Determinants and Consequences of Mortality and Fertility Trends

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FERTILITY AND MORTALITY have usually been in approximate balance, at least until modern times. High death rates were approximately matched by high birth rates. With rising levels of living, first the death rates and then the birth rates declined. The decline in birth rates tended to restore approximate balance between fertility and mortality.

But now it is feared that extension of modern health services to less developed countries will have appalling consequences (*1*). It is feared that the extension of alien methods and materials, with external technical and financial assistance, will disrupt the dynamic equilibrium of economic and demographic transition which was observed during the gradual industrialization of Western Europe.

The extreme experiences of Ceylon, Mauritius, and British Guiana are cited in support of claims that public health techniques at low cost per capita have resulted in precipitous reductions in the death rates in the postwar era, quite independently of any improvements in the levels of living, which may decline or be difficult to attain as a result. Lacking substantial improvements in the levels of living, there would be no reduction in fertility.

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Thus, the panel of distinguished scientists, brought together by the Committee on Science and Public Policy of the National Academy of Sciences to review and summarize the findings of others on population growth and its consequences, reported (*2*):

> The death rate in less-developed areas is dropping very rapidly—a decline that looks almost vertical compared to the gradual decline in Western Europe—and without regard to economic change. . . .
>
> The less-developed areas have been able to import low-cost measures of controlling disease, measures developed for the most part in the highly industrialized societies. The use of residual insecticides to provide effective protection against malaria at a cost of no more than 25 cents per capita per annum is an outstanding example. . . .
>
> The death rate in Ceylon was cut in half in less than a decade and declines approaching this in rapidity are almost commonplace. The result of a precipitous decline in mortality while the birth rate remains essentially unchanged is, of course, a very rapid acceleration in population growth. . . .
>
> In the longer run, economic progress will eventually be stopped and reversed unless the birth rate declines *or the death rate increases.* Economic progress will be slower and more doubtful, if less-developed areas wait for the supposedly inevitable impact of modernization on the the birth rate. They run the risk that rapid population growth and adverse age distribution would themselves prevent the achievement of the very modernization they count on to bring the birth rate down.

The dismal sequence was elaborated by Cipolla (*1*): "The higher the population growth, the harder becomes the task of breaking through

the Malthusian trap. A vicious spiral is set into operation. Because of a high rate of population growth, industrialization is difficult to attain. Because there is no industrialization, the birth rate and the rate of population growth remain high."

Yet to be seen, such a dismal sequence can not simply be dismissed and ignored as an alarmist non sequitur. Unless and until certain of the postulated determinants and consequences of mortality and fertility trends are shown to be contrary to or distortions of the natural dynamics of economic and demographic transition, planners may wonder whether modern health services have, in fact, a part in pushing less developed countries into the "Malthusian trap" and, if so, whether curtailment or at least less enthusiastic extension of modern health services would be a logical, although an unspeakable and unspoken, means of escaping the Malthusian trap.

This leads to the questions whether death rates in less developed areas are, in fact, dropping very rapidly without regard for economic change and whether fertility trends are, in fact, conditioned by the economic rather than the demographic aspects of economic and demographic transition.

Mortality Trends

If the sequence of events in Ceylon, Mauritius, and British Guiana had demonstrated that economic development is no longer a prerequisite for a decline in the death rate, it might have seemed plausible to postulate that modern public health measures would tend to reduce per capita income as well as mortality, should economic development lag, with the inference that per capita income would rise with a rise in mortality. But the postulation of such determinants and consequences of mortality trends is not confirmed by the experiences of Ceylon, Mauritius, and British Guiana.

The postwar reduction in the death rate in Ceylon, from 20 to 14 per 1,000 in the single year from 1946 to 1947, was attributed mainly to the spraying of insecticides (*1*, *3*, *4*). But, as I have already shown (*5*), the spectacular reduction in mortality was about the same for the area without malaria not protected by insecticides as for the area with malaria protected by insecticides. It has also been shown that the decline in mortality was associated with a commensurate development of the economy and rise in the levels of living (*6*, *7*).

The postwar reduction in the death rate in Mauritius, from 30 to 20 per 1,000 in the single year from 1946 to 1947, was also attributed mainly to the spraying of insecticides (*1*, *3*). But the spraying campaign was started in 1949 (*8*), 2 years after the dramatic reduction in the death rate in 1947. Moreover, the per capita production of sugar, the staple industry and virtually the sole export of the island, rose sharply as mortality declined.

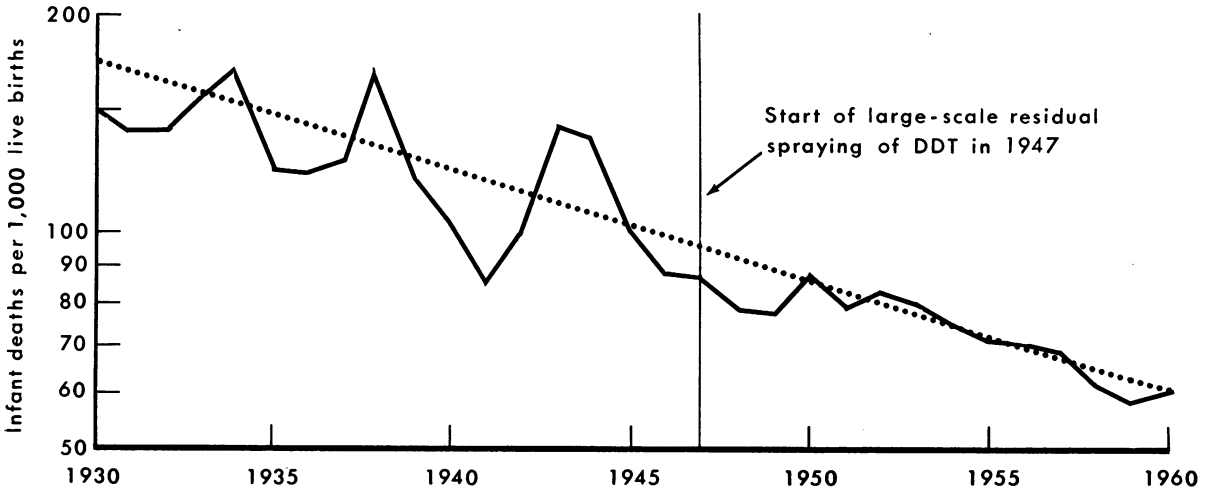
The average annual sugar production per capita and the average annual death rates for 1937 to 1951 in Mauritius were:

Year	*Sugar production per capita (kilograms)*	*Death rates per 1,000*
1937–41	720	27. 6
1942–46	598	29. 6
1947–51	918	17. 9

SOURCES: (*a*) Mauritius Chamber of Agriculture, 1853–1953. Port Louis, 1953; (*b*) Annual Reports of the Registrar General on Births, Deaths and Marriages, Colony of Mauritius.

"Like Ceylon, British Guiana has often been cited as a classic example of the rapid reduction in the prevalence of malaria, consequent upon a careful spraying campaign using DDT; and, as in the former case, the large postwar acceleration in her rate of population growth has often been attributed mainly to this factor" (*4*). Thus the Mission, organized by the International Bank for Reconstruction and Development, reported (*9*): "Before 1945, the drainage and irrigation canals of the coastal area had long furnished ideal breeding places for *Anopheles darlingi*, the malaria carrying mosquito, and malaria was the principal cause of sickness and death. In that year, a thorough campaign to spray all homes with DDT was undertaken. This, the first civilian campaign of its kind in the world, was strikingly successful, and in a very short time the *Anopheles darlingi* was virtually eliminated. The disappearance in malaria brought about a sharp fall in the death rate. . . . In particular, infant mortality showed a striking decrease from 110.7 per 1,000 live births in 1940–45 to 81.8 in 1946–51."

Figure 1. Infant mortality rates, British Guiana, 1930–60



NOTE: Trend for the pre-insecticide infant mortality rates between 1937 and 1946 is indicated by the least squares line ($y=130.84-3.37x$).

SOURCES: Demographic Yearbooks of the United Nations.

In fact, "systematic DDT control was begun in January 1947 and extended to the entire coastal area by March 31, 1948" (*10*), when infant mortality had already declined from the wartime peak to the long-term downtrend 3 years previously (fig. 1). Obviously, the long-term downtrend was not accelerated by the postwar application of insecticides. Malaria may have been the principal cause of sickness, but the control of malaria was not the principal factor in the postwar reduction in mortality.

Again, demographic change was associated with economic change. With an average annual rate of increase in commercial energy consumption per capita of 26 percent for the 17 years between 1937 and 1954, British Guiana had the third highest rate of increase among the 97 countries listed (*11*). The Mission of the International Bank for Reconstruction and Development reported a 45 percent increase in real national product and a 19 percent increase in real national product per capita between 1942 and 1951 (*9*).

Thus, the case histories of Ceylon, Mauritius, and British Guiana, three less developed countries with per capita products of about $122, $200, and $238 (U.S.) respectively in 1955, confirm and extend the validity of the findings (*12*) of my cross-national study of the determinants of postwar mortality trends in 21 more developed or less developed countries with per capita products ranging from $180 to $2,343 (U.S.) in 1955.

Correlations between age-specific mortality rates and economic variables from 21 countries, over a period of time as well as at a point in time, indicate highly negative correlations of per capita products at constant prices and of per capita consumption of newsprint, protein, and calories with age-specific mortality rates, particularly in the younger age groups. The coefficient of correlation between the logarithmic transformations of the per capita products at constant prices and the mortality rates for the age group 1–4 years was −0.86 in the cross-sectional comparison and −0.72 in the longitudinal comparison. But the coefficient of correlation between the logarithms of the number of physicians per 100,000 inhabitants and the mortality rates for the same age group, 1–4 years, was only −0.54 in the comparison at the same point in time and −0.21 in the comparison over the same period of time.

The case histories of Ceylon, Mauritius, and British Guiana, as well as correlations of longitudinal and cross-sectional variables from 21 countries, indicate that the beneficial effects of medical services are achieved in synergism with other improvements in the levels of living. This is confirmed by the rank correlations of

recent infant mortality rates with physicians per 100,000 inhabitants and with personal income per capita in the 50 States of the United States, where in 1963 infant mortality ranged from 41.3 to 18.6 per 1,000 and personal income per capita ranged from $1,390 to $3,386. However, the rank correlation of −0.59 between U.S. infant mortality and the ratio of physicians to population and the rank correlation of only −0.47 between infant mortality and personal income per capita in 1963 indicates that, for further reductions in mortality, development of the medical services may become relatively more important and the other components of the levels of living may become relatively less important as levels of living improve and mortality declines.

Those who overestimate the capabilities of modern health services hardly promote the extension of more such services when they believe such extension of ostensibly too efficient services may do more harm than good. Conversely, the demonstration that the beneficial effects of modern health services are achieved in synergism with other improvements in the levels of living justifies the extension of such services as integral parts of social and economic development.

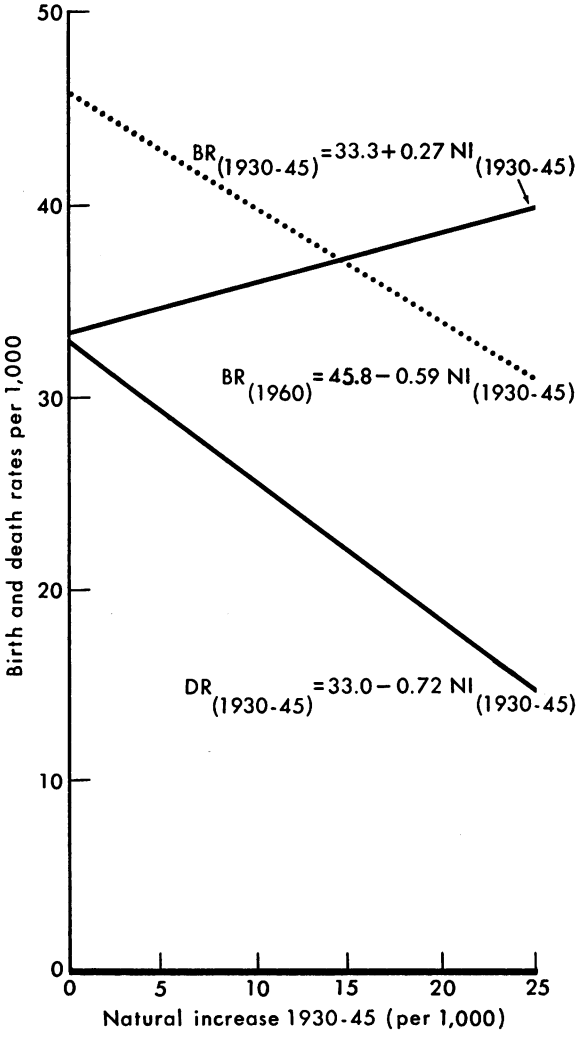
Thus, reductions in mortality as well as the promotion of health and productivity are not shown to be mixed blessings, particularly when it is also noted that reductions in the death rate have invariably preceded reductions in the birth rate.

Fertility Trends

"With high mortality, many children must be born to ensure that some will survive to take care of their parents" (*2*). If a low rate of natural increase were the sole objective and a satisfactory solution to the population problem, there would be no problem so long as the high death rate remains high, even when matched by a high birth rate. But, all humanitarian considerations aside, this would be contrary to the public interest. Only a low death rate will bring about a high rate of return on the investment in human resources, and only a low birth rate will bring about a high ratio of producers to dependents.

The question remains whether a decline in the birth rate will follow the decline in the death rate in the less developed countries or whether there will be a fundamental difference in the interaction of economic and demographic transition in the future of the developing countries and in the history of the West. There have been doubts whether reductions in mortality, considered to be independent of improvements in the levels of living, would be followed by declines in the birth rate. In fact, data

Figure 2. Lines of regression between birth rates 1960, birth rates 1930–45, death rates 1930–45, and the rates of natural increase 1930–45 in the 21 districts of Ceylon



SOURCE: reference 4.

Table 1. Postwar birth rates, death rates, rates of natural increase, and indices of relative change in the birth rates, by district in Mauritius

District [1]	Average annual rates, 1945–49 (per 1,000)			Indices of relative change in birth rates (1945–49=100)			
	Birth rates	Death rates	Rates of natural increase	1950	1955	1959	1964
Black River	32. 8	34. 7	−1. 9	140. 2	143. 0	134. 1	121. 3
Savanne	40. 5	30. 7	9. 8	120. 5	97. 5	98. 3	101. 2
Pamplemousses	40. 9	30. 9	10. 0	137. 2	103. 4	91. 9	82. 9
Flacq	39. 4	29. 0	10. 4	127. 7	109. 1	99. 7	102. 8
Grand Port	41. 2	30. 8	10. 4	123. 1	100. 0	93. 9	97. 6
Moka	46. 0	27. 5	18. 5	117. 2	85. 7	72. 2	80. 4
Port Louis	42. 2	22. 6	19. 6	116. 8	104. 3	95. 3	91. 9
Plaines Wilhems	41. 8	18. 5	23. 3	108. 1	93. 8	88. 0	85. 6
Riviere du Rempart	50. 3	25. 8	24. 5	115. 1	94. 4	82. 1	82. 9

[1] Listed in order of magnitude of the rate of natural increase, 1945–49.

SOURCES: (*a*) Annual Reports of the Registrar General on Births, Deaths and Marriages, Colony of Mauritius, Port Louis; (*b*) Yearbook of Statistics, Central Statistical Office, Colony of Mauritius, Port Louis, 1959; (*c*) Personal communication, Registrar General's Department, Central Civil Status Office, Port Louis, March 1966.

from the 21 districts of Ceylon (*6*) demonstrate such remarkable correlation between the previous levels of the death rates and current levels of the birth rates, that low death rates merit consideration as contributing factors, if not as prerequisites, for low birth rates in the less developed as well as the more developed countries (fig. 2).

The sequential relationship between mortality and fertility observed in the history of the West and again in 21 districts of Ceylon holds true in the 9 districts of Mauritius (table 1). The coefficients of correlation (product moment method) of the indices of relative change in birth rates in 1950, 1955, 1959, and 1964 (1945–49=100) with the average annual birth rates, death rates, and rates of natural increase in 1945–49 for the nine districts of Mauritius are:

Rates, Mauritius (9 districts)	*Indices (1945–49=100)*			
	1950	*1955*	*1959*	*1964*
Birth, 1945–49	−. 68	−. 83	−. 88	−. 84
Death, 1945–49	. 85	. 56	. 55	. 60
Natural increase, 1945–49.	−. 88	−. 80	−. 82	−. 83

SOURCE: table 1.

The inverse relationship between the initial rate of population growth and subsequent relative change in fertility also holds true in 15 districts in the coastal plain of British Guiana; all the districts for which somewhat tenuous estimates produced a series of data of uncertain comparability, particularly over a period of time (table 2).

The coefficients of correlation (product moment method) of the indices of relative change in the birth rates in 1950 and 1955 (1945–49=100) with the average annual birth rates, death rates, and notably the rates of natural increase in 1945–49 for the coastal districts of British Guiana show a certain consistency with the findings for Mauritius.

Rates, British Guiana (coastal districts)	*Indices (1945–49=100)*	
	1950	*1955*
Birth, 1945–49	−. 48	−. 66
Death, 1945–49	. 76	. 35
Natural increase, 1945–49	−. 68	−. 67

SOURCE: table 2.

Application of the same method of analysis to the demographic experience in the 21 districts of Ceylon again indicates an inverse relationship between the excess of birth rates over death rates and the subsequent relative change in the birth rates (table 3). After adjustment of the rates for under-enumeration at the census, the coefficients of correlation (product moment method) of the indices of relative change in the birth rates in 1960 and the average annual birth

Table 2. Estimated postwar birth rates, death rates, rates of natural increase, and indices of relative change in birth rates in coastal districts of British Guiana

Coastal districts [1]	Average annual rates, 1945–49 (per 1,000)			Indices of relative change in birth rate (1945–49=100)	
	Birth rates	Death rates	Rates of natural increase	1950	1955
New Amsterdam	30.5	17.8	12.7	104.6	120.0
Highbury	35.0	17.5	17.5	112.9	119.7
Georgetown	33.0	15.2	17.8	107.3	117.6
Lower Canje	38.7	14.8	23.9	108.3	117.8
Suddie-Anna Regina [2]	43.9	19.7	24.2	109.3	115.0
Peter's Hall	40.8	16.4	24.4	105.6	109.8
Bellevue	43.4	17.0	26.4	115.0	112.4
Plaisance-Mahaica [2]	42.8	15.9	26.9	101.9	101.4
Leonora	44.8	16.2	28.6	94.9	95.1
Mahaicony	41.8	12.2	29.6	98.3	105.5
Cotton Tree	43.9	12.9	31.0	90.7	106.4
Skeldon	43.7	11.9	31.8	89.7	117.8
Port Mourant	44.9	12.3	32.6	90.6	93.1

[1] Listed in the order of magnitude of the rate of natural increase, 1945–49.
[2] Two districts.

SOURCE: reference 4.

Table 3. Estimated birth rates, death rates, rates of natural increase, and indices of relative change in the birth rates in the 21 districts of Ceylon

Districts [1]	Average annual rates,[2] 1930–45 (per 1,000)			Indices of relative change in birth rate [2] (1930–45=100)	
	Birth rates	Death rates	Rates of natural increase	1946–60	1960
Puttalam	33.7	32.7	1.0	130.3	124.9
Vavuniya	33.6	32.5	1.1	139.9	170.5
Mannar	33.0	31.8	1.2	119.1	123.6
Anuradhapura	36.7	34.2	2.5	120.4	130.5
Hambantota	39.4	35.8	3.6	116.5	109.1
Trincomalee	34.4	26.4	8.0	118.3	133.7
Jaffna	32.3	22.8	9.5	105.9	99.4
Colombo	29.8	19.0	10.8	118.8	115.4
Batticaloa	40.6	29.7	10.9	107.6	121.9
Kurunegala	39.5	28.2	11.3	104.6	95.7
Negombo	28.6	16.3	12.3	106.6	101.7
Chilaw	31.2	18.0	13.2	106.7	96.8
Matale	41.3	27.0	14.3	105.8	102.2
Kalutara	31.9	16.0	15.9	99.1	88.1
Galle	36.1	19.3	16.8	95.3	88.6
Matara	38.5	20.6	17.9	101.3	93.2
Kegalla	36.6	18.5	18.1	97.3	88.5
Kandy	39.6	21.4	18.2	99.7	98.2
Ratnapura	38.4	20.0	18.4	102.6	94.8
Badulla	43.5	23.6	19.9	95.4	97.0
Nuwara Eliya	43.3	21.2	22.1	91.0	86.6

[1] Listed in the order of magnitude of the average annual rate of natural increase, 1930–45.
[2] Rates adjusted for under-enumeration of the censuses.

SOURCE: reference 4.

rates during 1946–60 (1930–45=100) with the average annual birth rates, death rates, and rates of natural increase in 1930–45 in the 21 districts of Ceylon were:

Rates, Ceylon (21 districts)	*Indices (1930–45=100)*	
	1946–60	*1960*
Birth, 1930–45	−.43	−.25
Death, 1930–45	.67	.68
Natural increase, 1930–45	−.91	−.80

SOURCE: table 3.

In the immediate postwar era, the short-term trend of the national birth rates in Ceylon, Mauritius, and British Guiana had been upward for various reasons, including a spurt in the marriage rate, an increase in the proportion of married women, and an improvement in the birth registration. However, the differential in the fertility experience by district demonstrates the inverse relationship with the preceding rate of population growth (tables 1–3 and text tables). The relative change in fertility was more consistently and highly correlated with the initial excess of birth rate over death rate (negative correlation) than with either the initial level of the birth rate (negative correlation) or with the initial level of the death rate (positive correlation). The districts with death rates too high and birth rates too low to insure replacement of the population subsequently experienced the greatest increase in the birth rates. The districts with the greatest excess of birth rates over death rates subsequently experienced the greatest decrease or the least increase in the birth rates. Thus, reductions in mortality still precede reductions in fertility.

The case histories of Ceylon, Mauritius, and British Guiana, three less developed countries with per capita products of about $122, $200, and $238 (U.S.) respectively in 1955, confirm and extend the validity of the findings (*12*) of my cross-national study of the determinants of postwar fertility trends in 21 more developed or less developed countries, heterogeneous in respect to economic system, political ideology, and religious doctrine, with per capita products ranging from $180 to $2,343 (U.S.) in 1955.

Table 4. Postwar population density, rate of natural increase, and indices of relative change in marriage rate, birth rate, and product per capita in 21 countries

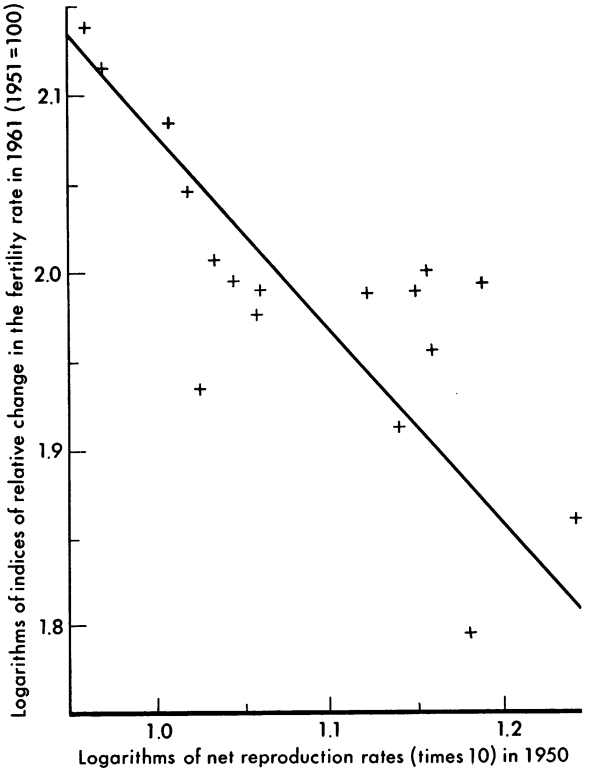
Country [1]	Population density per square kilometer, 1950	Rate of natural increase per 1,000 population, 1950	Indices of relative change		
			Marriage rate, 1960 (1950=100)	Birth rate, 1961 (1951=100)	Product per capita, 1960 (1950=100)
Japan	225	17.3	108.1	66.2	206.1
Israel	60	26.5	55.7	69.4	170.9
Finland	12	14.4	88.1	80.0	140.8
Yugoslavia	63	17.3	79.1	83.4	190.0
Argentina	6	16.5	86.3	88.5	96.2
Sweden	16	6.4	87.0	89.8	130.2
France	76	7.9	88.6	92.4	140.6
Denmark	99	9.4	85.7	93.7	129.1
Netherlands	312	15.2	95.1	95.1	139.1
Norway	10	10.0	98.8	95.2	128.2
United States	19	13.9	77.3	95.6	116.6
Canada	1	18.0	80.2	96.0	113.3
Portugal	93	12.2	102.6	96.8	138.0
Italy	154	9.8	101.3	102.1	167.4
Chile	8	19.0	92.4	102.4	113.6
Belgium	283	4.4	86.6	103.6	125.8
Spain	56	9.3	105.4	104.9	159.4
Switzerland	114	8.0	98.7	105.2	138.6
United Kingdom	207	4.4	93.8	113.2	123.1
West Germany	194	6.0	90.7	114.3	175.0
Austria	82	3.2	90.2	125.6	174.1

[1] Listed in the order of magnitude of the index of the birth rate in 1961 (1951=100).

SOURCES: Demographic and Statistical Yearbooks of the United Nations.

Correlations between economic and demographic variables from the 21 countries, for which comparable data are available in the postwar era, indicate only weak or no associations of changes in the birth rate with changes in economic variables, including per capita product at constant prices and per capita consumption of newsprint, protein, and calories. The coefficient of correlation between the logarithms of the decennial indices of relative change in the birth rate from 1951 to 1961 and in the product per capita at constant prices from 1950 to 1960 is only −0.23. Nor are the changes in the birth rates explained by the changes in the marriage rates. The coefficient of correlation between the logarithms of the decennial indices of relative change in the marriage rate from 1950 to 1960 and in the birth rate from 1951 to 1961 is only 0.37. But the logarithms of the decennial index of relative change in the birth rate from 1951 to 1961 are inversely proportional to the logarithms of the rate of natural increase or excess of birth rate over death rate in 1950, the coefficient of correlation being −0.73 (table 4).

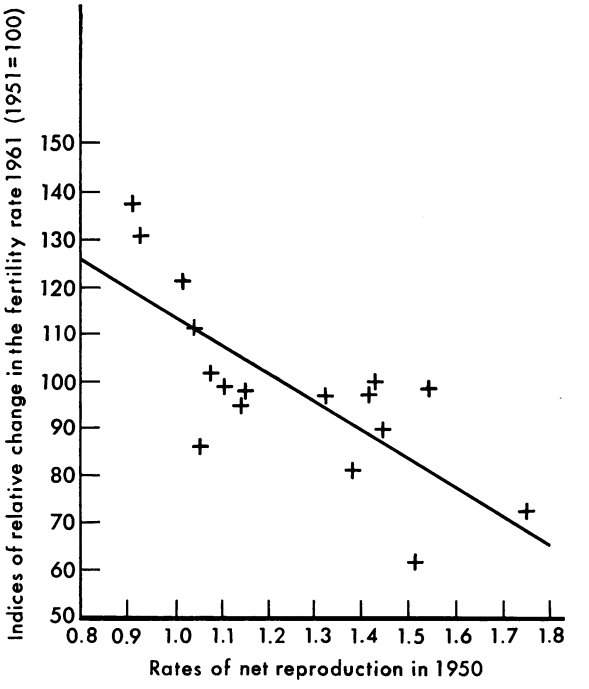
Figure 3. Logarithms of net reproduction rates (times 10) in 1950 and logarithms of indices of relative change in the fertility rate in 1961 (1951=100) in 17 countries



NOTE: The line of regression is indicated by the least squares line ($y=3.17-1.09\,x$).

SOURCES: Demographic Yearbooks of the United Nations.

Figure 4. Rates of net reproduction in 1950 and indices of relative change in the fertility rate in 1961 (1951=100) in 17 countries



NOTE: The line of regression is indicated by the least squares line ($y=172.4-58.9x$).

SOURCES: Demographic Yearbooks of the United Nations.

Without the logarithmic transformation, which was used in the previous study (*12*) to transform the relationships between economic and demographic variables from the 21 countries to linearity, the coefficient of correlation between the excess of birth rate over death rate in 1950 and the index of relative change in the birth rate in 1961 (1951=100) equals −0.79. Eliminating the effect of the change in the marriage rate between 1950 and 1960, the coefficient of partial correlation between the rate of natural increase in 1950 and the index of relative

Table 5. Birth rates, death rates, rates of natural increase, indices of relative change in birth rate, and absolute change in birth rate, by U.S. regions

Regions [1]	Rates (per 1,000), 1940			Indices of relative change in birth rate (per 1,000), 1964 (1940=100)	Absolute change in birth rate, 1940–64
	Birth rates [2]	Death rates	Rates of natural increase		
New England	15.9	11.7	4.2	127.0	4.3
Middle Atlantic	15.6	11.2	4.4	125.0	3.9
Pacific	16.6	11.5	5.1	123.5	3.9
East North Central	17.7	11.0	6.7	120.3	3.6
West North Central	18.4	10.3	8.1	112.0	2.2
South Atlantic	24.1	10.5	13.6	90.9	−2.2
Mountain	24.0	10.2	13.8	94.2	−1.4
West South Central	23.8	9.7	14.1	94.1	−1.4
East South Central	25.4	10.4	15.0	87.4	−3.2

[1] Listed in the order of magnitude of the rate of natural increase in 1940.
[2] Adjusted for under-registration.

SOURCES: (*a*) Vital Statistics of the United States, Public Health Service; (*b*) monthly Vital Statistics Report, National Center for Health Statistics, Public Health Service, October 1965.

change in the birth rate in 1961 (1951=100) remains highly negative; namely −0.76. Eliminating any effect of the change in the product per capita between 1950 and 1960, the coefficient of partial correlation between the rate of natural increase in 1950 and the index of relative change in the birth rate in 1961 (1951=100) again remains highly negative; namely, −0.80. Holding the population density in 1950 constant, the coefficient of partial correlation between the rate of natural increase in 1950 and the index of relative change in the birth rate in 1961 (1951=100) equals −0.78 (table 4).

The inverse relationship between the initial rate of population growth and the subsequent relative change in fertility also holds true when data from the same countries but different periods of time are used. The coefficient of the correlation between the logarithms of the average annual rate of natural increase during 1930–34 and the logarithms of the subsequent indices of relative change in the birth rates (1930–34=100) in 20 of the 21 countries for which comparable data are available was -0.49 during 1940–44 and −0.50 during 1945–49.

The inverse relationship between the initial rate of population growth and the subsequent relative change in fertility also holds true whether crude or refined measures are used. More refined measures of population growth and fertility are available for 17 of the 21 countries with per capita products ranging from $201 to $2,343 (U.S.) in 1955. The coefficient of the correlation between the logarithms of the rate of net reproduction (times 10) in 1950 and the logarithms of the decennial index of relative change in the fertility rate (births per 1,000 females 10–49 years of age) from 1951 to 1961 in the 17 countries equals −0.70 (fig. 3). Without the logarithmic transformation, which was used in the previous study (*12*) to transform the relationships to linearity, the coefficient of the correlation between the net reproduction rate in the base year and the decennial index of relative change in the fertility rate equals −0.76 (fig. 4).

The inverse relationship between the initial rate of population growth and the subsequent relative change in fertility also holds true when the same method of analysis is applied to the recent demographic experience of the most developed as well as the less developed countries in late as well as early stages of demographic transition. The coefficient of correlation between the rate of natural increase in 1940 and the index of relative change in the birth rate in the nine regions of the United States in 1964 (1940=100) equals −0.99 (tables 5 and 6).

Moreover, the inverse relationship with the initial rate of population growth holds for the

absolute as well as the relative change in the birth rate (tables 5, 6, and fig. 2). This seems to indicate that the apparent relationship is not solely and simply an artifact of a spurious correlation introduced by a particular measure of change.

But, with birth rates from the same year as entry for the denominator of one variable and for the numerator of another, the question has arisen whether chance variations and random errors of measurement have inflated the coefficients of correlation. If that were the case, the inflationary effects of the two sources of variation would be eliminated and the coefficients of correlation would be attenuated by deriving the relative change in the birth rates and the initial rates of natural increase from birth rates in different years. In fact, the two sources of variation seem to have a random effect on the coefficients of correlation (tables 7 and 8). It would seem that chance variations and random errors may attenuate as well as inflate the coefficients of correlation, whether birth rates from identical or different years are used to derive the two variables. In any event, the inverse relationship between the initial rate of population growth and subsequent change in the birth rate holds true whether birth rates from identical or different years, but from the same period of time, are used to derive the two variables.

Thus, a reduction in the death rate would seem to be a necessary, if not a sufficient, condition for a deliberate reduction in the birth rate, whether by spontaneous family planning or national population policy, regardless of economic system, political ideology, or religious doctrine. Moreover, the extension of health services provides facilities for the extension of family planning.

The findings amplify authoritative views (*13*):

Table 6. Rank correlations of absolute change in birth rate 1940–64 and indices of relative change in birth rates in 1964 (1940=100) with birth rates, death rates, and rates of natural increase in 1940 in 9 U.S. regions

U.S. rates (9 regions), 1940	Absolute change in birth rate, 1940–64	Indices of relative change in birth rates, 1964 (1940=100)
Birth	−0.95	−0.97
Death	.74	.73
Natural increase	[1] −.93	[1] −.95

[1] Coefficient of correlation by the product moment method is −0.99.

SOURCE: table 5.

Table 7. Rank correlations of the average annual rates of natural increase in the base years with the indices of relative change in the subsequent birth rates in the 9 districts of Mauritius

Average annual rates of natural increase in base years	Indices of relative change in birth rates in 1964 (average annual birth rates in base years=100)		
	1945, 1947, and 1949 =100	1946 and 1948=100	1945–49 =100
1945, 1947, and 1949	−0.58	[1] −0.67	−0.62
1946 and 1948	[2] −.55	−.63	−.59
1945–49	−.57	−.67	[3] −.61

Coefficients of correlation by the product moment method are: [1]−0.86; [2]−0.77; [3]−0.83.

SOURCES: Same as table 1.

Table 8. Rank correlations of the average annual rates of natural increase in the base years with the indices of relative change in the subsequent birth rates in the 21 districts of Ceylon

Average annual rates of natural increase in the base years, 1930–45	Indices of relative change in birth rates during 1946–60 (average annual rates in base years=100)		
	Even years 1930–45= 100	Odd years 1930–45= 100	All years 1930–45= 100
Even years	−0.90	[1] −0.95	−0.93
Odd years	[2] −.87	−.91	−.89
All years	−.90	−.94	[3] −.92

Coefficients of correlation by the product moment method are: [1]−0.93; [2]−0.85; [3]−0.91.

SOURCE: reference 4.

Before any of the under-developed countries can effectively spread the practice of family limitation, they must have reasonably well-developed services in maternal and child health, health education, and community development. . . . Occasionally, one hears the objection that such efforts only complicate the problem of population growth by reducing the death rate. In the narrow sense, it is true, but it is basically false. No efforts of social-economic development can be successful in a disease-ridden population, nor will a desire for small families be likely to emerge. Better health and improved chances for survival of the individual child lie at the root of the motivational change we are seeking. . . . The failure of birth rates to fall in other parts of the world clearly turns less on lack of effective means than on the absence of strong motivation.

Dynamics of Transition

The economic and demographic transition observed in modern history of the West provides ample evidence of a tendency toward self-regulation of population growth. The feedback mechanism of this rational system of homeostasis has been obscured by relating the reduction in fertility to improvements in economic components in the levels of living when, in fact, a deliberate reduction in fertility is a sequel to a reduction in mortality, which develops individual and collective motivation as well as the need for a commensurate restraint of fertility.

Combination of empirical equations (*12*) for the relative change in fertility and mortality in the 21 countries, for which comparable economic and demographic data are available, indicates the dynamic equilibrium of economic and demographic transition in the postwar era.

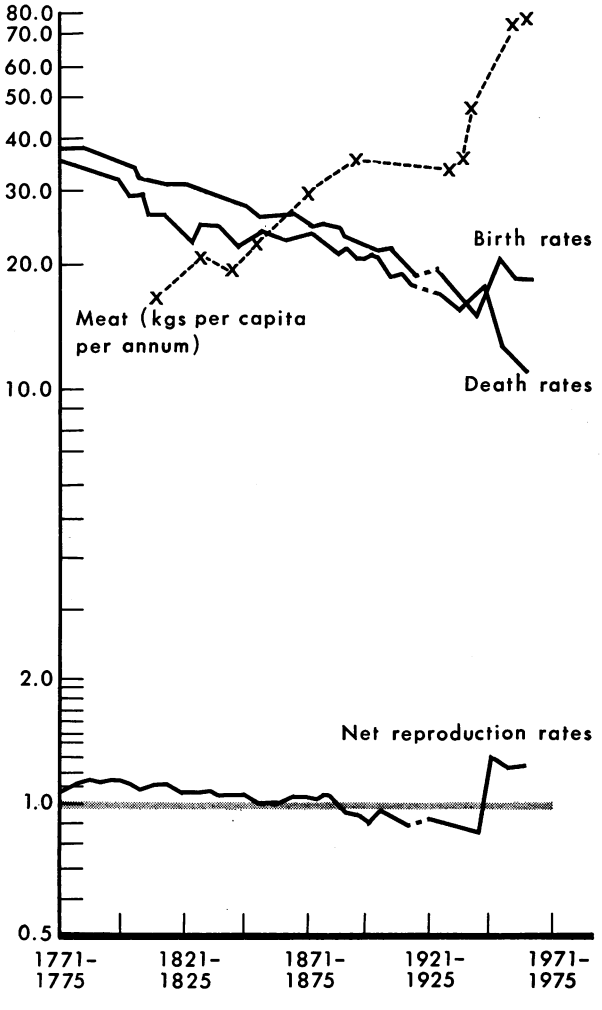
The logarithm of the index of relative change in the birth rate being inversely proportional to the logarithm of the rate of natural increase in the base year, the relative change in natality n in year t can be expressed in terms of natality n and mortality m in the base year o:

$$\log n_t - \log n_o = t\,[\log a - b \log (n_o - m_o)]$$

$$\frac{n_t}{n_o} = \left[\frac{a}{(n_o - m_o)^b}\right]^t$$

The logarithm of the index of relative change in the death rate being inversely proportional to the logarithm of the index of relative change in the per capita product at constant prices, the relative change in mortality m in year t

Figure 5. Average annual birth rates per 1,000, death rates per 1,000, and net reproduction rates in the quinquennia between 1771–75 and 1956–60, and annual consumption of meat and animal fat (kilograms per capita) between 1812 and 1960, France



SOURCES: (*a*) Annuaires Statistiques de la France. Institut National de la Statistique et des Etudes Economiques. Ministere des Finances et des Affaires Economiques, Republique Francaise; (*b*) Demographic and Statistical Yearbooks of the United Nations; (*c*) Bourgeois-Pichat, J.: The general development of the population of France since the eighteenth century. Ch. 20. Population history. Aldine Publishing Co., Chicago, 1965; (*d*) Clark, C.: The conditions of economic progress. MacMillan, London, 1951.

can be expressed in terms of the relative change at constant prices in per capita product p in year t:

$$\log m_t - \log m_o = t[\log c - d\ (\log p_t - \log p_o)]$$

$$\frac{m_t}{m_o} = \left[\frac{c}{\left(\frac{p_t}{p_o}\right)^d}\right]^t$$

Combining the equations for relative change in natality and mortality, the rate of natural increase $n-m$ in year t can be expressed in terms of natality n and mortality m in the base year o and the relative change at constant prices in per capita product p in year t:

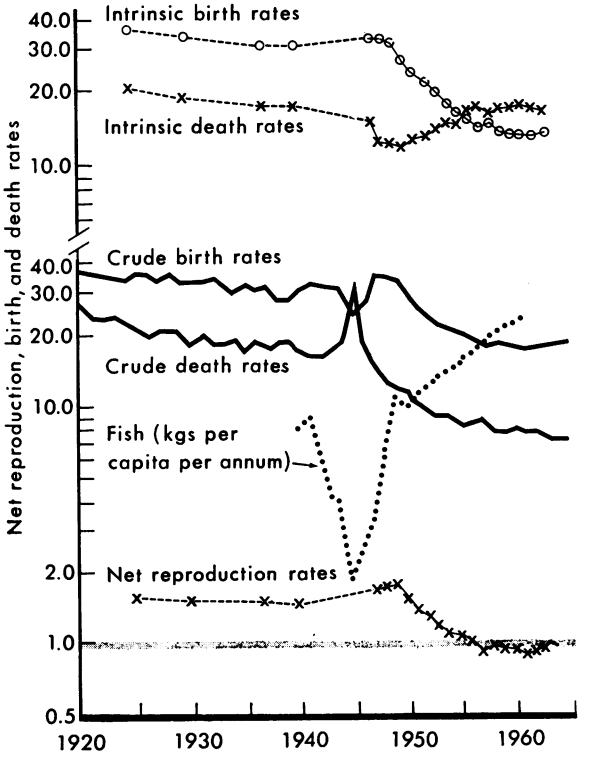
$$n_t - m_t = n_o\left[\frac{a}{(n_o - m_o)^b}\right]^t - m_o\left[\frac{c}{\left(\frac{p_t}{p_o}\right)^d}\right]^t$$

Thus, mortality varies inversely with economic indicators of the levels of living; in a balancing movement, fertility tends toward approximate equilibrium with mortality; that is, toward a rate of net reproduction above the replacement level but near unity. In fact, among the 17 countries for which more refined demographic data are available, those countries with net reproduction rates ranging from 1.06 to 1.75 in 1950 experienced a decrease in the fertility rates in the subsequent decade, whereas those countries with net reproduction rates ranging from 0.91 to 1.08 in 1950 experienced an increase in the fertility rates in the subsequent decade (fig. 4).

The recent demographic experience of the 17 countries reflects the historical tendency of fertility trends to maintain or restore approximate balance between mortality and fertility, as indicated by the demographic experience of France over the past two centuries, in the course of the transition from low to high levels of living and high to low death rates (fig. 5). A similar tendency toward approximate balance between mortality and fertility is indicated by the experience of Japan, where demographic transition began much later than in France (fig. 6). In Japan, the oscillation of the net reproduction rate above the replacement level was much greater in the course of the demographic transition, but the transition was greatly accelerated. The tendency toward approximate balance between mortality and fertility becomes even more apparent when comparison of mortality and fertility trends is based on intrinsic rather than crude rates (fig. 6). Thus, compensatory fertility trends tend to balance mortality trends so that net reproduction oscillates about the replacement level (figs. 4, 5, and 6).

The spiral of concurrent and sequential improvements in the levels of living, reductions in mortality, and balancing movements in fertility does not establish that optimum changes would result from concentration of efforts on the economic aspects of economic and demo-

Figure 6. Processed fishery products (kilograms per capita, per annum), crude and intrinsic birth rates and death rates per 1,000, and net reproduction rates, Japan, 1920–64



SOURCES: (*a*) Statistical Yearbooks, Prime Minister's Office, Japan; (*b*) Taeuber, I. B.: The population of Japan. Princeton University Press, Princeton, N.J., 1958.

graphic transition, whereby the desired changes in mortality and fertility would spontaneously and promptly follow, nor vice versa. With increased longevity increasing the returns from the development of human resources and decreased fertility decreasing the burdens of dependency, the maximum improvement in the levels of living, as well as the desired demographic changes, will result from the synergism of optimum efforts in the demographic as well as the economic aspects of transition.

Summary and Conclusions

Review of the case histories of Ceylon, Mauritius, British Guiana, the United States, France, and Japan, in early or late stages of demographic transition, confirms and extends the validity of the findings of a cross-national study of the dynamics of transition in 21 more developed or less developed countries for which comparable data on economic and demographic variables are available over a period of time as well as at a point in time in the postwar era.

After logarithmic transformation of the variables, mortality varies inversely with economic indicators of the levels of living. In a balancing movement, fertility tends toward approximate equilibrium with mortality; that is, toward a rate of net reproduction above the replacement level, but near unity.

The feedback mechanism of this rational system of homeostasis has been obscured by relating the reduction in fertility to improvements in economic components of the levels of living when, in fact, a deliberate reduction in fertility is a sequel to a reduction in mortality which develops individual and collective motivation as well as the need for a commensurate restraint of fertility. Moveover, the extension of health services provides facilities for the extension of family planning.

With increased longevity increasing the returns from the development of human resources and decreased fertility decreasing the burdens of dependency, the maximum improvement in the levels of living as well as the desired changes in mortality and fertility will result from the synergism of optimum efforts in the demographic as well as the economic aspects of economic and demographic transition.

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Report of the National Advisory Committee on Radiation

A report tracing growth in the uses of ionizing radiation in the health professions, industry, and other fields has been issued by the National Advisory Committee on Radiation for the Surgeon General of the Public Health Service. It notes a number of emerging problems concerning radiation protection which, if not alleviated, also threaten the quality of medical care in the United States and translation of the advances of atomic research into needed benefits for the people. These problems include (*a*) weaknesses in academic departments of radiology which have restricted efforts to provide adequate instruction of medical and postdoctoral students in the clinical applications of ionizing radiation, including radiation protection and (*b*) an increasing shortage of manpower in all branches of the radiological sciences. A concerted effort is needed by the Public Health Service to correct these large and complex problems.

The committee stated that alleviating the problems is but a part of a more comprehensive series of responsibilities faced by the Service in the radiological sciences. The Service must play an important role in the prevention of undue exposure of the population from medical, occupational, and environmental sources of ionizing radiation; at the same time, it must actively support the development and application of radiological methods in the diagnosis and treatment of diseases. In order that the Service may meet its enlarging responsibilities, the committee made a number of recommendations to the Surgeon General and urged that he take appropriate steps for their early implementation. The following is a summary of the recommendations.

1. The Public Health Service should take immediate steps to strengthen its programs in the radiological sciences by unifying administrative direction. Such action is needed to assure an orderly development of the broad spectrum of radiological activities for which the Service is responsible and to give continuous attention to the balance of benefit and risk in all matters pertaining to the human application of ionizing radiation.

2. The Service should undertake the following training and research and development programs to upgrade the quality of radiological services which have become a critical part of medical and dental care and to improve radiation protection practices in the health professions:

a. A series of training programs to strengthen radiological instruction of medical students, increase the number of academic radiologists in American medical schools, and increase the number of practicing radiologists in the United States.

b. A series of training programs to provide increasing numbers of radiochemists, radiological engineers, radiobiologists, radiological physicists, and radiological health specialists.

c. A series of training programs to provide increasing numbers of technologists in the several disciplines of the radiological sciences.

d. A series of applied research and development programs to increase the effectiveness and safety with which radiological procedures are employed in the health professions.

e. A series of programs to provide training and research facilities for academic departments of radiology in American medical schools.

3. The Service should take the initiative in the formulation and promulgation of

a. Standards dealing with the qualifications of personnel who operate X-ray equipment or use radioactive materials not regulated by the Atomic Energy Commission.

b. Design standards for sources containing radium and other radioactive materials that are not reactor byproducts.

c. Standards for the premarketing clearance of X-ray equipment used in the health professions and industry.

4. The Service should take appropriate action to assure that official health agencies play an increasingly prominent role in the appraisal of the health risks associated with construction and operation of major nuclear facilities.

5. The Service should take immediate steps to strengthen its laboratory and statistical resources in the radiological sciences. These resources are essential components of the Service's effort to meet the Surgeon General's responsibilities to the nation.

6. If needed, appropriate legislative authority should be sought at the earliest possible time to carry out the foregoing recommendations.