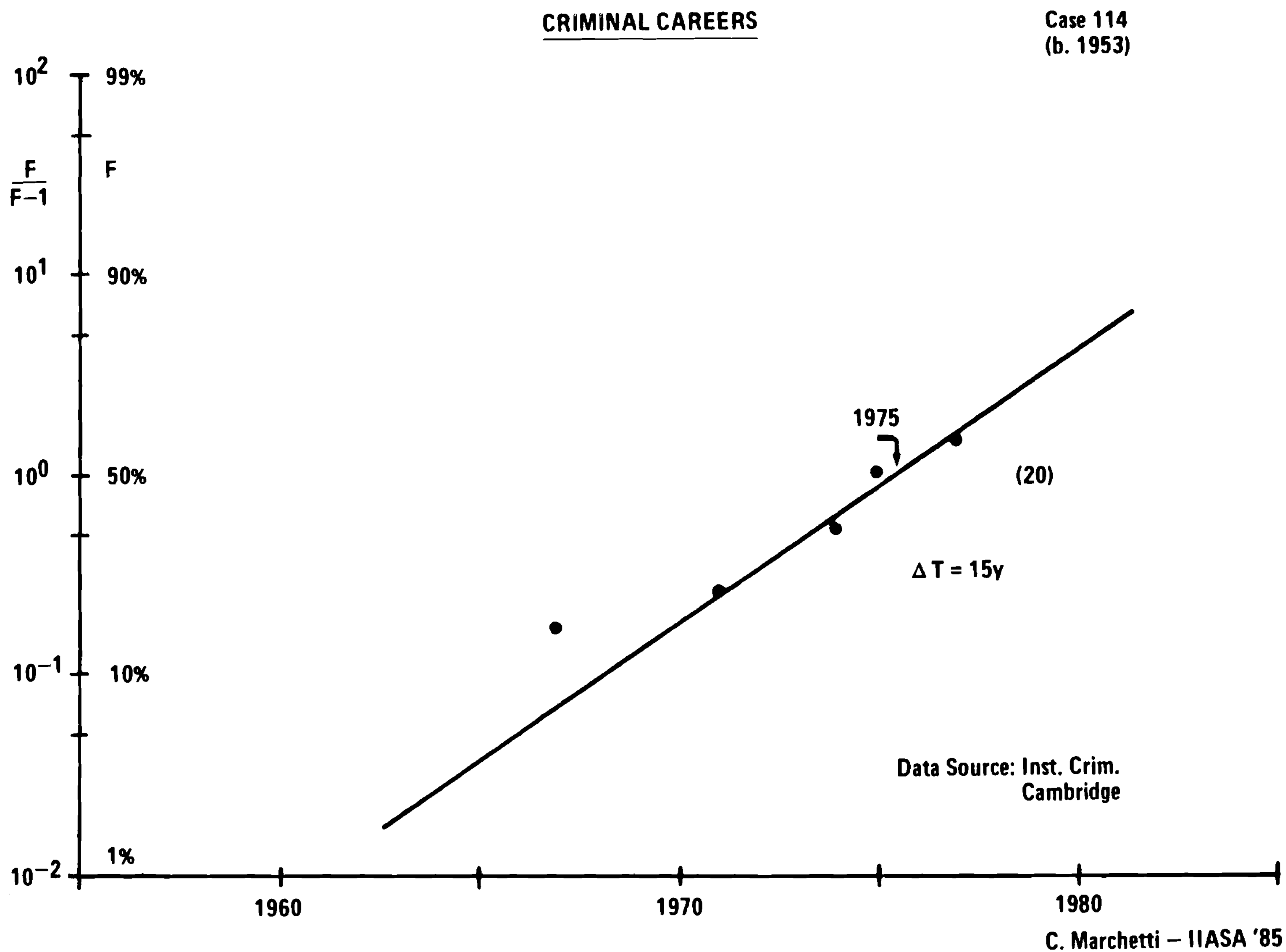


Figures 10a-d



CRIMINAL CAREERS
Case 013
(b. 1954)
10^2
99%
F/F−1
F
10^1
90%
10^0
50%
10^−1
10%
10^−2
1%
1972
ΔT = 15y
(14)
Data Source: Inst. Crim. Cambridge
1955
1960
1970
1980
C. Marchetti – IIASA '85

Figure 11a



CRIMINAL CAREERS
Case 114
(b. 1953)
10^2
99%
$\frac{F}{F-1}$
F
10^1
90%
10^0
50%
10^{-1}
10%
10^{-2}
1%
1975
(20)
ΔT = 15y
Data Source: Inst. Crim. Cambridge
1960
1970
1980
C. Marchetti – IIASA '85

Figure 11b

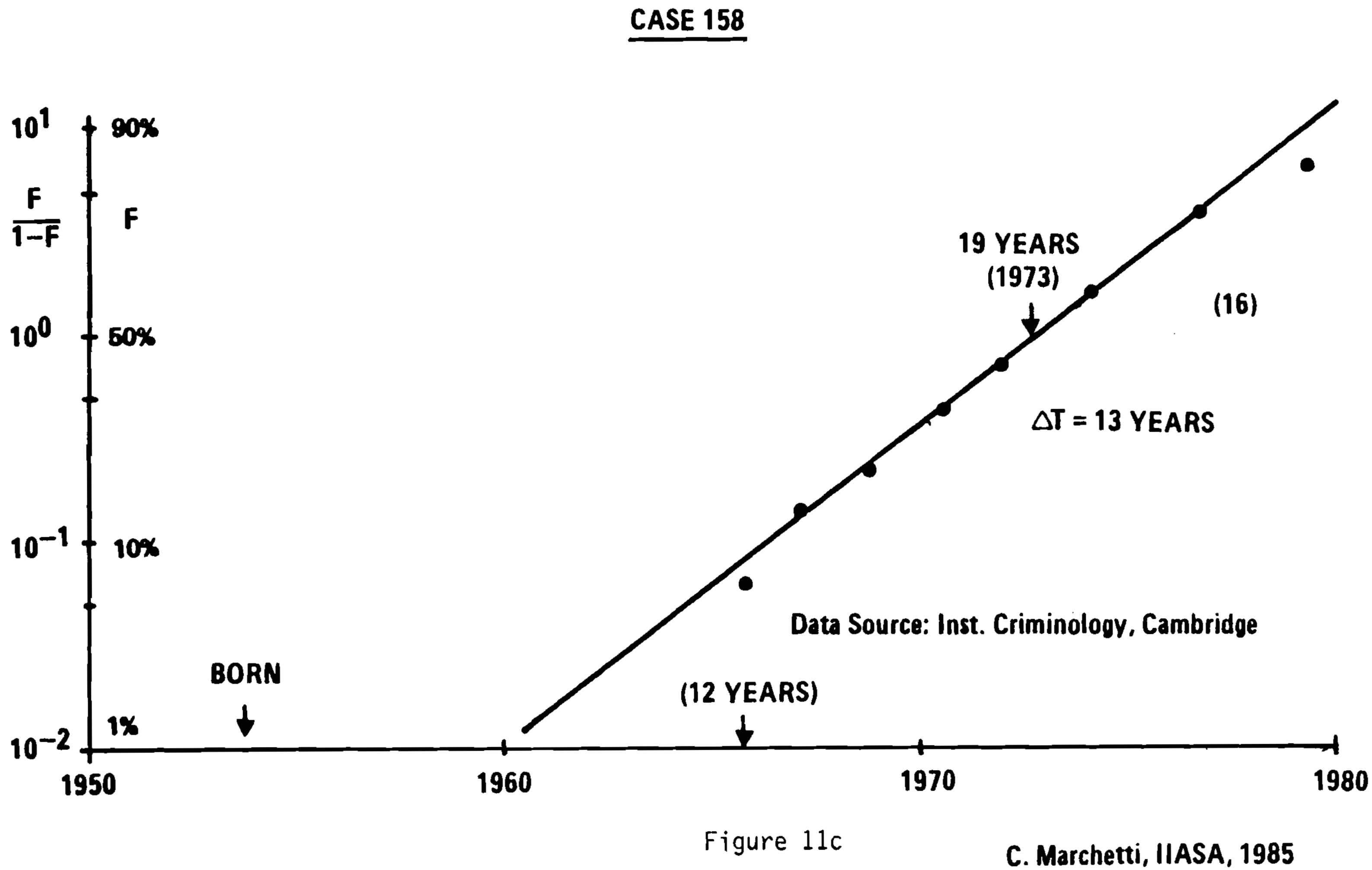

CASE 158
10^1
$\frac{F}{1-F}$
10^0
10^{-1}
10^{-2}
90%
F
50%
10%
1%
BORN
(12 YEARS)
19 YEARS
(1973)
(16)
$\Delta T = 13$ YEARS
Data Source: Inst. Criminology, Cambridge
1950
1960
1970
1980
C. Marchetti, IIASA, 1985

Figure 11c

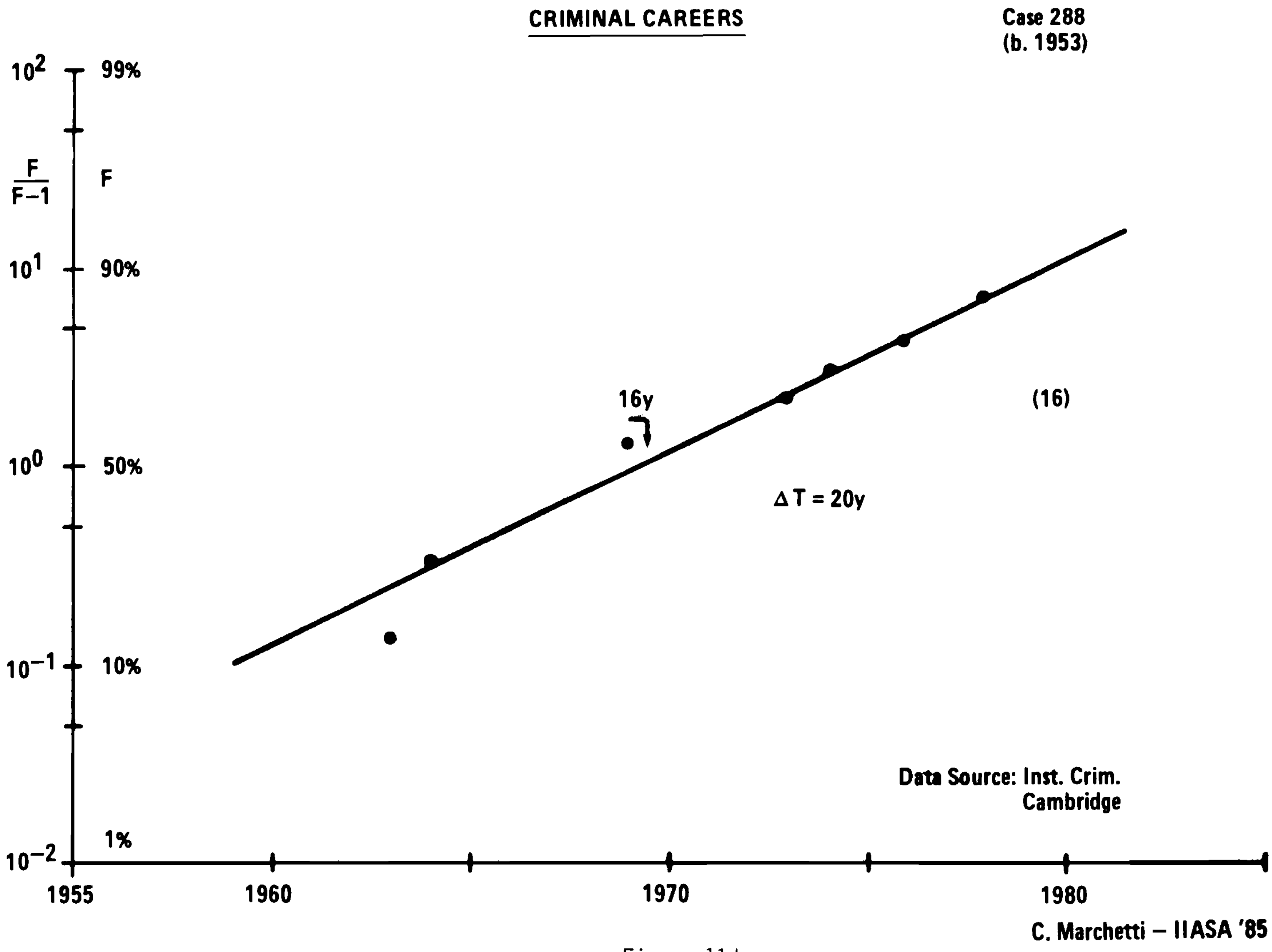

CRIMINAL CAREERS
Case 288
(b. 1953)
10^2
99%
F/F−1
F
10^1
90%
10^0
50%
10^−1
10%
10^−2
1%
16y
(16)
ΔT = 20y
Data Source: Inst. Crim.
Cambridge
1955
1960
1970
1980
C. Marchetti – IIASA '85

Figure 11d

CRIMINAL CAREERS

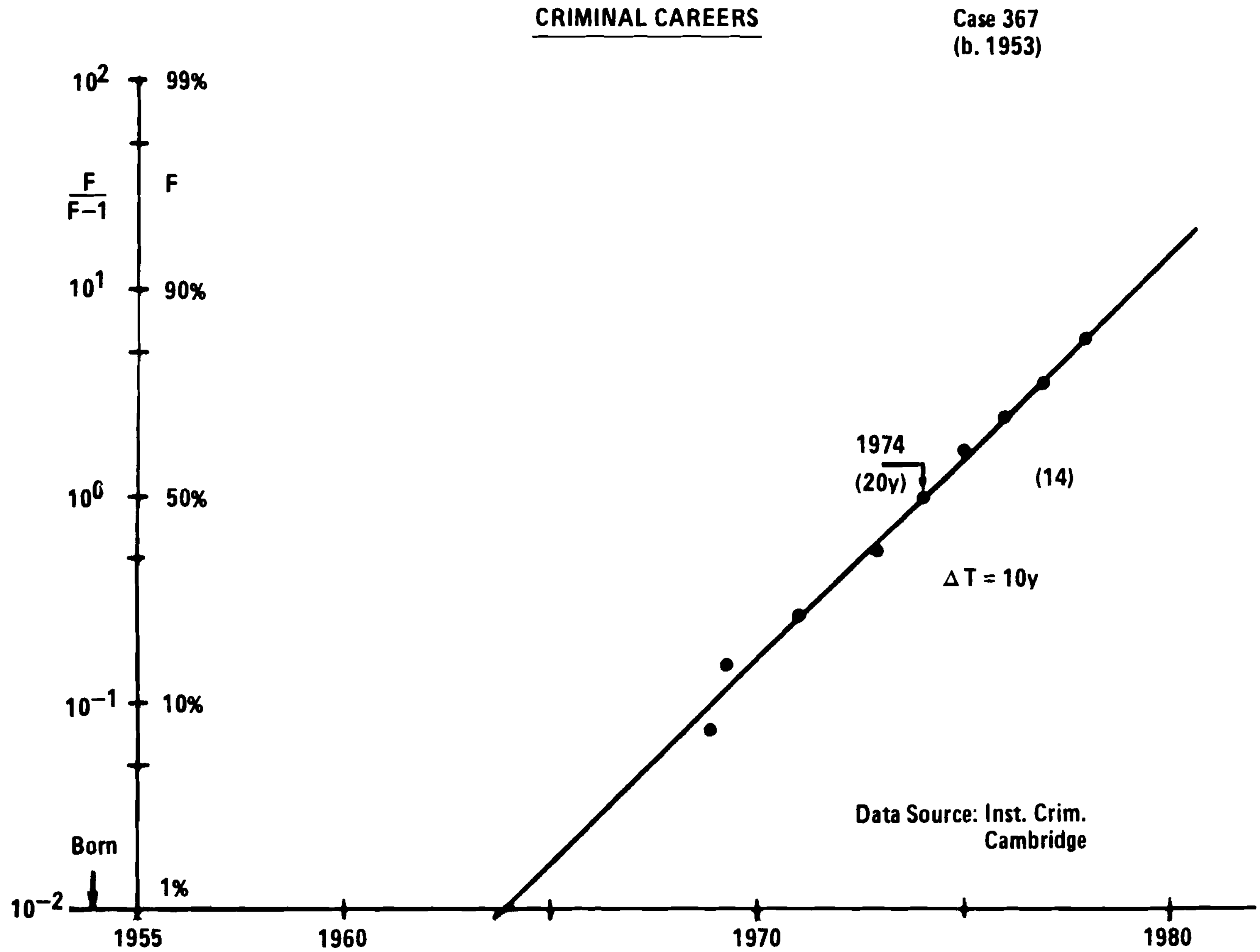


Figure 11e

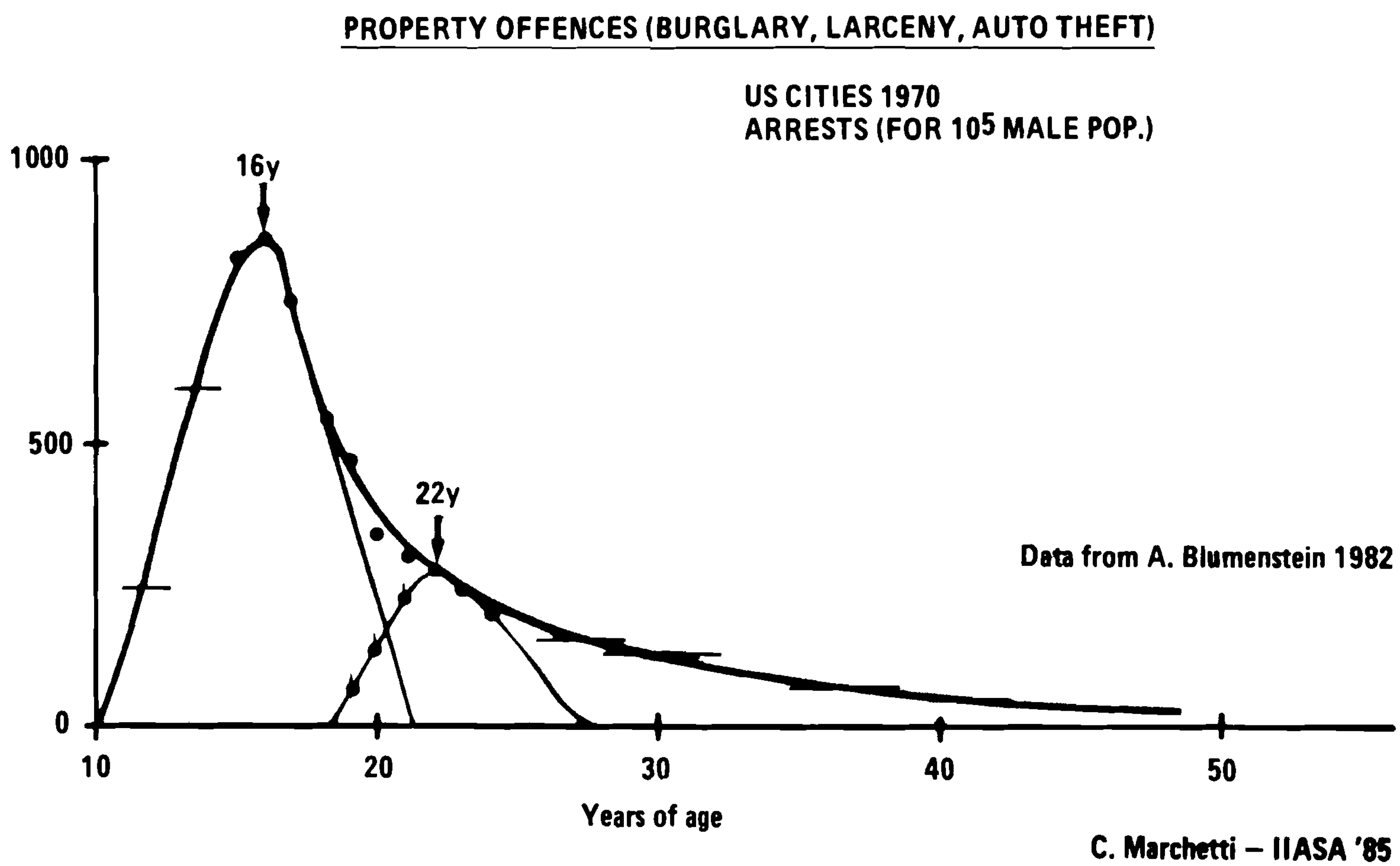

PROPERTY OFFENCES (BURGLARY, LARCENY, AUTO THEFT)
US CITIES 1970
ARRESTS (FOR 10⁵ MALE POP.)
1000
500
0
16y
22y
Data from A. Blumenstein 1982
10
20
30
40
50
Years of age
C. Marchetti – IIASA '85

Figure 12

PROPERTY OFFENSES – USA CITIES

Tentative analysis first pulse

Age	Cumulative Arrests
13	5.2
15	17
16	25.5
17	34.2
18	41.6
19	47.1
20	21.7
21	55.26
22	58.2
23	61

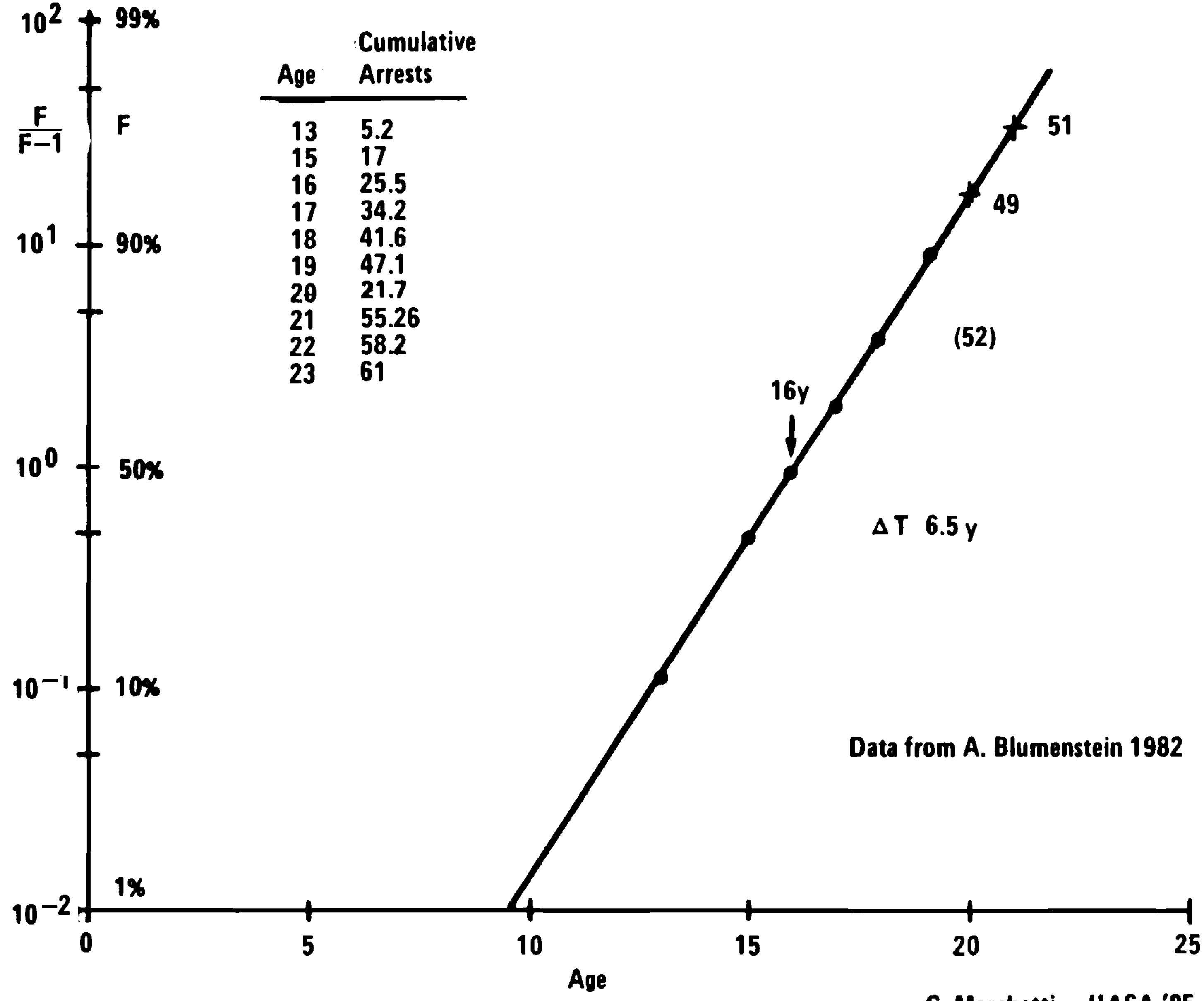


Figure 13

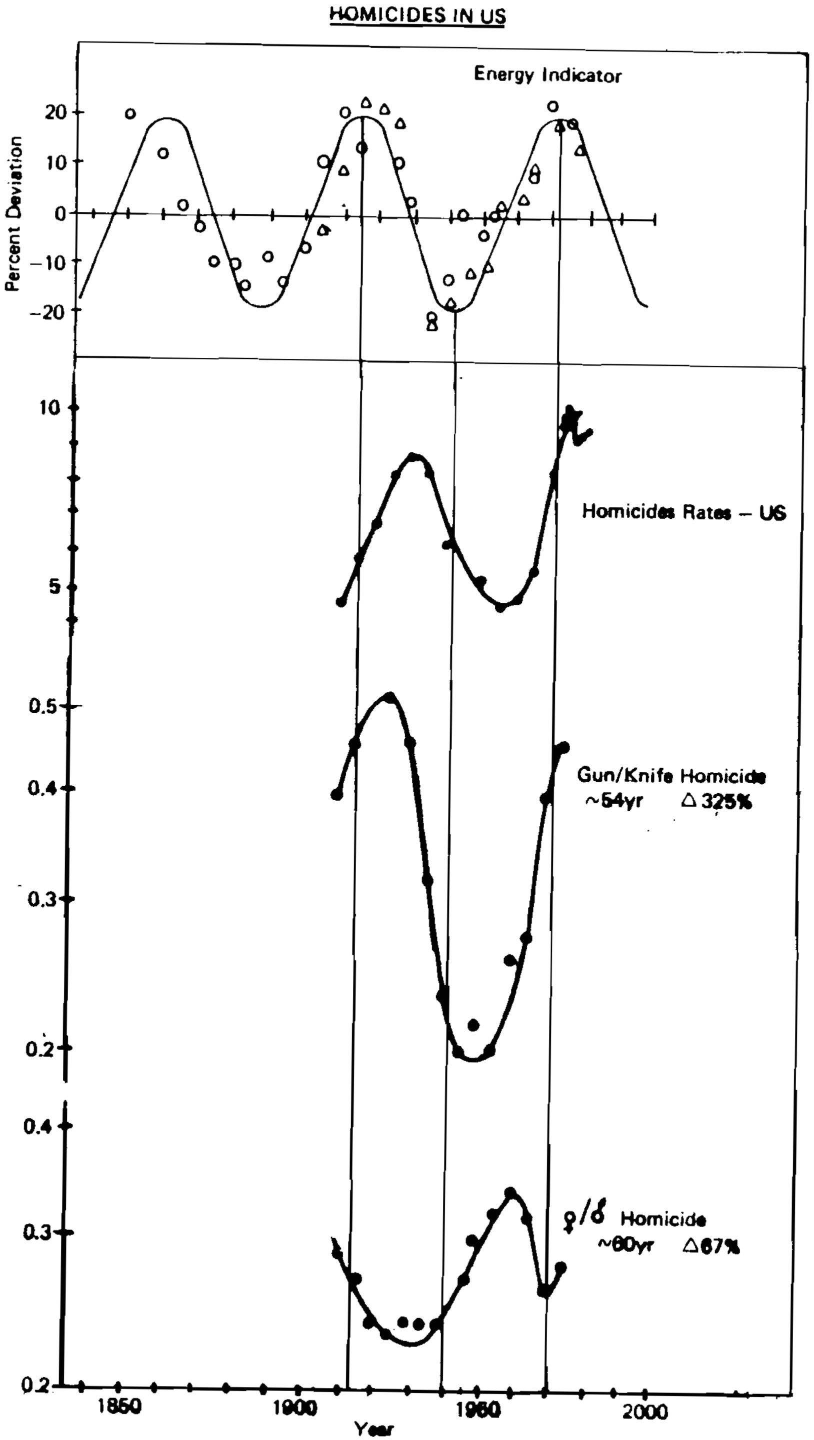


Figure 14

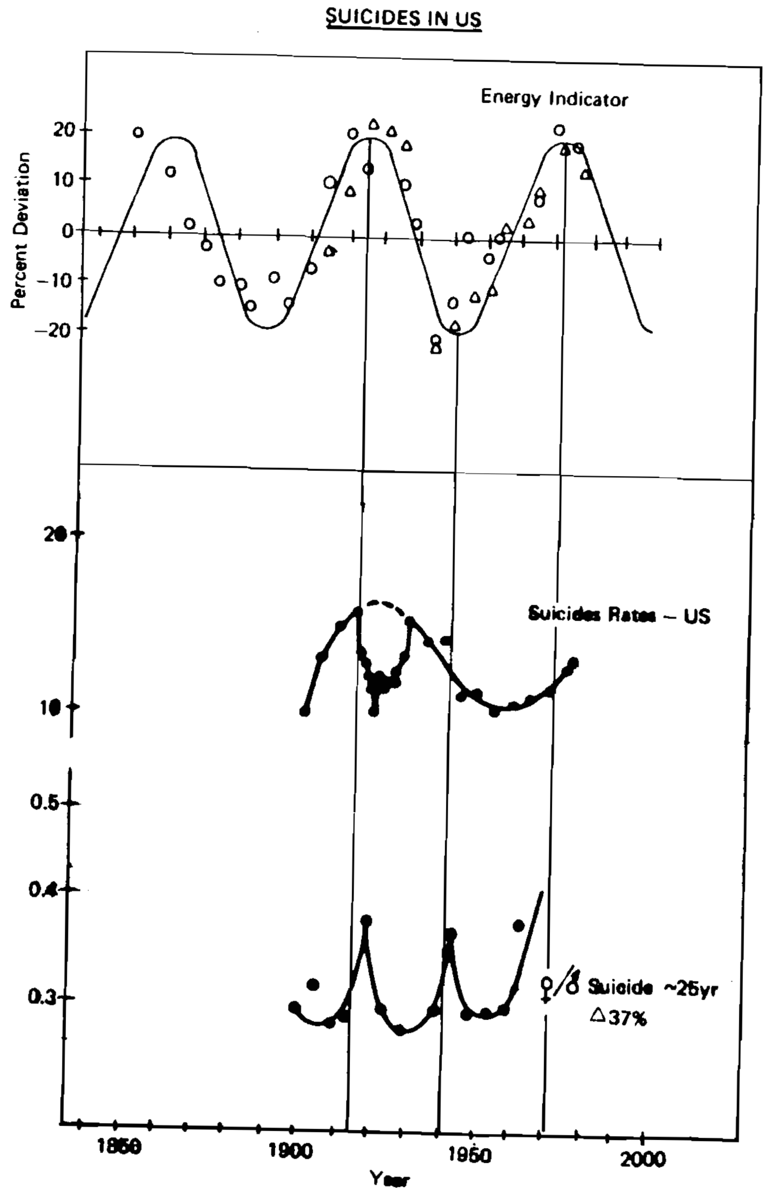


Figure 15