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Langner, Günther

Historical Social Research, Vol. 21 — 1996 — No. 4, 24-55

Fertility of Populations as a Function of the Attained Level of Life Expectancy in the Course of Human Evolution

Günther Langner*

Abstract: »Aging societies* with increasing life expectancies of the average of all their members are facts in modern history that are disputed by nobody. What is disputed by the most renowned names in demography, however, is that aging populations are a consequence of the fall in mortality and thus the increase in life expectancy. It is claimed that the principle reason for »aging» is to be found in a drop in fertility. In this sense today's demographers regard as a standard result: »Variations in fertility are of more significance for the age structure of populations than variations inmortality.» In the following paper this thesis, which is based on a neo-Malthusian interpretation of the role of fertility in the demographic process, will be questioned.

Statement of the Problem and the Results

»Aging societies» with increasing life expectancies of the average of all their members are facts in modern history that are disputed by nobody. What is disputed by the most renowned names in demography, however, is that aging populations are a consequence of the fall in mortality and thus the increase in life expectancy. It is claimed that the principle reason for »aging» is to be found in a drop in fertility. (Sauvy: 1966, 307; Wrigley: 1968, 28; Kühn and Schwarz: 1975, 75; Hauser: 1982, 73; Coale and Demeny: 1983, 31). In this sense today's demographers regard as a standard result: »Variations in fertility

*** Address all communications to Günther Langner, Steinbeiss Strasse 45, D-70839 Gerlingen, Tel.: (49) 7156 - 23225.**
Abbreviated English Version of a Paper for the Working Group »Historical Demography* of the German Society for Population Sciences Presented in November 1994.

are of more significance for the age structure of populations than variations in mortality. »(Dinkel: 1992, 68) In the following paper this thesis, which is based on a neo-Malthusian interpretation of the role of fertility in the demographic process, will be questioned. The main objection is derived from an historical interpretation of the fundamental assumptions or preconditions for »stable» or »Malthusian» populations. As a basis for this interpretation serves here Coale and Demeny's set of tables of »Stable Populations* and the conclusions drawn from them to which the argumentation of all of the authors named above can ultimately be traced. The critique is backed up by relevant findings from the fields of palaeodemography and historical demography. A model of total fertility rates for each level of life expectancy - valid »for all times» - has been developed on the basis of world population statistics of the latter half of the present century. The result can be summed up in this sentence: The level of and variance in fertility are functionally dependent on the level of life expectancy attained by the population in question.

Analysis

In Table XIII of the »Stable Populations« volume of tables, Coale and Demeny summarize the agestructures derived from the calculations of their tables and compare gross reproduction rates of 0.8 to 4.0 for each other level of life expectancy from 20 to 80 years of age. With Table XIII they demonstrate that the same gross reproduction rates at each level of lifeexpectancy will lead to approximately the same mean age of the population. The key sentence in Coale and Demeny's commentary is: »Note [...] the small effect of mortality and the large effect of fertility on the mean age of the populations (Coale and Demeny: 1983, 31). In the individual tables of the »Stable Populations« there is in all cases a considerable gap between the assumed highest female fertility rate and the fertility necessary for a Net Reproduction Rate (NRR) = 1. While life expectancy is inccreased from a level of 20 to 80 years in the set of tables the gap becomes wider step by step. The ever-increasing spread has been labelled as an increase in »demographic freedom« (Vishnevsky: 1983, 85). The range of possible variations between, on the one hand, the »demographic necessity« (the replacement of a mother generation in the same »mortality level«) and, on the other hand, the »demographic freedom« based on the theoretically possible average number of children per woman will keep increasing. According to the tables of Coale and Demeny, the »demographic freedom« would appear as sketched in Graph A (see Appendix). There would be a significant range in freely available fertility for populations at all levels of life expectancy anyway. But as life expectancy increases, this range of »free fertility« would increase continually and markedly.

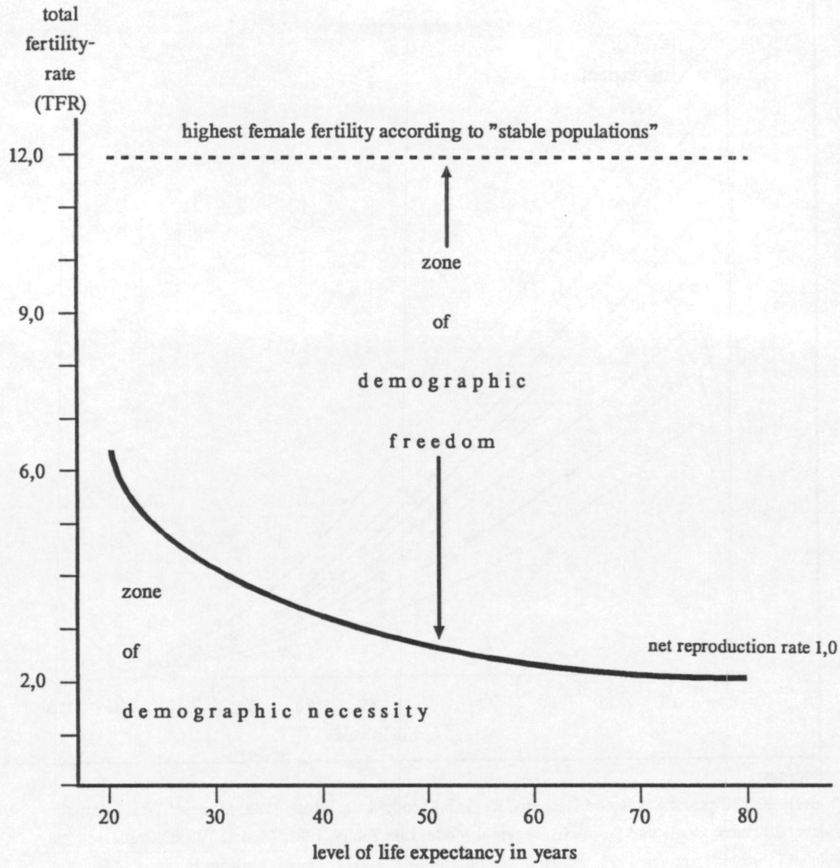
Table XIII *)
Selected parameters of "West" female stable populations
for different expectations of life at birth,
and gross reproduction rates
(mean age of fertility schedule 29 years)

e^0_0	Gross reproduction rate (m = 29) .80	1.00	1.50	2.00	3.00	4.00
	Population under age 15					
20	.098	.128	.196	.255	.349	.418
30	.116	.151	.228	.293	.391	.462
40	.129	.166	.250	.318	.419	.489
50	.137	.177	.265	.336	.438	.509
60	.145	.187	.278	.350	.453	.524
70	.149	.192	.286	.359	.463	.534
80	.141	.185	.281	.357	.464	.536
	Proportion at ages 65 and over					
20	.165	.134	.085	.058	.032	.020
30	.178	.142	.087	.055	.031	.019
40	.189	.149	.090	.059	.030	.018
50	.198	.154	.091	.060	.030	.017
60	.201	.156	.092	.059	.029	.017
70	.202	.165	.096	.061	.030	.017
80	.259	.202	.119	.075	.036	.021
	Mean age (years)					
20	44.5	41.5	35.7	31.6	26.2	22.7
30	43.8	40.5	34.2	29.9	24.4	21.0
40	43.5	39.9	33.2	28.8	23.3	20.0
50	43.3	39.5	32.6	28.1	22.5	19.3
60	43.1	39.1	32.0	27.5	21.9	18.7
70	43.3	39.2	31.9	27.2	21.6	18.4
80	45.6	41.1	33.0	27.9	21.9	18.6
	Birth rate (per thousand)					
20	9.6	13.3	22.3	31.5	47.7	61.4
30	9.7	13.4	22.5	31.0	45.9	58.1
40	9.7	13.4	22.3	30.5	44.5	55.9
50	9.7	13.3	22.1	30.0	43.4	54.2
60	9.7	13.3	21.9	29.7	42.6	52.9
70	9.6	13.1	21.7	29.3	41.9	51.8
80	8.9	12.4	20.9	28.5	41.1	51.1
	Death rate (per thousand)					
20	56.9	53.1	48.7	47.7	49.5	52.9
30	43.7	39.8	35.0	33.5	33.9	35.7
40	34.9	30.9	25.8	23.9	23.4	24.3
50	28.4	24.4	19.1	16.9	15.7	15.9
60	23.4	19.3	13.9	11.4	9.7	9.3
70	19.4	15.3	9.7	7.1	5.0	4.4
80	16.8	12.6	7.0	4.4	2.3	1.5

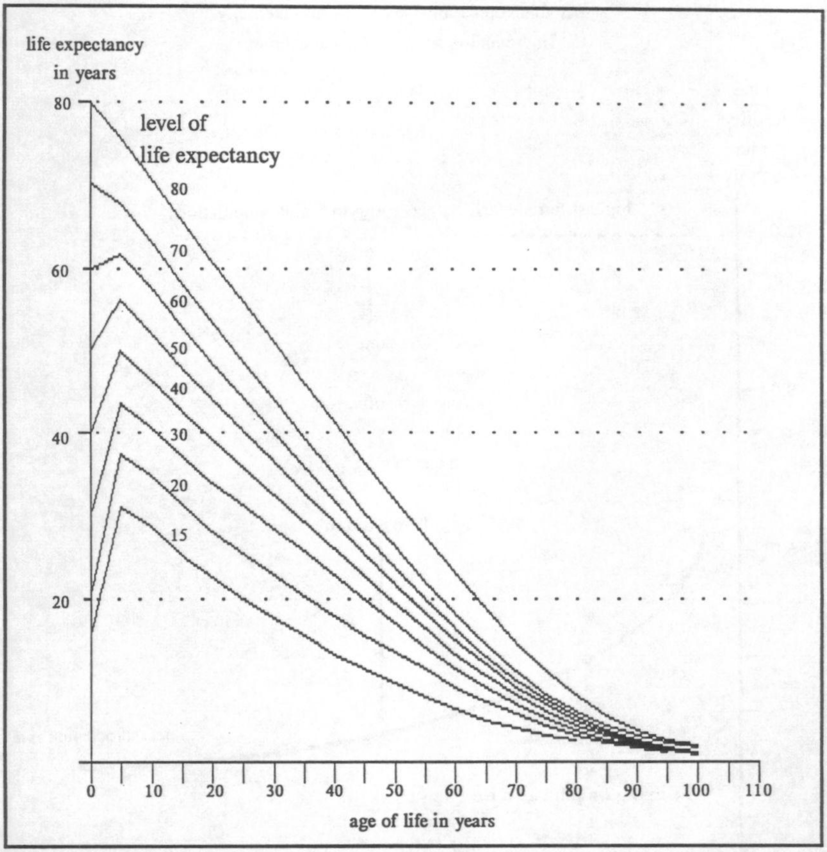
*) Coale and Demeny, Regional Model Life Tables and Stable Populations, Second Edition: 1983, 31

Graph A

DEMOGRAPHIC FREEDOM
and
DEMOGRAPHIC NECESSITY
according to the tables of
"Stable Populations" by Coale and Demeny
in ascending levels of life expectancy



Graph B
DIFFERENT LEVELS
of
LIFE EXPECTANCY
according to model life tables



Sources:
levels 30 - 80 years: Coale and Demeny, Regional Model Life Tables, 1983, Models "West", female.
level 20 years: Coale and Demeny, Regional Model Life Tables, 1983, Modell "West", male.
level 15 years: Langner, 1993, model based on archaeological remains, both sexes.

Table 1

All Total Fertility Rates for each Level of Life Expectancy, as exhibited in the tables of "Stable Populations" by Coale and Demeny (1983).

e^0_0	total fertility rate (TFR)																		
20	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
25	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
30	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
35	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
40	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
45	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
50	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
55	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
60	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
65	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
70	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
75	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
80	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0

In order to uncover the heart of the methodology upon which »Stable Populations« is founded it will be necessary to go into a short analysis of the basic assumptions, as they appear from the point of view here represented. The survival of a population is an historical process in the same way as the development of an egg into a fully-formed body is an historical process. Processes of this kind are factual and irreversible. Bearing this in mind, the »mortality schedule« - or, to put it another way, a specific level of life expectancy - is derived from historical reality and in the methodology of the classical natural sciences recognized and applied generally as a biological and social fact. Every level of life expectancy calculated in a period life table describes an average and special course taken by the survivor function based on observations of living populations. Each level is separated from the other and is invariable. The infant mortality in the level of a life expectancy of 20 years cannot be freely varied with infant mortality rates of another level, with, for example, the conditions in the level of a life expectancy of 80 years. A free variability of this type is excluded within the model system as it is in reality. The functional connection is assured. Since the line of argument in this paper is based upon the structure of the different levels of life expectancy they are shown in Graph B (see Appendix) as a reference pattern.

The place of fertility in the system of »Stable Populations« exhibits no recognizable differentiation. That is in contrast to the clearly differentiated levels of life expectancy. In their »Stable Populations»tables Coale and Demeny consistently apply an arithmetical progression to all levels of life expectancy which extends uniformly from an assumed minimum birth rate in a population to the maximum birth rate possible. In other words, fertility is schematically varied within a minimum and maximum context for the different levels of life expectancy from 20 to 80 years. Table 1 shows for each level of life expectancy the gross reproductive rates calculated by Coale and Demeny which are here referred to as »total fertility rate« = TFR (rounded off). All TFRs from 1.6 to 12 are assigned to each level of life expectancy. This table clearly reveals the fundamental approach of »Stable Populations*: The levels of life expectancy are different but the fertility rates are uniform. These tables give the impression that one could, for example, equally count on finding a TFR of 1.6 in a population at a level of life expectancy of 20 years as at a level of life expectancy of 80 years. And this is precisely what is demonstrated by Coale and Demeny's comment on the existence of a most favourable minimum death rate which in their words occurs at a TFR between 4.0 to 5.0 when life expectancy is 20 years, but at a TFR of 8.0 when it is 70. (Coale and Demeny: 1983, 31; see Table XIII) In contrast to the levels of life expectancy which in themselves do not vary, the fertility rates are freely varied independently of the particular living conditions of the populations. It can, in fact, only be concluded from these systematics that fertility within a total framework is being treated as a »free variable« (or as an unknown).

This leads to the thesis we are promoting here: »Stable Populations* is operating within two different logical categories for life expectancy (mortality) and fertility: on the one hand, in an observational dimension as in classical natural sciences, and on the other, in a speculative dimension as in humanistic sciences. Or one would need to look at it in yet another way: In the case of life expectancy, the basis is the observed facts in complete historical populations, while in the case of fertility the assumption is the theoretical potential of individuals or parts of a population. Probably it is the fact that fertility seems to be more capable of being influenced at the level of the individual than mortality that contributes to it being treated as a »free variable«. This attitude is expressed very clearly, for example, in Gary Becker's contribution to the conference »Demographic and Economic Change in Developed Countries* which was held under the chairmanship of Coale at Princeton. In the discussion of possible birth control even amongst so-called »primitive» peoples the following sentence occurs: »Since each person maintains some control over these variables, there is room for decision-making« (Becker 1960, 210). The entire neo-Malthusian conceptual structure of »Population Economics« in particular is based on this paradigm. The freedom of each individual leads in this interpretation as a matter of course to the conclusion that the entirety is also free.

The contribution of the Princeton school and of Coale in particular is to have proved that the course the survivor function takes in period life tables is valid for each specific level of life expectancy irrespective of time or country. »Model life tables« were developed on the basis of this regularity. In principle they are not independent models but rather summaries and systematizations of period life tables for different countries and for different times. The real model is actually the period life table. The basic material for the »Regional Model Life Tables« of Coale and Demeny has essentially been derived from observation of real and living populations over the last two centuries. (Coale and Demeny: 1983,5) The fertility rate - which is without doubt also a biological and sociological fact - is calculated within population statistics as a periodic dimension, as is life expectancy. The gross reproduction or total fertility rates derived from it are also models. They have been calculated on the basis of data acquired on real and living populations at a particular period. They provide information on the fertility conditions within a hypothetic generation of women who live through a full fertility phase in the population in question. In the meantime the UN has determined and published the total fertility rates for each country and period. These figures are for the most part based upon the census results of the countries in question and their continuations, as are the figures for mortality. These figures, which have been regularly published since 1950, may well be not entirely free of faults, but they are all the same, as are the mortality figures, data which can be observed, measured and systematized in a »scientific« manner.

Wrigley, a prominent advocat of the »standard result« of demography, pointed out in one section of his book »Population and History« that there is evidence for only a fairly limited series of combinations of figures for births and deaths in the history of human populations. (Wrigley: 1969,15) He did not present such a series in a systematic manner. If one attempts to verify his observation by linking the figures from the real world exactly as they originated, it must be possible to detect whether and to what extent there is a fixed relation between fertility and the level of life expectancy in a population, or whether the fertility is varied independently in the sense of »demographic freedom«. In its basic structure Table 2 corresponds to Table 1. It contains in addition as base all country details for the period 1950-1955 to 1985-90 as determined by the UN. Each TFR actually recorded has been assigned to the corresponding level of life expectancy, ignoring both the time and the size of the country. We are concerned here with 1248 individual figures. For each level of life expectancy the data which the scanned areas in the table describe can then be determined. It can be seen from Table 2 that

1. All peoples of the earth have in the period from 1950 until the present day realized levels of life expectancy of 30 to almost 80 years.
2. In actuality, over the last forty years only quite definite ranges of TFRs have been measured for each level of life expectancy. The scanned area confirms the statement made above, that the tables in »Stable Populations* mark out the frame for theoretically possible fertility for each level of life expectancy but within this frame they are only speculative in nature - in other words, the fertility rates are not derived from the reality of living populations.

As a basic rule, in complete populations which have actually been surveyed, TFRs of 9,10 and 12 children are not encountered at any level of life expectancy. In the range of the level of 30 to 50 life expectancy there are more examples of calculations in the model tables which do not occur in the real world. In this range no population is to be found, for example, with a TFR of less than 4.0. The minimum TFR is not 1.6 but never in fact occurs below 4.0. In these levels with 30 to 50 years of life expectancy a differentiation of the »Stable Populations« tables would be appropriate in half-increments within the TFRs between 4.0 and 8.5 in the same arithmetical sequence as has been done - superfluously - for TFRs up to 4.0. On the other hand at the high levels of 70 to 80 years of life expectancy the tables do not cover TFRs of less than 1.6, which do actually occur. All values above a TFR of 5.0 or 3.0 are calculated, although the existence of such rates cannot be proved for any population. The table supports Wrigley's observation that between life expectancy and fertility only a fairly limited series of combinations is to be found in demographic historical reality. It is therefore certainly problematic to demonstrate the same fertility rates for all levels of life expectancy as in Table XIII and to bring these forward as evidence for the small effect of mortality when there is not a single

Table 2
All Total Fertility Rates for each Level of Life Expectancy, as exhibited in the "Stable Populations" by Coale and Demeny. (1983) Compared with Actually Recorded Total Fertility Rates per Level of Life Expectancy for all Countries of the World from 1950 - 1990 (scanned areas)

e^0_0	total fertility rate (TFR)																		
20	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
25	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
30	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
35	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
40	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
45	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
50	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
55	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
60	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
65	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
70	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
75	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0
80	.	1.6	2.0	2.5	3.0	3.5	4.0	4.5	5.0	.	6.0	.	7.0	.	8.0	.	9.0	10.0	12.0

Base for TFRs in scanned areas: actual values for all countries of the world in quinquennial periods 1950–55 to 1985–90.

Source: World Population Prospects 1990, United Nations, New York 1991 rate which is found in reality throughout all levels of life expectancy. This can be seen very clearly indeed in the scanned area Not even a TFR of 4.0, which, at just below the minimum, obtained for levels of life expectancy of up to 55 years, can be traced throughout all levels. Above 75 years of life expectancy it is considerably in excess of the maximum which can be shown to exist

In the same way it is for example solely of theoretical interest to construct a minimum death rate for populations at levels of life expectancy of 70 years with a TFR of 8.0 - and even to emphasize this in commentaries - when at these levels of life expectancy only TFRs of 5.0 at the most can be measured in reality. Accordingly there is no doubt that one can object to a STANDARD RESULT, which is supposed to provide a fitting interpretation of historical reality, being based upon a way of proceeding as expressed in Table XIII. This means in particular that the role of fertility is linked considerably more closely in the demographic process with the level of life expectancy than can be seen from the model calculations of »Stable Populations«, which are used in this paper as representative examples of all similar theoretical calculations and interpretations.

In order to be able to recognize more precisely the relation between life expectancy and fertility of populations Table 3 has been drawn up. In the same way as the base in Table 2 it corresponds to all details for countries for the periods 1950-55 to 1985-90. Every TFR which was actually recorded and calculated for each quinquennium has been assigned to the corresponding level of life expectancy irrespective of the size of the country and irrespective of the time. This procedure corresponds methodologically to how the model life table were created by the UN or by Coale and Demeny, who obtained their values on the basis of actual period life tables from the last two centuries. Each element in the set thus defined therefore has the value of 1. The mean, maximum and minimum values can then be determined for each level of life expectancy, as can the standard deviation (or variance). As a reference, the TFR is shown in the table which corresponds to a NRR of 1.0 per level of life expectancy. As the TFR is a period model, just as the life expectancy, it can be interpreted in the same way. As in a period table, a vertical section through the population will be »longitudinally« interpreted (Feichtingen 1979).

This operation involves a step being methodically taken which has been in science only very recently acknowledged but which is of importance in generalizing the results. Historical time, which is unique and heterogeneous and therefore, according to Feichtinger, subject to extensive and unquantillable contingencies and can scarcely make any claim to possessing prognostic interest (1973, 71) is replaced by an abstract and homogeneous time. The model which is usual today - expressing the level of life expectancy or the level of fertility in numbers - derives from the observed data of a defined population from a section of time, a period of one or more succeeding years which have been compressed into a single unit of time. Mortality periods and

Table 3

Actual Total Fertility Rates (TFR) for each Level of Life Expectancy

Base:

Total fertility rates (recorded or estimated) for each level of life expectancy for all countries in the world in quinquennial periods 1950 - 55 to 1985 -90, in ascending levels of life expectancy, irrespective of the size of the country and independent of the time. Counted are 1248 single data.

life expectancy in years	total fertility rate (TFR)				standard–deviation	number of cases
	NRR 1,0	medium	maximum	minimum		
15.0 – 19.9	8,2					
20.0 – 24.9	6,5					
25.0 – 29.9	5,2					
30.0 – 34.9	4,4	6,35	7,38	4,10	0,741	41
35.0 – 39.9	3,8	6,45	7,79	4,06	0,572	111
40.0 – 44.9	3,4	6,56	8,29	4,06	0,670	167
45.0 – 49.9	3,1	6,64	8,49	4,26	0,741	152
50.0 – 54.9	2,8	6,52	8,12	4,68	0,749	124
55.0 – 59.9	2,6	5,94	7,92	3,05	0,964	117
60.0 – 64.9	2,4	5,06	7,44	2,50	1,378	126
65.0 – 69.9	2,3	3,50	6,90	1,73	1,197	181
70.0 – 74.9	2,2	2,49	5,08	1,36	0,711	190
75.0 – 79.9	2,1	1,80	3,01	1,32	0,329	40
summary 30.0 – 54.9		6,51	8,49	4,06		

Source for TFRs and life expectancy: World Popualtion Prospects 1990, United Nations, New York, 1991

Source for TFR at net reproduction rate (NRR) = 1: Coale and Demeny, Regional Model Life Tables and Stable Populations, Models "West", Second Edition, Academic Press, New York, 1983 birth periods, like fertility, are located in this model on a unidimensional time axis. (Historical) time is therefore eliminated and a hypothetical population within an abstract measured time is gained. In the model, time appears as an »absolute« and static parameter, and not as a relative and irreversible factor. It applies in precisely the same way horizontally and vertically to each level of life expectancy. The model reproduces the state of a particular period, but is converted into a process and thus into a quasi-prognostic statement for a hypothetical stretch of time.

The consequences of this way of looking at things are of fundamental importance, as here the procedure is in line with the most important assumptions of the classic natural sciences which had already proved their usefulness in the systems area in the Newtonian laws. Newton's methods have already been explained with great clarity by Wickert (1989, 67): the first step involves a »detemporalization« of the object - in other words, the exclusion of historical time (together with its contingencies) - while the second step is the assignment to physical measured time.

The »stable model« of demography operates with this symmetrical measured time and thus not within the historical dimension, but rather within the system of classical physics. Malthus, who when founding his »law« referred expressly to Newton and his »magnificent and logically consistent theory in his critique of Condorcet's visions of the future, followed this model form. (1798 /1977, 76). Lotka, the pioneer of this method, was correct to term this model of stable populations »Malthusian«.

The »arrow of time«, which in the reality of the course of the universe - as also of the life of man and populations - is solely forward-pointing, historic and assymmetric, is negated in this symmetrical, physical measured time. (Prigogine: 1985; Coveney and Highfield: 1990). The laws of classical physics, which allow conclusions to be drawn from the state of affairs at one point in time concerning the state of affairs at another point in time, apply in both directions. (+/-t) This means that those laws founded in the temporal symmetry of classical physics still apply despite time being historical and asymmetric The precondition for the derivation of a »law« are »states«, which have been quantified in line with the system, within defined sections of time. A »state« which has been demonstrated and measured today in a relevant experiment can be used as something applicable to both the past and the future. Regularities can then be formulated within the system which will be applicable to »all times« and reliable predictions made.

In this spirit it can be concluded: The states of the relations between life expectancy and fertility in the populations of the world as measured in defined sections of time over the last half-century reproduce irrespective of time and space the conditions of the same constellation at any other time also. The figures in Table 3 make one thing dear The fertility of the population behaves differently in the individual levels of life expectancy to what the replacement rate« (NRR = 1) requires or even free variability would permit

The total fertility rate of populations is stable at each level of life expectancy from 30 to 55 years. The mean value lies fairly precisely at a TFR of 6.5. Variance is relatively low, standard deviance remains between 0.6 and 0.7. At the transition to higher levels of life expectancy the TFR falls back, slowly at first, but then radically, until at the levels of life expectancy of 75 and more years it falls with 1.80 below the »population replacement rate«. Standard deviation still only amounts to 0.3. Fertility varies between very narrow limits. The TFR does not appear to have any direct connection with the »population replacement rate«.

In contrast to the »Stable Populations* interpretation with »free variability*, in reality »demographic freedom« does not increase, but rather falls radically. The NRR, which at the levels of life expectancy of 60 to 65 years reaches the maximum spread, between a minimum of 1.1 and a maximum of 3.2, falls back in the 75 to 80 years of life expectancy bracket to 0.6 to 1.2. A graphic presentation (Graph C) of the TFR curves plotted for mean, minimum and maximum values and for NRR = 1 clearly describes the area of interaction between fertility and life expectancy. As already explained, the TFR curves reproduce the demographic reality of equal constellations independently of historical time and historical space. In order to cover all of the life expectancy levels possible in human populations (Acsadi and Nemeskeri: 1970; Hassan: 1981), all levels of life expectancy from 15 years and up have been plotted on the x-axis.

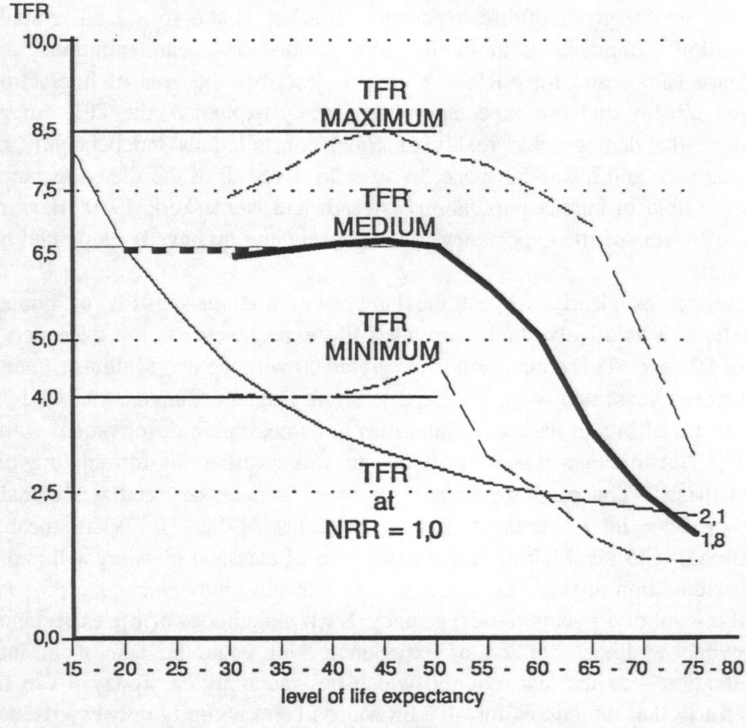
These curves clearly suggest the conclusion that the fertility of human populations is relatively stable, provided life expectancy has not exceeded a level of 50 years. This conclusion is in agreement with the one Malthus came to two hundred years ago when life expectancy in England fluctuated around 35 years. In his efforts to uncover regularities in demographic development while applying Newtonian research methods, he was justified in formulating his second thesis: »The passion between the sexes is necessary and will remain more or less in its present state.« (Malthus: 1798,11). What means, corresponding to his thinking in the categories of classical physics, will apply in either direction of time. This state of stable fertility only changes on the far side of a level of 50 years life expectancy. Such magnitudes of life expectancy lay beyond Malthus' horizon of experience. Nor could he take them into consideration - as the law required which he was applying. Today it can be seen clearly that the curves for all TFR values bend abruptly downwards at a level of life expectancy of 55 years and in Graph C, which is constructed with equal distances for each level of life expectancy, the curves run at an angle of approx. 45 degrees down to below the »population replacement rate«. Between the levels of life expectancy of 70 - 75 years it is possible to trace how the curve of the TFR mean value crosses and passes beneath the curve for TFR = NRR = 1.0.

Graph C

MODEL

TOTAL FERTILITY RATES (TFR)
for every
LEVEL OF LIFE EXPECTANCY (e^0_0)

Base: Total fertility rates (recorded or estimated) for each level of life expectancy for all countries in the world in quinquennial periods 1950 - 55 to 1985 - 90, in ascending levels of life expectancy, irrespective of the size of the country and independent of the time. Counted are 1248 single data.

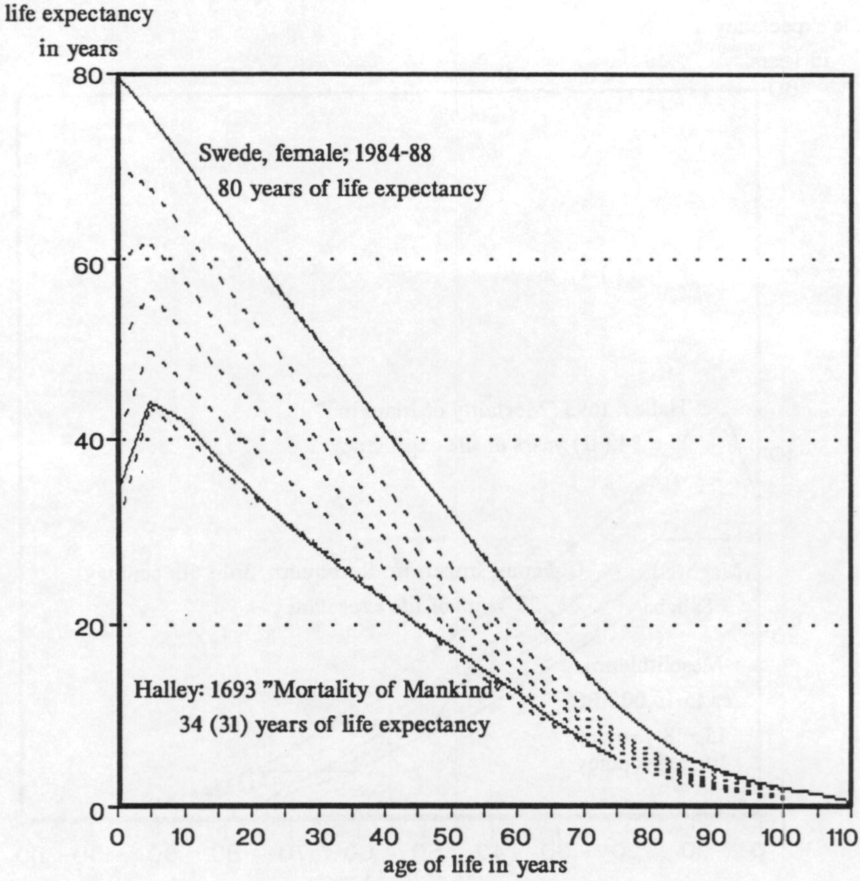


Source for TFRs and life expectancy: World Popualtion Prospects 1990, United Nations, New York, 1991

Source for TFR at net reproduction rate (NRR) = 1: Coale and Demeny, Regional Model Life Tables and Stable Populations, Models "West", Second Edition, Academic Press, New York, 1983

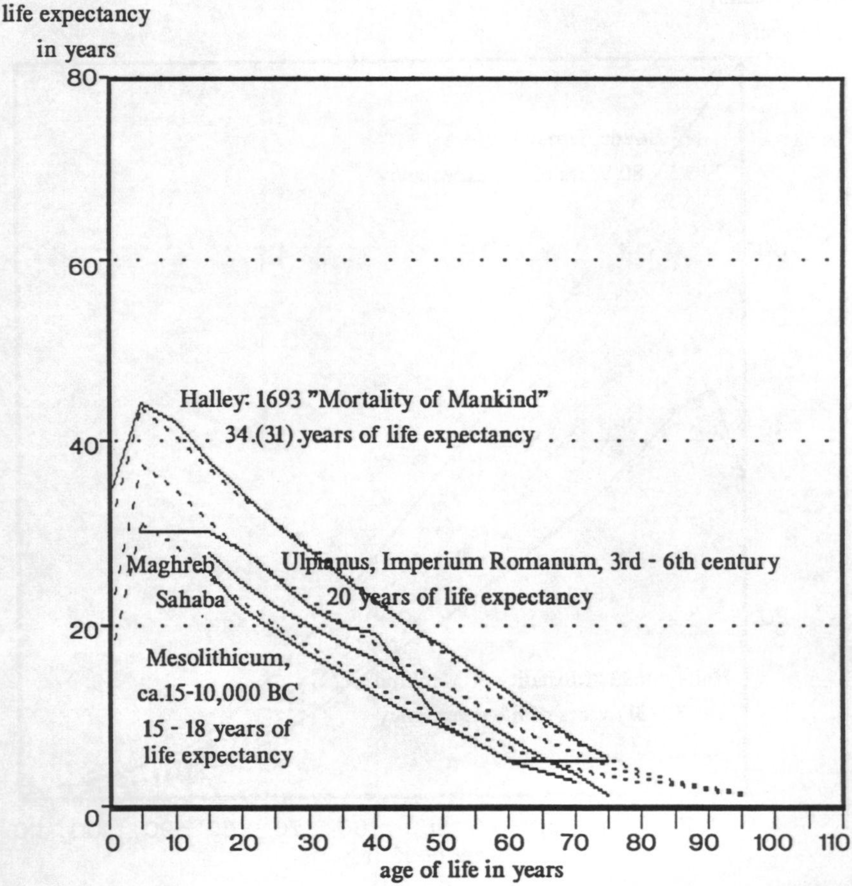
Graph D

EVOLUTIONARY STEPS OF LIFE EXPECTANCY
of
ANATOMIC MODERN MAN
based on
HISTORIC SOURCES
here:
17th - 20th CENTURY



Graph E

EVOLUTIONARY STEPS OF LIFE EXPECTANCY of ANATOMIC MODERN MAN based on HISTORIC and PREHISTORIC SOURCES here: 15.000 B.C. - 1700 A.D.



Up until this point our argumentation has been within the system of physical measured time. If a standard result for demography is to be established which is reality-related then historical time, which previously had been excluded, must be reintroduced into the system. This is done, as in a film, by adding one frozen snapshot of movement (one state) after the other in order to imitate the dynamics of time. Then a statement can be formulated which grants the elements of »life expectancy» and »fertility» their correct status in the historical process. To this end in Graph D the following have been plotted onto the lattice of Graph B:

1. Official calculations of the level of life expectancy reached by the female sex in Sweden for the period 1984 -1988. This level of life expectancy represents the top limit reached by individual present-day populations.

2. The life expectancy in the year 1693 calculated on the basis of Halley's original table in his Estimate of the Degrees of the Mortality of Mankind. Halley's claim to have calculated the mortality of Mankind is evidence of the fact that the maximum and normal life expectancies in the eighteenth century must have been very close together and did not exceed 30 years by any significant extent.

The increase in life duration, commencing in the levels of life expectancy of 30 years and today extended to as much as 80 years, took place over a period of approximately 300 years of historical development. The range of variation measured today in the countries of the planet corresponds therefore at the same time to a historical time period of 300 years in the most developed economies. In Graph E, also plotted onto the lattice of Graph B, we find:

3. The specifications, based on Ulpian (around 200 A.D.), for Roman jurisdiction, gathered together in the Corpus Juris Civilis of 528-35. (Digesta: Lib. XXXV, Tit. 2 68).

This is the first authentic written source which reports on a human survivor function. The curve based on these figures corresponds in the important (for antiquity) age group of the 18 to 46 year old »juniores» (which is followed in the Roman version immediately by the age class termed the »seniores») almost precisely to a level of life expectancy of 20 years in the model life table, male sex, and can be taken as fitting pretty precisely to the average level of life expectancy in the Imperium Romanum.

4. The further life expectancy of adults (basis, 15th year of life) of mesolithic populations, around 15,000 to 10,000 years before present.

The survivor functions have been calculated on the basis of finds of skeletal material. (Sahaba in the Nile valley, by Hassan: 1981,112 and the Maghreb model [Afalou and Taforalt] of Acsadi and Nemeskeri: 1970, 266, 267). As the skeletons of infants and children in prehistoric burial grounds have been preserved incompletely almost without exception - as with the Imperium

Romanum - relatively reliable calculations can be made only for the ages of adulthood. If conclusions regarding life expectancy at birth are drawn from the survivor function of adults - probably the only method applicable for »true« results - then the life expectancy of these populations would have been between 15 and 18 years. For the first hundred thousand years of the existence of Homo sapiens such low levels of life expectancy must be assumed to have been the rule, as is supported by other evidence. Without wishing to go into a more extensive analysis of the individual series, the graph in any case shows that the course of evolution has lead from low levels of life expectancy of 15 years to today's highest level of 80 years, and that this development can be followed by an historical interpretation of the »timeless« model life tables of Coale and Demeny.

Of particular importance for the historical approach is that anatomically modern man clearly, at the time of the Imperium Romanum - in other words, after more than one hundred thousand years of existence - had still not on average passed beyond levels of life expectancy of 20 years. Over thousands of generations the populations had a life expectancy which fluctuated between 15 and 20 years. These populations therefore hardly had a large growth potential in the high fertility required for survival. This historical interpretation is in full agreement with Coale's statement in the introductory chapter to »The Decline of Fertility in Europe« that: »During most of history, the world's population must have had average values of TFR and e_0^0 that in combination lay within a narrow band around the line representing combinations that lead to a growth rate of zero.« (Coale 1986, [3]). An actual »zero growth« is unanimously confirmed by researchers in demographic archaeology. (See Hassan: 1981). It is certainly justified to classify this perfect balance between the death rate and the birth rate throughout the millennia of prehistory as »natural«. These peoples were forbidden a control of fertility in the sense of Malthus' »preventive checks« by the compulsion and urge to survive.

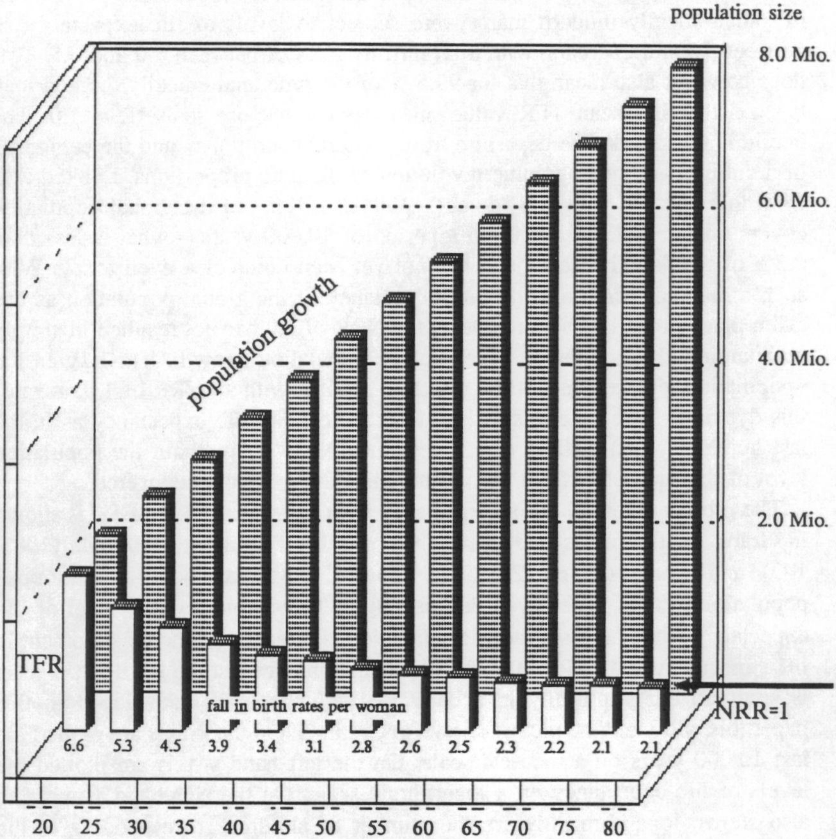
If the »out of Africa« theory (Fagan: 1990; Stringer and Gamble 1993) is followed when calculating the annual growth rates of mankind which dates the mutation to Homo sapiens to the time approx. 185,000 years ago +/-10%, then, assuming a theoretical initial population of three hundred individuals, an average, annual growth rate up until the time of the mesolithic can be calculated of 0.0058 %. This rate lies below today's rates used in demographic model calculations by some orders of magnitude. The same applies to the population growth between the mesolithic and the age of the Imperium Romanum, in other words, to a period of approximately 10,000 years. Assuming a base of 9 million human beings which Hassan calculates for the mesolithic era, and if a world population at the year O is taken of 170 million up to a maximum of 300 million - estimates are so widely scattered - then for the 10,000 years which he between these periods, we can calculate a mean growth rate of between 0.0294 % and 0.0351 % per year - or expressed roughly, four times higher than the growth rate of Homo sapiens from his origins up until the mesolithic, but one which is all the same a growth rate which by present understanding one would rather designate as »zero growth«. If it is further assumed that the natural fertility of populations is a TFR of 6.5, which spreads up to a maximum TFR of 8.0, then Coale's »average value« can be expressed in precise terms, and in the same way the survivor function of prehistoric populations in levels of life expectancy of 15 to 18 years, as reconstructed from skeletal findings, can be confirmed.

The transition from low to high levels of life expectancy occurred only in this present millennium and constitutes 0.5 % at most of the temporal existence of the species Homo sapiens. In 99.5% of the millennia to date, the populations of »anatomically modern man» were subject to levels of life expectancy of between 15 and 20 years, with total fertility rates of between 8.0 and 6.5. This does however also mean that for 99.5 % of the time anatomically modern man has existed the mean TFR value must have lain close to NRR = 1.0. The neolithic thus marks the departure from »natural conditions* and the beginning of a cultural and demographic revolution of gigantic proportions. Looked at it from this point of view the »demographic transition* of the global population covers on the scale of evolution a period of 10,000 years - what is less than 0.5% of man's existence - and has not yet been completed even today. With such a marked increase in the life expectancy of the global population as has taken place in the last hundred years the NRR of 1.0 has not resulted in simply maintaining the population level but in population growth. The expression »population replacement level», which is equated with an NRR of 1.0, negates this dynamic. When there is a short-term increase in life expectancy as in the last hundred years, fertility can be less than NRR = 1 without the population level of the time of birth of the mother generation being endangered.

The growth potential of life expectancy with a constant NRR of 1.0 is shown in Graph F. It converts into visual form a train of thought of Hofsten (1983, 143) and Coale (1986, [25]) and shows in addition how an enormous population growth is achieved despite falling TFRs from level to level of life expectancy when only the mother generation is replaced. If the development in life expectancy and TFR of the global population over just the last 10,000 years is summarized graphically in accordance with the model developed in this paper this will yield the picture shown in Graph G. On the x-axis are plotted the last 10,000 years on a metrical scale. On the left hand y-axis are plotted the levels of life expectancy on a logarithmic scale. On the righthand y-axis and also shown logarithmically are the number of children corresponding to the TFRs realized on average. Graph G assumes an increasing rise in life expectancy from 15.5 years ten thousand years ago to 20 years during the Imperium Romanum. With a population growth rate of virtually zero this means that the average TFR of the world population must have fallen from 8.2 to 6.5 during this time. The real revolution actually took place during the last

Graph F

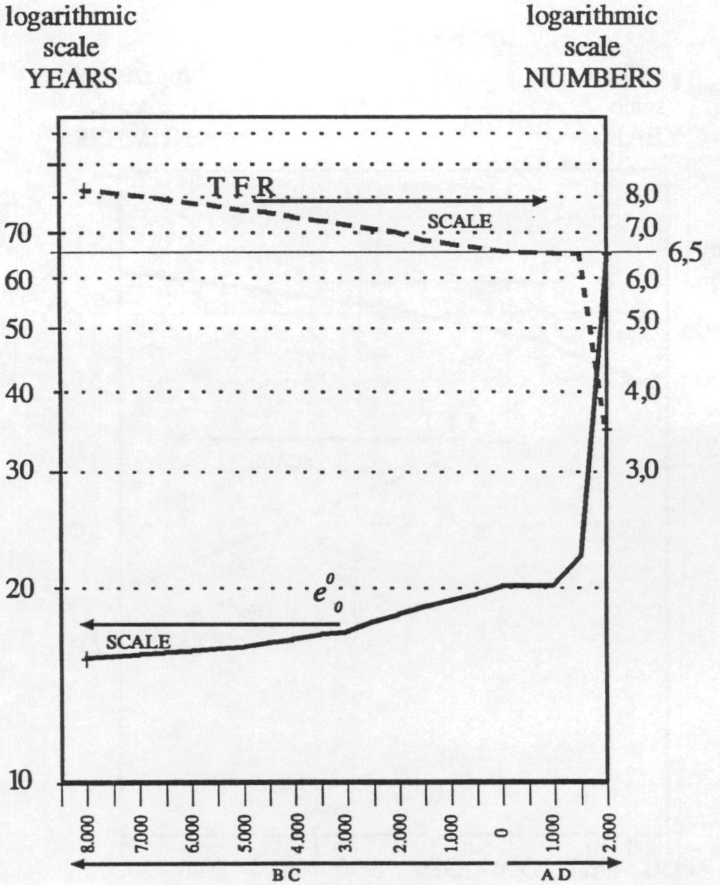
TOTAL FERTILITY RATES (TFR)
at
REPLACEMENT LEVELS (NRR = 1.0)
and resulting
POPULATION SIZES (T_x)
for 100.000 life births per year
in ascending levels of
LIFE EXPECTANCY



Graph G

WORLD POPULATION
8.000 BC - 2.000 AD

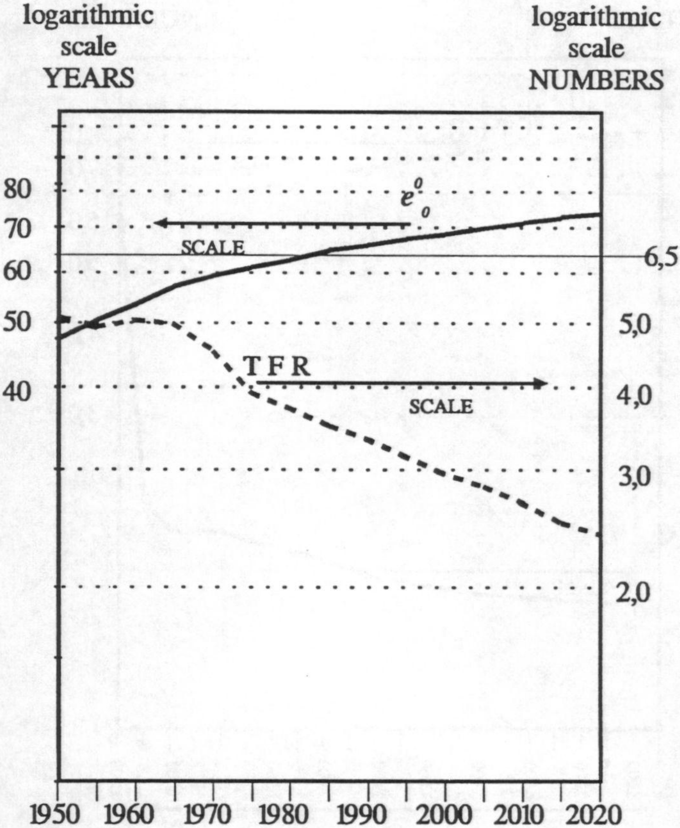
LIFE EXPECTANCY (e^o_o)
and
TOTAL FERTILITY RATE (TFR)



Graph H

WORLD POPULATION
1950 - 2025

LIFE EXPECTANCY (e^0_0)
and
TOTAL FERTILITY RATE (TFR)

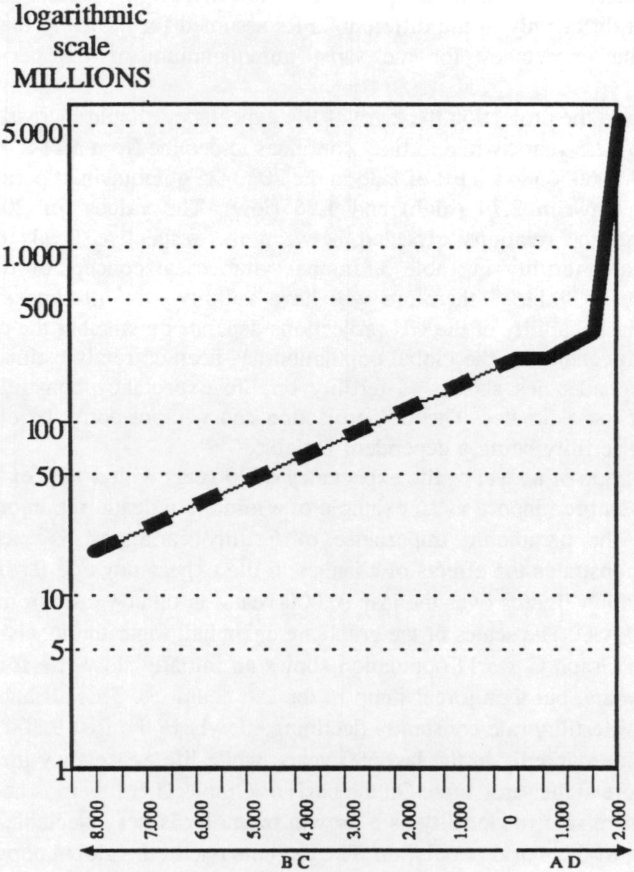


Graph I

WORLD POPULATION

8.000 BC - 2.000 AD

POPULATION GROWTH



few hundred years. The curves admit of only one conclusion, and that is that the markedly diametric movements of life expectancy and fertility rate have been mutually influencing each other over the last thousand years. This statement, by the way, is also correct when UN's latest projection of world population is considered. Following the medium variant, world population in the period 2020-25 will reach a level of 8.5 thousand millions. (UN: 1993). Graph H shows on the same scale as Graph G the change rates for life expectancy and fertility used as basis for the estimate. The UN assumes for their three versions of projections one uniform estimation of the development of life expectancy in the future and varies only fertility. High, medium and low variants thus differ only in the different TFRs assumed for basically the same levels of life expectancy for the same quinquennium of the period of estimation.

According to the projection the level of life expectancy should increase from 50.4 years to 72.5 years, while fertility continues to decline from a TFR of 4.97 in the period 1960-65 to a TFR of 2.36 in the 2020-25 quinquennial period, the mean value between 2.74 (high) and 1.96 (low). The values for 2020-25 correspond to the relations expected between the respective levels of life expectancy and fertility in Table 3. In the symmetrical concept of time of classical physics Table 3 therefore will have validity »for all times«. This means that the reliability of the UN projections depends on whether the change in the life expectancy of the global population has been correctly estimated or not. The dependencies shown of fertility on life expectancy constitute the backbone of the estimates. The UN projection can without doubt be cited as evidence for fertility being a dependent variable.

A combination of a level of life expectancy of 70 years with a TFR of 8.0, as has been given prominence as an example of a minimum death rate in order to demonstrate the paramount importance of fertility variations, is excluded. Graph I demonstrates the effects of changes in life expectancy and fertility on world population figures over the last 10,000 years, in other words from 8000 B.C. to 2000 A.D. The scales of the graph are again half logarithmic. Using the figures from Graph G world population shows an initially slow rise for more than 9.500 years, but then a real jump in the last centuries. This all happened with the total fertility rate constantly declining, slowly in the first 9.500 years, and then more markedly in the last 500 years, while life expectancy increases more and more at the same time. On the basis of Graphs G,H,I there is no doubt that a dominant role for fertility as a growth promoter is not detectable in the development of the world population. The extreme rise in the global population only occurs while the TFR has dropped radically. The successes or failures of family planning programs in the modern world are clearly founded in this dependence of the mean fertility on the level of life expectancy attained.

The two most populous countries of the present day, India and China, are proofs of this. Amongst all the criticism of China's way of preceding it is often overlooked in »success bulletins« from China that it has been possible to implement the rather low TFR, which has in the meantime fallen to 2.45 (1985-90), while life expectancy has at the same time been increased to almost 70 years. India, on the other hand, has only been able to lower the TFR to 4.3. Life expectancy now barely reaches 60 years. (Population Prospects 1990: UN, 1991) In both cases the TFR thus lies close to the mean value to be expected at the corresponding level of life expectancy, as can be seen from Table 3. The case of China is noteworthy in that the per capita real output as share of the population of working age (15-64) according to Summers and Heston is considerably lower than that of India. This points to biological factors - longer life expectancy - being apparently of greater decisive importance for the variation in the TFR than economic.

Historical examples for this functional dependence are provided also by the industrial countries where, as has particularly been the case in France over the last hundred years, despite massive family promotion programs it has not been possible to prevent the NRR falling to 0.87 while life expectancy in the meantime has risen to 76.0 years. (Germany: International Statistical Yearbook 1990, 198). The French TFR of 1.8 corresponds precisely to the average TFR value for these levels (Table 3).

Today once again there is a loud claim to reduce the TFRs in all countries of the world immediately to a maximum of two children. What is not realized in nearly all the discussions is that this goal - if it is one - can only be attained when raising life expectancy is successful. The UN projection for the 2020-25 quinquennium illustrates this fact. By that time the world population will have nearly reached the »TFR-goal«, but it has risen to 8.5 thousand million. This increase in the global population is unavoidable, as the goal of an average TFR value close to NRR = 1 will be reached first at levels of life expectancy of over 70 years. It is a matter of importance that this insight should finally win out worldwide. All other »scenarios« are presumably illusions. Since the birth rates originate in millions of individual decisions, even when attempts are made to control these centrally or to use the most varied means to brake them or even to stimulate them, one must probably accept the fact that control processes are effective in a population which lead to a reduction in the children number within these populations only with the transition to the levels of life expectancy of over 60 years.

Applied to »Stable Populations« this means: Precisely in the way that the »mortality schedule« was derived by observation from the development of living populations, so must the associated, functionally dependent »fertility schedules« of the development of living populations be accepted as they arise from observations. The »demographic freedom« of populations is restricted to varying extents. The essential regulating element for the variance of fertility is the life of the population as a whole, expressed in the level of life expectancy attained. The whole is more than the sum of its parts. The functional biological order and sequence in time will not and cannot be changed, no more than the stages in the development of an embryo to a fully grown living creature can be changed. Even the millions of more or less conscious individual decisions regarding the control of the frequency of birth will have to be regarded from the standpoint of the overall system of a population as autonomous control or self-regulation. From the point of view of the family there certainly does exist an individual freedom of decision concerning the number of children and one which is influenced by economic considerations, as is shown in the words of Gary Becker quoted above and in the conceptual structure he has built upon this assumption. (Becker: 1992,185-201; Nobel Prize for Economics, 1992) The freedom of the individuals and families in a society is however embedded in a demographic system controlled by the whole, which at the level of life expectancy by and large prescribes the range of variation of fertility for the population.

In concrete terms this means that for populations which exist at levels of life expectancy of up to 50 years the room individuals and families have for manoeuvre in decision-making lies within a frame which results in TFRs of 4.0 to 8.5 in the population in question which spread around a mean TFR value for the world population of 6.5. For those populations which have reached the levels of life expectancy of 75-80 years, the room for manoeuvre for individual decisions falls however within a frame which in the population in question permit TFRs of between only 1.32 and 2.36 with a mean TFR value of 1.8 in the world. The »demographic freedom« of the TOTAL POPULATION is restricted to a different extent for each level of life expectancy. The possible age structure of the populations is also determined by this restriction at each level. It is not fertility but rather the survivor function which appears to be the decisive regulating mechanism in the demographic control process. The »standard result« of demography which was cited at the beginning can be derived from the conditions at levels of life expectancy from 20 to 50 years where the mean TFK value is constantly found to be 6.5. As Table XIII shows, under these conditions a dramatic drop in mortality from 49.5 to 15.7 per thousand with a TFR of 6.0 has only relatively minor effects on the mean age of the populations: it falls from 26.2 to 22.5 years. The Malthusian approach of steady-state calculations consequently leads in these areas to justifiable results. But it should be remembered that Malthus proceeded on the basis of postulating the constancy of the »passion between the sexes«. For populations which have reached levels of life expectancy of more than 55 years the constancy of fertility is no longer applicable, as can be seen from Table 3 and Graph C. Malthus' postulate no longer applies. The foundations have been pulled out from beneath steady-state calculations.

The historical and demographic experiences of the last hundred years presents us with the conclusion: Since humans as all other creatures are concerned with their own lives in the first place, they were exceptionally successful in combatting mortality. In the course of the evolution they could afford to have a continually smaller number of offsprings than »natural« to secure their survival and to emancipate their women from their biological obligations. Capable of being influenced by human actions are primarily the living conditions of a population. From this it follows: The level of and variance in fertility are functionally dependent on the level of life expectancy attained by the population in question.

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