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DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS

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PREFACE

The *Population Bulletin of the United Nations* presents brief articles relating to population which, by their nature, do not require separate publication. Material for the *Bulletin* is selected in the light of the interests and needs of Governments, international organizations, research institutions and individuals engaged in social and economic research, as well as the public interested in population.

The first seven issues of the *Population Bulletin* were prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat between 1951 and 1963. In accordance with the endorsement and recommendation of the Population Commission at its eighteenth session, the *Bulletin* was reinstated as a United Nations publication, beginning with the publication of *Bulletin* No. 8 in 1977. As in the past, the *Bulletin* is prepared by the Population Division.

Most of the articles published in the *Bulletin* are prepared by the United Nations Secretariat in pursuance of the programme of work recommended by the Economic and Social Council and the Population Commission. Studies by consultants and reports of meetings organized by the United Nations, or excerpts from such studies and reports, may also be included. In addition, contributions are solicited from the specialized agencies of the United Nations, the secretariats of the regional commissions and scholars.

Explanatory notes

The following symbols have been used in the tables throughout the report:

Three dots (. . .) indicate that data are not available or are not separately reported.

A dash (—) indicates that the amount is nil or negligible.

A blank in a table indicates that the item is not applicable.

A minus sign (–) indicates a deficit or decrease, except as indicated.

A full stop (.) is used to indicate decimals.

A slash(/) indicates a crop year or financial year, e.g., 1970/71.

Use of a hyphen (-) between dates representing years, e.g., 1971-1973, signifies the full period involved, including the beginning and end years.

Reference to "tons" indicates metric tons, and to "dollars" ($) United States dollars, unless otherwise stated.

Annual rates of growth or change, unless otherwise stated, refer to annual compound rates.

Details and percentages in tables do not necessarily add to totals, because of rounding.

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A REASSESSMENT OF WORLD POPULATION TRENDS

*Ansley J. Coale**

SUMMARY

This reassessment is limited to observations concerning trends in mortality and fertility and concerning long-run prospects for population growth. Recorded changes in mortality are compared with three projections made many years ago. Projections of European mortality made in 1941–1942 understated by a wide margin the actual increase in expectation of life because of unforeseen technological changes in the prevention and cure of fatal disease. On the other hand, a projection made in 1955 for India, foreseeing a rapid rise in the 1950s and slower progress later on because of the exhaustion of the easier gains, appears to have been accurate and also to depict the prospects in other populations of relatively high mortality and low income. A different projection of life expectancy in Mexico was also quite close to actual changes in Mexican mortality; it was based on a universal curve constructed to represent how life expectancy rises, increasing ever more slowly as it approaches an upper limit. This curve (one for each sex), constructed for projection of Mexican mortality, is employed as a standard of comparison for mortality changes in many countries. A number have followed the standard for females very closely for more than three decades; in developed countries male life expectancy has generally fallen short of the standard.

The almost universal low fertility in developed countries contrasts with the great diversity of levels and trends of fertility in developing countries, some of which retain undiminished high fertility and others of which have recently attained rates of childbearing as low as in the developed areas. Instances of surprisingly little change and surprisingly rapid change in fertility are described.

In the future, growth of populations of developed countries will probably be slight; the future rate of increase in the developing areas depends on the unpredictable timing and pace of the reduction of childbearing in populations where fertility remains high.

In the long run, world population growth may resume its typical pattern of moderate growth interrupted by catastrophic set-backs.

Any general assessment of population trends that I might attempt would be redundant in view of recent authoritative and thoughtful assessments by Léon Tabah (1980) and Parker Mauldin (1980), and especially in view of the thorough summary and analysis (about 200,000 words and 110 tables) prepared by the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat, in 1979 as part of its biennial monitoring of trends and policies (United Nations, 1980a and b).

These remarks are limited, therefore, to some particular observations on trends in mortality and fertility and on long-run future prospects of population growth.

MORTALITY TRENDS

In considering how to assess contemporary mortality trends, it occurred to me to reexamine three of my own projections of mortality made so long in the past that the projections can be compared with how mortality has actually evolved over a period of 20 years or more. The success or failure of different past attempts to foresee the evolution of mortality may provide some help in understanding the present and some guidance in foreseeing changes yet to come.

Projections of European mortality

My first projection of future mortality trends occurred 40 years ago when I was a research assistant at the Office of Population Research, waiting to be called up for military service. Princeton had undertaken a study of the future population of Europe (for the League of Nations); it was my responsibility to prepare projections from 1940 to 1970 of the populations of 29 European countries (Notestein and others, 1944). It seemed sensible to develop uniform procedures for estimating the future peace-time course of fertility and mortality in every country. (The effects of the Second World War were deliberately ignored on the grounds that losses of persons and deficits in births could be allowed for after the War had ended.)

The method of estimating the future course of mortality in Europe was to construct a composite curve for the rate of decline of each age-specific death rate—a curve embodying the typical pace of decline in each age-specific rate at all different levels, based on data from life tables for Europe (plus Australia and New Zealand) from the 1870s to the 1930s. (Expected declines from values that

*Office of Population Research, Princeton University, Princeton, New Jersey, United States of America.

were the lowest observed were extrapolated by an exponential extension, at a constant rate of decrease, of the most recent experience of the lowest mortality populations.) The future mortality at each age in any population was assumed to follow this composite curve. In other words, the decline in the death rate at each age from its level in the 1930s in each population was assumed to duplicate the average pace of decline from level to level in recent European experience. An implication of this procedure is that the estimated future increase in expectation of life at birth for each population followed the average pace of increase (generally a slower pace as e_o^o rises) characteristic of European populations before the Second World War.

The projected mortality rates all turned out to be too high, the projected life expectancies too low. For example, the lowest projected expectation of life at birth for females in 1970 was 56 years for Romania and Yugoslavia; the observed values in 1970 are 70 years in both populations. The highest projected female e_o^o for 1970 was 72 in the Netherlands and Norway, compared to a recorded 77 for both. In every country mortality had fallen by the 1950s more than calculated by this projection—despite the occurrence of a devastating war in which many countries suffered extensive human casualties and material damage. Past trends were in this instance poor predictors.

Projections of mortality for India

The next time I tried to develop a method for projecting mortality was in 1955 when it was necessary to estimate the future course of death rates in India as part of the research project Edgar Hoover and I were engaged in (Coale and Hoover, 1958). The procedure we devised for projecting mortality was thought of as particular to the Indian population in the period from 1951 to 1981 and was not intended for other countries or other times. It involved these assumptions: (*a*) the extra reductions in mortality achieved from 1936–1945 to 1950–1952 in malarious districts of Sri Lanka (in excess of the reduction occurring in the non-malarious districts) would be matched during 1951–1961 in that part of the Indian population living in malarious areas; (*b*) in addition there would be a reduction in mortality at the recent average annual rate of reduction experienced in other low-income countries with substantial public health programmes. Mortality above age 10 was assumed to decline until 1971, and infant mortality until 1981. From 1961 to 1971 the projected decline was slower than in the preceding decade because the effects of the anti-malarial campaign were expected to have been realized by 1961. After 1971 the "assumption of an arrested decline in mortality is based on an impression that once the relatively easy public health measures have been exploited, further improvements in mortality will be more difficult to gain" (Coale and Hoover, 1958, p. 69).

The estimation of the course of mortality in India from 1951 to 1981 was a much more successful prediction than the earlier projection of European mortality. The expectation of life at birth in India was estimated to increase from 32.3 in 1951 to 52.3 in 1981. There are no complete and accurate data from which a recent Indian life table can be constructed; but the projected death rate for 1976 of 15.2 per thousand (compared to 31.0 per thousand in 1951) is virtually identical with the 15.4 per thousand average death rate from 1970 to 1978 reported in India's sample registration system, a near equality implying that the projected expectation of life was close to the mark.[1] The assumption of a rapid decline in death rates at first, and a slackening of the reduction when mortality is still rather high, seems to have been appropriate.

Projections of mortality in Mexico

My third exercise in mortality projection was for a second set of future estimates of population prepared in collaboration with Edgar Hoover. We analysed prospective population trends in Mexico as a complement to our study in India, and needed projections of Mexican mortality. The estimated expectation of life at birth in Mexico in 1955 already exceeded the life expectancy we had projected for India in 1981; the experience of Sri Lanka's anti-malarial campaign and of broad public health campaigns in other developing countries could not be used as guides to the future decline in mortality in a country as advanced in life expectancy as Mexico. The approach chosen was to estimate the future increase in expectation of life in Mexico from the composite experience of different national populations from the 1930s to the 1950s.

When our study of Mexico began (in 1956), it was apparent that mortality had fallen more in all higher-income countries than anticipated. In other words, the failure of the mortality forecasts in ***The Future Population of Europe and the Soviet Union*** (Notestein and others, 1944) was very evident. The broad reason for the accelerated increase in expectation of life in Europe was clear enough: radical improvements in preventive and curative medicine had occurred, including the development of the first generally effective antibiotic and chemical agents for curing infectious diseases, of highly effective residual insecticides that could interrupt the transmission of insect-borne diseases, of new and better vaccines, and of improved techniques of health education and administration. The problem was how to allow for the effects of these innovations (which had surely already contributed to lower mortality in Mexico) in estimating the further increases in expectation of life after 1955.

The device used for estimating how e_o^o would change in Mexico was the fabrication of a curve intended to approximate a sort of universal time-path for the increase in life expectancy in populations able to adopt modern procedures for controlling mortality. Twenty-six pairs of male and female life tables were selected from populations with good data on mortality. The two tables were always at least five years apart in time reference; in most instances one table pertained to mortality before the Second World War (in the 1930s) and the other to post-War mortality in the late 1940s or early 1950s. For each pair of tables, the average annual change in expectation of life at birth was determined, along with the mean of the two e_o^o's. The higher the average e_o^o, the slower the rate of change. In fact, the linear correlation between the average rate of change in e_o^o and its average level was $-.91$ for males and $-.85$ for females. We assumed that as time passed Mexican life expectancy would rise at the average rate characteristic of the level of e_o^o at each moment. A linear relation between the annual change in e_o^o and the level of e_o^o implies that the difference between e_o^o at a given time t

[1]Because there is evidence of under-registration by some 10 per cent of deaths, the projected life expectancy probably exceeds the actual e_o^o for the 1970s.

and an upper limit (when the annual change becomes zero) declines exponentially. The exact relation is as follows:

$$\text{for females } e_o(t) = 84.2 - (84.2 - e_o(t_1))e^{-.0303(t-t_1)};$$

$$\text{for males } e_o(t) = 76.2 - (76.2 - e_o(t_1))e^{-.0350(t-t_1)}.$$

Starting from life tables for 1955 based on Mexican vital statistics (with e_o^o of 51.0 for males and 54.8 for females), we estimated later life expectancy by using these equations. The estimate for males in 1975 is 63.6 years; in the Mexican life table for 1975 e_o^o is only 0.8 years less, at 62.8 years. The estimate for 1975 of female life expectancy is even closer: projected 67.8 years compared to recorded 67.4 years.

Interpretation of the success and failure of mortality projections: less developed countries

The three forms of projection just described—a projection assuming continuation of gradual reductions in mortality in Europe, a projection of fairly rapid increases in life expectancy followed by slowing progress in India, and a projection for Mexico of a composite curve of marked increases in e_o^o that rise at a diminishing pace to an upper limit—help to interpret recent mortality trends in various populations. The European projections were wrong because the technological possibility of more readily attaining a greater e_o^o was not foreseen. This point is nicely illustrated by Samuel Preston's demonstration of a close relation between e_o^o and per capita income in various countries in the 1930s and again in the 1960s (when per capita income is expressed in constant United States dollars) along a curve in 1960 that shows higher e_o^o at each per capita income than in the 1930s. The higher curve in 1960 can be naturally interpreted as a reflection of health technology more effective than in 1930 (Preston, 1976).

The composite curve expressing how rapidly e_o^o rises at each level (typifying general experience from the 1930s to the 1950s of countries with good data) was successful in predicting the course of mortality in Mexico because Mexico was able to take advantage of the new technological possibilities—possibilities that continued to improve as time passed. For a population to stay on this rising curve it must progressively eliminate deaths associated with infectious disease. Even with limited resources in health care (even with few doctors, nurses, midwives and other paramedical personnel, with hospitals and clinics restricted to a few urban centres, with few retail outlets for modern medicines, with poor environmental sanitation, including contaminated food and water, and with adequate nutrition) improved medical technology can allow mortality to fall; but with such handicaps, mortality from a number of causes remains high as many diseases remain widely prevalent and ineffectually treated. In the 1960s and 1970s, most very low income countries still have high mortality because their resources in health care are limited in the ways just listed—their life expectancy has risen, but further increases are impeded because, for example, children acquire intestinal diseases from contaminated food and water as soon as breast-feeding is supplemented, and die of diarrhoea and enteritis, or of pulmonary disease because of reduced resistance. Malnutrition in the form both of protein and caloric deficiency often contributes to high mortality among infants and young children.

A low-income population, then, can be expected to follow a course of rising e_o^o more or less like that projected for India (slackening its increase when the easier measures have had their effect), unless it attains dramatic increases in per capita income. It is not literally higher per capita income that makes possible a continued rapid rise in e_o^o in a low-income country—it is the extension of effective health services, better nutrition and uncontaminated food and water to all sectors of the population; plus sufficient education for all so that proper health practices will be understood and followed. Generally, national capacity to make these provisions coincides with the attainment of large increases in national income, but there are exceptions.

In figure I, the rise in e_o^o (generally for each sex) is shown for eight low-income populations. In each instance the universal curve employed to project e_o^o for Mexico is shown for comparison. Note that in Taiwan Province and Puerto Rico the increase from about 1940 to the mid-1960s was more rapid than along the "universal" curve, and that from the mid-1950s to the late 1970s, the increase in e_o^o very closely adhered to the standard curve. (In Puerto Rico after 1950 the males failed to keep up with the standard, a feature almost universal in European experience since 1950, as we shall see.) These are populations in which *per capita* income did indeed increase very substantially, and evidently improvement in health facilities kept pace. In Costa Rica the increase in e_o^o since 1950 for both sexes has slightly surpassed the standard curve.

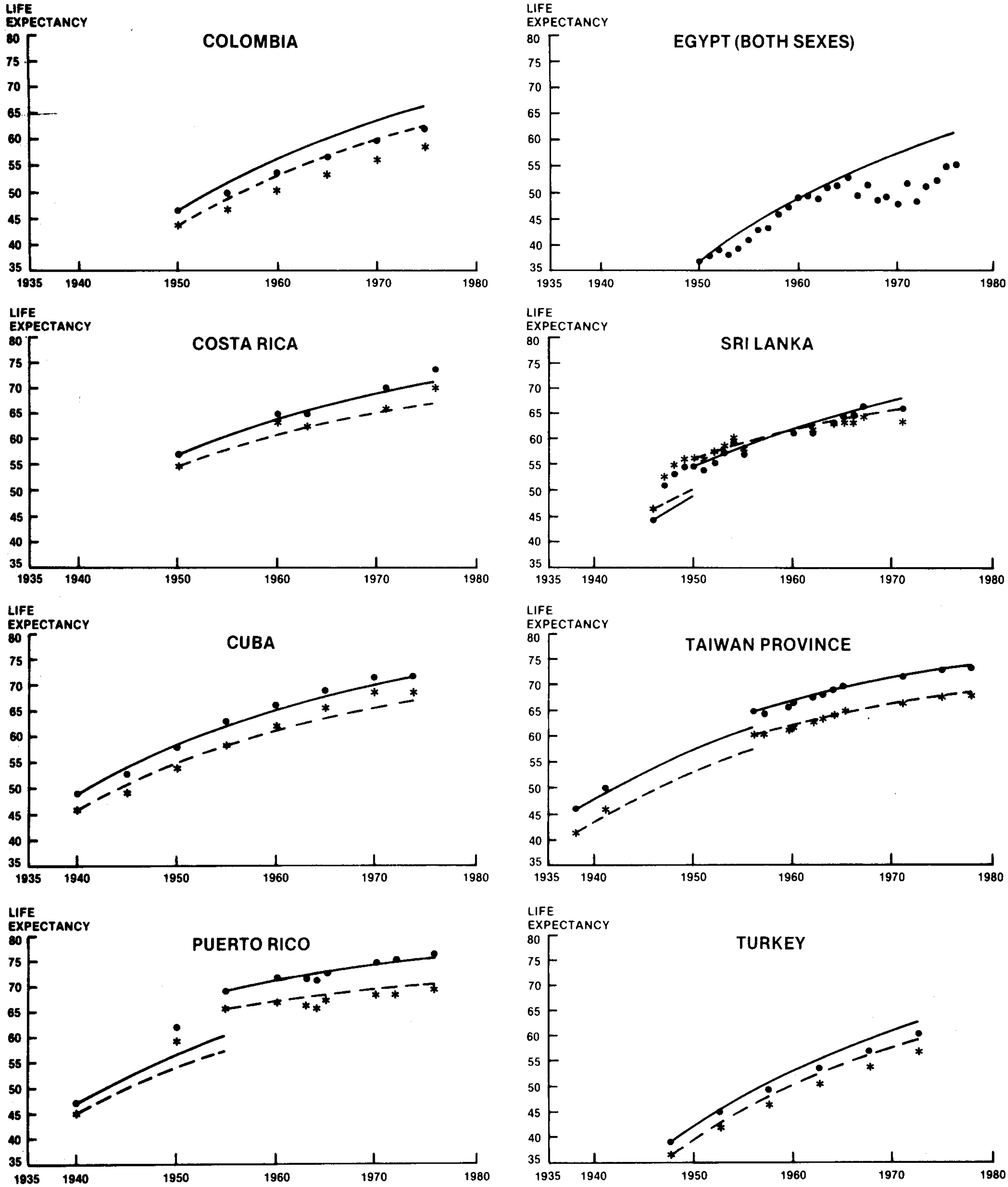
In Cuba the increase in e_o^o from 1940 to 1950 (females) or 1958 (males) was as rapid as the standard; from the mid-1950s to the 1970s life expectancy rose more rapidly than along the composite curve. Increases in per capita income in Cuba have not been exceptionally rapid; it is the extension of education and basic health services and the provision of adequate nutrition that probably explains the sustained reduction in mortality.

In Sri Lanka the very abrupt rise in e_o^o after 1946, coinciding with the island-wide and very effective anti-malarial campaign, was followed by 20 years of further increases paralleling the standard curve for each sex. (Note that the anomalous higher male than female e_o^o was reversed during this period, just as the slower increase in male e_o^o on the standard curve would predict.) Although education and health services were improved in Sri Lanka during these years, per capita income remained relatively low. Though no later values of e_o^o are available, data on the death rate in Sri Lanka suggest a levelling off of e_o^o in the 1970s, as indicated by the last points (for 1971) in the figure. Estimates of e_o^o for Turkey and Colombia are from draft reports of Panels of the Committee on Population and Demography of the United States National Academy of Sciences (NAS). In both countries the estimated sequence of e_o^o for 25 years shows an extensive increase, but less rapid than the standard curve over the same range.

In Egypt, estimated e_o^o (for the two sexes combined taken from the report on the Panel on Egypt of the NAS Committee) follows the standard curve quite closely from 1950 to 1965 and then levels off until the later 1970s. This sequence could be an instance of the difficulty of sustaining an increase in life expectancy in a very low income environment (as envisaged in the India projection), although interpretation is complicated by the wars of 1967 and 1973.

A particularly interesting instance of mortality reduction has occurred in China, with a population of about one billion. Data on the Chinese population are very sparse, but recently released fragments make it obvious that

Figure I. Expectation of life at birth, male and female, in selected developing countries. Also "standard" time sequence of rising e_o^o, with starting points that match observed e_o^o's (*Key:* * = male, ● = female)



mortality is remarkably low, even after allowance for some underreporting of deaths. Preston and Banister (1981) estimate an expectation of life at birth (both sexes) of about 63.5 years in 1975, even with their estimate that death recording is only about 85 per cent complete. Chinese sources list a reduction in the crude death rate from 14.0 per thousand in the 1950s to 7.0 in the 1970s. At the Office of Population Research we estimated e_o^o for rural China in 1930 as about 24 years, with a crude death rate of about 40 per thousand (Barclay and others, 1976). Soon after the Second World War mortality rates in China were probably not much lower than in India or Egypt. Suppose the expectation of life at birth in 1950 had been about equal to that in Egypt, at the time, about 36 years. If the standard curve had been followed, e_o^o would have reached 60 years in 1975; instead it was 63 or more. Yet per capita income in China is estimated, by the Chinese, at only $US 139, about the same as estimated for India (Chen, 1979). Thus China is an instance of a population with very low income that apparently reduced mortality more rapidly than along the standard curve. It is a country in which health facilities, education and adequate nutrition have been provided in the context of an economy that remains little developed—primarily agrarian, with hand cultivation of small acreage the norm. According to data from the State Statistics Bureau, there were about 400,000 senior doctors (of Western medicine), 400,000 junior doctors, 400,000 nurses and 1.6 million "barefoot doctors"—paramedics with secondary school education and a few months' training. Some kind of medical service apparently extends to almost every rural community, and health programmes have been vigorous.

The two different projected time trends of e_o^o that fairly well predicted what would happen in India and Mexico from the mid-1950s to the mid-1970s provide a framework for a crude classification of recent and prospective trends in the developing countries not yet specifically considered. In Asia the high mortality countries that are still at low levels of income—such as Afghanistan, Bangladesh, Nepal, Indonesia and Pakistan—have current death rates and face prospects similar to the death rate of India. Expectation of life in these countries can reach 50 years or a little more, but increases much above this level are likely to be slow without a spurt in general economic progress or intensive development of health facilities, health education, nutrition and uncontaminated food and water. Asian countries in which e_o^o has already progressed well above 50 years—such as Thailand and the Philippines—may follow a path like the course of life expectancy in Turkey—steadily increasing, but not as rapidly as the standard developed for the projection of Mexican mortality. North African populations—such as Algeria, Tunisia and Morocco—may follow trends like that of Egypt, where e_o^o rose as rapidly as the standard, only to falter at a level well short of 60 years.

In tropical Africa there is too little information from which to derive an unambiguous impression of recent mortality trends. Incomplete data indicate expectations of life at birth less than 50 years in all but a few countries in sub-Saharan Africa. Mortality has surely fallen in Kenya, where several surveys at different dates make it possible to discern an unmistakable trend of rising rates of child survival, and less satisfactory evidence indicates some fall in mortality at adult ages. Future changes in Africa seem likely to follow the pattern projected for India—slow progress once e_o^o has risen to about 50 years.

In Latin America, we have seen that e_o^o has followed or surpassed the standard path of increase in Mexico, Costa Rica, Puerto Rico and Cuba. In Colombia, the estimated rise since 1950 has been somewhat slower, but e_o^o is still rising as it approaches 60 years. In all but the poorest populations, such as Haiti, progress like that projected for Mexico, or a little slower, seems plausible. Before turning to a brief comparison of trends in the developed countries with the composite time-trend constructed for Mexico, I shall ask whether the mortality trends in the developing countries imply the "end of an era", a term Davidson Gwatkin employed to characterize the slowing of the decline in mortality that he perceived as characteristic of the recent past (Gwatkin, 1980). For the developing countries as a whole, and for many individual countries, the rate of increase in e_o^o has almost certainly diminished. The slow-down should be judged, however, in the light of the projections made in the 1950s of the future mortality of India and Mexico. At the time, the projections were viewed as over-optimistic (particularly for India), yet both foresaw a slowing pace in the rise of e_o^o. In India the slow-down was foreseen as a result of a ceiling imposed until radical improvements could be made in health services, nutrition and education; in Mexico the slow-down was foreseen as a tendency for e_o^o to rise less rapidly at higher levels. In other words, the slow-down may be arrival at an inherently slow stage of mortality reduction rather than any adverse change in circumstances.

There are several ways in which mortality in the high mortality regions of Southern and Eastern Asia, and sub-Saharan Africa, might join a time-path of rapid increase in e_o^o, similar to the composite curve constructed for the Mexican projection. One way is somehow to attain a rapid increase in per capita incomes (with associated social and economic change), as in Mexico, Puerto Rico or Costa Rica. A second way is to develop especially effective programmes of education, health facilities and nutrition, as in Sri Lanka, Cuba or China. The third way is for the laboratories of the world to produce further technological progress that might permit reduction in mortality in those populations that only slowly attain the prerequisites for progress within the present technological framework.

Two examples illustrate the possibilities for technical change that might significantly raise Preston's curve of association between e_o^o and per capita income. The first example is "oral rehydration therapy". It has long been known that victims of various diarrhoetic diseases become dehydrated and that dehydration exacerbates their symptoms and contributes to high mortality rates. Intravenous replenishment of body fluids is an effective treatment but scarcely practicable for the rural population of poor countries. It has recently been discovered that a solution of sodium chloride, sodium bicarbonate, potassium chloride and glucose in water administered orally will cause rehydration, contribute to weight gain and greatly reduce mortality. The cost of packaged solid ingredients is only about 8 cents per litre, but preparation of the proper strength with non-contaminated water is not readily achieved where health services are weak and education levels low. In Nepal, for example, the normal treatment for a child with diarrhoea is to withhold fluids since the stool is abnormally liquid. Oral rehydration therapy is an example of a low-cost innovation that might contribute to an accelerated rise in e_o^o in high mortality populations (Johns Hopkins Population Information Program, 1980).

A more general basis for technical innovations in low-cost reduction of mortality is the revolutionary advances in fundamental biology that are sometimes compared with the extraordinary progress in physics earlier in the century. Unravelling the molecular structure of RNA and DNA may lead to further increases in agricultural productivity at a lesser cost in energy inputs and also to treatment of viral infections and other human diseases not responsive to antibiotics or chemotherapy.

Mortality trends in the developed countries compared to the universal curve devised to project e_o^o for Mexico

The projection of mortality for European countries based on a continuation of trends observed before the Second World War erred consistently by underestimating the actual rise in e_o^o. What about the "standard" curve derived from the relation of level and rate of change of e_o^o in 26 countries from the 1930s to the 1950s? In figure II, the actual course of e_o^o from before the Second World War to the 1970s in selected low mortality countries is compared with the standard curve having the same starting point. It is remarkable that in eight countries female e_o^o in the late 1970s was within half a year of the e_o^o projected from nearly 30 years earlier (on the basis of the method of projection devised for Mexico). The actual and projected increase was more than 10 years in all instances, about 18 years in Italy, and nearly 20 years in Portugal. In all of these populations, e_o^o for males failed to keep up with the projection.

In figure III, the trend in e_o^o is compared with the standard curve of rising e_o^o from about 1950 until the 1970s for a number of more developed countries in which little increase in e_o^o can be seen for an extended period, mostly in the 1960s. For males there was no increase in e_o^o recorded for intervals ranging in length from 5 to 18 years in England and Wales, Scotland, Finland, the Federal Republic of Germany, Denmark, the United States of America and Australia. In many of these countries the rise in female life expectancy was noticeably slowed, without actual declines or failures to increase at all. The remarkable rise in e_o^o for males and females in Japan is shown in the eighth panel of figure III. At all times the increase is more rapid than the standard. In figure IV, trends in e_o^o in the Soviet Union and socialist countries of Eastern Europe are shown in comparison with the composite trend.[2] In the Soviet Union expectation of life at birth for females is essentially constant after 1964/65, with a slight decline in the 1970s; for males e_o^o falls after 1964/65, with a total reduction of more than two years. A slackened pace of increase for females, and especially for males, occurs after 1964 in the other socialist countries of Eastern Europe.

Figure V shows the changing trends of e_o^o in the more developed countries by a different device. The average values and average annual changes in e_o^o are shown for five time periods: from the 1930s to the 1950s (the original 26 countries upon which the Mexican projection was based), for periods centered in the 1950s, 1960s and 1970s, and the longer period from about 1950 until the mid-1970s. In each panel, the line relating annual change to level that underlies the standard curve is shown. The female points showing the annual rate of change in e_o^o for a given level are well represented in the 1950s by the line based on the 26 countries used to construct the standard time path for the Mexican projection—except for Bulgaria, Poland, Spain and Czechoslovakia, where the rate of increase in e_o^o was more rapid than in the "standard" relation. In the 1960s the annual rate of increase in female e_o^o was almost always less than the standard relation to the level of e_o^o; in the 1970s about as many points of slope of female e_o^o *vs* a level of e_o^o are above as below the standard line, but the correlation between height and slope is not visible in this cluster of points. For the longer interval from around 1950 to the mid to late 1970s, the average annual increase in female e_o^o is highly correlated with the average value, but the annual increase at a given level is generally a little below the annual increase at the same level predicted from the 26 countries (for the earlier period from the 1930s to the 1950s).

The same comments apply to the males, except that in every period more of the average annual increases in male e_o^o fall below the "standard" than in the corresponding female panel.

In most low mortality populations, there is little further room for reduction in death rates at younger ages or from infectious diseases. Future gains must be from fewer deaths caused by accidents and "degenerative" factors—malignant neoplasms and cardiovascular disease—and will be most important at older ages. The slow progress in reducing mortality from these causes is expressed by the lesser slope of e_o^o at higher levels. In many countries at high e_o^o the pace of increase turned up again in the 1970s. This renewed rise may be the result of continued medical discoveries in the treatment of neoplasms and circulatory ailments, reductions in smoking and more sensible régimes of diet and exercise.

Perhaps basic discoveries in biology will contribute to radical new possibilities of reduced mortality at older ages. If so, the upper asymptote of 84.2 for females and 76.1 for males in our composite curve of rising e_o^o will be exceeded. If not, the standard curve may serve as a good predictor of increases in life expectancy in low mortality populations for two or three more decades.

FERTILITY TRENDS

Fertility trends in more developed countries

The most conspicuous recent feature of fertility in the developed countries is the very low fertility that most have reached in the past few years. As of the most recent date for which information could be found, all of the countries of Northern and Western Europe (except Ireland and Northern Ireland) had net reproduction rates below 1.0, as did Italy, Hungary, Japan, the United States of America, Canada and Australia; fertility in Greece, Yugoslavia, Bulgaria, Poland and New Zealand was no more than 10 per cent above replacement, and in the Soviet Union, Czechoslovakia, and Portugal no more than 15 per cent above replacement. The countries with fertility insufficient to maintain growth in the long run include well over half the population of the more developed world.

The low level and narrow range of fertility in the wealthier countries do not imply that their future fertility can be confidently predicted. Most Western Europe countries arrived at the low fertility of the late 1970s after reaching an earlier low point in the 1930s as the culmination of a protracted decline, then experienced an increase

[2]Expectation of life at birth in the Soviet Union was calculated from official data on age-specific mortality rates. Because of anomalies in the time series of rates for persons over 70, perhaps associated with changed age misstatement in the 1970 census, a fixed e_o^o of 11.6 years for females and 9.5 for males was assumed. Thus these e_o^o's differ from those given in Soviet sources, but the trend is implicit in the data.

Figure II. Expectation of life at birth, male and female, in selected developed countries that for females closely match "standard" time sequence of rising e°_{o}, shown with starting points that match earliest e°_{o} in sequence (*Key:* * – male, ● – female)

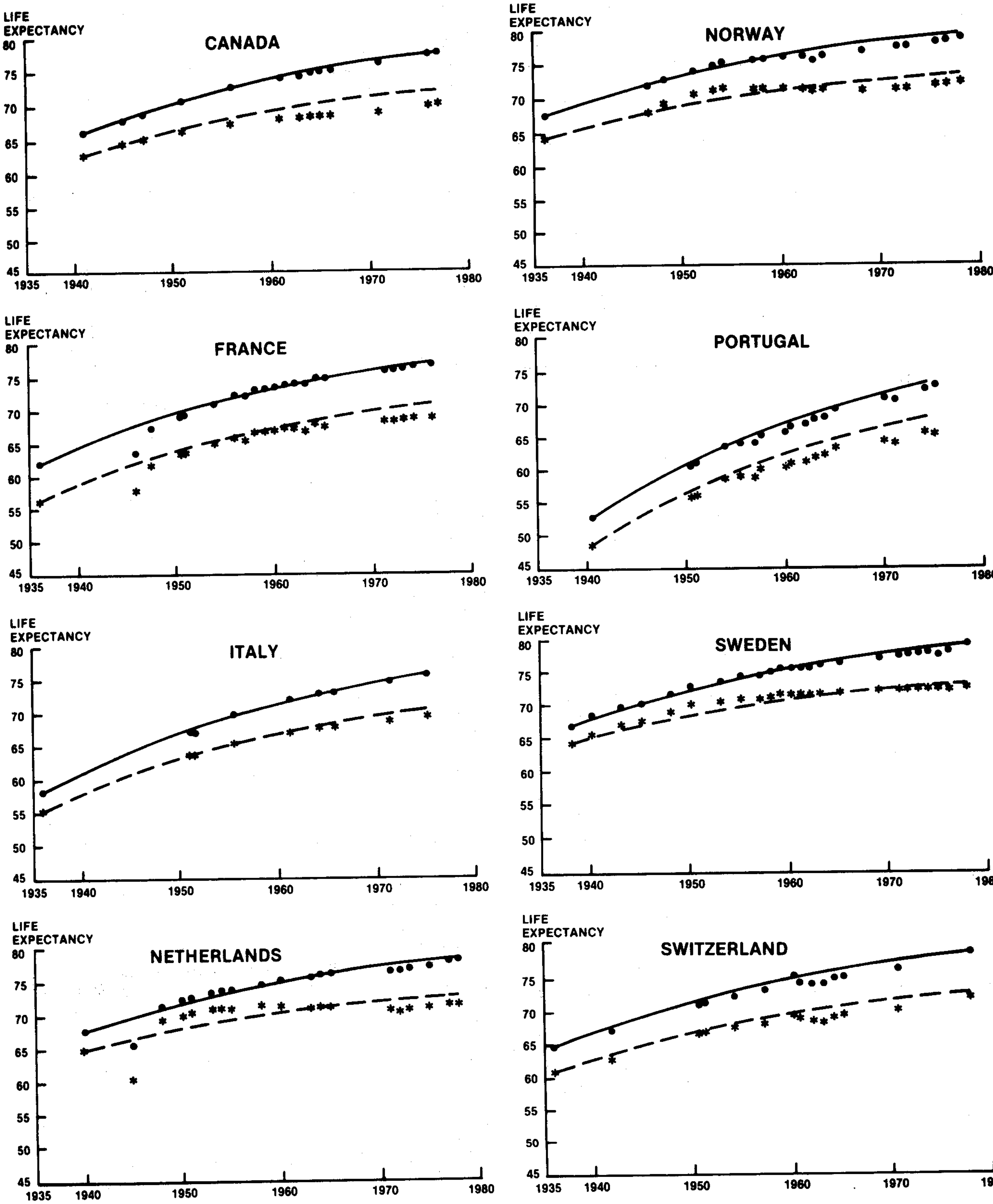


Figure III. Expectation of life at birth, male and female, in Japan and selected developed countries that for extended period fall short of "standard" time sequence of rising e_0^o, shown with starting points matching chosen observed e_0^o's (*Key:* * = male, ● = female)

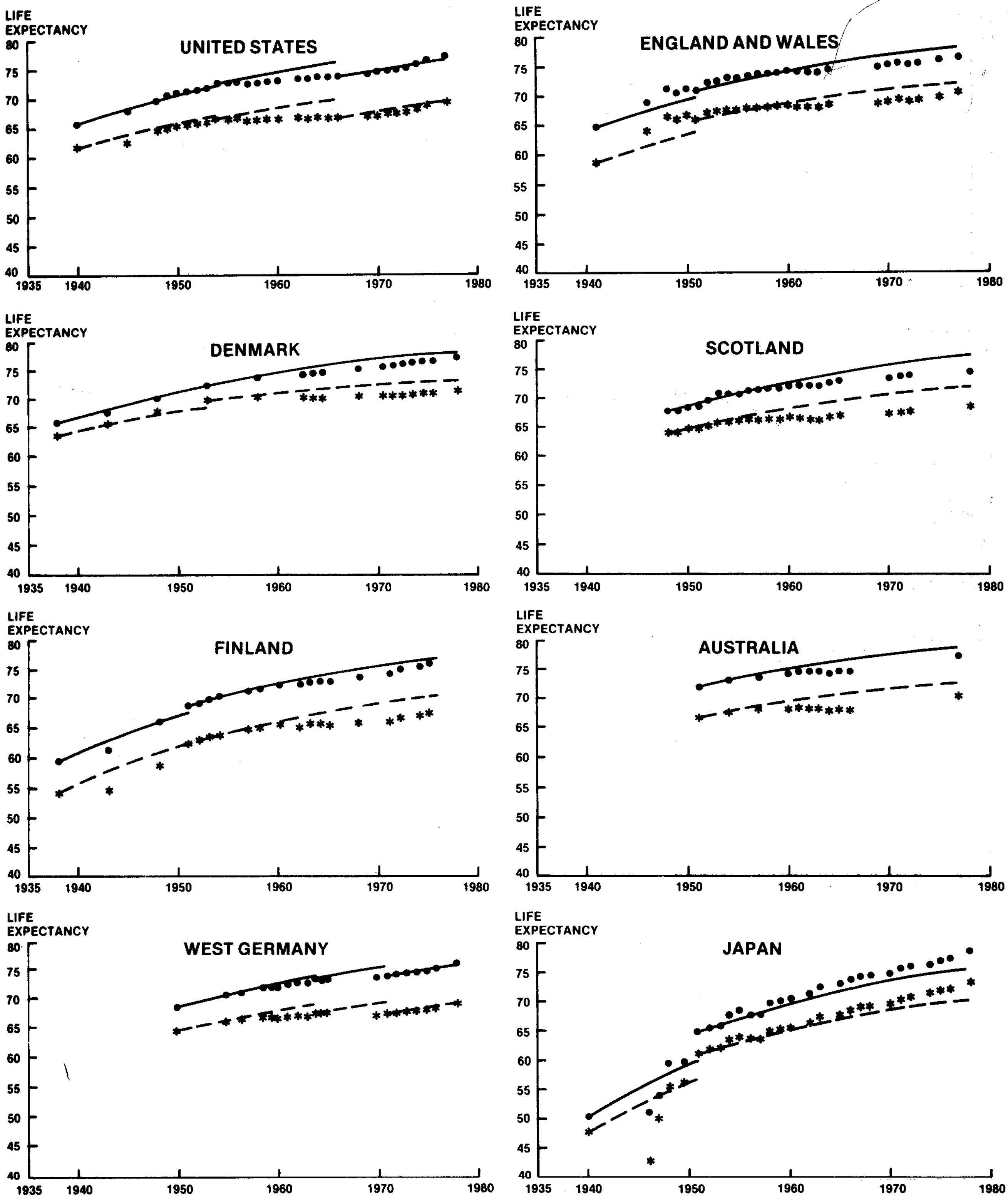


Figure IV. Expectation of life at birth, male and female, in the Soviet Union and the socialist countries of Eastern Europe. Also "standard" time sequence of rising e_0^o, with starting points that match observed e_0^o's (*Key:* * – male, ● – female)

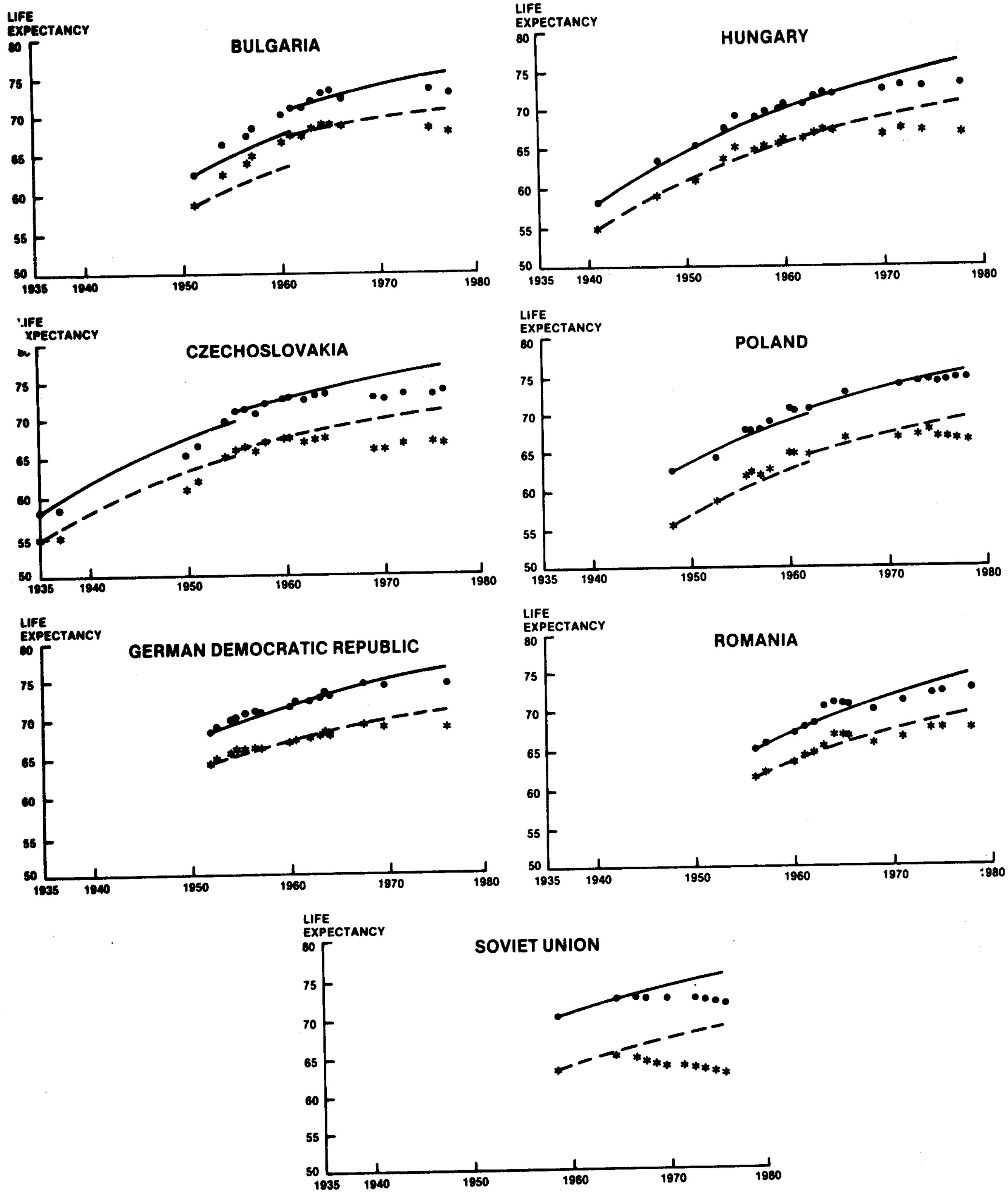
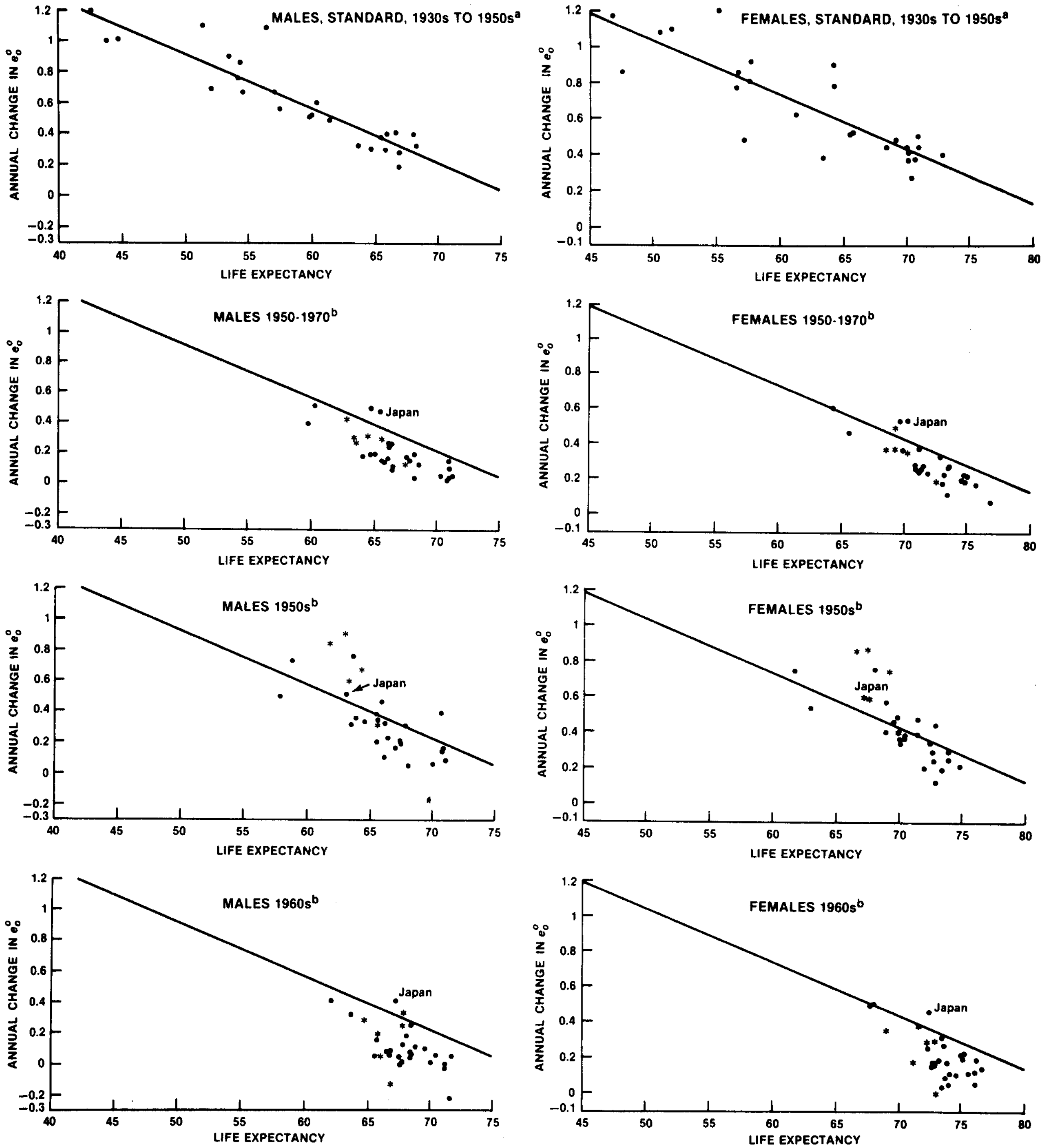


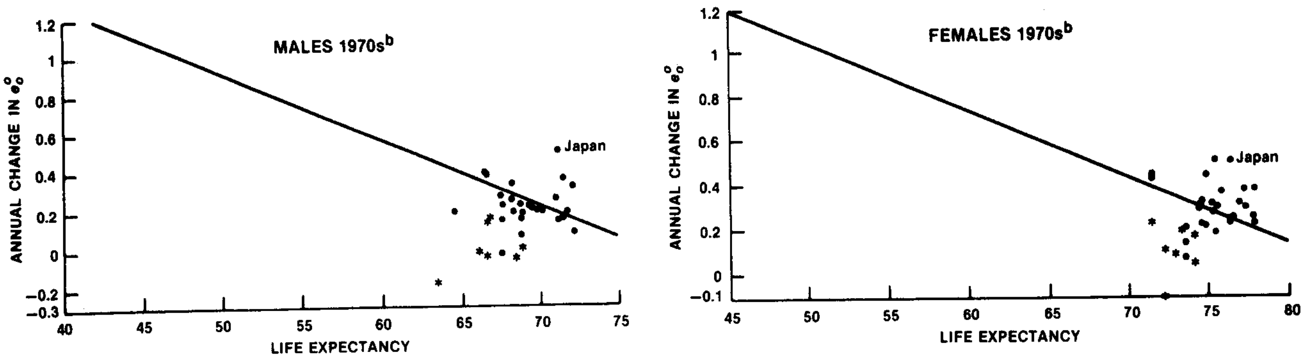
Figure V. Plot of annual change in e°_o ($\Delta e_o / \Delta t$) versus average e°_o



that peaked in the late 1940s and again in the early 1960s; finally there was a large drop, in some countries of 50 per cent, between 1964 and the late 1970s. In the United States of America, Canada, Australia and New Zealand, the peak was around 1960 and was followed by a decline of at least 50 per cent in Canada and the United States, and of 40 per cent in Australia and New Zealand. On the other hand, some countries of Eastern and Southern Europe (Poland, Greece, Italy and Portugal), plus the Soviet Union and Japan, had relatively high fertility before the Second World War and no rise in fertility in the late 1950s or early 1960s. In these countries the minimum reached in the 1970s was not a second minimum, with an intervening baby boom, but the latest point in a sustained decline that had been disturbed by fluctuations during and after the Second World War.

Several interpretations can be given of the baby boom where it was most protracted and conspicuous. Figure VI

Figure V (*continued*)



Note: Standard line repeated in each panel.
[a]Twenty-six pairs of life tables for 1930s–1950s.

[b]In developed countries during designated time period. Soviet Union and socialist countries of Eastern Europe indicated by an *.

shows the total fertility rate in the United States of America from 1800 to 1979. It can be seen that the low rates in the 1970s are a comfortably fitting extension of the long-term downward trend from 1800 to 1920. Superimposed on this long-term trend is a steepening decline in the 1920s, which creates a negative deviation with its low point in the mid-1930s, followed by an upswing, creating a positive deviation with its high point around 1960. Richard Easterlin (1973) and Ronald Lee (1976) propose the hypothesis that these swings are part of a self-sustaining cycle, itself produced by relative cohort size, which may cause a second baby boom in the late 1980s and 1990s. Other demographers see more particular explanations of the baby boom and its end and do not expect continued cyclical fluctuations.

Although there are undeniable advantages that are inherent in being born in a small cohort, in terms of less crowded educational facilities and greater relative demand for employment of persons in the cohort at each age from entry into the labour force to retirement, I am not convinced that such advantages (and corresponding disadvantages for those born into large cohorts) are the source of a self-perpetuating fertility cycle. Rising rates of female participation in the labour force, more concern for equal treatment of men and women, falling marriage and remarriage rates and rising rates of marital dissolution are trends that have a momentum of their own and will tend to impede a large and long-lasting increase in fertility. On the other hand, these changes were not widely foreseen during the baby boom itself, and if a reversal should occur (perhaps at a time that does not fit the Easterlin cycle), it will be because of changes no better foreseen than the baby boom and its reversal.

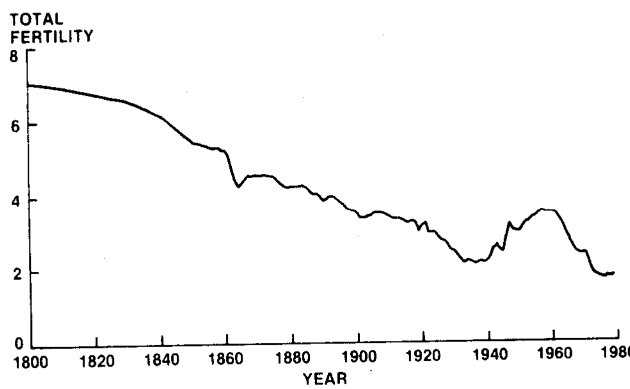
One of the unknowns in considering future trends in fertility in more developed countries is the nature and effectiveness of policies designed to affect fertility. Concern about the adverse effects of fertility too far below replacement has been expressed in a number of more developed countries, and has led several Eastern European countries, France and Luxembourg to adopt measures designed to raise, or at least maintain, the rate of childbearing.

Since some form of deliberate limitation of fertility has become almost universal in the developed countries, fertility rates are more volatile than when the majority of married couples did not vary their reproductive behaviour according to the number of children already born. Thus variation is to be expected, but probably within a range not very far from the level of fertility required for replacement.

Fertility trends in less developed countries

Unlike fertility in the developed countries, current levels and trends of the rates of childbearing in developing countries are quite diverse. In several countries classified by the United Nations as developing, fertility is low enough to fall within the range of those classified as developed. In 1977 the total fertility rate of Singapore was 1.86 (well below replacement), in Hong Kong 2.42,

Figure VI. Total fertility rate, United States of America, 1800–1979



and in Taiwan Province 2.70. In Barbados, Cuba, Mauritius, the Republic of Korea, Puerto Rico, Trinidad and Tobago, and China, fertility in the late 1970s was lower than in the United States of America in the late 1950s. At the other extreme, there are countries with fertility that is still about as high as has ever been reliably recorded for national populations; for example, total fertility rates are 8.0 or higher in Kenya and Afghanistan, 7.0 or higher in much of tropical Africa, Bangladesh, Pakistan, Morocco and Honduras.

Most of the developing countries with very low fertility had high fertility quite recently. The change from high to low has been very abrupt. For example, in Taiwan Province, the total fertility rate fell from 6.2 in the late 1950s to 2.7 in the late 1970s. The total fertility rate of the United States of America was 6.2 in about 1840 and did not fall to 2.7 until 1928; in European Russia the total fertility rate was 6.2 in about 1907 and did not fall to 2.7 in the Soviet Union until about 1952. In most European countries the total fertility rate has been below 6.2 since records of fertility began; if the rate has ever been as high as 6.2, the interval between a total fertility rate of 6.2 and a rate of 2.7 must have been several centuries.

The decline in Taiwan Province is surpassed in speed and extent by the fall of fertility in Singapore—from a total fertility rate of about 6.5 in the late 1950s to 1.9 in 1977 (a change that required nearly a century and a half in the United States). Very rapid declines have also occurred in Mauritius (total fertility rate falling from above 6 to about 3 in 15 years), the Republic of Korea (from 6.0 to 3.2 in 15 years) and Costa Rica (from over 7 to less than 4 in a little more than a decade).

There are, at the same time, many high fertility populations in which fertility has not declined significantly or has even risen slightly. Such populations are in South Asia (Bangladesh, Nepal, Pakistan and several populous states within India); in tropical Africa, where no national population has experienced a definitive decrease and where fertility in several countries has risen; in Western Asia (Afghanistan, rural Iran, Jordan); and in some Latin American and Caribbean countries (Honduras, Haiti).

The majority of the developing countries are intermediate in fertility trends between these extremes, having experienced moderate declines or fairly extensive reductions (25 per cent or more) in fertility. Among those with moderate declines are India, Indonesia, the Philippines, Egypt, Tunisia, Bolivia, Peru, Guatemala and Venezuela. Because of the absence of complete records of births in many developing countries, it is difficult to judge whether or not recent declines in fertility are as much as 25 per cent. Among the countries where a reduction of one quarter or more has occurred are Thailand, Sri Lanka, Peninsular Malaysia, Fiji, Turkey, Colombia and possibly Brazil and Mexico.

Variations in proportions married and in marital fertility as factors in the levels and trends in fertility in the developing countries

In considering the presence or absence of reductions in fertility in developing countries, it is useful to factor overall fertility into two components: first, the proportion of potentially fertile women living in a sexual union; and second, the rate of childbearing among the sexually active women. If consensual unions are included with legal marriage, in most developing countries fertility can be factored into the proportion currently married and the rate of childbearing by married women of potentially fertile age.[3]

Separate consideration of the proportion of women currently married as a factor in fertility is useful because an increase in age at first marriage (and attendant reduction in the proportion 15 to 50 who are married) has occurred very widely. Indeed, some increase in age at first marriage seems to have been universal wherever very early marriage (mean age at first marriage for women less than 19 years) has been the custom.

The most obvious source of differences and changes in marital fertility is current differences between countries, and increases within countries, in the resort to contraception, surgical sterilization and abortion. These practices are the basis of low marital fertility in the developed countries, and their rapid adoption in some of the developing countries accounts for a sharp drop in their marital fertility.

In some developing countries marital fertility has risen, especially in the early years of marriage. The most frequent source of increased marital fertility is the attenuation of customary practices that contributed to longer intervals between live births. The most important of these customs is prolonged breast-feeding of sufficient intensity and frequency to postpone the resumption of ovulation. For example, in rural areas of the Republic of Korea, marital fertility was more than 30 per cent higher in 1960 than in 1930, and marital fertility for younger married women continued to increase after 1960 (Coale, Cho and Goldman, 1981). Data from the Korean Fertility Survey show a large and continuous decrease in the proportion of women who nurse their children for very large periods.

Another custom that prolongs inter-birth intervals is sexual abstinence following the birth of a child. Avoidance of intercourse during lactation is common in many societies; in others, especially in Africa, the prohibition of sexual relations often extends beyond weaning. The explanation given by those who practise such abstinence is protection of the health of both the mother and the young child. The proportion of couples abstaining, and the duration of the interval of abstention are declining, especially among the educated and in urban populations.

A third change contributing to an increase in marital fertility is reduction in the prevalence of pathological sterility, often caused by venereal infections that are curable by antibiotics.

Changes in proportion married and marital fertility in selected developing countries—in countries where fertility has fallen and in countries where it remains high

In many countries in which the total fertility rate has fallen, a rise in age at marriage has reduced the proportion currently married and contributed significantly to the reduction of overall fertility; for example, in the Republic of Korea, Taiwan Province, Hong Kong, Singapore, Sri Lanka, the Philippines, Egypt and Tunisia. In the Republic of Korea, the total fertility rate was about the same in 1960 as in 1930. A large increase in age at marriage lowered the proportion of women 15 to 50 who were currently married, but there was an offsetting increase (of 20 per cent) in marital fertility, probably a

[3]This formulation is less meaningful for the present fertility in some developed countries where childbearing by women who are not yet married or are formerly married is usual.

result of curtailed breast-feeding. After 1960 marital fertility fell, as contraception and abortion were adopted, especially by older women; the proportion currently married continued to decline as age at marriage continued to rise. In 1975 the total fertility rate in the Republic of Korea was a little more than 50 per cent of the rate in 1930; the proportion married had fallen more (35 per cent compared to 23 per cent) than marital fertility.

In Egypt there was a moderate decline in the total fertility rate (from 6.7 to 5.5) from 1960 to 1976. As in the Republic of Korea, the decline in proportion married was greater than the decline in marital fertility (12 per cent compared to 6 per cent). The reduction in marital fertility was large (20 per cent) only in Cairo and Alexandria. The rise in age at marriage in the 1960s and early 1970s that led to the reduction in the proportion married was possibly a response to recurrent wars; judging from the rising number of registered births since 1976, the total fertility rate has increased, perhaps because of a boom in marriages.

Other countries in which increased age at marriage has contributed a large part of whatever overall decline in fertility has occurred include Taiwan Province, Hong Kong, Singapore, China (as may be inferred from the age schedule of fertility), the Philippines, Sri Lanka and Tunisia.

There has also been a rise in age at marriage in countries where little change in fertility has occurred—for example, Bangladesh, Nepal, Pakistan and Kenya. Even the younger cohorts are marrying very early in these populations—at least 60 per cent of the younger women have married by age 20 and about 90 per cent by age 25. Thus the increase in age at marriage has not very much reduced exposure to potential childbearing.

The principal immediate source of differences in marital fertility in developing countries is the extent to which couples practise contraception (including surgical sterilization) or abortion. The World Fertility Survey (WFS) has provided a rich body of data as comparable as can be feasibly collected on contraceptive practice; the difference between the countries that have low marital fertility and those that do not is evident in comparative tables drawn from WFS reports. The percentage currently practising among "exposed"[4] women 15–49 varies from low values of 3 per cent in Nepal, 7 per cent in Pakistan, 9 per cent in Kenya and 10 per cent in Bangladesh to 65 per cent in Panama and 78 per cent in Costa Rica.

Future changes in the fertility of developing countries

Until the 1960s demographers frequently called attention to the acceleration in the rate of increase in world populations, a gradual acceleration starting in the eighteenth century and a sharper acceleration in the twentieth, when very rapid rates of increase appeared in the developing countries. The recent rapid reduction in fertility in some developing countries, and the more gradual turn to lower fertility in others, has created a turning point—a decline in the overall rate of increase in the world and in the combined populations of the developing regions.

Will the decline continue in the countries where it has begun, will it be as rapid in the countries just starting a reduction as in those that have recently reached low fertility, and will it spread to the populations where fertility is still as high as ever?

No one can answer these questions with any certainty. To indicate the difficulty of foreseeing the future course of fertility in the developing countries, I shall cite three instances of surprising trends in fertility—two in which the absence of a fertility decline (or the small extent of fertility decline) is surprising, and one in which the large extent and rapid pace of the drop in fertility is surprising.

Continued high fertility in the rural population of the Central Asian Republics of the Soviet Union

In a book on fertility in the Soviet Union (Coale and others, 1979), the continuing high fertility of the rural populations of the Central Asian Republics was noted as a somewhat puzzling anomaly. Briefly, marital fertility for these populations rose by 25 per cent from 1926 to 1959, and by a total of 49 per cent from 1926 to 1970. As of 1970 rural marital fertility was 2.5 times as high as in the rural population of the largest Republic (the Russian Soviet Federated Socialist Republic) and was at about the same level as in the rural population of European Russia in 1897. The age pattern of marital fertility in the Central Asian Republics is the pattern characteristic of populations in which little contraception or abortion is practised. This maintenance of high fertility (after a substantial increase of marital fertility since 1926, very much as in the Republic of Korea from 1930 to 1960) is surprising because in 1970 more than 90 per cent of the women 20 to 29 in these Republics had at least primary education, and the crude death rate was very low. This record seems to be an example of fertility that does not correspond to the saying, "Development is the best contraceptive." Still more puzzling is the failure of the birth rate in these Republics to decline in the 1970s; recent data show a rate as high in 1979 as in 1970. (In the Uzbek and Tadzhik Soviet Socialist Republics the registered birth rate is higher in 1979 than in 1970, but in these Republics there is evidence of under-registration of births at the earlier date.) Thirty-eight per cent of the population of these Republics was urban in 1970; it seems very improbable that the high overall birth rate has been maintained (at 34.4 per thousand) without the continuation until 1979 of rural fertility at about as high a level as in 1970. By 1979 more than 90 per cent of the women 30–39 (and very nearly all of the younger women) must have had at least primary education. Yet—more than 60 years after the revolution—rural marital fertility is as high as ever.

Only a slight reduction in the fertility of India

Another population in which the slight extent of the reduction in fertility is surprising is the population of India. The estimated birth rate in India declined from about 44 per thousand in 1951–1961 to about 42 per thousand in 1961–1971 (Mukherjee, 1976); the birth rates recorded in the Sample Registration System declined from 37.2 per thousand in 1970–1972 to 33.3 per thousand in 1976–1978. Data from the Sample Registration in India are believed to understate the true number of births, but many demographers and economists believed that the fall in fertility after the decade of the 1960s would be large enough to cause a lower rate of population increase in the 1970s. The census of 1981 has revealed an average annual rate of increase for the decade 1971–1981 that is virtually identical (2.21 per cent compared to 2.22

[4]Currently married women living with their husbands, not pregnant, not sterilized and reporting no impairment of fecundity.

per cent) to the rate in the preceding decade. The expected reduction did not occur.

From a closer look at intercensal rates of increase of the individual Indian states it can be seen that the growth rate for the 1970s is higher than in the 1960s in five of the most populous states (Uttar Pradesh, Bihar, Andra Pradesh, Karnataka and Rajasthan), with nearly 45 per cent of the total population in 1981. In seven other major states, the growth rate in the later decade is lower. It may be inferred that in most of India mortality was lower in the 1970s than in the 1960s, leading to accelerated growth in the states in which there was little or no reduction in fertility. In the other states, mortality fell, but the reduction in the birth rate was greater than the reduction in the death rate; and the rate of increase declined. Probably, for India as a whole, the birth rate for the decade 1971–1981 fell to about 38 per thousand from 42 per thousand in 1961–1971, while the death rate declined from about 20 per thousand to about 16.

For those who expect a rapid decline in the birth rate in some of the poorest countries that are already densely populated, the slow progress in India is a disappointment.[5] Family planning was incorporated in India's first five-year plan in 1951; government programmes to provide services, education and incentives to reduce fertility have been pursued with varying emphasis and vigour ever since. With a population of 684 million, India is not a demographically homogeneous country; in areas containing hundreds of millions there evidently has been a large fall in fertility, but little or no change in other areas peopled by hundreds of millions.

The rapid reduction of fertility in China

In contrast to these instances of no change or only a slight reduction in fertility is the surprisingly large reduction in China. The birth rate in China has evidently declined from about 40 per thousand in the mid-1960s to less than 20 per thousand in the late 1970s, a decline at a pace rivalling the rapid fall of fertility in the much smaller, more urbanized populations of Singapore, Hong Kong, Taiwan Province, and the Republic of Korea. The evidence for such a reduction in fertility in China is reviewed in two articles recently published (Coale, 1981a and b).

The decline is attributed by some to the success of a campaign by the Government of China to encourage young Chinese to marry late and to have few children widely spaced—a campaign that has for some time provided a network of family planning services and supplies and that now includes propaganda, incentives and penalties aimed at promoting one-child families. Others feel that reduced fertility was part of the over-turn of traditional behaviour during the restructuring of the Chinese economy and society since the revolution. To these possibilities might be added the apparent receptivity of populations whose culture is of Chinese origin to forces that lead to lower fertility, as indicated by the large and rapid reduction in Singapore, Taiwan Province, Hong Kong and the Republic of Korea.

FUTURE TRENDS IN FERTILITY AND MORTALITY AND FUTURE POPULATION GROWTH

The developed countries have only a modest potential for future growth. Because survival from birth to the ages of parenthood is already close to 100 per cent, further increases in expectation of life will not significantly increase the future stream of births in these countries but will merely add to the number and the proportion of the aged, increasing the growth rate only slightly and temporarily as the numbers at advanced ages reach their limit. There may be future fluctuations in fertility—periodic or non-periodic—but a sustained increase to much higher total fertility rates does not seem to me in the cards. Most of the modest growth yet to come in the developed countries will be the result of the modest momentum inherent in their age structure.

The likely future growth of the population of developing countries is much greater than the growth expected in the developed countries, as everyone knows. The future growth of populations in the developing countries is also much more uncertain, as suggested by the surprising recent change (or surprising absence of change) in fertility in China, India and the Central Asian Republics of the Soviet Union.

The faster future growth in population of the less developed regions is inherent in two forms of momentum to which the increase of population in these regions is subject. One form of momentum is the necessity for fertility to fall from high levels, a process that takes time even when the decline is rapid. Singapore reduced its fertility from several times the level required for replacement to below replacement in no more than two decades, and China may experience an equally rapid decrease; but in India and Indonesia the process is much slower. The second form of momentum is built into the age structure of high fertility populations—a structure in which the proportion by age declines steeply as age increases. This structure means that the number of potential parents is destined to increase extensively as the now large cohorts under age 20 move into the ages of parenthood. This increase in numbers at parental ages causes the population to increase even if the rate of childbearing is from this moment just sufficient for replacement of each couple. These two forms of momentum help explain why 92 per cent of the increase in world population projected by the United Nations from 1980 to 2000 is in the less developed regions.

Just how great the future growth in the less developed regions will be is uncertain because it is so difficult to judge when fertility will start to fall where it still remains unchanged and how fast it will decline once it starts.

The two regions of greatest uncertainty of future population growth are the populations of sub-Saharan Africa and the countries in which the population is mostly Muslim. Most Muslim countries and most countries in tropical Africa have not yet begun any substantial decline in fertility. Turkey is an exception—a Muslim country in which the total fertility rate has fallen by at least 25 per cent. Egypt is a partial exception, but as we have seen, the reduction of Egyptian fertility was mostly an effect of changes in proportions married, changes that may have partially reversed since the early 1970s. Large reductions in marital fertility in Egypt are confined to Cairo and Alexandria. Even in the wealthy oil-exporting Muslim countries and even in the formerly Muslim Central Asian Republics of the Soviet Union, there has been little or no

[5] A similar disappointment is provided by the 1981 census in Indonesia. The rate of increase for the whole Indonesian population was greater (2.34 per cent compared to 2.07 per cent) in 1971–1981 than in 1961–1971. In Indonesia 19 of 28 provinces grew at least as rapidly in the more recent decade as in the earlier; the slower growing provinces (such as Bali) grew about equally slowly in the two decades. Apparently the low fertility areas retained their low fertility, but did not reduce the birth rate faster than the death rate.

reduction in marital fertility. Per capita incomes of Kuwaitis are higher than per capita incomes in Europe or America, school enrolment is virtually universal, female expectation of life at birth is around 70 years, yet in 1975 the total fertility rate was still around 7.0.

A possible explanation of persistent high fertility in Muslim populations is that Muslim traditions are particularly resistant to the acceptance of reduced fertility and that the fertility-reducing effects of universal education, lower mortality, the reorganization of production and perhaps the reversal of intergenerational flows of wealth will be seen only after a longer delay than in non-Muslim societies.

None of the populations of tropical Africa has reached the level of income, education or low mortality of Kuwait or, for that matter, of the Central Asian Republics, so that it is tempting to explain the generally undiminished high fertility in the region by its early stage of development. There are, however, indications of a propensity towards high fertility that is stronger in Africa than in other areas at a comparable level of general development.

In all countries in which the results of a WFS-sponsored fertility survey have been published, more than 50 per cent of women who have four or more living children say that they want no more—except in Kenya, where only among women with eight or more children do more than 50 per cent say that they want no more. In Nepal (to pick a specific example) fewer "exposed" women practise contraception (3 per cent) than in Kenya (9 per cent); but in Nepal 58 per cent of women with four living children say they want no more; in Kenya only 16 per cent of women with four living children say they want no more.

A further indication that a decline in fertility is not imminent in Kenya is the virtual absence of differentials in marital fertility according to the woman's education.

Growth implications of delayed reductions in fertility

At present the high fertility of the less developed regions leads to much more rapid growth (estimated by the United Nations as 2.21 per cent per year in 1975–1980) than in the more developed regions (estimated as 0.67 per cent per year). By the end of the century, the developed countries will have declined from about 27 per cent of the world's population in 1975 to about 21 per cent. By then there may be a new growth differential: between the less developed areas that reduced their fertility sharply before 1980 and thus will have spent much of their momentum by 2000, and the laggards that may at best have only recently begun a reduction in the rate of childbearing and at worst still have very high rates. Projections made in 2000 might anticipate a wholly disproportionate share of the future growth in world population, not in the less developed regions as a whole, but in those areas that as of 1980 had not begun to reduce fertility.

The longer range future of world population growth

Many analysts have observed that the acceleration that raised the rate of increase in the population of the world from no more than 0.4 per cent a year before 1750 to nearly 2 per cent in the 1960s must inevitably be followed by a deceleration, because continued rapid growth leads by compound interest to ridiculously large numbers in a time that is short compared to the tens of thousands of years of human existence, or the thousands of years during which a high state of human culture has existed. Suppose that the rate of increase were to decline linearly from 2 per cent in the 1960s to zero in *N* years. If *N* were 230, the world's population would be multiplied by 10; if *N* were 460, it would be multiplied by 100; if 690, by 1000. It would be a physical impossibility to wait many centuries for the growth rate to fall to zero. Thus, if 2000 years from now a graph were made of the time sequence of the rate of increase of world population, the era of rapid growth that began a couple of centuries ago would look like a unique and narrow spike.

It is essential to keep the spike narrow enough to avoid an uncomfortably large total for the world and also to shorten the down side of this brief spurt of growth in every region. Populations growing at 3 per cent or more would be multiplied by 10 or more if their approach to the replacement level of fertility were leisurely.

When a long perspective of the growth of world population is taken, looking either forward or backward, it must be borne in mind that the sequence of experience has consisted and will consist of intervals of population decrease as well as increase. In the millennia from the origin of man, the very gradual average increase in the total population must have occurred in a kind of saw-tooth pattern of fairly extensive increase in favourable periods, interrupted by decreases in periods of famines, epidemics or other catastrophes.

With modern technology, transport and communications, the world is cushioned against these traditional set-backs; indeed, world population grew by many millions even during the decade of the Second World War. Famines can still occur, but almost never in our day has a national population failed to increase in any year because of a shortage of food. Nevertheless, the future quite probably—perhaps almost certainly—contains the seeds of catastrophes that could again reduce the whole world's population. I refer to the weapons that are stored in the secret arsenals of at least six countries and will in due time be created in many more. The total number is in the tens of thousands, and the destructive potential of each is on average greater than the bombs that devastated Hiroshima and Nagasaki. Their existence has quite possibly inhibited the recurrence of the great-Power conflicts that began in 1914 and 1939. What is the chance that no war between great Powers will occur in the next two centuries? Or that smaller Powers will not use nuclear weapons? If a war with unrestricted weapons comes, the later it is the more destructive it will be.

There is all too real a possibility that the world's population may some day be drastically reduced. The survivors may experience a reduced expectation of life at birth and to reduce the death rate may face the necessity of finding ways of mitigating the effects of residual radiation. The world might again, as in most of man's long history, experience an era of positive increases in population interspersed with catastrophic reductions.

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LONG-RANGE GLOBAL POPULATION PROJECTIONS, AS ASSESSED IN 1980

*United Nations Secretariat**

SUMMARY

United Nations medium-range projections prepared in the 1980 assessment projected the population of individual countries up to the year 2025. The long-range projections discussed here were prepared by projecting the population of eight major world regions from 2025 to 2100. The purpose of the projection was to observe the implications of the changes from the 1978 assessment made in the 1980 medium-range projections on the long-range projections of the world's population.

As in previous projections, high, medium and low variants were prepared in which fertility is assumed to become constant at the replacement level but at different times in the future. In addition, these projections contain two variants not previously prepared—namely, the "growth" and "decline" variants, in which the ultimate net reproduction rate is 1.05 and 0.95, respectively. In all the variants, expectation of life at birth is assumed to reach 75 years for males and 80 years for females.

According to the current medium variant projection, the earth's population will become stationary after 2095 at 10.2 billion persons, compared with a total of 10.5 billion projected in the 1978 assessment. The lower projection is largely attributable to a recent decline in the growth rate of several countries in South Asia which was greater than previously assumed. When the world population becomes stationary, both the crude birth and death rates would be about 13 per thousand. In the decline variant, total population would peak at 7.7 billion in 2055, then decline gradually to 7.2 billion in 2100. The total population as projected by the growth variant would equal 14.9 billion in 2100 and would still be growing slowly.

Between 1980 and 2050, 95 per cent of the world's growth will occur in the currently less developed regions. Their share of total population will increase from 75 to 85 per cent during that period.

The age structure in all regions is expected to converge to one in which the median age is 39 years, the proportion both below age 15 and above age 64 is about 19 per cent each and the dependency ratio is about 60.

A precise degree of accuracy cannot be specified, but the argument is made that the actual future population of the world is very likely to fall within the range of the projection variants and probably not far from the medium variant.

INTRODUCTION

The United Nations Population Division has prepared the long-range population projections reported in this paper by extending its 1980 assessment of world population trends.[1] That assessment presents population projections for individual countries up to the year 2025. The long-range projections extend to the year 2100 but are prepared only for eight major regions of the world. Previous long-range projections[2] were based on the United Nations 1978 assessment of population prospects,[3] which gave individual country projections only up to the year 2000.

The long-range projections described herein are intended to update those based on the 1978 assessment. In the medium variant of the current projection, the population of the world will stabilize at 10.2 billion persons, compared with an ultimate size of 10.5 billion in the previous projection. While the ultimate size of the projected world population has been reduced somewhat, the range between the population as projected for the year 2100 by the lowest and highest variants has been widened. In the 1978 assessment, the range was from 8.0 to 14.1 billion, whereas in the 1980 assessment five variants fall between 7.2 and 14.9 billion. Since the results of projections carried over a 120-year span are not greatly altered by a revision following the previous exercise by only two years, comprehensive tables will not be published for this assessment. For those who wish information more detailed than that presented in the accompanying summary tables, computer print-outs of the projection results are available upon request.[4]

A significant change in the revised projections is the addition of two variants outside of the previous low and

*Population Division, Department of International Economic and Social Affairs.

[1] *World Population Prospects as Assessed in 1980* (United Nations publication, Sales No. E.81.XIII.8).

[2] "Long-range global population projections based on data as assessed in 1978" (ESA/P/WP/75).

[3] *World Population Trends and Prospects by Country, 1950–2000: Summary Report of the 1978 Assessment* (ST/ESA/SER.R/33).

[4] Population Division, Department of International Economic and Social Affairs, United Nations Secretariat, New York, New York 10017, United States of America.

high variants. These are called the "decline" and "growth" variants because they do not assume an ultimate stationary population but rather assume very small constant rates of growth (negative and positive) near the end of the projection period. The significance of these additional variants may be seen by considering the world population as projected to the year 2100. In the low and high variants, the total population in 2100 is 7.5 and 14.2 billion, respectively, whereas in the decline and growth variants it equals 7.2 and 14.9 billion, respectively. The wider range in total population projected by the growth and decline variants is meant to demonstrate that future demographic trends are not expected to be as smooth as implied by the projection assumptions. It is unlikely that fertility will remain at the replacement level without fluctuating or that the expectation of life will be fixed at 77.4 years for both sexes in all regions.

This paper will also attempt an elementary evaluation of the accuracy of the long-range projections. An analysis of previous United Nations projections will be reviewed and a comparison of the current projections with those produced elsewhere will be made. There is reason to believe that United Nations population projections are becoming more accurate.

These projections are intended to encompass a reasonable range of possible future events without allowing the range to become so broad as to be meaningless. Naturally, uncertainty increases with the length of the projection period, and the range between projection variants increases accordingly. No attempt is made to foresee major catastrophes or social or technological changes which would greatly alter the direction of current demographic trends.

Since these projections up to 2025 were prepared in 1980 and the extension to 2100 was made in 1981, little information from the 1980 and 1981 round of censuses was available for consideration. Preliminary census results which have subsequently been released generally confirm, however, that the projections are quite close to the actual population totals. This correspondence is not surprising since the projections, while relying generally on 1970 data for the base population, incorporate estimates of fertility and mortality that cover most of the 1970–1980 period. The United Nations projections for individual countries will be revised during 1982 and the long-range prospects will then be reassessed.

The following sections of the paper will describe the assumptions upon which the projections are based, review their results, discuss their probable accuracy and consider some conclusions suggested by the long-range projections.

Assumptions

Base population

The base year of the projections as discussed here is taken to be 1980, although in most cases the 1980 population was derived by a projection from an earlier date, usually 1970 or 1975. In the 1978 assessment the world population equalled 4,415 million in 1980; in the current assessment the total is 4,432 million. The totals for the regions are nearly unchanged with the exception of an increase of 39 million in the estimate for East Asia, because of an upward revision for China, and a decrease of 18 million for South Asia, attributable to lower estimates for several countries of Eastern South Asia.

Fertility assumptions

All input assumptions and results of the long-range projections are identical to those of the 1980 medium-range assessment up to 2025. Three projections variants are presented in the medium-range projections—namely, high, medium and low. In general, the medium variant represents future demographic trends that seem more likely to occur considering observed past demographic trends, expected social and economic progress, ongoing government policies and prevailing public attitudes toward population issues. In contrast, the high and low variants indicate the plausible, but not exhaustive, range of future deviations from the medium variant projections because future fertility, mortality and migration rates could take alternative courses under various conditions.

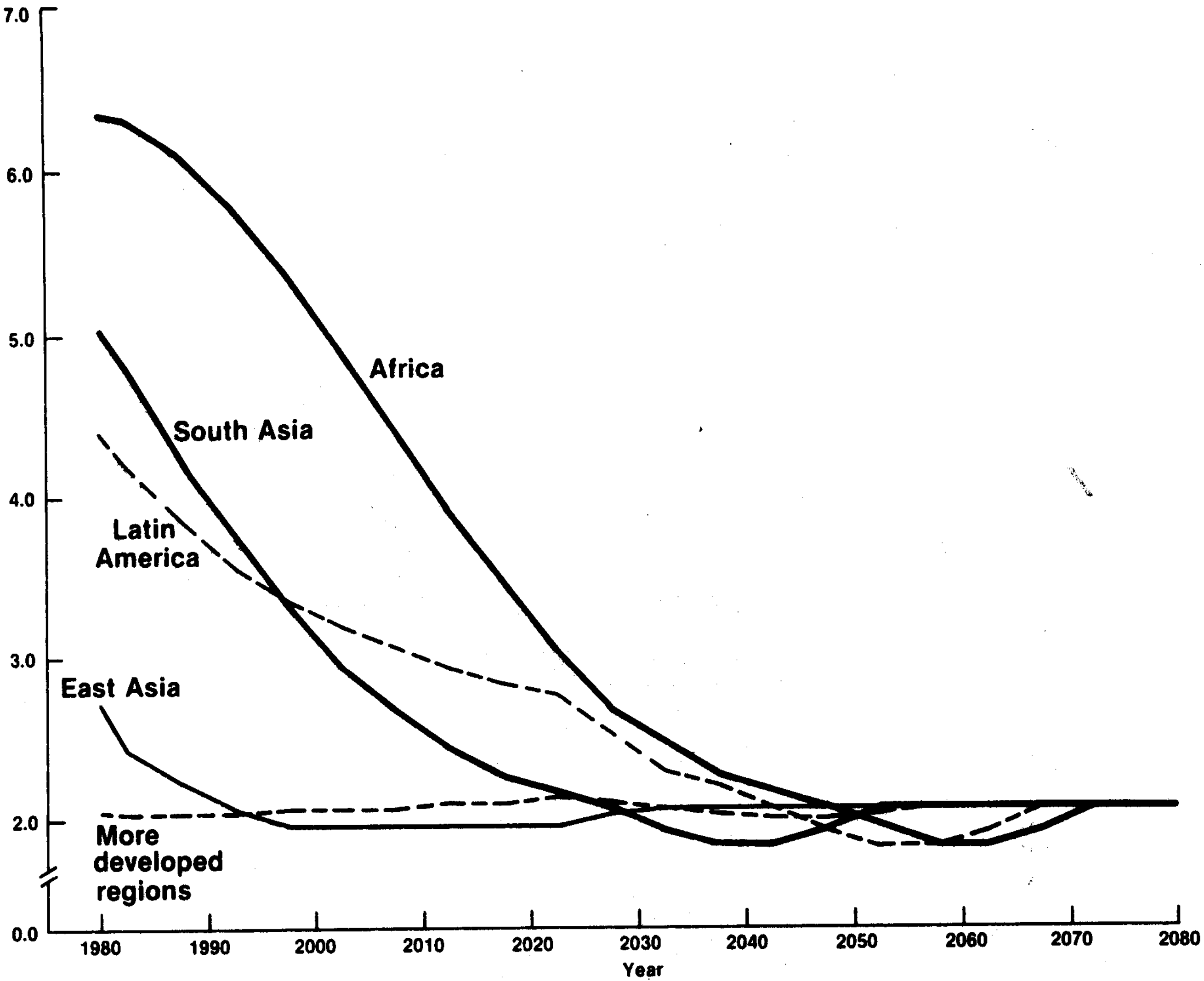
In the long-range projections five variants are produced by adding a "growth" and a "decline" variant. There is no reason to believe that the net result of fertility decisions of millions of couples in any major population will result in a constant net reproduction rate of 1.0. This level is usually hypothesized as the ultimate level of fertility in long-range projections, however, because any other level of fertility, if maintained indefinitely, would eventually cause a population to expand to an improbable size or to decline to the point of disappearing. In order to allow for the possibility that future long-term fertility trends may not conform precisely to the replacement level, the two further variants of the long-range projections were prepared. These "growth" and "decline" variants do not differ from the high and low variants, respectively, until after 2025. They are so named to indicate that in the long term they do not produce stationary populations, but rather ones which continue to change (grow or decline) at a low rate.

Medium variant

The ultimate level of fertility assumed in the medium variant is that at which a population will continue to replace itself, that is the net reproduction rate equals 1.0 and the total fertility rate equals about 2.1. It is assumed, however, that the momentum of fertility decline generated as the total fertility rate falls to 2.1 will not suddenly cease when that level is reached, based on the experience of countries which currently have below-replacement fertility. For regions with fertility currently above replacement, the total fertility rate is assumed to decline to a minimum of 1.84 (equivalent to the rather arbitrary level of a gross reproduction rate of 0.90 when the sex ratio at birth equals 1.05). Then in order to prevent a major diminishing of a population in the long term, fertility is assumed to increase again to the replacement level. For Africa, South Asia and Latin America, fertility would be below replacement for 20 years. Based on the recent fertility trends and goals in China, fertility in East Asia is assumed to be below replacement from 1990 and 2040. According to the medium-range assumptions, the total fertility rate in China declines to a minimum of 1.84 in the low variant and to a minimum of 1.95 in the medium variant. For the areas in which fertility is currently below replacement level, it is assumed to increase gradually until it reaches replacement.

Projected total fertility rates for major areas are graphed in figure I. The fluctuations in the total fertility rate for the more developed regions apparent in figure I result from the application of these assumptions for

Figure I. Projected total fertility rate by region, medium variant, 1980–2080, as assessed in 1980



Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

Northern America, Japan, Europe and Australia, where fertility is currently below replacement, and for the USSR, where it is above replacement. Assumptions regarding future trends for individual countries are heavily influenced by trends in the recent past, but no single model of fertility decline is applied to all countries. Assumed future declines take into account the factors listed in the first paragraph of the section on fertility assumptions above. Thus, fertility is assumed to decline more rapidly in South Asia than in Latin America over the next 45 years, although the amount of decline during the 1970s was nearly equal in the two regions. Medium variant total fertility rates for selected periods are shown in table 1.

High variant

Fertility in the high variant of the projections is assumed to be somewhat above that in the medium variant. The size of the difference is related both to the level of fertility and the degree of uncertainty in its estimation. On average, the total fertility rate in the year 2000 is 0.3 greater in the high than the medium variant, but the difference is as large as 0.7 for Africa. For areas where fertility is currently above replacement, the total fertility rate will decline to 2.1 about 20 years later than according to the medium variant (see table 2). In these areas it is assumed in the high variant that fertility will remain constant once it has reached the replacement level, rather than dip below that level as assumed in the medium variant. For areas where fertility is already below the replacement level, it is assumed to increase so as to reach that level between 10 and 25 years earlier than in the medium variant.

Low variant

In the low variant projection, the total fertility rate is assumed to be somewhat below that in the medium variant. The average difference for the world in 2000 is 0.4, with the gap greater for high fertility regions. In regions with above replacement-level fertility, replace-

TABLE 1. FERTILITY AND MORTALITY ASSUMPTIONS BY MAJOR AREAS, MEDIUM VARIANT, SELECTED PERIODS 1980 TO 2045, AS ASSESSED IN 1980

Major areas	Total fertility rate				Expectation of life at birth, both sexes			
	1980–1985	2000–2005	2020–2025	2040–2045	1980–1985	2000–2005	2020–2025	2040–2045[a]
World	3.62	2.83	2.35	2.00	59.2	65.5	70.4	74.3
More developed regions	2.02	2.07	2.14	2.01	72.4	74.2	75.4	76.9
Less developed regions	4.17	3.01	2.39	2.00	57.0	64.2	69.6	73.9
Africa	6.30	4.89	3.02	2.15	50.8	59.9	67.2	72.6
Latin America	4.20	3.18	2.77	2.05	64.1	69.0	71.8	74.6
Northern America	2.01	2.08	2.10	2.07	73.3	74.3	75.1	76.5
East Asia	2.43	1.97	1.97	2.06	69.9	73.3	74.8	76.6
South Asia	4.79	2.95	2.16	1.84	52.8	61.7	68.6	73.0
Europe	1.91	1.93	2.10	2.07	72.7	74.6	75.7	77.4
Oceania	2.74	2.48	2.26	2.02	66.7	71.0	73.8	76.3
USSR	2.36	2.29	2.25	1.84	70.0	72.4	74.6	76.4

[a]After 2045, the expectation of life increases gradually to the ultimate level of 77.4 years.

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

ment is assumed to be achieved about 25 years sooner on average than in the medium variant. Fertility would continue to decline until the total fertility rate equalled 1.84, remain at that level for 20 to 30 years, then increase to the replacement level. In the major areas where fertility is now below replacement, it is assumed that an increase to that level will take considerably longer than in the medium variant.

Growth and decline variants

For the growth variant the assumptions about fertility trends are exactly the same as in the high variant, except that the value of the net reproduction rate becomes constant at 1.05 rather than at 1.00. This projection path leads to a stable population with a growth rate of 0.18 per cent per annum (if the mean age of childbearing is 27.1 years). Similarly, according to the decline variant fertility follows the same path as that in the low variant, except that it reaches net reproduction rate of only 0.95 when increasing from its minimum level, then remains constant. The decline variant yields a stable population with a growth rate of −0.18 per cent per annum. In carrying out these projections no population was allowed to decrease to less than 80 per cent of its peak size, as an arbitrary constraint. Thus the net reproduction rate was increased to 1.0 in the low and decline variants for Europe and in the decline variant for Japan at dates which would stabilize their ultimate population at 80 per cent of their maximum size.[5]

Mortality assumptions

The assumptions about mortality trends in United Nations projections are expressed in terms of future expectation of life at birth, by sex. Assumed life expectancies up to 2025 are presented in the 1980 assessment. They increase at a diminishing rate up to a maximum of 73.5 years for males and 80 years for females. They are slightly higher in the high variant and lower in the low variant compared with the medium variants. The

[5]In the long-range projections, Japan was projected separately from the rest of East Asia so that its population could be summed with that of the more developed regions. Australia and New Zealand were also projected separately from the rest of Oceania for the same reason.

TABLE 2. FERTILITY ASSUMPTIONS BY MAJOR AREAS FOR LONG-RANGE PROJECTIONS, AS ASSESSED IN 1980

Major areas	Year in which net reproduction rate (NRR) first reaches 1.0			Year in which NRR first reaches ultimate level	
	Medium	High	Low	NRR = 1.05 Growth	NRR = 0.95 Decline
World	2035	2065	2010	2060	2025
More developed regions[a]	2005	1980	2060	1990	2030
Less developed regions	2035	2065	2010	2060	2025
Africa	2045	2065	2030	2060	2030
Latin America	2040	2060	2025	2055	2030
Northern America[a]	1995	1985	2035	1990	2030
East Asia	1990	1995	1985	1995	1985
South Asia	2020	2040	2010	2025	2015
Europe[a]	2020	1995	2025	2000	2025[b]
Oceania	2035	2055	1995	2045	2025
USSR	2030	2045	1990	2035	2030

[a]In these regions, fertility in 1980 was below the assumed ultimate level and thus approaches the level from under it.

[b]For Europe, the decline variant is the same as the low variant, since if an NRR = 0.95 were maintained after 2025 the total population would diminish to less than 80 per cent of its peak value before 2100.

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

TABLE 3. NET INTERREGIONAL MIGRATION ASSUMPTIONS, ALL VARIANTS, 2025–2080, AS ASSESSED IN 1980

Period	Net number of migrants in five-year period (thousands)			
	Latin America	Northern America	South Asia	Oceania
2025–2030	−1 000	2 000	−1 200	200
2030–2035	−1 000	2 000	−1 160	160
2035–2040	−1 000	2 000	−1 120	120
2040–2045	−1 000	2 000	−1 080	80
2045–2050	−1 000	2 000	−1 040	40
2050–2055	−1 000	2 000	−1 000	0
2055–2060	− 800	1 600	− 800	0
2060–2065	− 600	1 200	− 600	0
2065–2070	− 400	800	− 400	0
2070–2075	− 200	400	− 200	0
2075–2080	0	0	0	0

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

assumed expectations of life for selected periods of the projection are presented in table 1.

The expectation of life at birth assumed in these projections falls considerably below the targets established by the World Population Plan of Action in 1974.[6] That Plan called for the attainment of an average expectation of life of 62 years by 1985 and 74 years by the year 2000 for the world as a whole, whereas the projections are based on assumed figures of 60.8 years in 1985–1990 and only 65.5 years in 2000–2005. Even the more modest goal of a minimum life expectancy of 60 years in all countries by the year 2000 envisaged for the Third United Nations Development Decade[7] is not assumed to be realized in the majority of African countries and in several countries of South Asia.

Only one mortality trend is employed for each major area after 2025. Expectation of life is assumed to increase to 75 years for males and 80 years for females. The Coale-Demeny model life tables[8] were used in making the projections, with model North used for Africa and West for all other areas.

Migration assumptions

As in the case of fertility and mortality, the assumptions made about volume and trends in net international migration up to 2025 are the same as those made for the United Nations medium-range projections as assessed in 1980.[9] Migration totals for the major areas of the world are actually the sum of figures employed for the individual countries in each area. For the period after 2025, the assumptions were made only for major areas and took into account the requirement that net migration at the global level should be nil (see table 3). One set of assumptions is used for all five projection variants after 2025. The assumption that net migration levels will decline to zero between 2050 and 2075 is operationally useful in permitting regional population totals to become stationary but is quite arbitrary.

[6] *Report of the United Nations World Population Conference, 1974,* Bucharest, 19–30 August 1974 (United Nations publication, Sales No. E.75.XIII.3), para. 22.

[7] *Sharing Accelerated Development and International Changes* (United Nations publication, Sales No. E.80.II.A.4).

[8] Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations* (Princeton, Princeton University Press, 1966).

[9] *Demographic Indicators of Countries: Estimates and Projections as Assessed in 1980* (United Nations publication, forthcoming).

RESULTS

Global results

According to the medium variant, the population of the world will stabilize after 2095 at 10.2 billion persons, after reaching 6.1 billion in 2000 and 8.2 billion in 2025 (see table 4). Nearly 90 per cent of the future world growth after 1980 would occur before 2050 when the population would reach 9.5 billion. The average annual growth rate from 2050 to the end of the projection period (2100) would be only 0.14 per cent.

Although growth rates among the five projection variants do not differ greatly, when the differences are maintained for over a century, a fairly wide range of future total population figures results. The total population of the world would peak at 7.7 billion in 2060 according to the low variant but would reach 14.2 billion by 2100 according to the high variant, both of which assume that fertility will be constant at the replacement level in the long term.

Were the long-term net reproduction rate to differ from the replacement level by as little as 5.0 per cent, however, the range of future growth possibilities would be even wider. In the decline variant, total population reaches a maximum of 7.7 billion in 2055, but then declines very slowly to 7.2 billion in 2100. In the growth variant, the population at the end of the twenty-first century equals 14.9 billion and continues to grow slowly.

Hence, while the medium variant of the long-range projections yields an ultimate world population of 10.2 billion under the assumption of eventual stabilization, a reasonable range of projections of the population in 2100 extends from 7.2 to 14.9 billion, with the upper figure more than double the lower figure.

The population of the world would stabilize as the crude birth rate falls from 27.5 in 1980–1985, to 22.5 in 2000–2005, to 16.9 in 2025–2030, and finally to a constant level of about 13, according to the medium variant (see table 5). Although fertility assumptions were prepared independently, with no targets in mind, the projected crude birth rate conforms to the goal specified in the World Population Plan of Action[10] of a crude birth rate equal to 30 in the developing countries as a whole by 1985. The projected crude birth rate for the less developed regions is 29.9 for 1985–1990.

The older age structure of the world population, which results more from declining fertility than from increasing life expectancies, will eventually lead to an increasing crude death rate, even as expectation of life continues to increase. The medium variant crude death rate for the world as a whole is projected to decline steadily from its 1980–1985 level of 10.6 to a minimum of 8.3 between 2010 and 2020, then to rise slowly until it matches the crude birth rate at 13 in 2095–2100.

Regional results

Projected future population growth of the world's major areas is illustrated in figure II. According to the medium variant, most growth up to 2100 will have occurred by 2050, after which there would be only minor changes in the distribution of the earth's population among the major areas. It is also apparent from figure II that most future growth will occur in the currently less

[10] *Report of the United Nations World Population Conference, 1974....*

TABLE 4. TOTAL POPULATION OF THE WORLD AND MAJOR AREAS ACCORDING TO FIVE VARIANTS, SELECTED DATES 1980 TO 2100, AS ASSESSED IN 1980

	Variant (millions)				
Major areas	*Medium*	*Growth*	*High*	*Low*	*Decline*
World					
1980	4 432	4 441	4 441	4 420	4 420
2000	6 119	6 337	6 337	5 837	5 837
2025	8 195	9 135	9 135	7 168	7 168
2050	9 513	11 690	11 629	7 687	7 667
2075	10 097	13 642	13 355	7 662	7 562
2100	10 185	14 927	14 199	7 524	7 247
More developed regions					
1980	1 131	1 132	1 132	1 130	1 130
2000	1 272	1 304	1 304	1 233	1 233
2025	1 377	1 488	1 488	1 251	1 251
2050	1 402	1 625	1 610	1 194	1 190
2075	1 419	1 758	1 701	1 151	1 137
2100	1 421	1 858	1 733	1 137	1 102
Less developed regions					
1980	3 301	3 308	3 308	3 290	3 290
2000	4 847	5 033	5 033	4 604	4 604
2025	6 818	7 647	7 647	5 917	5 917
2050	8 111	10 065	10 018	6 493	6 477
2075	8 677	11 884	11 654	6 511	6 425
2100	8 764	13 069	12 466	6 387	6 145
Africa					
1980	470	471	471	469	469
2000	853	886	886	756	756
2025	1 542	1 850	1 850	1 109	1 109
2050	2 166	2 998	2 998	1 341	1 341
2075	2 507	3 966	3 934	1 385	1 385
2100	2 591	4 575	4 444	1 354	1 333
Latin America					
1980	364	364	364	363	363
2000	566	586	586	544	544
2025	865	984	984	761	761
2050	1 096	1 424	1 424	868	868
2075	1 215	1 787	1 767	885	883
2100	1 238	2 019	1 948	859	841
Northern America					
1980	248	249	249	247	247
2000	299	304	304	284	284
2025	344	366	366	301	301
2050	364	409	405	294	291
2075	378	449	433	289	279
2100	382	477	442	288	266
East Asia					
1980	1 175	1 175	1 175	1 174	1 174
2000	1 475	1 519	1 519	1 436	1 436
2025	1 712	1 826	1 826	1 610	1 610
2050	1 765	1 958	1 933	1 611	1 594
2075	1 762	2 038	1 963	1 576	1 525
2100	1 763	2 123	1 972	1 567	1 465
South Asia					
1980	1 404	1 410	1 410	1 395	1 395
2000	2 075	2 166	2 166	1 988	1 988
2025	2 819	3 116	3 116	2 548	2 548
2050	3 198	3 814	3 790	2 772	2 772
2075	3 306	4 227	4 117	2 757	2 724
2100	3 284	4 491	4 230	2 698	2 596
Europe					
1980	484	484	484	483	483
2000	512	526	526	499	499
2025	522	572	572	476	476
2050	509	603	597	433	433
2075	503	640	620	407	407
2100	504	674	629	404	404

TABLE 4 (*continued*)

Major areas	*Variant (millions)* Medium	Growth	High	Low	Decline
Oceania					
1980	23	23	23	23	23
2000	30	31	31	29	29
2025	36	40	40	32	32
2050	40	48	47	33	33
2075	43	53	52	33	32
2100	42	56	53	32	30
USSR					
1980	265	266	266	265	265
2000	310	318	318	303	303
2025	355	381	381	332	332
2050	375	436	433	336	336
2075	384	481	468	330	328
2100	381	511	481	322	311

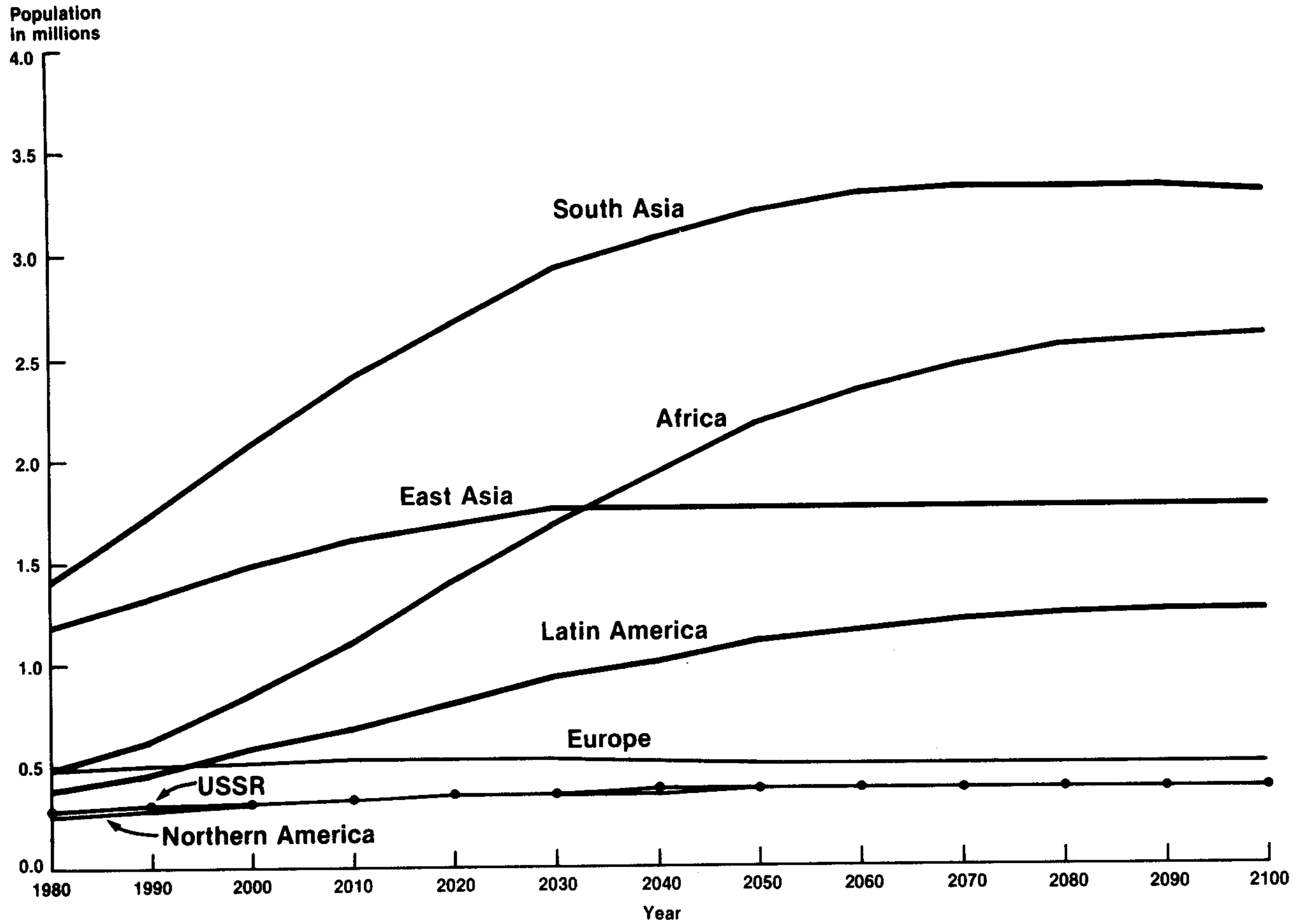
Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

TABLE 5. PROJECTED ANNUAL RATE OF GROWTH, CRUDE BIRTH RATE AND CRUDE DEATH RATE, WORLD AND MAJOR AREAS, MEDIUM VARIANT, 1980 TO 2105, AS ASSESSED IN 1980

Major areas	*1980–1985*	*2000–2005*	*2025–2030*	*2050–2055*	*2075–2080*	*2100–2105*
	Annual rate of growth (percentage)					
World	1.70	1.39	0.82	0.36	0.10	−0.03
More developed regions	0.68	0.40	0.15	0.07	0.02	−0.01
Less developed regions	2.04	1.64	0.96	0.41	0.11	−0.03
Africa	3.00	2.77	1.70	0.84	0.31	−0.03
Latin America	2.38	1.92	1.25	0.52	0.20	−0.06
Northern America	1.04	0.62	0.32	0.22	0.06	0.03
East Asia	1.24	0.89	0.33	−0.03	−0.04	0.01
South Asia	2.17	1.53	0.77	0.30	0.01	−0.04
Europe	0.34	0.15	−0.08	−0.08	−0.00	0.01
Oceania	1.44	0.92	0.64	0.19	0.07	0.00
USSR	0.93	0.60	0.38	0.16	−0.00	−0.06
	Crude birth rate					
World	27.5	22.5	16.9	13.8	13.0	12.9
More developed regions	15.8	14.1	13.3	13.0	12.9	13.0
Less developed regions	31.4	24.6	17.6	14.0	13.0	12.9
Africa	45.6	37.2	23.2	15.2	13.2	12.8
Latin America	32.3	25.9	19.9	13.8	12.8	12.8
Northern America	17.3	14.3	13.4	13.2	13.1	13.0
East Asia	19.1	16.1	13.7	12.9	12.8	12.9
South Asia	34.8	24.1	16.0	13.8	13.0	12.9
Europe	14.1	12.8	12.5	12.8	13.0	13.0
Oceania	21.4	18.2	14.9	13.2	13.0	13.0
USSR	18.8	16.1	14.5	13.0	12.7	12.9
	Crude death rate					
World	10.6	8.6	8.7	10.3	12.0	13.1
More developed regions	9.6	10.4	12.2	12.6	12.8	13.0
Less developed regions	11.0	8.2	8.0	9.9	11.8	13.2
Africa	15.6	9.6	6.2	6.8	10.2	13.1
Latin America	8.2	6.6	7.1	8.5	10.8	13.4
Northern America	9.1	9.4	11.3	12.1	12.5	12.8
East Asia	6.7	7.2	10.4	13.1	13.2	12.8
South Asia	13.2	8.8	8.3	10.8	12.8	13.3
Europe	10.7	11.3	13.3	13.7	13.0	12.9
Oceania	8.8	8.4	9.6	11.4	12.3	13.0
USSR	9.4	10.1	10.7	11.4	12.7	13.5

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

Figure II. Projected total population of major regions, medium variant, 1980 to 2100, as assessed in 1980



Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

developed regions.[11] In fact, 95 per cent of the projected growth between 1980 and 2050 would occur in the less developed regions. Their share of the world's population would increase from nearly 75 per cent to 85 per cent during that period. The proportion of the world's population resident in Africa is projected to increase from 10.6 per cent in 1980, to 22.8 per cent in 2050 and to 25.4 per cent in 2100. Latin America's share would expand from 8.2 per cent in 1980 to 11.5 per cent in 2050; East Asia's would contract from 26.5 to 18.6 per cent; and South Asia's would increase from 31.7 to 33.6 per cent by 2050.

The proportion of the global population in each of the more developed regions would decrease over the next 70 and more years. Northern America's share would decline from 5.6 per cent in 1980 to 3.8 per cent in 2050, Europe's from 10.9 to 5.4 per cent and that of the USSR from 6.0 to 3.9 per cent. It is possible that the proportion of the world's population in the more developed regions would contract even more were their future demographic trends to follow the low variant while the trend in less developed regions followed the medium variant. The assumed fertility level was arbitrarily increased to replacement in 2040 for Japan in the decline variant and in 2025 for Europe in the low and decline variants in order to prevent their projected population from falling to below 80 per cent of their maximum level. In reality, it cannot be known if fertility will increase in that manner but it seems plausible to assume that no population would indefinitely maintain a level of fertility which would lead to its own extinction.

Age structure

The distribution by age of the population of the major regions in 1980 reflects their past demographic trends. The more developed regions are characterized by low levels of both fertility and mortality, which have produced a relatively old age distribution. The median age in those regions taken as a whole is 31.4 years. Only 23 per cent of the population are aged 0–14 and the dependency ratio is a low 52 per 100. On the other hand, more than 11 per cent of their population are aged 65 and over (see table 6). In marked contrast, moderate-to-high fertility levels combined with generally moderate mortality levels have produced much younger age distributions in the less developed regions, taken individually or in the aggregate. In those regions, the median age is just 20, and the propor-

[11] For the purposes of these projections, more developed regions are defined as Northern America, Europe, USSR, Japan, Australia and New Zealand. Less developed regions are Africa, Latin America, East Asia excluding Japan, South Asia and Oceania excluding Australia and New Zealand. No provision is made for the transfer of countries between the categories during the projection period.

tion 0–14 averages 39 per cent while that aged 65 and over is only 4 per cent. The dependency ratio was about 76 per 100 in 1980.

Since the assumptions about future demographic trends in the high, medium and low variants establish that in all regions constant fertility at the replacement level and a low level of mortality will be reached and maintained, the projected age distribution of all regions becomes stationary (fixed and with a zero rate of growth) in the long run. The convergence to the stationary state may be observed by comparing the 1980 distribution with that of 2050 for both the more and less developed regions as shown in figures III and IV. The stable population (characterized by constant birth and death rates and an unchanging age distribution) in 2100, as projected for both the more and less developed regions, would have a median age of about 39. The proportion under age 15 and over age 64 would be nearly equal at about 19 per cent and the dependency ratio would be near 60 (see table 6).

Comparison with previous projection results

The population of the world as projected by the medium variant of 10,185 million in 2100 represents a decrease of 340 million from the total projected in the United Nations 1978 assessment. The revised projections also yield a somewhat wider range of possible future population totals. The revised low variant gives a population in 2100 of 7.5 billion, compared with 8.0 billion in the previous assessment. In the high variant, the total for 2100 equals 14.2 billion, compared with 14.1 billion in the previous projection. As described above, the decline and growth variants yield a slightly larger range.

The reduction of the ultimate size of the world population projected by the 1980 assessment relative to the 1978 assessment is by no means uniform among the major areas of the world. The revised projection yields population totals in 2100 which are greater than in the previous projection by 402 million for Africa, 51 million for Latin America, 64 million for Northern America and 37 million for East Asia. These increases are more than offset by a decrease of 36 million in the projection for Europe and of 861 million for South Asia. The large reduction in the projected future population of South Asia is achieved with seemingly modest changes in fertility and mortality assumptions, which are significant because of the size of the region. Fertility in several countries of Eastern South

TABLE 6. PROJECTED AGE STRUCTURE OF THE WORLD AND MAJOR AREAS, MEDIUM VARIANT, SELECTED YEARS 1980 TO 2100, AS ASSESSED IN 1980

Year and indicator	*World*	*More developed regions*	*Less developed regions*	*Africa*	*Latin America*
1980					
Median age........	22.6	31.4	20.1	17.5	19.7
Per cent 0–14.....	35.0	23.1	39.1	44.9	39.8
Per cent 15–64...	59.1	65.6	56.9	52.1	55.9
Per cent 65+	5.9	11.3	4.0	3.0	4.3
Dependency ratio[a]	69.2	52.4	75.8	92.0	78.8
2000					
Median age........	26.1	35.8	24.1	17.8	23.0
Per cent 0–14.....	30.7	21.0	33.2	43.9	34.7
Per cent 15–64...	62.7	66.0	61.9	52.9	60.4
Per cent 65+	6.6	13.0	4.9	3.2	4.9
Dependency ratio	59.4	51.6	61.6	89.0	65.5
2025					
Median age........	30.8	38.2	29.5	22.8	27.4
Per cent 0–14.....	25.0	19.9	26.1	34.1	29.0
Per cent 15–64...	65.7	63.3	66.2	61.6	63.8
Per cent 65+	9.3	16.7	7.8	4.3	7.2
Dependency ratio	52.2	57.9	51.2	62.4	56.7
2050					
Median age........	35.7	38.8	35.2	31.0	33.0
Per cent 0–14.....	20.6	19.1	20.8	24.1	22.2
Per cent 15–64...	66.2	63.1	66.7	67.9	66.9
Per cent 65+	13.2	17.8	12.5	8.0	10.8
Dependency ratio	51.1	58.4	49.9	47.2	49.4
2075					
Median age........	39.1	39.3	39.1	38.2	38.7
Per cent 0–14.....	19.2	19.2	19.1	19.4	19.6
Per cent 15–64...	63.7	62.7	63.9	65.5	64.9
Per cent 65+	17.1	18.1	17.0	15.1	15.6
Dependency ratio	56.9	59.5	56.5	52.6	54.2
2100					
Median age........	39.5	39.1	39.6	40.3	39.6
Per cent 0–14.....	19.1	19.3	19.0	18.7	19.1
Per cent 15–64...	61.9	62.3	61.9	61.5	61.8
Per cent 65+	19.0	18.4	19.1	19.8	19.1
Dependency ratio	61.5	60.5	61.6	62.6	61.7

TABLE 6 *(continued)*

Year and indicator	*Northern America*	*East Asia*	*South Asia*	*Europe*	*Oceania*	*USSR*
1980						
Median age	29.7	23.7	19.1	33.0	26.4	29.4
Per cent 0–14	23.0	32.7	41.1	22.3	29.5	24.3
Per cent 15–64 ...	66.5	61.5	55.7	64.7	62.6	65.6
Per cent 65+	10.6	5.8	3.1	13.0	7.9	10.0
Dependency ratio	50.4	62.6	79.4	54.5	59.7	52.4
2000						
Median age	34.8	30.9	23.0	37.3	30.0	33.4
Per cent 0–14	22.0	24.1	34.0	19.3	26.2	23.7
Per cent 15–64 ...	67.0	68.1	61.9	66.2	64.9	64.2
Per cent 65+	11.1	7.9	4.1	14.5	8.9	12.0
Dependency ratio	49.4	46.9	61.5	51.1	54.1	55.7
2025						
Median age	37.5	37.7	30.4	40.4	34.0	35.2
Per cent 0–14	20.4	19.2	24.5	18.6	22.7	22.2
Per cent 15–64 ...	63.7	67.2	68.6	63.3	64.8	63.4
Per cent 65+	15.9	13.6	6.9	18.2	12.5	14.4
Dependency ratio	57.0	48.8	45.9	58.1	54.3	57.6
2050						
Median age	38.2	39.6	37.3	39.6	37.1	37.9
Per cent 0–14	19.8	18.8	19.2	18.9	20.0	18.8
Per cent 15–64 ...	63.1	63.0	67.7	61.9	64.5	65.2
Per cent 65+	17.1	18.2	13.1	19.2	15.5	16.0
Dependency ratio	58.6	58.8	47.7	61.6	55.0	53.3
2075						
Median age	38.7	39.3	39.9	39.1	39.0	40.1
Per cent 0–14	19.5	19.2	18.7	19.2	19.5	18.8
Per cent 15–64 ...	62.8	62.1	63.2	62.5	63.1	63.1
Per cent 65+	17.7	18.7	18.0	18.3	17.4	18.1
Dependency ratio	59.4	61.2	58.1	60.1	58.4	58.6
2100						
Median age	38.9	39.1	39.4	39.1	39.0	39.4
Per cent 0–14	19.4	19.4	19.1	19.3	19.4	19.2
Per cent 15–64 ...	62.6	62.2	62.0	62.5	62.2	61.7
Per cent 65+	18.0	18.4	18.9	18.2	18.4	19.1
Dependency ratio	59.7	60.7	61.2	60.0	60.7	62.1

[a]The dependency ratio is the number of persons aged 0–14 and 65 and over per 100 persons aged 15–64.

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

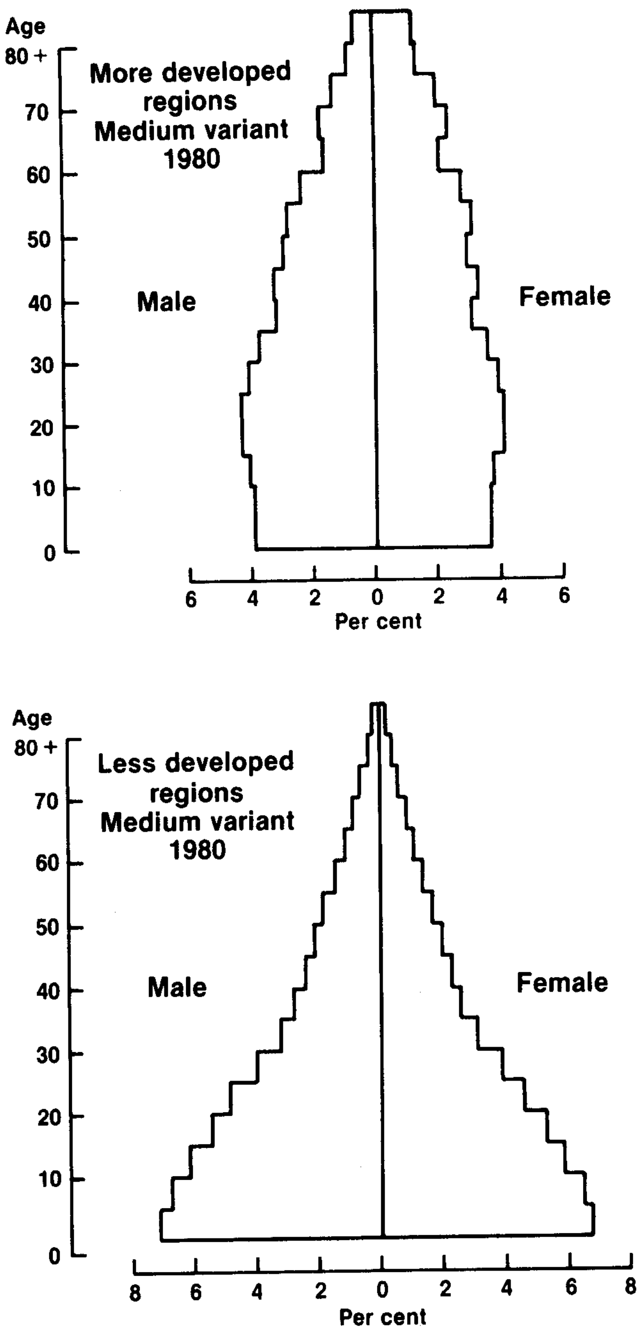
Asia fell more rapidly during the late 1970s than assumed earlier. As a consequence, in the revised projection the crude birth rate up to 2020 in South Asia is 1 or 2 points below that yielded by the previous assumptions on fertility. In addition, life expectancy in the region has increased a little more slowly than assumed in the previous projection and the trend is reflected in a crude death rate which is about 1 point higher in the revised projection throughout the projection period.

Africa's total population was projected to equal 2.2 billion in 2100 according to the previous assessment but 2.6 billion by the 1980 assessment, medium variant. The large increase is produced by relatively small changes in fertility and mortality, but ones carried over long periods of time. There has been little evidence that an anticipated fertility decline in several African countries has actually begun, so fertility assumptions are somewhat higher in the 1980 assessment. The resultant crude birth rate in the revised projection is generally 2 to 3 points higher than in the previous one. The difference increases to a maximum of 3.4 points in 2010–2020, then decreases steadily. The crude death rate in the two assessments is nearly the same up to 2020, after which the revised crude death rate is slightly lower than the previous rate. Although changes in the projection assumptions for Latin America and Northern America are minor, when carried over 125 years they lead to somewhat different results at the end of the projection period.

ACCURACY OF PROJECTIONS

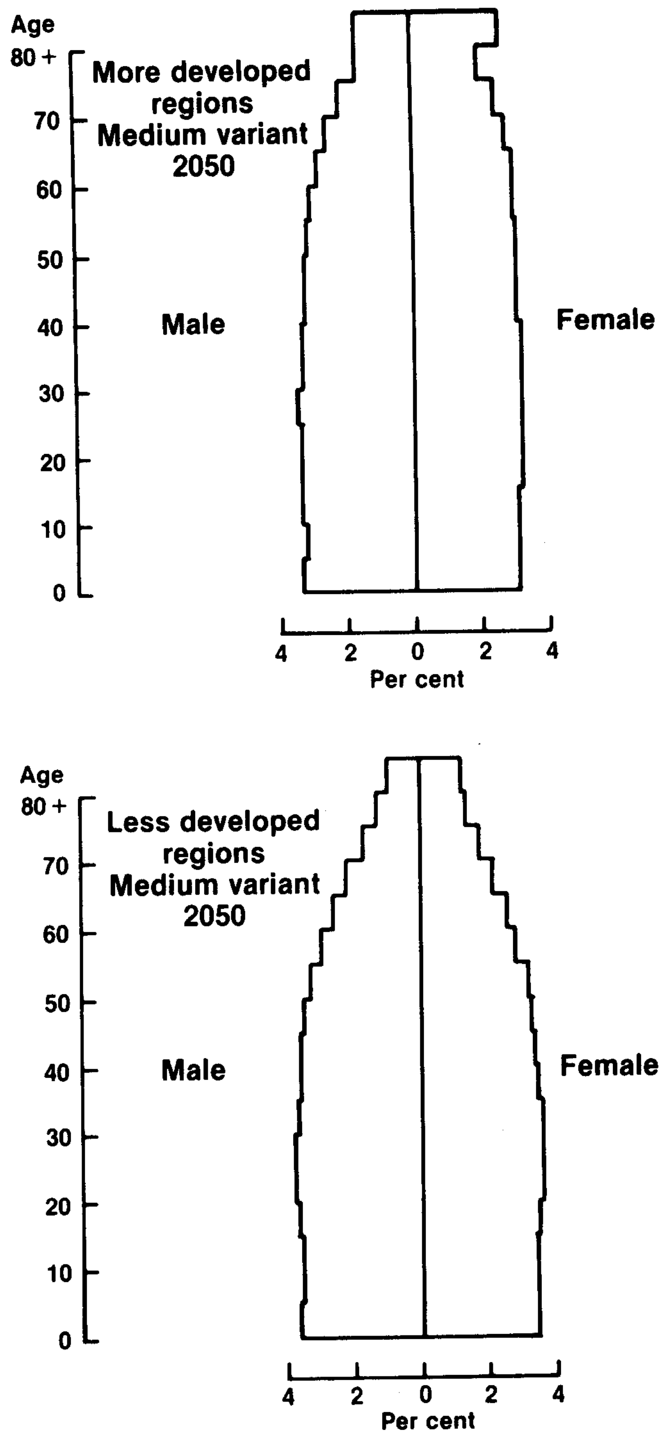
How likely is it that future population totals of the world or any major region will be near those projected by the medium variant or that they will fall within the wide range between the decline and growth variants? A precise answer cannot be given because the problem is not of a probabilistic nature; but based on the evidence presented below it can be argued that the degree of confidence in projecting the world's population is improving (although this may not be the case for certain areas of the world, particularly Africa). Two factors account for the greater degree of confidence.

Figure III. Percentage distribution of population by age and sex, more developed and less developed regions, medium variant, 1980, as assessed in 1980



Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

Figure IV. Percentage distribution of population by age and sex, more developed and less developed regions, medium variant, 2050, as assessed in 1980



Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

The first is the considerable improvement in the availability and quality of demographic information for most of the world's populations, especially the larger ones. Most notably, China has begun to release official annual population totals and vital rates. In addition, reasonable estimates of vital rates are available from the Sample Registration System in India and from major fertility surveys in Bangladesh, Indonesia and Mexico, for example.

The other factor which should improve the accuracy of long-range projections is that the rate of growth of the world population has peaked and begun to decline. The highest global growth rate was an average of about 2.0 per cent a year during the 1960s. The rate declined to 1.8

per cent during the 1970s and is estimated to be 1.7 per cent currently. If this trend leads to a long-term steady decline in the rate of growth, it will improve the demographer's ability to project future population totals accurately.

An impression of the degree of accuracy can be obtained, however, by reviewing the intended meaning of the variants and the accuracy of previous rounds of United Nations projections. In the publication of the 1973 round of United Nations projections[12] the intention of each of the variants was explained as follows:

> "... the medium estimates are intended to represent the most plausible future population trend in view of what is known of past experience and current circumstances in each country. The high and low variants are intended to represent the upper and lower boundaries of a zone of greatest plausibility. It must be emphasized, however, that future trends outside the limits of the high and low variants are by no means impossible."

Thus, the range of the United Nations projections is intended to cover the most plausible future population trends, but not all possible trends. The intended meaning of the variants remains somewhat imprecise, however. One approach to measuring the expected accuracy of the current projections is to review the accuracy of previous projections. Nathan Keyfitz[13] has attempted a quantifiable evaluation of the accuracy of United Nations projections prepared in 1958, 1963 and 1968 by comparing the growth rate projected for major countries with the actual rate that ensued. Keyfitz calculated the square root of the mean of the squares of the difference between the projected and actual growth rates for all countries. He concluded that the odds are 2 to 1 that the forecast rate of increase ±0.4 points will straddle the realized rate of increase over future periods.

There are several reasons to believe, however, that the current United Nations projections will prove to be even more accurate than that. First, Keyfitz found that each round of United Nations projections which he considered was more accurate than the previous round, with the root-mean-square error for the 1968 projections equal to 0.357. The improvement is most likely explained by better estimates of the base population and growth rates which have become possible with the world-wide improvement in the quality of demographic data. Some of the improvement may also be attributed to the fact that world population has behaved more predictably since the early 1960s.

Keyfitz also found that the error was less for countries with lower growth rates, as would be anticipated. Since the growth rate for the vast majority of countries in the world is currently declining, each succeeding round of projections can be expected to exhibit less error.

When the error in the projected growth rate is calculated only for the total population of the world, positive and negative errors for countries are cancelled out, yielding a net error considerably smaller than the root-mean-square error for all countries. To illustrate, the error in projecting the growth rate of the world population from the base year to 1980 in the 1958, 1963, 1968 and 1973

TABLE 7. AVERAGE ANNUAL GROWTH RATE OF THE WORLD POPULATION AS PROJECTED IN 1980
(Percentage)

Period	*Variant*		
	Medium	*Growth*	*Decline*
1980–2000....	1.61	1.79	1.38
1980–2025....	1.37	1.61	1.07
1980–2050....	1.09	1.39	0.78

Source: Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

assessments was calculated. The root-mean-square error of these four errors was 0.13 percentage points. These observations indicate that, with the odds of 2 to 1, the expected error of growth rate for the world total would be much smaller than ±0.4 percentage points or, stated differently, the odds would be much larger than 2 to 1 that the actual error might end up with ±0.4 percentage points or less.

The deviation of the growth and decline variants from the medium variant in terms of the average annual growth rate is shown in table 7. It can be seen that the range of error incorporated by the growth and decline variants increases from about ±0.2 percentage points in the short run to ±0.3 in the longer term. Were the Keyfitz range of ±0.4 percentage points applied to the projection for the period 1980 to 2050, the average annual growth rates would be expected to be between 0.69 per cent and 1.49 per cent. The world population in 2050 would be within the range from 7.2 billion to 12.6 billion. By comparison, the decline and growth variants yield totals of 7.7 billion and 11.7 billion, respectively, in 2050.

Total error in previous United Nations projections has been divided into three components by Inoue and Yu.[14] The components are (*a*) error in the estimate of the base population, (*b*) error in the estimation of the growth rate of the population immediately prior to the base date and (*c*) error in the projection assumptions regarding the future. The study showed that for the first 10 years of the projection period, type (*a*) error was the greatest. In projections prepared in 1963 and earlier, type (*b*) error was the most significant for projection periods of 15 or more years. In the 1968 and 1973 rounds, however, it appears that forecast error, type (*c*), is the most significant in the longer term. As the quality of demographic estimates improves, it should be possible to reduce greatly type (*a*) and (*b*) errors—those caused by errors in the estimates of the base population and growth rate. As a consequence, total error should be reduced significantly.

Frejka has attempted to delimit the range of plausible future population totals for the major regions of the world.[15] For the less developed areas, the range was determined by choosing the earliest and latest plausible dates by which fertility in each region would decline to a net reproduction rate of 1.0. For each of the more developed regions it was assumed that the net reproduction rate would equal 1.0 after 2015 and the lowest and highest plausible levels were selected for the intervening

[12] *World Population Prospects as Assessed in 1973* (United Nations publication, Sales No. E.76.XIII.4), p. 12.

[13] Nathan Keyfitz, "The limits of population forecasting", *Population and Development Review*, vol. 7, No. 4 (December 1981), pp. 579–593.

[14] S. Inoue and Y. C. Yu, "United Nations new population projections and analysis of *ex post facto* errors" (Paper presented at annual meeting of Population Association of America, Philadelphia, 25–28 April 1979).

[15] Tomas Frejka, "Long-term prospects for world population growth", *Population and Development Review*, vol. 7, No. 3 (September 1981), pp. 489–511.

TABLE 8. LOWEST AND HIGHEST VARIANTS OF POPULATION PROJECTIONS PREPARED BY FREJKA AND BY THE UNITED NATIONS

	Frejka's projections		*United Nations projections*	
Year	*Plausible low variant*	*Plausible high variant*	*Decline variant*	*Growth variant*
2000...	6.046	6.353	5.837	6.337
2050...	8.762	11.015	7.667	11.690
2100...	9.208	12.348	7.247	14.927

Sources: Tomas Frejka, "Long-term Prospects for World Population Growth," *Population and Development Review*, vol. 7, No. 3 (September 1981), pp. 489–511; Population Division, Department of International Economic and Social Affairs, United Nations Secretariat.

period. The plausible low and high projections for each region were then aggregated to obtain low and high estimates for the world as a whole. These estimates (in millions) may be compared with those of the United Nations decline and growth variants as in table 8. The projected range of Frejka's variants is significantly narrower than that of the United Nations projections, and with the exception of the high estimate for the year 2000, all totals fall within the United Nations range. These results would seem to reinforce the impression of accuracy of the United Nations projections but should be interpreted with caution for two reasons. First, the base population for 1980 used by Frejka is the United Nations estimate for that date. Second, both the United Nations and Frejka have assumed that fertility will converge to near the replacement level in the medium range and remain constant in the long term. Since both sets of projections begin with the same base data and employ very similar assumptions, their results are necessarily similar. The similarity of assumptions demonstrates a consensus about plausible future trends based on historical experience, knowledge of population growth dynamics, and knowledge of social, economic and demographic relationships.

A number of steps will be taken in an attempt to improve further the accuracy of the United Nations 1982 round of long-range projections. The 34 countries that are projected to have a population over 50 million in 2025 will be projected individually and the remaining population in each subregion will be projected as a unit.

The maximum expectation of life attainable by females will be allowed to exceed 80 years, since a few countries are very near that level now. It is likely that the ultimate fertility level in the low and high variants will be allowed to diverge somewhat from exact replacement.

CONCLUSIONS

The global implications of the long-range projections based on data assessed in 1980 are little different from those based on the 1978 assessment. The ultimate size of the earth's population is projected by the medium variant to equal 10.2 billion in 2100, compared with 10.5 billion in the earlier projection. In the previous projections, the low and high variants yielded a population of 8.0 and 14.2 billion, respectively, in the year 2100. The current assessment incorporates a somewhat greater degree of uncertainty and the low-to-high range is 7.5 to 14.2 billion in 2100.

While the changes in the global assessment are not large, the significance of changes in projected regional composition is greater. Higher growth rates have been projected for Africa in the revised assessment. As a consequence, that continent's share of the world population in 2050 is expected to equal 22.8 per cent, compared with 19.0 per cent according to the 1978 projection. On the other hand, the assessment of both the current population size and future growth rates in South Asia has been lowered so that region's proportion of the total population in 2050 equals 32.7 per cent, compared with 39.3 per cent in the previous projection.

In the low, medium and high variants the ultimate level of fertility corresponds to a net reproduction rate of 1.00, or exact replacement of each generation, and yields a stationary population. Two variants have been incorporated in the 1980 assessment in which the ultimate level differs from 1.0. In the growth variant the ultimate net reproduction rate is 1.05 and in the decline variant it is 0.95. These variants yield a slightly wider range of likely population totals in 2100, from 7.2 billion and slowly declining to 14.9 billion and growing slowly. The differences between these variants and the low and high variants, respectively, are modest; in fact, the variants are identical up to 2025. The significance of the additional variants lies in their assumption that it is unlikely that future population growth rates will converge toward zero, then remain constant, yielding stationary populations.

These projections are based on a continually improving set of demographic data and estimates. The growth rate of the world's population is declining, which should reduce the range of error in projecting that growth. Since the early 1960s population trends in the world have been rather predictable—that is, both fertility and mortality in the great majority of countries have been declining steadily. For the above reasons, and from analysis of the results of previous rounds of United Nations projections, it is argued that it is unlikely that the actual population totals will be outside the range of these variants.

Although future population totals are expected to be within the range of these variants, future trends are not likely to be as smooth as the projections indicate. Fertility and mortality within regions and countries are likely to change at a varying pace. Levels of vital rates and total population near the end of the twenty-first century are not likely to be constant, but to fluctuate. It is impossible to predict these fluctuations, however, so all variants converge to levels that may represent the middle of a range of fluctuating values.

While it is considered unlikely, it is not impossible that future population will grow outside the range of these variants. It may be that fertility in the high fertility countries will change at rates slower than has been anticipated or that in the low fertility developed countries it will recover more quickly and remain at a higher level than expected and world population would exceed that yielded by the growth variant. Unforeseen technological breakthroughs may also greatly increase average longevity or the carrying capacity of the earth's environment and lead to unexpectedly large population totals. Conversely, as a result of rapid socio-economic change in combination with effective population programmes, fertility in the high fertility countries may decline more rapidly than now anticipated. If at the same time fertility in the more developed regions remains significantly below the replacement level, world population may be less than indicated by the low variant of the projections.

At the same time, these projections do not make allowance for possible catastrophes such as global war or massive famines. They are implicitly predicated on the assumptions of steady social and economic growth in all countries in the future. Should that growth be slowed by agricultural or environmental crises, for example, mortality levels may rise and total population growth may slow. Conversely, unanticipated developments in technology or social organization may greatly reduce the desire for children, and the world's population may pass through long periods of declining numbers. Again, none of these eventualities seems predictable at this time and none is incorporated in the assumptions of the long-range projections.

INFANT MORTALITY: WORLD ESTIMATES AND PROJECTIONS, 1950–2025

*United Nations Secretariat**

SUMMARY

Although the infant mortality rate is considered one of the preferred indicators for describing both demographic conditions and the overall social and economic well-being of a country, comparable and consistent estimates and projections of infant mortality for all countries of the world have been lacking. In an attempt to improve this situation, the United Nations Population Division, with the support and encouragement of the United Nations Children's Fund (UNICEF) and the assistance of the World Health Organization (WHO) and the United Nations regional commissions, has recently completed a comprehensive project that provides estimates and projections of infant mortality for all countries of the world for the period from 1950 to 2025.

This article reviews the estimates and projections produced by this project. The various sources and the quality of the data, as well as the methods employed to estimate current and past levels of infant mortality and to project future trends, are reviewed and evaluated. The article concludes with a discussion of the results vis-à-vis the goals set for infant mortality by the World Population Plan of Action and the International Development Strategy for the Third United Nations Development Decade.

INTRODUCTION

One of the most serious problems in analysing levels and trends of infant mortality has been the lack of accurate and comparable information. For countries with vital registration systems, estimates of infant mortality are published by national statistical offices and compiled annually in the United Nations *Demographic Yearbooks*. Occasionally, for countries lacking reliable registration systems, estimations obtained from survey or census data have also been included in these *Yearbooks*. A more comprehensive evaluation of the available data and estimates is carried out on a regular basis by the World Bank (1980) and the United States Bureau of the Census (1980), which publish sets of infant mortality estimates for developed countries and many developing ones.[1] However, those infant mortality estimates, especially those for the developing countries, suffer seriously from a lack of comparability and comprehensiveness, since they generally do not refer to the same time period and those for a significant number of developing countries are missing.

The aim of this project was to overcome these deficiencies. More specifically, the primary goal was to produce a series of infant mortality estimates referring to comparable past periods, and on the basis of such series to project their future values on a country-by-country basis. Although a thorough interpretation of these estimates and projections and their significance in terms of health or development is beyond the scope of this paper, the broad picture revealed by these figures is presented and its main implications are discussed.

As is done for the demographic estimates and projections prepared by the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat, the estimates and projections of infant mortality are presented for the world as a whole, its more developed and less developed regions, 8 major areas, 24 regions[2] and 156 countries or groups of countries. The results are provided for each quinquennial period between 1950 and 2025.[3]

It should be noted that the date separating the estimates and projections varies among the countries. For most developed countries where registered data were available up to 1980, the projections start after 1980. For other countries the projections start at earlier dates—namely, from the time when the latest reliable estimate derived from observed data is available.

METHODS AND SOURCES AND QUALITY OF DATA

Methods of estimating infant mortality

The infant mortality rate may be estimated either directly or indirectly. Direct estimates are usually obtained from the data gathered by a vital registration

*Population Division, Department of International Economic and Social Affairs.

[1] In addition, several studies have reviewed levels and trends of infant mortality for selected countries (e.g., Palloni, 1981). More extensive global studies of infant mortality have also been attempted (e.g., Vallin, 1976, and Boulanger and Tabutin, 1980).

[2] For convenience in presenting global demographic trends, the Population Division has been using the three levels of country classification mentioned in the text, of which the last two are essentially geographical groupings. The bisection of the 24 regions into the "less developed" and the "more developed" regions has also been made on the basis of demographic and other social and economic indicators. The less developed regions include all regions of Africa, Asia (excluding Japan), Latin America and Oceania (excluding Australia and New Zealand). The more developed regions include all regions of Europe, the Union of Soviet Socialist Republics, Northern America and the regions just cited as being outside the less developed category.

[3] The major results of this project have also been presented in "Infant mortality rates: estimates and projections, 1970–2000," the final report prepared by the Population Division and presented to UNICEF in March 1982.

system. Direct estimates may also be obtained from data gathered on a sampling basis in a multi-round or follow-up survey (i.e., follow-up visits to each household asking whether any births or deaths have occurred in the household during the time between visits). At the same time a survey is conducted, there may be a second system of data collection, such as sample registration; the results of the two systems can be matched in order to detect omissions from the survey and the sample registration.

Direct estimates of infant mortality may also be calculated from retrospective questions in a census or survey. Questions can be asked of each woman interviewed about the date of occurrence of each birth, whether the child is still alive and, if dead, how long the child survived. Such data have been gathered by surveys carried out in many countries, in particular recently under the programme of the World Fertility Survey.

It is also possible to estimate the infant mortality rate from information that is only indirectly related to the mortality level to which children are subject—that is, from the proportion of children dead among those ever born to women of different age groups. These proportions can be calculated from information on the number of children ever born and the number surviving classified by age of mother. Questions on the number of children a woman has had and the number surviving have been asked in many censuses and surveys over the years. Brass (1964) was the first to suggest a method to transform the observed proportions of children dead by age of mother into life-table mortality measures or probabilities of dying between birth and ages 1, 2, 3, 5, 10, 15 and 20.[4] Infant mortality rates can be derived from these estimated probabilities via an adequate model life-table system. However, in theory, such derivation requires that the age pattern of mortality (or at least for younger ages) be known. If the model life tables selected do not reflect adequately the mortality pattern prevalent in the population being studied, infant mortality estimates derived from observed proportions of children dead may be seriously biased.

The mortality estimates derived from the proportion of children dead for different age groups of women refer to different points in time prior to the census or survey. For example, while the proportion of children dead to women 20–24 reflect the mortality conditions in the recent past, the proportion of children dead to women age 45–49 reflect mortality conditions in a more distant past.

Feeney (1976 and 1980) and Coale and Trussell (1978) have developed methods showing how these mortality estimates can be "dated." Thus, the estimates of child mortality derived from the proportions of children dead observed among those ever borne by women in different age groups consist of two elements: the life table probabilities of dying between birth and age x ($q(x)$) and the time period to which each $q(x)$ value refers. The methods that provide these two elements have proven to be reliable, based on comparisons of the mortality estimates from these methods and those obtained from other available sources. However, while the estimates based on the reports of women in age groups 20–30 or 20–34 have proven to be accurate, it is often best to ignore the estimates based on the reports of older women, since there is a greater tendency among older women to omit dead children in their response, and as a consequence, the resulting mortality estimates based on their reported experiences are too low. The estimates based on reports of women aged 15–19 years should also be ignored since children of these young mothers suffer relatively higher mortality rates than do children of mothers at older ages. A further problem with the reports by women 15–19 years old is that the number on which the estimates are based is relatively low.

Methods of projection

The projections of infant mortality rates in this project have been based on the overall mortality projections prepared at the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat.[5] In preparing these projections, first an estimate of life expectancy at birth for a given date is established, and then assumptions are made about its future trends. These assumptions are based, for the most part, on a working model of mortality decline or improvement in life expectancy at birth. Since the 1950s, several working models have been developed and utilized by the United Nations (United Nations, 1956, 1977a). The most recent working model which was developed for the 1978 round of population estimates and projections is summarized in table 1.

TABLE 1. WORKING MODEL FOR MORTALITY DECLINE IN TERMS OF LIFE EXPECTANCY AT BIRTH BY ANNUAL AND QUINQUENNIAL GAINS ACCORDING TO MORTALITY LEVELS

	Average increase of e_0^0			
	Males		*Females*	
e_0^0	*Annual*	*Quinquennial*	*Annual*	*Quinquennial*
Less than 55	0.50	2.50	0.50	2.50
55.0–57.5	0.44	2.20	0.48	2.40
57.5–60.0	0.41	2.05	0.46	2.30
60.0–62.5	0.38	1.90	0.44	2.20
62.5–65.0	0.35	1.75	0.42	2.10
65.0–67.5	0.24	1.20	0.40	2.00
67.5–70.0	0.15	0.75	0.36	1.80
70.0–72.5	0.09	0.45	0.28	1.40
72.5–75.0	0.04	0.20	0.20	1.00
75.0–77.5	—	—	0.14	0.70
77.5–80.0	—	—	0.04	0.20

The working model is based on average annual gains in life expectancy at birth at different levels of mortality, using data available in 1978 from countries with reliable death statistics. In the model, mortality trends assume an average quinquennial gain of 2.5 years in life expectancy at birth until life expectancy reaches 55 years, followed by a slow-down of the gain thereafter. The maximum level of life expectancy at birth that could be attained in this model was assumed to be 73.5 years for males and 80 years for females.

However, even in previous sets of projections produced by the United Nations, evidence from selected developing countries suggested that this model of mortality decline implies a faster change for them than seemed plausible. Therefore, to project their populations the model presented in table 1 was adjusted to represent a somewhat slower decline. For present purposes, life expectancy was

[4]Today there exist several variants of the method first proposed by Brass. See Sullivan, 1972; Trussell, 1975; Feeney, 1976; and Preston and Palloni, 1977.

[5]For a more detailed description of the projection methodology, see *Prospects of Population: Methodology and Assumptions* (ST/ESA/SER.A/67) and *World Population Prospects as Assessed in 1973* (ST/ESA/SER.A/80).

assumed to increase by two years every quinquennium until an e_o^o of 60 years for males or 65 for females was reached; thereafter the increases outlined in table 1 were followed. As a result of the findings of this study, an expanded set of countries for which the use of this adjusted model of mortality decline seemed appropriate was defined. It includes most of the high-mortality countries (those with an initial e_o^o of less than 55 years) from Africa and Eastern and Middle South Asia, with the exception of those for which the evidence available did validate the acceptability of a faster increase in life expectancy.

After assumptions about future trends in life expectancy are formulated, assumptions are made about the age pattern of mortality corresponding to the different levels of life expectancy at birth. From these age patterns of mortality the age-specific survival ratios, which are actually the needed input for the projections, can be derived. For countries without detailed data, it is assumed that the age patterns of survivorship of the population resemble those given in a selected model life table.[6]

For countries where reliable data on mortality by age and sex are available, that information is used. A national life table for a given date is used as a base for the projections. It is then assumed that the survival ratios from the national life table will gradually approach the survival ratios of a model life table (usually the West region of Coale and Demeny's model life tables), with the highest survival ratios that a population may attain being those given by the highest level of the model life tables. This procedure has been referred to as the "modified method" of mortality projection (United Nations, 1977b). As life expectancy at birth for females was assumed to be 80 years, the Coale and Demeny model life tables were extrapolated to incorporate survival ratios corresponding to this higher level of life expectancy.

As the modified method employs survival ratios and the infant mortality rate may be transformed into a survival ratio, the modified method technique was used to project infant mortality. The infant mortality rate in a national life table is expected to approach the infant mortality rate of a selected model life table according to the modified method. When life expectancy at birth reaches the value given by the highest level of the model life tables, the infant mortality rate will be the same as that corresponding to the highest level of the model life table.

One difficulty that arises with this procedure, however, is the choice of a model life table. Figure I shows the relation between the infant mortality rate and life expectancy at birth for females for the four regions of Coale and Demeny's model life tables. While the infant mortality rates for the West, North and East regions converge when life expectancy reaches 80, the infant mortality rate for the South region is significantly higher. Since for higher life expectancies the life table functions for the South region (as well as the other regions) are extrapolations rather than being based on actual data, it was assumed that for countries where the age pattern of mortality currently is believed to resemble South, this pattern would change in the future and gradually approach that of the West, according to the modified method referred to above.

For 20 out of 30 Latin American countries or groups of countries, the Population Division adopts the estimates and projections prepared by the Latin American Demographic Centre (CELADE), which follows a slightly different approach from the above (Somoza, 1979). CELADE starts with an estimate of the level of mortality—that is, with a life table for a recent period—makes assumptions about future trends in life expectancy, and assumes that some time in the future the mortality rates by age and sex will approach the biological limits set by Bourgeois-Pichat (1952). The life expectancy for females in this limit life table is 78.2 years, with an infant mortality of 9 per thousand, which is about the same as the infant mortality in the West region of Coale and Demeny's model life tables corresponding to this life expectancy.

Sources of data

In the table presented in the annex below, all of the countries are classified into one of five categories of data that were used as a basis for the infant mortality estimates: (1) vital registration, (2) vital registration and national surveys or censuses, (3) two or more national surveys or censuses, (4) one national survey or census, (5) no data (i.e., incomplete vital registration and no national survey or census with data relevant to infant mortality). The countries are not grouped according to all the data that were reviewed but according to those data that were selected as a basis for the final estimates. For example, although data for the United Republic of Tanzania were available from the 1967 census and from a national demographic survey taken in 1973, the estimates from the two sources were not consistent. As the survey results were viewed as less plausible than the census results, only the results from the 1967 census were used in deriving a final set of estimates for the United Republic of Tanzania.

Developed countries

For developed countries in Northern America and Europe, and for Japan, Australia, New Zealand and the USSR, the estimates of infant mortality were derived using registered data on births and infant deaths as reported to the United Nations Statistical Office, with little or no adjustments. Only for Greece, 1950–1970, and Yugoslavia, 1950–1960, were the data adjusted (Greece, 1978; Macura, 1972). The estimates for Albania were derived using indirect estimates based on tabulations of children ever born and surviving by age of mother from the 1960 census, and then assuming the same mortality decline that occurred for other Southern European countries when they had similar mortality levels.

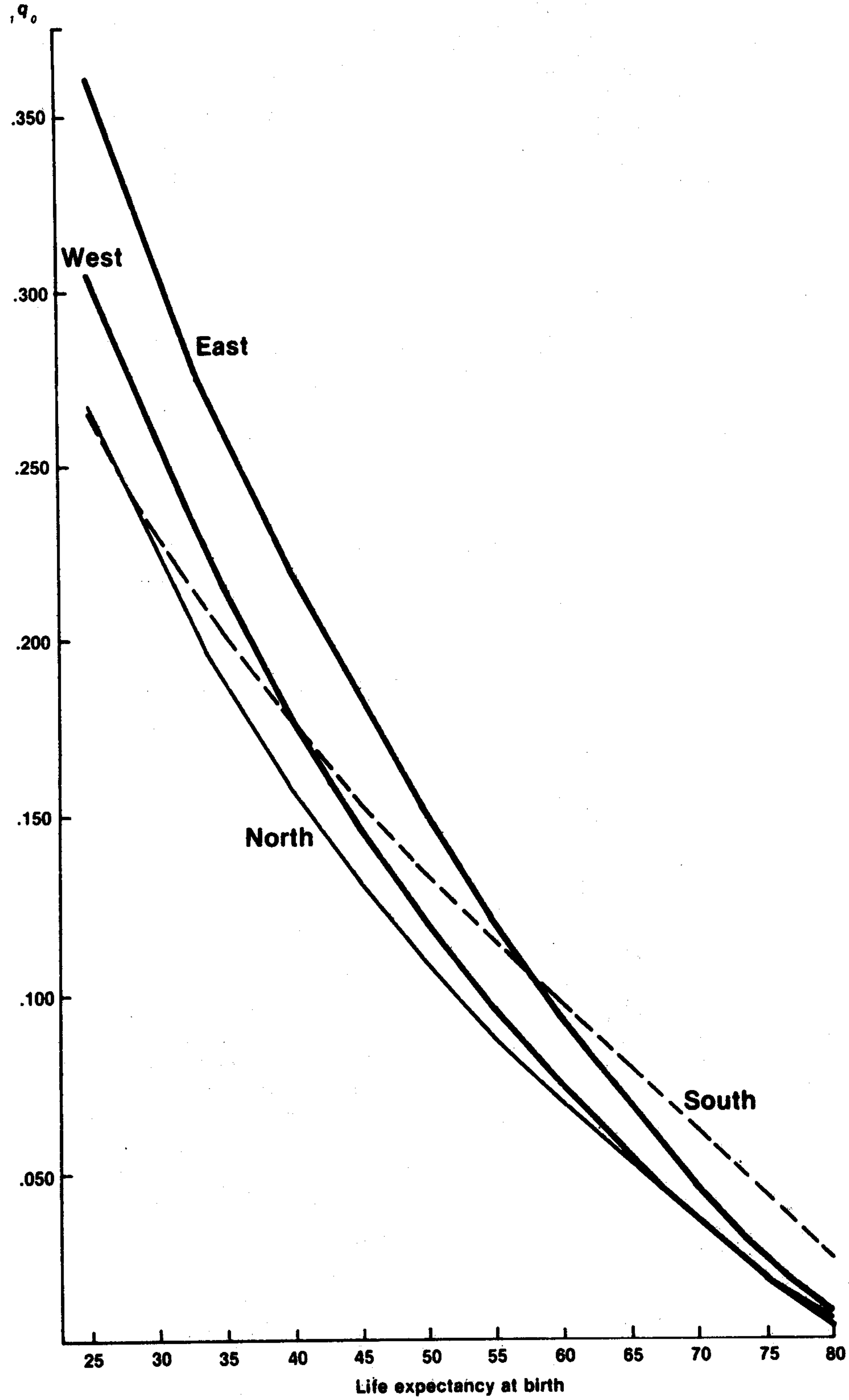
For all countries, with the exception of Portugal and the USSR, registered data were available up to 1979 or 1980. For Portugal registered data were available up to 1975; hence the rate shown for 1975–1980 is a projected rate. For the USSR national registered data were available only up to 1974. In preparing the infant mortality rate for the USSR for the period 1975–1980, the United Nations took note of estimated data from several sources, referring to specific years during that quinquennium.[7]

With the exception of Albania, the projections for all the developed countries were based on the latest available

[6]The model life tables prepared by Coale and Demeny (1966) were used, when appropriate, along with the model life tables of the United Nations (1956).

[7]The sources considered were a *New York Times* article (1981) referring to a press conference by a representative of the USSR State Planning Committee; figures published by the United States Department of Commerce, Bureau of the Census (1980); and figures cited by Kutzik (1981).

Figure I. Changes in $_1q_0$ with increases in life expectancy at birth for the West, North, East and South regions of Coale-Demeny life tables (for females)



national life tables. In some cases, where national life tables were not available for a recent period, life tables calculated by the United Nations or by WHO from registered deaths classified by age and sex and from population registers were utilized as the basis for the projections.

Developing countries

Rather than considering the developing countries by region—Africa, Asia, Latin America and Oceania—the countries are discussed according to the sources and the quality and quantity of the data that were available, since these characteristics varied considerably within the regions. For those countries where registered data on births and infant deaths are reported to be complete (that is, they are believed to cover at least 90 per cent of all events occurring each year) and where independent sources of information for evaluating the quality of the infant death registration were available, this information was used, when necessary, to correct or adjust the registered data. The types of independent information that were used to adjust the registered data included: (*a*) indirect estimates of infant and child mortality based on tabulations of children ever born and surviving by age of mother; (*b*) direct estimates of infant mortality derived from prospective surveys or from pregnancy histories, such as the kind collected in the World Fertility Survey (World Fertility Survey, 1981); and (*c*) other information gathered by surveys specifically designed to estimate the completeness of registration. For countries in this group, the projections of infant mortality were derived from national life tables with adjusted infant and child mortality rates or from life tables calculated at the Population Division of the Department of International Economic and Social Affairs that were based on the age-sex distributions from the population censuses and on adjusted registered deaths classified by age and sex.

When the registered data on births and infant deaths were reported to be complete but there were no independent sources of information to evaluate the quality of the death registration system, the registered data were used essentially as reported. The most recent national life tables for these countries were used as the basis for the projections of infant mortality.

For those developing countries where adequate registration statistics were lacking, other sources of information were needed to estimate infant mortality rates. In order to determine these rates, an attempt was made to gather all relevant information. For example, tabulations of children ever born and surviving by age of mother were compiled in order to compute indirect estimates of infant mortality. Estimates derived from multi-round surveys and from maternity histories were also compiled. In addition, estimates from small-scale surveys and from vital registration were collected and used for comparative purposes. When two or more estimates for different period were available for a country, interpolations were made between such estimates.

As indirect estimates based on children ever born and surviving by age of mother from a census or survey refer to different points in time before the census or survey, they provide a trend in mortality. This trend, however, may not represent the true mortality decline. For instance, estimates derived from data referring to older women (which of course refer to earlier periods) may be too low because older women have a greater likelihood to omit dead children from their reports. As a result, the complete set of estimates may indicate a mortality decline that is too slow or, in some cases, even an increase in the level of mortality. In general, the estimates based on reports by women aged 20–24 and 25–29 are considered to be the most accurate, since the omissions of dead children are relatively low.

When only one source of information was available—such as indirect estimates based on the numbers of children ever born and surviving by age of mother from a census or survey, or a direct estimate obtained from a nationally representative survey—the trends in mortality could not be established without making additional assumptions. Accordingly, each country needed to be treated differently depending on the type of information available. For example, for some of these countries, national mortality trends were derived by (*a*) extrapolating trends obtained from a small-scale sample survey in the same country; (*b*) adopting those implicit in registered rates; (*c*) adopting the mortality trends observed in neighbouring countries with similar culture and general socio-economic conditions; or (*d*) accepting the trends estimated for the overall or the adult mortality levels of the country in question.[8]

For countries where no information on the level of infant and child mortality was available, infant mortality rates were derived from the particular model life tables that were used in the mortality component of the 1980 assessment of population estimates and projections prepared by the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat.[9] For these countries, the estimates of the overall mortality level were derived from analyses of the age distributions of the population as reported in one or more censuses or surveys (United Nations, 1967; Brass, 1975; Preston, 1981) or, if age distributions were not available, by comparison with neighbouring countries in similar social and economic circumstances.

Quality of estimates

Since it is not always possible to assess the quality of the various censuses or surveys, it would be difficult to assign detailed quality codes to the estimates. It may be said, however, that the most accurate estimates are probably those for developed countries. For these countries the infant mortality estimates were calculated from the data as published by the countries or as officially reported to the United Nations Statistical Office. Comparatively speaking, the data in most of the developed countries posed few problems and the infant mortality estimates are believed to be reasonably accurate.[10] For the developing countries in which registration is reported to be complete and where no external sources of information were available to check the extent of completeness, the data were used as reported, provided the estimated infant mortality rates seemed plausible.

[8]Estimates of adult mortality were usually obtained by the methods proposed in United Nations, 1967; Brass, 1975; and Preston, 1981.

[9]For the results of the 1980 assessment, see United Nations, 1981 and United Nations, forthcoming.

[10]The estimates have not been adjusted to take into account differences in the definitions of live births and deaths of WHO (United Nations, 1973). However, it has been shown, for a selected number of European countries, that differences in the definitions for these countries play a negligible part in producing differences in infant mortality (Höhn, 1981).

TABLE 2. INFANT MORTALITY RATE BY REGION AND COUNTRY OR AREA, 1950–2025, MEDIUM VARIANT

Region and country or area	Infant mortality rate (per thousand births) 1950–1955	1955–1960	1960–1965	1965–1970	1970–1975	1975–1980	1980–1985	1985–1990
World total	142.1	126.0	112.8	103.1	93.8	88.6	80.8	73.0
More developed regions*	55.7	40.8	31.5	25.7	21.5	19.3	16.9	15.3
Less developed regions†	164.2	146.0	130.4	117.5	106.4	100.4	91.5	82.2
Africa	184.3	172.3	160.3	149.4	138.5	127.1	116.4	106.0
Eastern Africa[a]	171.7	159.6	147.9	137.4	127.3	118.0	109.1	99.1
Burundi	157.3	152.6	148.0	142.8	134.6	126.6	116.6	107.3
Comoros	154.9	142.8	127.7	115.1	105.9	96.9	88.3	79.8
Ethiopia	190.0	180.0	170.0	162.0	155.0	150.0	143.4	132.5
Kenya	163.0	145.0	130.0	118.0	106.0	92.0	81.6	72.1
Madagascar	125.6	114.2	103.6	93.8	84.5	75.7	66.8	58.8
Malawi	212.0	208.5	205.0	197.2	189.9	178.9	164.9	151.9
Mauritius[b]	98.0	80.0	60.9	66.9	55.3	38.3	31.7	27.1
Mozambique	177.0	166.0	154.0	142.0	129.8	119.6	110.0	100.9
Réunion	140.0	109.0	88.0	69.0	41.1	20.5	19.3	18.3
Rwanda	161.0	151.0	142.0	132.0	121.6	111.9	102.7	93.8
Somalia	190.0	180.0	170.0	162.0	155.0	150.0	143.4	132.5
Uganda	160.4	145.7	132.0	119.1	107.3	100.5	93.8	85.3
United Republic of Tanzania	172.8	158.5	144.5	131.4	119.1	107.4	98.4	89.6
Zambia	174.1	158.5	144.0	130.3	120.1	110.5	101.4	92.4
Zimbabwe	136.8	123.6	111.4	100.1	89.1	78.8	69.7	61.4
Middle Africa[c]	185.3	172.3	161.6	150.8	139.3	127.9	117.6	107.9
Angola	230.9	215.0	200.0	185.9	172.8	160.4	148.5	137.3
Central African Republic	211.1	200.0	189.4	179.4	166.5	154.3	142.8	132.0
Chad	211.1	200.0	189.4	179.4	166.5	154.3	142.8	132.0
Congo	185.9	176.1	166.5	157.1	145.5	134.5	124.0	114.0
Equatorial Guinea	203.5	193.0	182.6	172.8	160.4	148.5	137.3	126.6
Gabon	172.8	160.4	151.4	142.8	132.0	121.6	111.9	102.7
United Republic of Cameroon	186.5	170.1	154.8	140.4	127.0	114.5	103.0	91.9
Zaire	165.0	154.0	146.0	137.0	127.0	116.6	107.3	98.3
Northern Africa[d]	180.0	168.2	155.7	144.9	132.5	117.4	103.7	91.2
Algeria	180.0	170.0	160.0	150.0	138.0	125.3	109.8	95.6
Egypt	183.0	166.7	151.8	140.0	127.0	110.0	96.7	84.2
Libyan Arab Jamahiriya	180.0	165.0	150.0	135.0	121.2	106.9	93.4	81.7
Morocco	180.0	167.0	154.0	143.1	129.6	114.4	100.0	87.3
Sudan	183.0	173.0	165.0	156.0	144.8	131.1	117.8	105.5
Tunisia	175.0	163.0	151.7	138.0	124.5	106.5	93.0	80.6
Southern Africa	151.6	140.7	130.5	120.8	111.6	102.7	93.7	85.1
Botswana	125.6	118.1	111.0	104.1	96.1	87.5	79.1	71.0
Lesotho	154.3	147.4	140.5	134.1	127.7	120.0	110.4	101.2
Namibia	168.0	158.8	149.9	141.4	133.2	125.3	115.4	106.0
South Africa	151.6	140.2	129.4	119.3	109.7	100.6	91.7	83.2
Swaziland	160.0	154.0	150.0	147.0	144.0	140.1	129.3	119.2
Western Africa[e]	205.7	193.5	180.7	168.7	157.6	146.4	135.2	124.5
Benin	218.8	211.1	200.0	185.9	172.8	160.4	148.5	137.3
Cape Verde	140.0	127.1	115.1	104.1	93.4	86.8	77.1	68.1
Gambia	225.9	224.2	220.3	218.0	215.0	203.5	193.0	179.4
Ghana	160.4	148.5	137.3	126.6	116.6	107.3	98.3	89.5
Guinea	225.1	213.4	202.1	191.6	181.3	171.5	159.1	147.4
Guinea-Bissau	203.5	193.0	182.6	172.8	163.4	154.3	142.8	132.0
Ivory Coast	185.9	179.4	166.5	154.3	142.8	132.0	121.6	111.9
Liberia	210.4	199.3	188.7	178.7	168.9	159.8	148.0	136.8
Mali	211.1	200.0	189.4	179.4	169.5	160.4	148.5	137.3
Mauritania	203.5	193.0	176.1	166.5	157.3	148.5	137.3	126.6
Niger	207.3	196.5	185.9	176.1	166.5	151.4	140.0	129.3
Nigeria	203.5	190.1	176.7	164.0	152.0	140.5	129.8	119.6
Senegal	195.1	185.9	177.4	168.3	160.4	152.6	141.1	130.3
Sierra Leone	239.1	235.8	231.7	229.2	225.9	215.0	200.0	185.9
Togo	204.0	193.0	170.0	140.6	127.3	114.7	103.2	92.1
Upper Volta	265.9	256.8	247.8	239.1	230.9	218.8	203.5	189.4
Latin America	127.9	114.3	101.8	91.7	81.8	71.4	62.9	55.7
Caribbean	124.3	107.9	90.4	79.8	70.7	64.4	57.8	52.0
Barbados	131.8	87.1	60.8	46.4	33.8	27.0	25.5	22.5
Cuba	85.1	72.2	59.6	47.8	33.8	22.5	20.4	18.6
Dominican Republic	149.4	128.9	110.0	96.3	83.6	73.1	63.5	54.6
Guadeloupe	67.4	54.4	44.7	50.8	41.9	26.3	24.0	21.5
Haiti	219.6	193.5	170.5	150.2	134.9	120.9	108.2	96.6
Jamaica	84.9	71.3	54.4	47.0	42.0	30.1	26.2	23.3
Martinique	64.2	55.7	47.7	42.5	34.8	23.0	21.0	19.4
Puerto Rico	63.2	51.2	44.5	33.3	25.3	19.5	15.9	14.9
Trinidad and Tobago	73.7	60.2	48.0	45.0	40.4	34.6	29.9	26.4
Windward Islands[f]	106.9	100.4	79.5	56.5	47.8	40.0	34.3	29.6
Other Caribbean[g]	80.0	67.5	50.5	43.5	36.6	31.5	27.5	24.6

Infant mortality rate (per thousand births)							
1990–1995	*1995–2000*	*2000–2005*	*2005–2010*	*2010–2015*	*2015–2020*	*2020–2025*	*Region and country or area*
66.2	59.5	53.1	47.4	42.0	37.0	32.6	World total
13.9	12.8	11.8	11.1	10.5	10.0	9.6	More developed regions*
74.1	66.3	59.1	52.7	46.6	41.0	36.0	Less developed regions†
96.2	87.0	78.3	70.2	62.7	55.8	49.4	Africa
89.7	80.7	72.2	64.4	57.1	50.6	44.8	Eastern Africa[a]
98.3	89.5	81.1	72.9	65.0	57.5	50.2	Burundi
71.6	63.8	56.3	49.3	42.8	37.3	33.0	Comoros
122.1	112.3	103.2	94.3	85.7	77.4	69.3	Ethiopia
63.6	55.8	48.8	42.4	36.9	32.7	29.7	Kenya
51.5	44.8	38.8	34.4	30.2	27.5	25.1	Madagascar
139.6	128.0	116.8	106.0	95.6	85.5	75.8	Malawi
23.6	20.8	18.4	16.7	15.1	13.6	12.7	Mauritius[b]
92.1	83.6	75.3	67.4	59.7	52.3	45.3	Mozambique
17.4	16.5	15.5	14.6	13.7	12.8	12.0	Réunion
85.3	77.0	68.9	61.2	53.9	47.1	40.9	Rwanda
122.1	112.3	103.2	94.3	85.7	77.4	69.3	Somalia
77.0	68.9	61.2	53.9	47.1	41.0	36.0	Uganda
81.1	72.9	65.1	57.5	50.5	43.9	38.4	United Republic of Tanzania
83.9	75.6	67.6	60.0	52.7	46.0	39.9	Zambia
53.9	47.1	40.9	35.9	31.8	28.6	26.1	Zimbabwe
98.5	89.6	81.2	73.3	65.6	58.3	51.6	Middle Africa[c]
126.6	116.6	107.3	98.3	89.5	81.1	72.9	Angola
121.6	111.9	102.7	93.8	85.3	77.0	68.9	Central African Republic
121.6	111.9	102.7	93.8	85.3	77.0	68.9	Chad
104.8	95.8	87.2	78.8	70.7	62.9	55.5	Congo
116.6	107.3	98.3	89.5	81.1	72.9	65.0	Equatorial Guinea
93.8	85.3	77.0	68.9	61.2	53.8	46.7	Gabon
81.5	72.2	63.7	56.0	48.9	42.5	37.2	United Republic of Cameroon
89.5	81.1	72.9	65.0	57.5	50.2	43.2	Zaire
79.6	68.9	59.1	50.4	43.4	37.5	33.0	Northern Africa[d]
82.7	70.8	60.0	50.6	43.2	37.4	32.8	Algeria
73.1	63.0	53.7	45.1	38.4	33.1	29.2	Egypt
70.4	60.6	51.4	43.3	37.2	32.2	28.4	Libyan Arab Jamahiriya
75.2	64.7	54.8	46.1	39.5	33.8	30.1	Morocco
94.1	83.1	73.3	64.7	56.9	49.8	43.3	Sudan
69.4	59.1	49.8	42.3	36.7	32.1	28.4	Tunisia
76.8	68.7	61.0	53.7	46.9	40.8	36.0	Southern Africa
63.1	55.7	48.7	42.4	37.1	32.8	29.3	Botswana
92.4	83.8	75.6	67.6	59.9	52.7	46.0	Lesotho
97.0	88.4	79.9	71.8	64.0	56.6	49.6	Namibia
75.0	67.0	59.4	52.2	45.4	39.4	34.8	South Africa
109.6	100.5	91.7	83.1	74.9	67.0	59.3	Swaziland
114.5	105.0	95.9	87.2	78.8	70.8	63.2	Western Africa[e]
126.6	116.6	107.3	98.3	89.5	81.1	72.9	Benin
60.0	52.6	45.8	39.8	35.2	31.0	28.2	Cape Verde
166.5	154.3	142.8	132.0	121.6	111.9	102.7	Gambia
81.0	72.8	65.0	57.4	50.4	43.8	38.3	Ghana
136.2	125.6	115.6	106.4	97.4	88.7	80.2	Guinea
121.6	111.9	102.7	93.8	85.3	77.0	68.9	Guinea-Bissau
102.7	93.8	85.3	77.0	68.9	61.2	53.8	Ivory Coast
126.1	116.1	106.8	97.8	89.1	80.7	72.5	Liberia
126.6	116.6	107.3	98.3	89.5	81.1	72.9	Mali
116.6	107.3	98.3	89.5	81.1	72.9	65.0	Mauritania
119.1	109.6	100.5	91.7	83.1	74.9	67.0	Niger
110.0	100.9	92.1	83.6	75.3	67.4	59.7	Nigeria
120.1	110.5	101.4	92.5	84.0	75.7	67.8	Senegal
172.8	160.4	148.5	137.3	126.6	116.6	107.3	Sierra Leone
82.1	72.8	65.0	57.4	50.4	43.8	38.3	Togo
176.1	163.4	151.4	140.0	129.3	119.1	109.6	Upper Volta
49.6	44.1	39.7	35.5	32.1	29.0	26.4	Latin America
47.7	44.1	40.2	36.9	33.8	30.9	28.4	Caribbean
20.2	18.3	16.6	15.2	13.9	13.1	12.3	Barbados
17.0	15.8	14.6	13.6	12.9	12.1	11.5	Cuba
47.7	41.8	37.8	34.1	30.9	28.3	26.2	Dominican Republic
19.5	17.8	16.2	14.8	13.7	12.8	12.2	Guadeloupe
86.2	76.9	67.5	60.2	53.7	48.0	43.0	Haiti
20.7	18.4	16.9	15.4	14.3	13.4	12.7	Jamaica
18.2	16.8	15.6	14.5	13.5	12.6	12.0	Martinique
14.0	13.1	12.3	11.9	11.4	10.9	10.4	Puerto Rico
23.5	20.8	18.9	17.3	15.6	14.5	13.6	Trinidad and Tobago
26.1	23.2	20.5	18.8	17.0	15.5	14.3	Windward Islands[f]
21.8	19.5	17.9	16.2	14.7	13.8	12.9	Other Caribbean[g]

(continued)

TABLE 2 (*continued*)

Region and country or area	Infant mortality rate (per thousand births)							
	1950–1955	1955–1960	1960–1965	1965–1970	1970–1975	1975–1980	1980–1985	1985–1990
Middle America[h]	117.5	105.0	94.2	84.9	74.6	64.9	56.3	48.8
Costa Rica	92.5	85.5	80.6	65.6	50.9	29.3	25.7	23.1
El Salvador	155.0	143.0	128.0	112.0	101.0	84.8	71.0	59.9
Guatemala	144.0	129.5	114.9	101.5	90.2	79.0	67.7	57.3
Honduras	169.3	152.6	136.8	124.0	110.7	95.4	81.5	69.0
Mexico	108.1	95.9	86.2	78.6	68.6	59.8	52.1	45.4
Nicaragua	167.4	151.6	136.4	122.2	108.9	96.5	84.5	73.0
Panama	83.9	72.6	62.6	53.9	43.8	36.2	32.5	29.3
Temperate South America[i]	82.7	79.7	76.2	68.2	56.4	46.5	41.8	38.3
Argentina	64.2	61.6	59.5	56.4	51.3	47.2	43.2	39.6
Chile	126.1	117.3	110.5	95.1	69.5	46.3	40.0	36.4
Uruguay	57.4	53.0	47.9	47.1	46.3	41.7	37.6	34.0
Tropical South America[j]	140.9	125.3	111.0	100.3	90.7	79.0	69.7	61.9
Bolivia	175.7	169.7	163.6	157.5	151.3	138.2	124.4	109.9
Brazil	137.7	124.5	111.8	102.3	94.9	82.4	72.4	64.1
Colombia	123.3	102.2	84.5	74.2	66.9	59.4	53.3	48.6
Ecuador	167.7	147.6	132.3	114.5	100.1	86.0	77.2	68.0
Guyana	94.2	73.7	62.2	55.3	57.6	47.9	40.5	35.2
Paraguay	105.7	91.1	80.6	66.9	52.6	48.6	45.0	41.7
Peru	195.1	173.4	152.3	132.8	106.5	93.5	81.9	71.7
Suriname	89.2	76.2	63.5	54.6	46.7	39.2	33.8	29.1
Venezuela	110.9	92.2	76.9	64.9	52.4	44.8	38.6	34.0
Northern America[k]	28.5	26.8	25.3	22.1	17.9	13.9	12.0	11.4
Canada	35.9	30.1	26.3	21.3	16.4	12.2	10.4	9.9
United States of America	27.8	26.4	25.2	22.2	18.1	14.0	12.1	11.5
East Asia	135.3	111.1	88.5	70.5	55.7	45.0	38.1	32.7
China	143.9	117.9	94.3	75.3	60.0	48.7	41.0	35.0
Japan	50.6	36.8	24.3	15.6	11.6	8.8	7.4	7.2
Other East Asia[l]	114.3	84.6	68.8	56.2	42.2	36.2	30.9	26.5
Hong Kong	78.5	54.3	32.5	22.6	17.1	12.8	11.9	11.3
Korea	115.7	85.8	70.8	57.5	42.6	36.7	31.5	26.9
Democratic People's Republic of Korea	115.7	85.8	70.8	57.5	42.6	36.7	31.5	26.9
Republic of Korea	115.7	85.8	70.8	57.5	42.6	36.7	31.5	26.9
Mongolia	149.8	120.7	96.8	79.5	67.1	59.1	50.1	42.6
South Asia	181.7	165.2	150.3	138.7	127.6	119.8	108.7	97.6
Eastern South Asia[m]	159.0	144.2	130.7	118.1	104.9	91.8	79.0	68.9
Burma	183.0	166.0	150.0	135.0	120.7	107.1	94.3	82.8
Democratic Kampuchea	165.0	152.0	139.5	130.0	180.9	263.2	159.9	129.7
East Timor	264.3	241.7	220.6	201.1	183.3	253.5	183.3	165.6
Indonesia	165.6	154.9	144.8	129.9	111.9	98.7	86.7	75.9
Lao People's Democratic Republic	180.1	160.0	150.0	147.5	145.0	135.0	122.5	110.0
Malaysia	97.5	81.4	63.4	51.2	39.9	33.3	28.8	25.6
Philippines	134.9	114.8	96.8	81.6	68.3	58.9	50.5	42.9
Singapore	66.0	41.1	30.2	23.6	18.9	12.5	11.1	10.3
Thailand	131.7	111.0	95.0	84.0	65.2	58.9	50.6	42.9
Viet Nam	180.1	165.0	149.7	144.7	139.1	106.4	93.6	82.2
Middle South Asia[n]	188.9	172.0	157.2	146.5	136.6	130.9	120.7	109.5
Afghanistan	249.9	238.8	227.9	217.0	204.8	204.8	204.8	189.9
Bangladesh	179.5	161.9	156.0	150.3	150.3	139.6	132.6	122.1
Bhutan	210.0	200.0	189.0	178.0	167.0	156.3	144.0	132.1
India	190.0	173.0	157.0	145.0	133.0	128.9	117.9	106.4
Iran	182.9	170.0	156.0	143.0	129.4	114.8	100.7	87.6
Nepal	210.0	200.0	189.0	178.0	167.0	156.3	144.0	132.1
Pakistan	190.0	170.0	153.0	146.0	140.0	131.2	119.8	108.9
Sri Lanka	90.7	76.2	65.0	61.0	56.0	47.7	40.6	34.7
Western South Asia	202.8	179.6	157.1	137.8	122.0	109.7	95.3	83.0
Arab countries[o]	182.9	165.1	147.2	129.2	113.2	99.0	86.2	75.0
Bahrain	160.0	145.0	110.0	82.0	66.0	57.0	49.6	43.6
Democratic Yemen	230.9	217.3	201.6	185.4	169.4	153.3	138.5	124.2
Iraq	164.0	148.0	130.0	111.0	96.0	84.0	72.0	60.9
Jordan	162.0	145.0	126.0	108.0	87.0	75.1	63.4	52.6
Kuwait	125.0	101.0	77.0	55.0	43.4	36.0	31.8	27.9
Lebanon	87.0	73.0	62.0	52.0	48.0	43.7	38.7	34.1
Oman	222.3	202.5	184.1	166.4	150.1	135.2	121.1	107.5
Qatar	165.0	150.0	120.0	87.0	66.0	57.0	49.6	43.6
Saudi Arabia	220.0	195.0	174.0	154.0	136.9	121.1	106.5	93.4
Syrian Arab Republic	155.0	140.0	124.0	107.0	85.0	67.2	56.7	48.2
United Arab Emirates	165.0	150.0	120.0	87.0	66.0	57.0	49.6	43.6
Yemen	230.9	217.8	205.4	193.7	181.6	169.6	153.4	138.3
Non-Arab countries	221.8	193.5	167.5	147.3	132.3	123.2	107.6	94.8
Cyprus	53.3	30.6	29.1	27.3	28.0	19.5	16.7	15.2
Israel	40.9	35.6	29.2	25.0	23.3	18.3	15.5	14.0
Turkey	233.0	203.0	176.0	155.0	140.0	131.0	114.2	100.3

Infant mortality rate (per thousand births)							
1990–1995	1995–2000	2000–2005	2005–2010	2010–2015	2015–2020	2020–2025	Region and country or area
42.3	36.5	32.8	30.0	28.1	26.7	25.6	Middle America[h]
21.4	20.5	19.7	19.2	18.7	18.3	17.9	Costa Rica
50.6	42.2	37.8	34.4	31.2	29.0	27.2	El Salvador
48.3	40.4	36.6	33.0	30.2	28.1	26.6	Guatemala
57.4	46.3	40.0	34.9	31.9	30.0	29.3	Honduras
39.5	34.4	30.9	28.3	26.9	25.8	24.9	Mexico
62.0	51.4	45.9	41.0	36.7	33.2	30.0	Nicaragua
26.9	25.3	24.3	23.5	22.9	22.5	21.7	Panama
35.4	33.1	31.2	29.8	28.7	27.9	27.4	Temperate South America[i]
36.8	34.5	32.6	31.2	30.1	29.3	28.8	Argentina
33.6	31.3	29.4	28.0	26.9	26.1	25.6	Chile
31.2	28.9	27.0	25.5	24.5	23.7	23.1	Uruguay
55.3	49.2	43.9	38.7	34.1	29.9	26.5	Tropical South America[j]
93.4	74.4	63.7	54.7	49.3	44.3	39.9	Bolivia
57.2	51.1	45.3	39.8	34.7	30.0	26.4	Brazil
44.3	40.5	37.0	33.8	30.9	28.2	25.8	Colombia
60.0	53.0	46.6	40.8	35.6	30.8	26.8	Ecuador
31.6	28.7	26.3	24.2	22.7	21.1	20.0	Guyana
38.6	35.7	33.0	30.6	28.3	26.2	24.3	Paraguay
62.7	54.8	47.8	41.7	36.3	31.4	27.2	Peru
26.0	23.1	20.5	18.7	17.0	15.3	14.4	Suriname
30.5	27.7	25.3	23.2	21.7	20.2	19.1	Venezuela
10.8	10.3	9.7	9.2	8.8	8.4	8.1	Northern America[k]
9.5	9.1	8.7	8.4	8.1	7.8	7.5	Canada
10.9	10.4	9.8	9.3	8.9	8.5	8.1	United States of America
28.2	24.8	22.2	19.6	17.8	16.2	14.7	East Asia
30.3	26.6	23.8	21.0	19.0	17.3	15.7	China
7.0	6.8	6.6	6.5	6.4	6.3	6.2	Japan
22.8	20.1	17.9	16.0	14.6	13.3	12.1	Other East Asia[l]
10.8	10.3	9.8	9.3	9.0	8.6	8.3	Hong Kong
23.0	20.2	18.0	16.0	14.6	13.3	12.1	Korea
23.0	20.2	18.0	16.0	14.6	13.3	12.1	Democratic People's Republic of Korea
23.0	20.2	18.0	16.0	14.6	13.3	12.1	Republic of Korea
36.3	31.9	27.6	24.7	21.8	19.3	17.9	Mongolia
87.2	77.3	67.8	59.1	51.1	44.1	38.1	South Asia
59.8	52.0	44.8	38.2	32.8	28.7	25.2	Eastern South Asia[m]
72.3	62.8	54.1	46.1	38.8	33.8	28.8	Burma
115.7	102.4	89.8	78.1	68.1	58.9	50.6	Democratic Kampuchea
149.5	135.0	120.8	107.1	94.4	82.9	72.5	East Timor
66.0	57.1	48.9	41.2	35.2	30.5	26.8	Indonesia
97.0	84.7	73.8	63.6	54.9	47.1	39.8	Lao People's Democratic Republic
22.7	20.4	18.4	16.7	15.3	14.4	13.6	Malaysia
36.2	31.4	27.4	24.5	21.7	19.8	18.1	Philippines
9.8	9.4	9.0	8.7	8.4	8.1	7.9	Singapore
36.2	31.4	27.4	24.5	21.7	19.8	18.1	Thailand
71.8	62.3	53.7	45.8	38.6	33.2	28.7	Viet Nam
98.7	88.1	77.9	68.2	59.3	51.0	44.1	Middle South Asia[n]
176.0	162.1	147.9	134.0	119.9	106.3	93.4	Afghanistan
111.8	102.1	92.7	83.7	75.0	66.7	58.8	Bangladesh
120.8	109.8	99.3	89.2	79.5	70.2	61.4	Bhutan
95.2	84.1	73.3	63.4	54.2	46.2	39.6	India
75.4	64.2	54.7	46.5	40.5	35.0	30.8	Iran
120.8	109.8	99.3	89.2	79.5	70.2	61.4	Nepal
98.4	88.3	78.7	69.4	60.7	52.5	45.5	Pakistan
29.9	26.4	24.5	20.8	18.9	17.2	15.6	Sri Lanka
71.9	62.1	53.4	45.5	39.5	34.4	30.4	Western South Asia
65.4	57.4	50.2	43.3	37.5	32.9	29.1	Arab countries[o]
38.1	33.1	29.7	26.6	23.4	21.6	20.0	Bahrain
110.6	98.0	86.1	75.4	65.6	56.8	48.7	Democratic Yemen
50.6	43.3	37.2	32.9	28.9	25.4	23.1	Iraq
45.2	38.7	34.2	29.9	26.3	23.8	21.3	Jordan
24.5	22.0	19.8	17.6	16.3	15.3	14.3	Kuwait
29.6	26.7	24.7	22.6	21.4	20.1	19.0	Lebanon
94.9	83.4	72.9	63.3	54.7	46.7	39.4	Oman
38.1	33.1	29.7	26.6	23.4	21.6	20.0	Qatar
81.3	70.3	60.4	51.1	43.0	36.9	31.8	Saudi Arabia
41.5	36.5	31.8	28.1	25.4	22.6	20.1	Syrian Arab Republic
38.1	33.1	29.7	26.6	23.4	21.6	20.0	United Arab Emirates
124.3	110.7	97.8	86.1	75.4	65.6	56.7	Yemen
82.3	70.4	59.3	49.7	42.9	36.8	32.6	Non-Arab countries
13.8	12.5	11.6	11.1	10.6	10.1	9.6	Cyprus
12.7	12.0	11.5	11.1	10.6	10.2	9.8	Israel
87.0	74.5	62.8	52.8	45.3	38.7	34.3	Turkey

(continued)

TABLE 2 (*continued*)

Region and country or area	*Infant mortality rate (per thousand births)* 1950–1955	1955–1960	1960–1965	1965–1970	1970–1975	1975–1980	1980–1985	1985–1990
Europe	62.3	48.5	36.9	29.9	23.8	18.8	16.2	14.6
Eastern Europe	83.0	62.4	43.8	35.7	28.3	23.3	20.8	18.8
Bulgaria	92.4	62.3	36.4	30.5	25.7	22.2	20.1	18.2
Czechoslovakia	53.9	30.0	22.7	23.2	21.3	19.2	16.7	15.2
German Democratic Republic[p]	57.6	44.1	31.4	21.4	17.0	13.3	12.5	11.6
Hungary	71.2	57.6	43.6	36.4	34.1	26.7	22.3	19.8
Poland	94.5	72.4	51.2	36.4	27.1	23.0	21.4	19.5
Romania	100.9	77.8	59.8	51.7	39.5	31.1	26.7	23.6
Northern Europe[q]	25.8	23.5	20.9	17.9	15.9	12.4	10.6	9.9
Denmark	28.0	23.3	19.9	16.2	12.0	9.1	8.4	8.2
Finland	33.8	25.5	19.2	14.8	11.6	8.6	7.4	7.2
Iceland	21.4	17.4	17.0	13.3	11.2	8.8	7.4	7.2
Ireland	41.2	33.8	28.0	22.7	18.1	14.5	11.8	10.9
Norway	23.4	20.0	17.3	14.3	11.8	9.3	8.3	7.9
Sweden	19.7	16.9	15.1	12.5	10.2	7.9	6.7	6.5
United Kingdom	24.5	23.8	21.6	19.0	17.4	13.7	11.7	10.8
Southern Europe[r]	79.8	64.5	52.3	41.4	30.2	22.9	19.0	17.1
Albania	135.0	115.0	95.0	74.0	58.9	49.5	44.1	38.7
Greece	60.0	56.1	50.2	42.4	25.8	20.2	19.3	18.3
Italy	59.7	47.9	39.6	32.9	26.0	17.7	14.3	13.0
Malta	74.6	40.0	34.3	28.2	21.8	15.2	14.7	13.4
Portugal	101.8	85.7	76.2	60.8	44.6	38.4	31.7	27.7
Spain	61.2	50.3	41.6	33.0	21.6	15.2	11.5	11.0
Yugoslavia	128.8	104.1	79.9	60.9	45.3	34.9	30.1	26.3
Western Europe[s]	43.7	33.0	25.8	21.2	18.2	12.7	11.2	10.4
Austria	53.4	41.8	31.8	26.5	24.4	16.5	13.8	12.4
Belgium	44.0	34.5	27.1	22.6	18.7	12.5	11.1	10.3
France	44.9	32.7	24.9	20.5	15.9	11.3	9.9	9.5
Germany, Federal Republic of[p]	47.9	36.5	28.3	23.3	22.4	15.3	13.4	12.1
Luxembourg	43.5	36.7	28.7	21.1	16.2	12.9	11.4	10.6
Netherlands	24.2	19.0	16.1	13.7	11.7	9.6	8.4	8.0
Switzerland	31.4	23.3	20.2	16.5	13.3	9.5	8.2	7.8
Oceania	67.7	61.7	54.6	50.9	43.4	42.9	38.5	34.8
Australia-New Zealand	24.1	21.7	19.8	18.0	16.5	12.7	11.1	10.5
Australia	23.6	21.2	19.6	18.1	16.6	12.5	10.6	10.1
New Zealand	26.3	23.6	20.6	17.9	16.1	13.7	13.0	11.9
Melanesia	183.8	170.5	148.5	134.2	115.7	103.0	90.6	79.3
Papua New Guinea	190.0	176.0	154.0	141.0	125.0	110.9	98.1	86.3
Other Melanesia[t]	135.0	129.0	111.0	90.0	59.0	50.3	42.4	35.1
Micronesia-Polynesia	105.8	92.8	77.3	62.7	51.1	44.0	38.1	33.2
Micronesia[u]	155.0	147.0	116.0	96.0	79.9	69.4	60.0	51.5
Polynesia	92.7	78.6	67.0	53.0	41.5	35.8	30.9	27.1
Fiji	88.0	73.0	63.0	53.0	47.0	39.5	33.8	29.3
Other Polynesia[v]	98.0	85.0	71.3	53.0	37.0	32.2	28.0	25.1
USSR	73.0	44.0	31.5	26.2	25.7	28.8	25.1	22.3

NOTES: Data for small countries or areas, generally those with population of 300,000 or less in 1975, are not given in this table separately. They have been included in their regional population figures.

*More developed regions include Northern America, Japan, all regions of Europe, Australia-New Zealand and Union of Soviet Socialist Republics.

†Less developed regions include all regions of Africa, all regions of Latin America, China, other East Asia, all regions of South Asia, Melanesia and Micronesia-Polynesia.

[a]Including British Indian Ocean Territory, Djibouti and Seychelles.

[b]Including Agalesa, Rodrigues and St. Brandon.

[c]Including Sao Tome and Principe.

[d]Including Western Sahara.

[e]Including St. Helena.

[f]Including Dominica, Grenada, Saint Lucia, and Saint Vincent and the Grenadines.

[g]Including Antigua, Bahamas, British Virgin Islands, Cayman Islands, Montserrat, Netherlands Antilles, St. Kitts-Nevis-Anguilla, Turks and Caicos Islands and United States Virgin Islands.

[h] Including Belize and Panama Canal Zone.

[i] Including Falkland Islands (Malvinas).

[j] Including French Guiana.

The least accurate estimates are probably those for countries lacking even a single census or survey that would permit the estimation of infant mortality. This is particularly true of the estimates for countries that were not comparable to other countries in terms of circumstances or conditions, such as Democratic Kampuchea and East Timor. The infant mortality rates for these countries were derived from model life tables with the life expectancies assumed for the different periods based on recent United Nations population projections.

A serious problem affecting the quality of nearly all types of estimates is omissions of registered births and deaths, of reported births and infant deaths in survey and of children who died in reports of children ever born and

Infant mortality rate (per thousand births)							
1990–1995	1995–2000	2000–2005	2005–2010	2010–2015	2015–2020	2020–2025	Region and country or area
13.4	12.5	11.7	10.9	10.4	9.9	9.5	Europe
17.0	15.5	14.1	13.1	12.4	11.7	11.1	Eastern Europe
16.5	14.9	13.8	13.0	12.2	11.8	11.3	Bulgaria
13.8	12.5	11.6	11.1	10.6	10.1	9.6	Czechoslovakia
10.9	10.2	9.8	9.4	9.0	8.7	8.4	German Democratic Republic[p]
17.9	16.1	14.6	13.6	12.8	12.1	11.5	Hungary
17.6	16.1	14.6	13.6	12.8	12.1	11.5	Poland
20.8	18.8	17.0	15.2	14.2	13.4	12.6	Romania
9.4	9.1	8.7	8.4	8.1	7.9	7.6	Northern Europe[q]
7.9	7.8	7.6	7.4	7.2	7.0	6.9	Denmark
7.0	6.8	6.6	6.5	6.4	6.3	6.2	Finland
7.0	6.8	6.6	6.5	6.4	6.3	6.2	Iceland
10.3	9.9	9.5	9.1	8.8	8.5	8.2	Ireland
7.5	7.3	7.1	6.9	6.7	6.6	6.5	Norway
6.4	6.3	6.1	6.0	5.9	5.9	5.9	Sweden
10.2	9.8	9.4	9.0	8.7	8.4	8.1	United Kingdom
15.6	14.4	13.2	12.3	11.5	11.0	10.6	Southern Europe[r]
33.7	30.1	26.9	24.0	21.0	19.4	18.5	Albania
17.4	16.5	15.5	14.6	13.7	12.8	12.0	Greece
12.1	11.3	10.5	9.8	9.3	9.1	9.0	Italy
12.5	11.6	10.8	10.1	9.7	9.4	9.2	Malta
24.7	22.0	19.5	17.6	16.4	15.4	14.4	Portugal
10.5	10.1	9.7	9.4	9.0	8.7	8.5	Spain
23.2	20.9	18.6	16.5	15.5	14.5	13.7	Yugoslavia
9.9	9.4	9.0	8.6	8.3	8.0	7.7	Western Europe[s]
11.5	11.0	10.5	10.1	9.6	9.2	8.9	Austria
9.8	9.4	9.0	8.7	8.4	8.1	7.9	Belgium
9.1	8.7	8.3	7.9	7.6	7.4	7.1	France
11.5	10.9	10.4	9.9	9.5	9.1	8.8	Germany, Federal Republic of[p]
10.0	9.6	9.2	8.8	8.5	8.1	7.9	Luxembourg
7.7	7.3	7.0	6.7	6.6	6.5	6.5	Netherlands
7.4	7.0	6.7	6.6	6.6	6.5	6.4	Switzerland
31.0	27.1	24.3	21.7	19.1	16.9	15.0	Oceania
10.1	9.7	9.4	9.0	8.7	8.4	8.1	Australia-New Zealand
9.8	9.5	9.2	8.9	8.5	8.2	7.9	Australia
11.0	10.5	10.1	9.6	9.2	9.0	8.7	New Zealand
69.2	60.1	52.1	44.7	37.9	32.4	28.1	Melanesia
75.6	65.7	56.8	48.7	41.1	34.9	30.2	Papua New Guinea
30.4	25.8	23.0	20.2	18.5	16.8	15.3	Other Melanesia[t]
28.9	25.2	22.3	19.9	18.2	16.8	15.5	Micronesia-Polynesia
43.3	35.9	31.1	26.5	23.6	20.8	18.2	Micronesia[u]
24.0	21.4	19.2	17.6	16.4	15.4	14.5	Polynesia
25.9	23.1	20.3	18.8	17.7	16.7	15.8	Fiji
22.2	19.8	18.1	16.5	15.0	14.1	13.3	Other Polynesia[v]
19.7	17.6	15.8	14.5	13.5	12.8	12.3	USSR

[k] Including Bermuda, Greenland and St. Pierre and Miquelon.
[l] Including Macau.
[m] Including Brunei.
[n] Including Maldives.
[o] Including Gaza Strip.
[p] The data which relate to the Federal Republic of Germany and the German Democratic Republic include the relevant data relating to Berlin, for which separate data have not been supplied. This is without prejudice to any question of status which may be involved.
[q] Including Channel Islands, Faeroe Islands and Isle of Man.
[r] Including Andorra, Gibraltar, Holy See and San Marino.
[s] Including Liechtenstein and Monaco.
[t] Including New Caledonia, Norfolk Island, Solomon Islands and Vanuatu.
[u] Including Canton and Enderbury Islands, Christmas Island, Cocos (Keeling) Islands, Johnston Island, Midway Islands, Pitcairn Island, Tokelau and Wake Islands, Kiribati, Guam, Nauru, Niue, Pacific Islands and Tuvalu.
[v] Including American Samoa, Cook Islands, French Polynesia, Samoa, Tonga and Wallis and Futuna Islands.

surviving. Because the effects of such omissions are likely to produce a downward bias in the infant mortality estimates, it was decided as a general rule that whenever two estimates for a country were not consistent with each other, the higher estimate would be chosen.

Although the derived infant mortality rates were sometimes adjusted by demographic techniques, the rates often were accepted or rejected mainly on the basis of their plausibility and consistency. In this regard, one of the major strengths of this study is that not only were all the derived estimates for a country analysed and examined for internal consistency, but the estimates were also compared with estimates for neighbouring countries with similar social and economic circumstances.

Results

Main findings

The estimates and projections of infant mortality rates shown in table 2, in figures II and III and in maps 1, 2, 3 and 4 indicate a number of important points. To begin with, for the world as a whole the estimated infant mortality rate of 142 per thousand in 1950–1955 declined to 87 per thousand in 1975–1980. For more developed regions, the decline was from 56 to 19 per thousand, a rate which is nearly a third of its value in 1950–1955. The infant mortality rate for the less developed regions declined more rapidly in absolute terms, but much less on a relative basis—from 164 to 100 per thousand, which is about 40 per cent during the 25-year period. Although the levels of the infant mortality rate for more and less developed regions have converged somewhat since the 1950s, the disparity remains large—in 1975–1980 the difference in the infant mortality rates between the two regions was 81 per thousand.

Considerable differences in the levels of infant mortality and their rates of decline may be observed among the regions. Africa, for example, has the highest infant mortality in 1975–1980 (127 per thousand) and the slowest decline in its rate between 1950–1955 and 1975–1980 (from about 184 to 127). Although all the estimates for African countries with data available for at least two points in time show a decline, with the exception of a few countries, such as the United Republic of Cameroon, Togo and the small islands of Mauritius and Réunion, the declines have been slower than previously implied in the United Nations demographic assessment in 1980 (United Nations, 1981). However, the limited available data show no signs of a slow-down in the rate of mortality decline.[11]

In contrast, in South Asia the data do show a slow-down in the decline of infant mortality for some countries. For example, while earlier sources of data for India indicated a decline in the infant mortality rate during the 1950s and the 1960s, data from the Sample Registration System show that infant mortality remained more or less constant during the 1970s (India, 1980). From the various sources of data on infant mortality for Bangladesh, no consistent trend is discernible. However, a possible slow-down in the rate of decline may have occurred, since the estimated five-year averages for 1965–1970 and 1970–1975 are identical, 150 per thousand. At this point it should be mentioned that since only five-year averages are given, short-term fluctuations, if any, are not evident. For instance, although the registered infant mortality in Sri Lanka increased between 1971 and 1974 and then declined again, the five-year averages show a decline between 1965–1970 and 1970–1975, which is somewhat slower than in previous periods.

As can be seen in figure II, the initial faster mortality decline in South Asia as compared to Africa was followed by a slow-down. The widening differences after 1980 are due to assumptions made about the age patterns of mortality and the model life tables utilized. While the mortality decline in terms of life expectancy at birth is assumed to be the same, the different rates of decline in infant mortality are due to different choices of model life tables used for the two regions.

In 1950–1955 Latin America had the lowest infant mortality rate among the less developed regions, 128 per thousand. Although its decline has been more rapid than the decline in Africa and South Asia, it has been slower than the decline in East Asia. Consequently, the estimated infant mortality for Latin America in 1975–1980 is considerably higher than the rate for less developed countries in East Asia, 71 per thousand versus 48 per thousand.

The fastest mortality decline observed in any region occurred in East Asia. From a high of 135 per thousand in 1950–1955, the infant mortality rate reached about 45 per thousand in 1975–1980. Furthermore, relative declines in certain specific countries of East Asia are even more dramatic. For example, registered data for Hong Kong and indirect estimates for the Republic of Korea show that infant mortality declined from 79 to 13 per thousand and from 116 to 37 per thousand respectively between 1950–1955 and 1975–1980, or by approximately 80 per cent and 70 per cent.

In absolute terms, possibly one of the most rapid declines in infant mortality may have occurred in China; from an estimated 144 per thousand in 1950–1955 the infant mortality rate fell to an estimated 49 per thousand in 1975–1980. The estimates and projections beginning from 1970 were based on an adjusted life table for 1972–1975, which used data from a survey of cancer epidemiology (Banister and Preston, 1981). The official infant mortality rate for 1975 of 18 per thousand which was reported to WHO is about one third the infant mortality rate estimated from the survey; the official figure was not used as it seems implausibly low vis-à-vis other estimates.

It is noteworthy that despite the fact that China has the largest population in the world, even a sizable relative difference in its estimate of infant mortality would not change the world total very much because both its fertility and mortality are comparatively low. For example, a difference of 10 per cent in the 1980 estimate of infant mortality for China would affect the world total by less than 1 per cent. In contrast, a difference of 10 per cent in the estimated infant mortality rate for India would change the world average rate by almost 3 per cent.

Rapid mortality declines were also found among some of the Arab countries of Western South Asia. It appears that some of the oil wealth has no doubt been translated into social and economic gains for the general population. It is important to realize, however, that the rapid decline in infant mortality is not confined to the oil-exporting countries, but also may be observed in the non-oil-exporting countries, such as Jordan and the Syrian Arab Republic. In Jordan, for example, the infant mortality declined from an estimated 162 per thousand in 1950–1955 to 75 per thousand in 1975–1980, which is a decline of about 54 per cent.

The speed of decline in the average infant mortality rate for the less developed regions and the world total slowed down markedly in the 1970s. This is in part due to the slower decline in some of the larger countries of South Asia (e.g., India and Bangladesh). However, the major reason for the slow-down was a change in the regional contributions to the infant mortality rates for the world and less developed regions. The rapid decline in infant

[11] In order to detect a slow-down in the rate of mortality decline, it is necessary to have data for at least three points in time. For the few countries where such data were available (e.g., Ghana, Kenya and Tunisia), there is no sign that the pace of mortality decline has slowed. For countries where vital registration is available, fluctuations or short-term increases in the registered mortality rates may be due to variations or improvement in the registration coverages. For example, the registered infant mortality rates for Mauritius increased in 1965–1970 and then declined again.

Figure II. Estimates and projections of infant mortality rate by major regions, 1950–2025

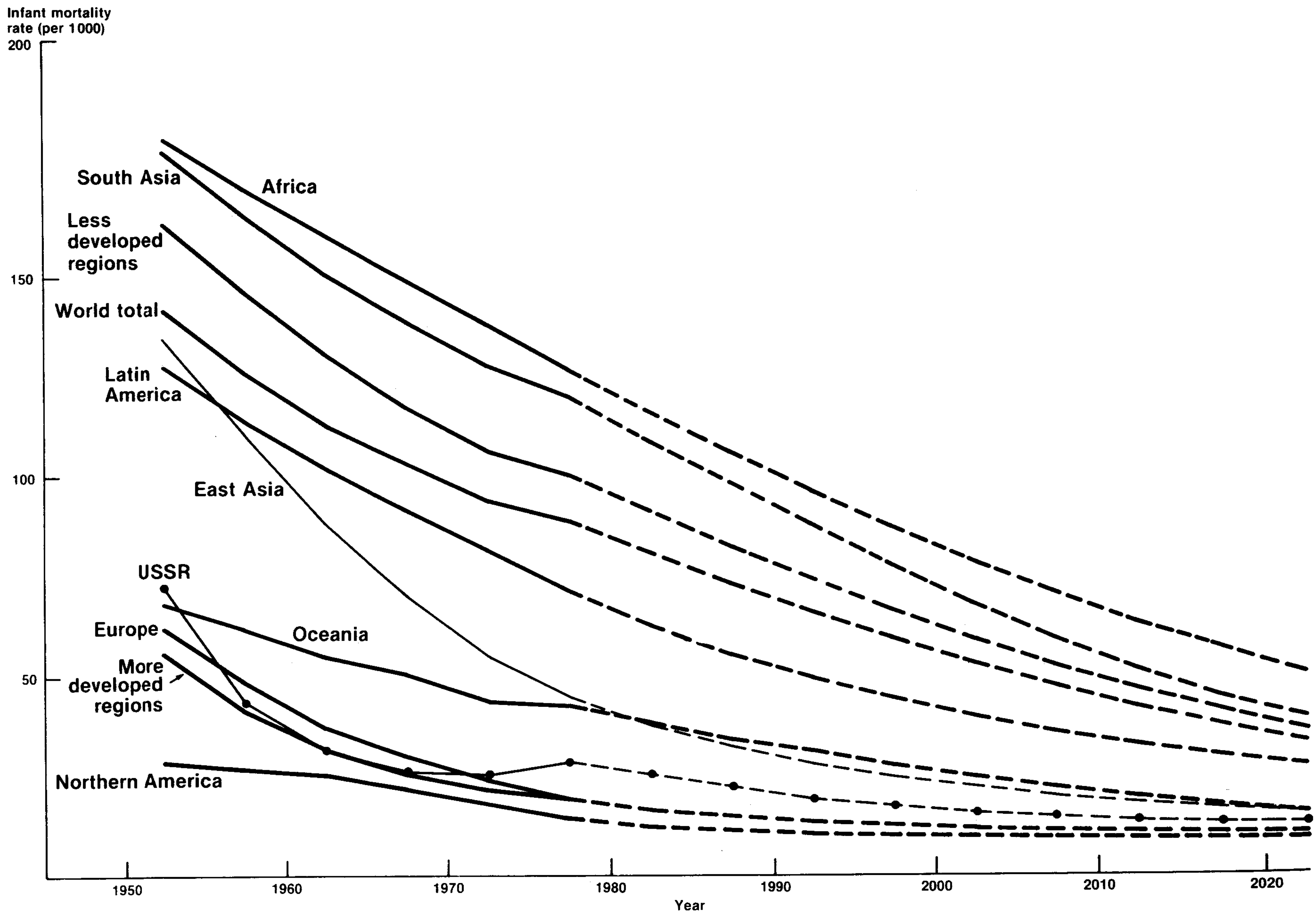


Figure III. Estimates and projections of infant mortality rates for 1950–1955, 1975–1980 and 2020–2025 by region, according to their ranking in 1975–1980

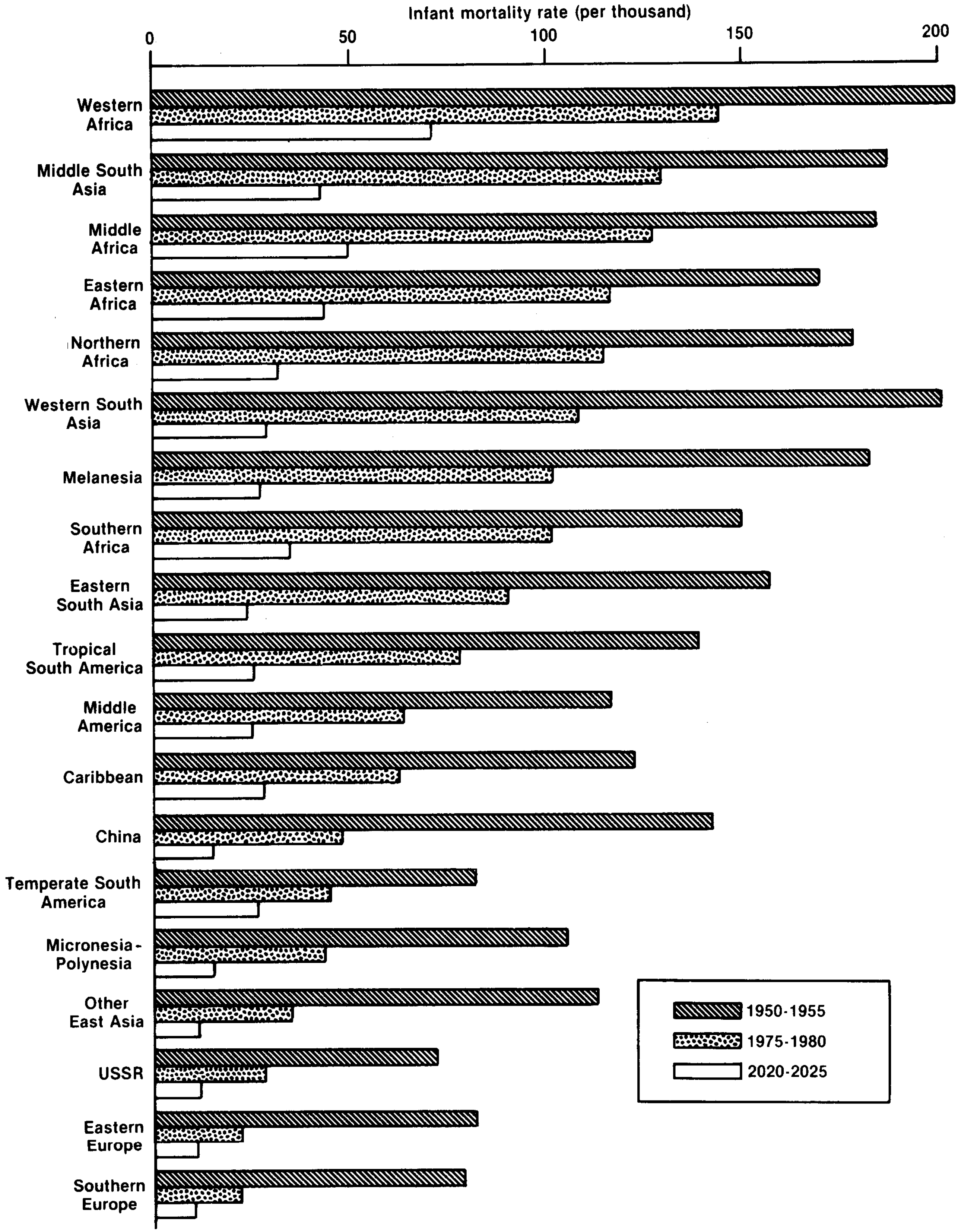
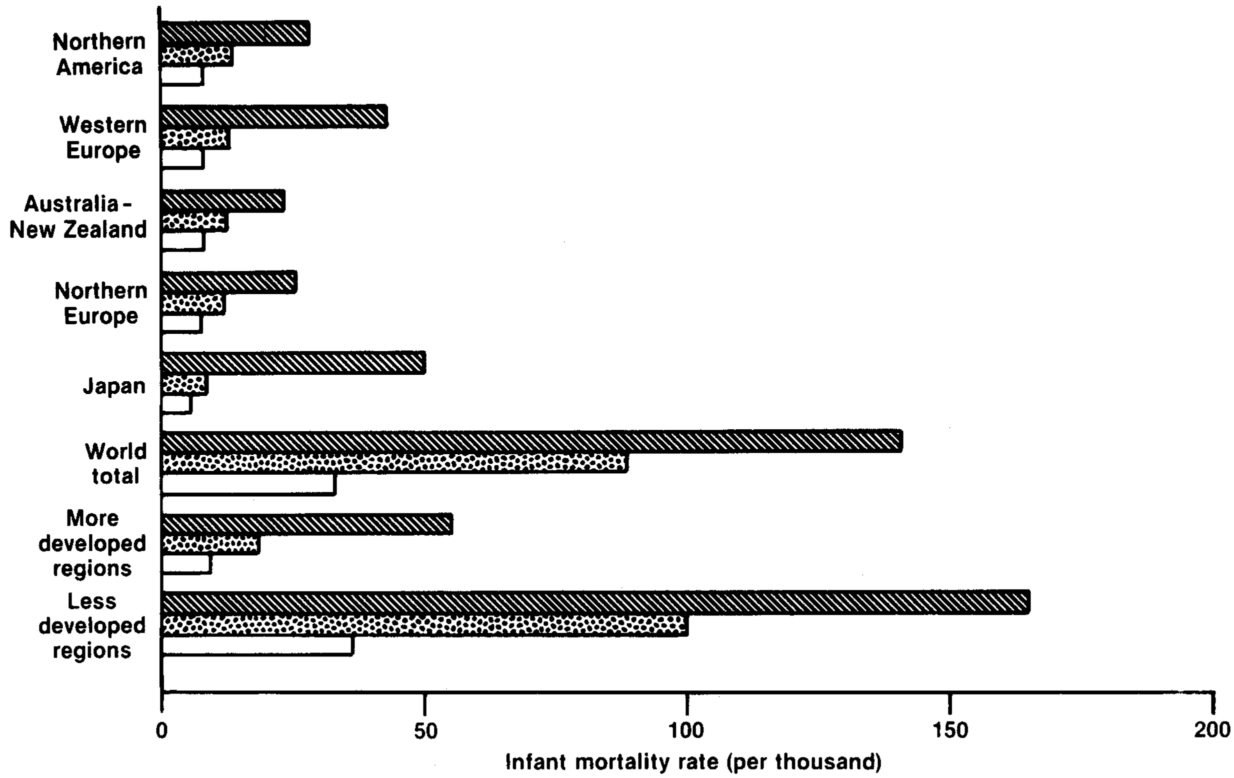


Figure III (*continued*)



mortality in East Asia was accompanied by a rapid decline in its levels of fertility, so that the high mortality and high fertility countries of Africa and South Asia contributed larger shares to the world infant mortality rate.

The apparent slow-down in the decline of infant mortality in Oceania in the 1970s is a statistical anomaly, since the estimates for each country in the region declined steadily. Because births are used as weights to obtain the regional averages, and since Australia and New Zealand both had an increase in the number of their births in 1971 and 1972, the lower estimates for these two countries had a larger weight in 1970–1975 than they did in other periods.

Among the developed regions, the USSR had the most rapid decline in infant mortality between the early 1950s and 1960s, both in absolute and relative terms. Between 1950–1955 and 1960–1965 the infant mortality rate declined from 73 to 32 per thousand, which is about a 55 per cent drop in 10 years. However, between 1965 and 1980 the rate of decline slowed down and the infant mortality rate is believed to have then increased somewhat. More specifically, the estimates of infant mortality for 1965–1970, 1970–1975 and 1975–1980 are 26.2, 25.7 and 28.8 per thousand, respectively. After 1980, a rate of decline similar to that in other countries is projected.

In 1950–1955 Japan had a relatively high infant mortality rate, 51 per thousand. By 1975–1980, however, Japan had the lowest infant mortality rate of the 24 subregions, 8.8 per thousand. For this period Japan had about the same infant mortality as the Scandinavian countries, but since Ireland and the United Kingdom, which had relatively higher rates, are included in the Northern Europe subregion, the average infant mortality for this subregion was higher than the rate for Japan.

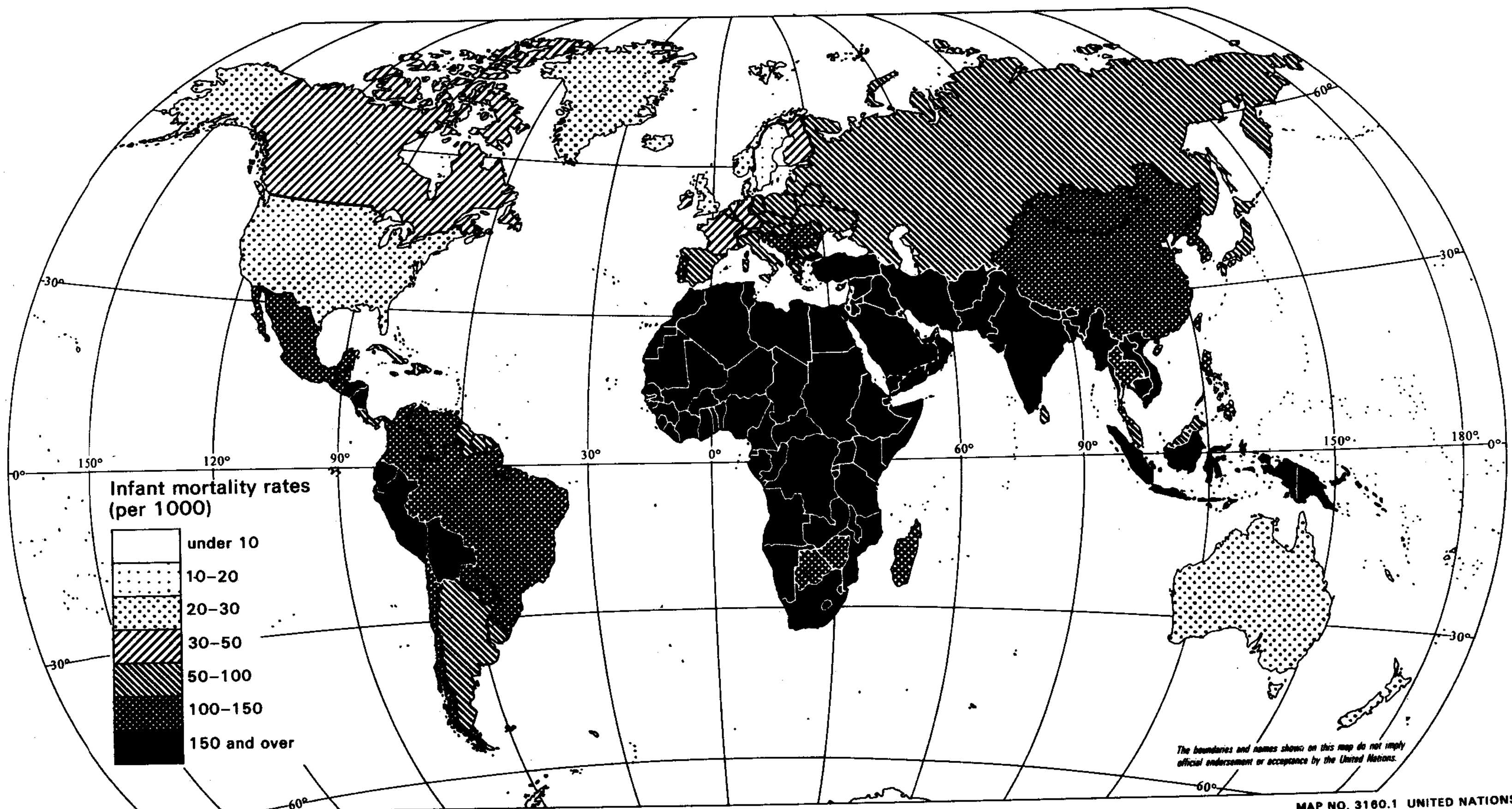
During the period 1950–1980 Sweden consistently had the lowest infant mortality rate. It is interesting to note that not only has Sweden's infant mortality rate reached levels that were previously thought to be highly unlikely to be reached, but the rate continues to decline annually. For example, the registered rate for Sweden declined from 7.5 per thousand in 1979 to 6.7 per thousand in 1980. Sweden's gains in this area have regularly surpassed the assumptions of possible declines made in its own national mortality projections.

While for developed countries mortality improvements in terms of life expectancies at birth were rapid in the 1950s, slowed down in the 1960s, and regained speed again in the 1970s, the improvements in infant mortality did not follow the same pattern. The rate of decline in infant mortality varies among countries and regions in the 1950s and 1960s. However, with the exception of Japan, Eastern Europe and the USSR, the most rapid relative decline in infant mortality for developed subregions occurred in the 1970s. For some countries where infant mortality rates were already low in the 1950s, both the absolute and relative declines were most rapid in the 1970s. In Japan the rate decline was roughly uniform throughout the period; and in Eastern Europe and the USSR the declines slowed down after 1960.

Figure III shows the estimated and projected infant mortality rates for the 24 subregions for the periods 1950–1955, 1975–1980 and 2020–2025, ranked according to the rate of 1975–1980. Although the rates of decline in infant mortality in the past differed among the subregions, as well as among the countries within the

MAP 1

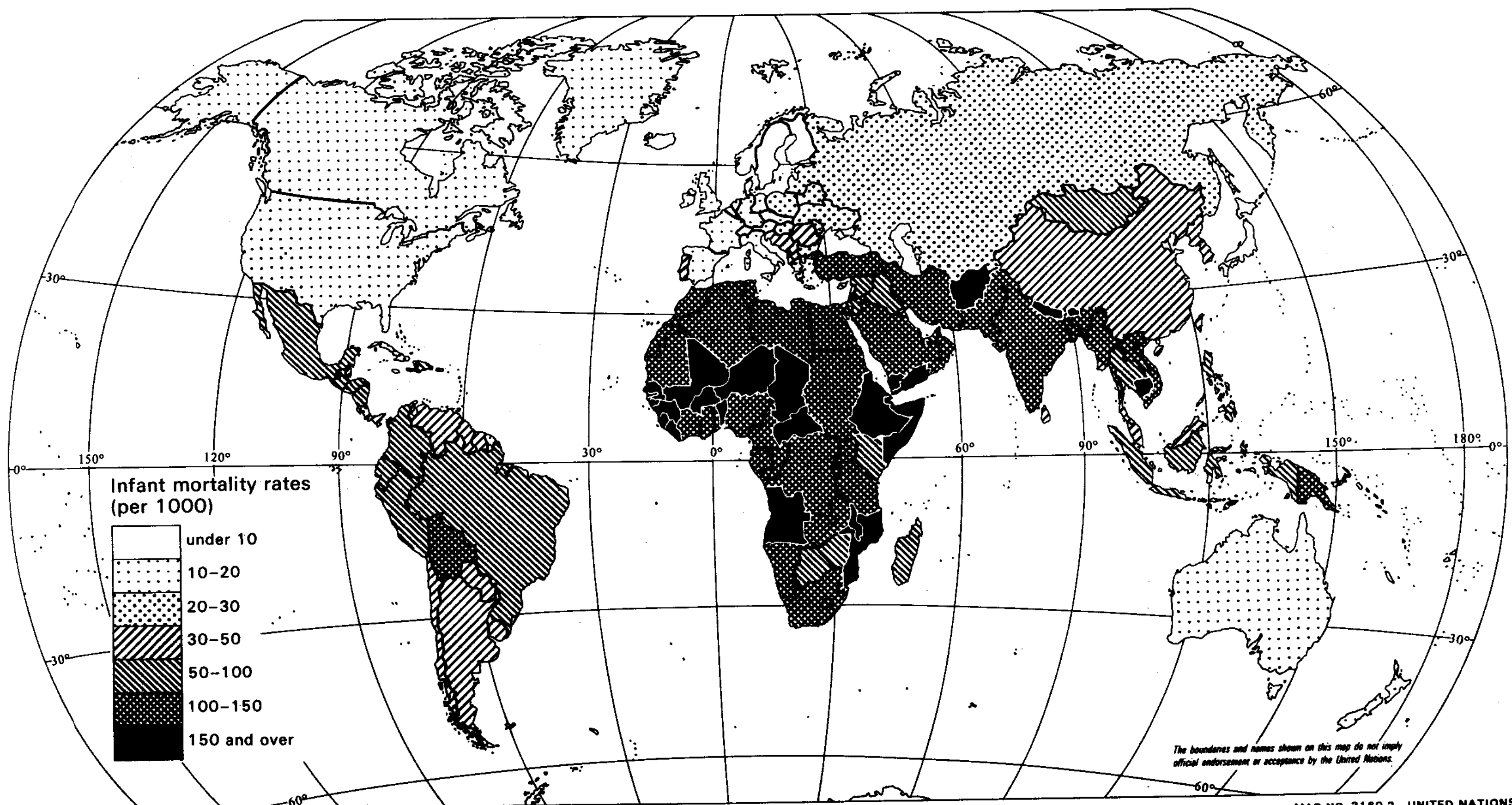
ESTIMATES OF INFANT MORTALITY RATES, 1950-1955



Source: Population Division of the Department of International Economic and Social Affairs of the United Nations Secretariat, 1982.

ESTIMATES OF INFANT MORTALITY RATES, 1975-1980

MAP 2

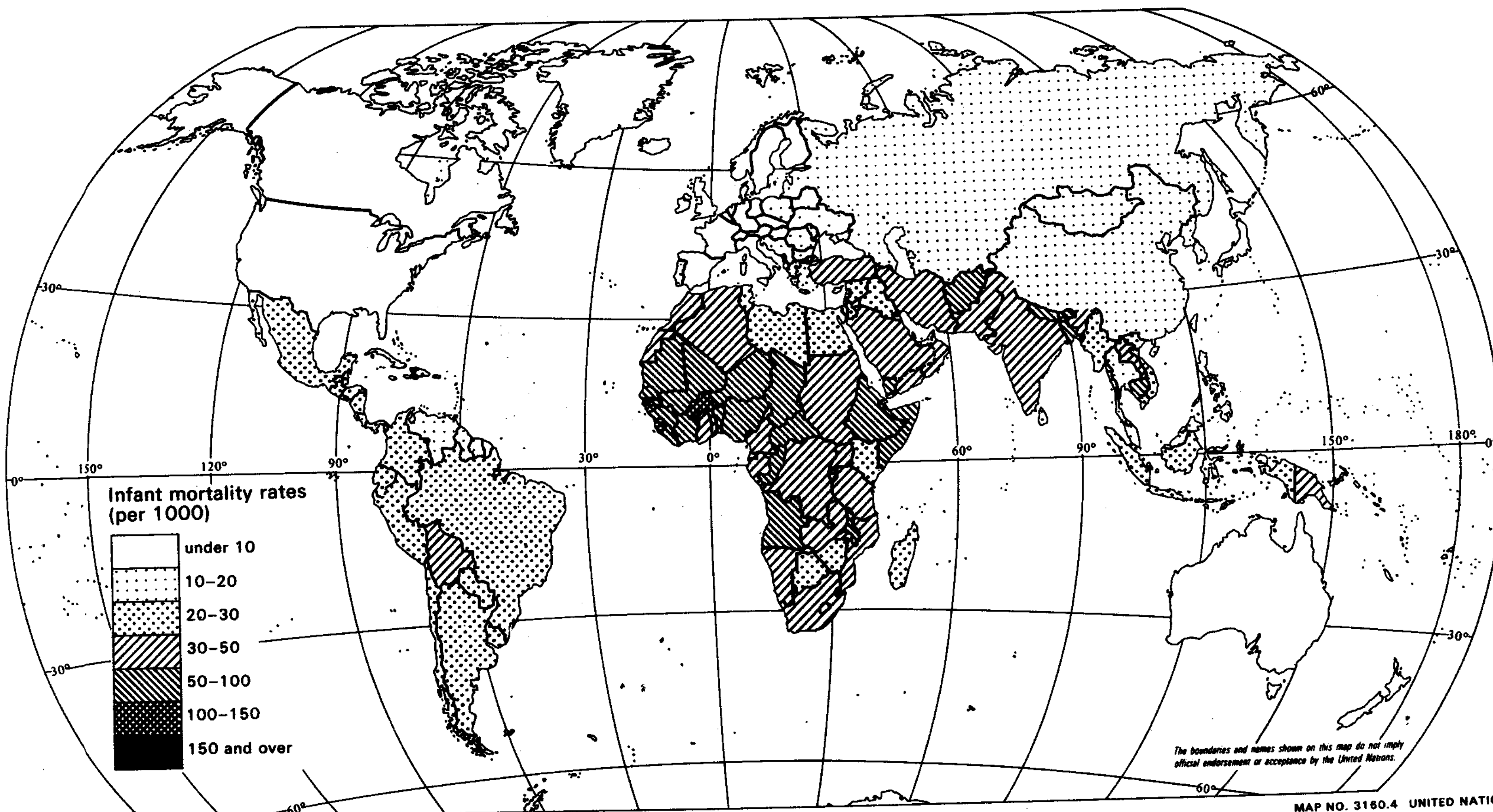


Source: Population Division of the Department of International Economic and Social Affairs of the United Nations Secretariat, 1982.

MAP NO. 3160.2 UNITED NATIONS
MARCH 1982

MAP 3

PROJECTIONS OF INFANT MORTALITY RATES, 2020-2025

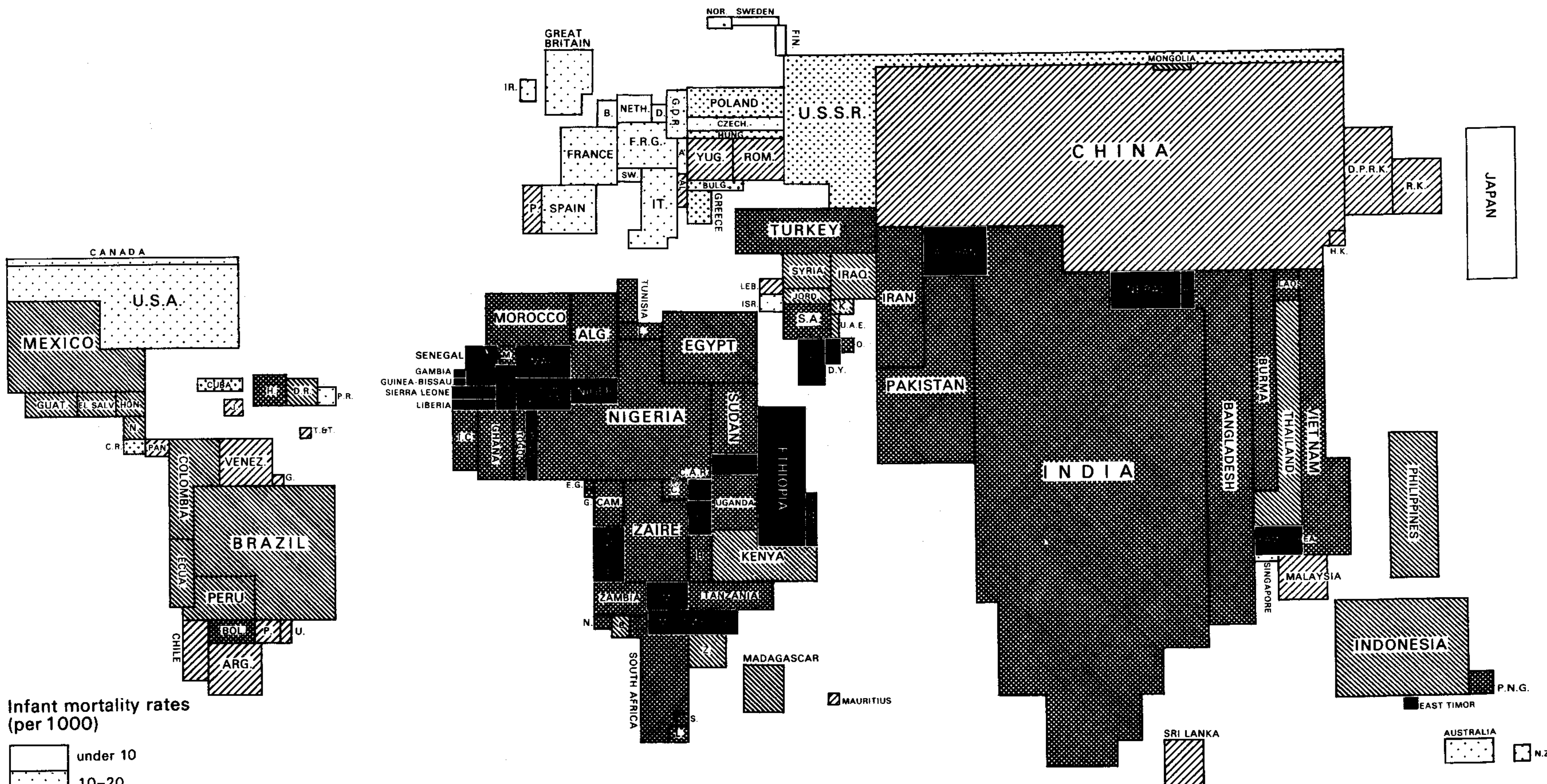


Source: Population Division of the Department of International Economic and Social Affairs of the United Nations Secretariat, 1982.

MAP NO. 3160.4 UNITED NATIONS
MARCH 1982

ESTIMATES OF INFANT MORTALITY RATES, 1975-1980

(Sizes of countries are proportional to the estimated average annual number of births, 1975-1980)



Infant mortality rates (per 1000)

- under 10
- 10–20
- 20–30
- 30–50
- 50–100
- 100–150
- 150 and over

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

MAP NO.3167 UNITED NATIONS
APRIL 1982

Source: Population Division of the Department of International Economic and Social Affairs of the United Nations Secretariat, 1982.

subregions, an effort was made so far as was possible to keep the 1980 ranking of countries in the projections of future trends. However, primarily because various life tables were used in the projections, some minor changes in the ranking of the subregions and countries occur after 1980.

The distribution of countries and percentage distribution of births according to level of infant mortality for selected periods are shown in tables 3 and 4; the levels for these periods are also illustrated graphically in maps 1, 2 and 3. While in 1950–1955 not a single country had an infant mortality rate below 10 per thousand, 8 countries had reached this level by 1975–1980 and 28 countries are expected to have infant mortality rates below 10 by 2020–2025. Although some of these countries are large in terms of population size (e.g., the United States of America), fertility in all of these countries is expected to remain low; consequently, only 8.1 per cent of the births in 2020–2025 are expected to occur in these 28 countries.

At the other extreme, in 1950–1955, 77 countries, accounting for 44 per cent of the world's births, had estimated infant mortality rates of 150 per thousand or over. By 1975–1980, this category contained 23 countries, representing only 5 per cent of the world's births; and by 2020–2025, no countries are expected to fall into this category.

In contrast to maps 1, 2 and 3, map 4 offers quite a different perspective. While the same shading system is used for the countries, the sizes of the countries do not reflect their geographic areas but are drawn proportional to the estimated average annual number of births for the period 1975–1980. Some of the countries with low infant mortality rates—such as Canada, the Scandinavian countries and Australia—virtually disappear on this map. In contrast, South Asia—which contains India, the country with the largest number of births and infant deaths—becomes considerably larger, covering a surface more than twice the size of Africa.

Comparison of the results with the goals set by the World Population Plan of Action and by the International Development Strategy for the Third United Nations Development Decade

The World Population Plan of Action, adopted at the World Population Conference in Bucharest 1974, recommended that mortality levels, particularly infant and maternity mortality levels, should be reduced to the maximum extent possible. More specifically, countries with the highest mortality levels should aim by 1985 to have an infant mortality of less than 120 per thousand live births (United Nations, 1975). According to the results of this study, it appears likely that 29 countries will not reach this goal. Of these countries, 20 are in Africa (of which 12 are in Western Africa) 1 is in Latin America (Bolivia), and 8 are in South Asia.

Among the objectives of the International Development Strategy for the Third United Nations Development Decade,[12] one is the reduction of the infant mortality rate in all countries to a maximum of 50 per thousand live births by the year 2000. If the general mortality trends assumed in this study should hold, this goal would not be met. By the year 2000, the regions of Africa and South Asia would still have infant mortality rates above 50 per thousand. As a result, the averages for the world total and for the less developed regions would also be above 50 per thousand. The infant mortality rates for Africa and South Asia in the year 2000 are projected to be 83 per thousand and 73 per thousand, respectively. Africa and South Asia are expected to reach the target level after 2020 and 2015, respectively.

Of the approximately 156 countries for which the projections were made, 67 countries are not expected to reach an infant mortality rate of 50 per thousand by the year 2000. Of these countries, 45 are in Africa, 3 are in Latin America (Haiti, Bolivia and Peru), 18 are in South Asia, and 1 is in Oceania (Papua New Guinea). Although a majority of the countries are in Africa, many of them are small countries. In terms of the projected number of births, South Asia will have the largest share of children born in countries with infant mortality higher than 50 per thousand. According to the results of these projections, about 55 per cent of the births in the year 2000 will occur in countries where the average infant mortality will be over 50 per thousand.

TABLE 3. DISTRIBUTION OF COUNTRIES BY LEVEL OF INFANT MORTALITY RATE FOR SELECTED PERIODS

Infant mortality rates (per thousand)	*1950–1955*	*1975–1980*	*1995–2000*	*2020–2025*
Under 10	—	8	16	28
10–20	1	21	27	37
20–30	8	11	20	32
30–50	9	26	22	29
50–100	34	28	44	27
100–150	27	39	23	3
150 and over	77	23	4	—
TOTAL	156	156	156	156
Median infant mortality rate	149.6	75.4	40.5	25.7

TABLE 4. PERCENTAGE DISTRIBUTION OF BIRTHS BY LEVEL OF INFANT MORTALITY RATE FOR SELECTED PERIODS

Infant mortality rates (per thousand)	*1950–1955*	*1975–1980*	*1995–2000*	*2020–2025*
Under 10	0.0	1.9	3.3	8.1
10–20	0.1	7.2	9.5	23.6
20–30	5.6	5.1	18.0	21.1
30–50	2.6	21.3	8.8	30.9
50–100	12.8	16.2	45.9	15.7
100–150	35.0	43.1	13.3	0.6
150 and over	43.9	5.2	1.2	0.0
TOTAL	100.0	100.0	100.0	100.0
Estimated and projected average annual number of births (thousands)	95 980	121 067	140 905	143 096
Median infant mortality rate	143.0	98.0	62.1	28.9

CONCLUSIONS

This study has had a set of ambitious objectives. In brief, it has attempted both to estimate past levels of infant mortality and to anticipate their future trends up to the year 2025. Although some of the estimates will need to be revised when more data become available, these internationally comparable estimates are considered to be the best that can be produced at this time, since they are based on an exhaustive search of the relevant data and studies that are currently available.

The sources of data used to prepare the estimates and the basis for the projections have included vital registra-

[12] General Assembly resolution 35/56 of 5 December 1980.

tion and information relevant to infant mortality in censuses and surveys. For developed countries, the estimates have been based on registered data, and comparatively speaking, the preparation of these estimates posed few problems.

For developing countries, the estimates were based mainly on census and survey data. Indirect methods for estimating infant mortality from the proportion of children dead by age of women were applied in every census and survey where these questions had been asked. When it was possible to compare the estimates derived using indirect methods with those based on other sources, the indirect methods proved to be reliable. The major difficulty in preparing estimates for the developing countries was the paucity of data. The importance of the availability of data, their quality and their frequency cannot be over-emphasized. With no data, unreliable estimates are virtually certain; with improved data sets, the accuracy and reliability of the estimates increase commensurately.

The projections of infant mortality were for the most part based on the assumptions of the overall mortality decline in the population projections as assessed in 1980 by the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat (United Nations, 1981). However, as a result of the findings in this project, a less rapid future mortality decline has been projected for high mortality countries than was previously assumed. The projected decline may still seem rather optimistic for many African and South Asian countries in light of recent past trends. In contrast, for low mortality countries and the developing countries where the mortality decline has been relatively rapid, the projected future decline may be somewhat conservative in comparison to past trends.

The estimates and projections of infant mortality should be updated or revised in the near future because a considerable amount of new data for developing countries are expected to become available soon—for example, the results from the 1980 round of censuses and the final results of the remaining country surveys conducted under the programme of the World Fertility Survey. The results obtained from the birth histories collected in the World Fertility Survey, for example, may make it possible to estimate the relation between infant and child mortality for a large number of developing countries. As assumptions about the relation between infant and child mortality are needed in the indirect methods for estimating infant mortality, the results of these surveys should improve the estimates of infant mortality.

Irrespective of the differences in the estimates and projections that may be found in future analyses, the overall conclusions from this project are clear. First, the results show that over the past 30 years important progress has been made in reducing infant mortality throughout the world. The estimated average infant mortality rate for the world, for example, declined from 142 per thousand in 1950–1955 to 89 per thousand in 1975–1980. Infant mortality declined relatively rapidly in the developed countries, in the countries of East Asia and in a number of other developing countries, such as some of the Arab countries of Western South Asia. For most high mortality countries, in contrast, the decline was significantly lower.

Second, despite the decline in the infant mortality rates over the previous three decades, considerable differences continue to exist among more and less developed countries. For example, in 1975–1980 the average estimated infant mortality rate for the less developed regions was about five times as large as the average rate for the more developed regions—100 versus 19 per thousand, respectively. The highest levels of infant mortality, at times in excess of 150 per thousand, occur among the developing countries of Africa and South Asia. The only less developed region with an average infant mortality rate currently below 50 per thousand is East Asia, which in 1975–1980 had an infant mortality rate of about 48 per thousand (excluding Japan).

Among the developed countries, the lowest rates, generally below 10 per thousand, are found in Japan and the Scandinavian countries. Most of the rates for the other Western European countries, as well as for Australia, New Zealand, Canada and the United States of America, fall between 10 and 15 per thousand. The overwhelming majority of the remaining developed countries have rates ranging from about 20 to 40 per thousand.

Finally, the projections of infant mortality indicate that unless Governments should make an extraordinary effort to remedy the situation and/or some technological breakthrough should take place permitting the infant mortality rate to drop more rapidly than expected, the goal of an infant mortality rate of 50 per thousand for all countries by the year 2000, set in the International Development Strategy for the Third United Nations Development Decade, is not likely to be achieved. The results of this project show that if past mortality trends should continue, 67 countries out of approximately 156 will have infant mortality rates greater than 50 per thousand by the end of this century. Furthermore, although these 67 countries represent about 43 per cent of the countries in the world, they contribute a disproportionate share to the average world rate. On the basis of the total number of births, close to three out of every five births in the year 2000 are expected to occur in countries having infant mortality rates greater than 50 per thousand.

ANNEX

Sources of data

TABLE LIST OF COUNTRIES ACCORDING TO TYPE OF DATA USED AS A BASE FOR THE ESTIMATES AND PROJECTIONS OF INFANT MORTALITY

1. Vital registration	
Africa	*Europe*
Cape Verde	Austria
Mauritius	Belgium
Réunion	Bulgaria
South Africa[a]	Czechoslovakia
Latin America	Denmark
Argentina	Finland
Barbados	France
Chile	German Democratic Republic
Cuba	Germany, Federal Republic of
Guadeloupe	Greece
Martinique	Hungary
Other Caribbean	Iceland
Puerto Rico	Ireland
Uruguay	Italy
Windward Islands	Luxembourg
Northern America	Malta
Canada	Netherlands
United States of America	Norway
East Asia	Poland
Hong Kong	Portugal
Japan	Romania
South Asia	Spain
Israel	Sweden
Singapore	Switzerland

TABLE (*continued*)

1. Vital registration

Europe (continued)	*Oceania*
United Kingdom	Australia
Yugoslavia	New Zealand
	USSR

2. Vital registration and national surveys or censuses

Africa	*South Asia*
Egypt	Cyprus
Latin America	Kuwait
Costa Rica	Malaysia[b]
Guatemala	Sri Lanka
Guyana	
Jamaica	
Mexico	
Panama	
Trinidad and Tobago	
Venezuela	

3. Two or more national surveys or censuses

Africa	*East Asia*
Burundi	Republic of Korea
Ghana	*South Asia*
Kenya	Bangladesh
Lesotho	India
Malawi	Indonesia
Mozambique	Jordan
Rwanda	Lebanon
Senegal	Pakistan
Swaziland	Syrian Arab Republic
Togo	Thailand
Tunisia	Turkey
United Republic of Cameroon	Yemen
Zaire	*Oceania*
Latin America	Fiji
Bolivia	Micronesia
Brazil	Other Melanesia
Colombia	Other Polynesia
Dominican Republic	Papua New Guinea
El Salvador	
Honduras	
Paraguay	
Peru	

TABLE (*continued*)

4. One national survey or census

Taken in 1970 or later	*Taken before 1970*
Africa	*Africa*
Algeria	Angola
Botswana	Benin
Gambia	Central African Republic
Libyan Arab Jamahiriya	Chad
Morocco	Comoros
Sierra Leone	Congo
Somalia[c]	Gabon
Sudan	Guinea
Latin America	Guinea-Bissau
Ecuador	Ivory Coast
Haiti	Liberia
Nicaragua	Madagascar
East Asia	Mali
China	Niger
South Asia	Uganda
Afghanistan	United Republic of Tanzania
Bahrain	Upper Volta
Iran	Zambia
Iraq	Zimbabwe
Nepal	*Europe*
Oman	Albania
Philippines	
United Arab Emirates	

5. No data (incomplete vital registration and no national survey or census with data relevant to infant mortality)

Africa	*South Asia*
Equatorial Guinea	Burma
Ethiopia	Bhutan
Mauritania	Democratic Kampuchea[e]
Namibia	Democratic Yemen
Nigeria	East Timor
Latin America	Lao People's Democratic Republic
Suriname[d]	Qatar
East Asia	Saudi Arabia
Democratic People's Republic of Korea	Viet Nam
Mongolia	

[a]Vital registration is reported to be complete for Whites, Coloureds and Asians. The estimates for the total population was obtained by assuming that the infant mortality for Bantus was the same as that for Coloureds.

[b]Vital registration for Peninsular Malaysia, indirect estimates from two censuses for Sabah and Sarawak.

[c]Preliminary results from the 1975 census.

[d]Vital registration is reported to be complete, but the infant mortality rates are very low compared to neighbouring countries.

[e]Indirect estimates are available from the 1962 census, but these could only be used as a base for the estimates before the war.

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CONSTRUCTION OF THE NEW UNITED NATIONS MODEL LIFE TABLE SYSTEM

*United Nations Secretariat**

SUMMARY

Previous systems of model life tables were based on empirical data from the now developed countries (the Coale and Demeny models) or, when patterns from less developed countries were included (the original United Nations set and the Lederman set), included data of poor or unknown quality. However, with the advent of new demographic techniques of data evaluation and of improved survey, census and vital registration systems, it has become possible to construct a new model life table system based on reliable data from less developed countries and hence more applicable to demographic analysis within that milieu.

The new United Nations model life tables are based on carefully evaluated age-sex specific mortality data found in developing countries. Analysis of these data indicated four major age patterns of mortality. These patterns have been labelled the Latin American pattern, the Chilean pattern, the South Asian pattern and the Far Eastern pattern, according to the geographical region predominant in each pattern. An overall average pattern, labelled the general pattern, has also been constructed.

Along with the model life tables themselves, the United Nations is also producing models of sex differences in life expectancy, single-year mortality and stable populations. A manual of computer programs to facilitate use of these models is also being prepared.

INTRODUCTION

Construction of a model life table system is similar to the search for a mathematical expression of the law of mortality. For example, in 1825 Benjamin Gompertz proposed the well-known law:[1]

$$\mu_x = BC^x$$

where μ_x is the force of mortality (or instantaneous death rate) at age x and B and C are parameters specific to a given life table. This two-parameter law of mortality has often been used to model mortality from about ages 20 or 25 up to the oldest age group. According to this law, the instantaneous death rises exponentially with age.

Observed life table q_x functions also tend to grow exponentially with age in a Gompertz fashion. However, in the case of the q_x function, the Gompertz law only applies approximately up to a given age x_o, after which the observed q_x tends to "bend back," departing from the familiar straight line when plotted on semi-logarithmic paper. It usually still continues to increase monotonically however. This "bending back" occurs for two reasons. First, q_x's represent probabilities and by definition must therefore fall within the open interval (0,1); the q_x function at its upper limit must therefore be asymptotic to 1.0. The second reason is heterogeneity in the population. Redington has shown that if a population is made up of several subpopulations, each subpopulation having mortality which perfectly follows the Gompertz function with identical C-values but at different levels of mortality, the q_x function for the combined, heterogeneous population must bend back simply owing to changing composition of the surviving population at each age.[2] The explanation is simple: the older the age group, the higher proportion of total survivors from the low mortality subpopulations.

To account for this bending back, the Institute of Actuaries Continuous Mortality Investigation Committee[3] has suggested that a formula of the form

$$\frac{q_x}{1 - q_x} = BC^x \text{ or equivalently } q_x = \frac{BC^x}{1 + BC^x}$$

may be more appropriate because it limits the q_x values to the (0,1) interval. This formula is similar to Perks' Law (1932).[4]

Taking logarithms of both sides we have

$$\ln \frac{q_x}{1 - q_x} = \ln B + x \ln C$$

or

$$\text{logit}\ (q_x) = b + xc$$

*Population Division of the Department of International Economic and Social Affairs.

[1]B. Gompertz, "On the nature of the function expressive of the law of human mortality; and on a new mode of determining the value of life contingencies", *Philosophical Transactions R.S.*, vol. 115 (1825), p. 513.

[2]F. M. Redington, "An exploration into patterns of mortality", *Journal of the Institute of Actuaries*, vol. 95 (1969), pp. 243–317.

[3]Institute of Actuaries and Faculty of Actuaries, Continuous Mortality Investigation Committee, "Considerations affecting the preparation of standard tables of mortality", *The Journal of the Institute of Actuaries*, vol. 101 (1974), pp. 135–201.

[4]B. Benjamin and J. H. Pollard, *The Analysis of Mortality and Other Actuarial Statistics* (London, Heinemann, 1980), p. 305.

if we ignore the scaling factor of 1/2 when defining the logit and define $b = \ln B$ and $c = \ln C$.

This formula can be generalized to apply for all ages from birth to the end of life by assuming b to be a function of age x, $b(x)$, and c to be multiplied by another function of age x, $g(x)$ rather than by age x.

The resulting new equation,

$$\text{logit}\ (q_x) = b(x) + c \cdot g(x)$$

is the equation used by the United Nations for producing one-component model life tables. The above equation can be further generalized by addition of extra Gompertz-type terms so that

$$\text{logit}\ (q_x) = b(x) + \sum_{i=1}^{k} c \cdot g_i\ (x)$$

This is the general "law" of mortality that underlies the new United Nations tables. The functions $b(x)$ and $g_i(x)$ are discrete functions of x, or vectors, which have been estimated by principal components analysis. In this form the vector $b(x)$ represents an average pattern of mortality, as defined by the logit (q_x) function; $g_1\ (x)$ represents first order deviations from this average pattern, or the average age pattern of mortality change; $g_2\ (x)$ represents second order deviations; and so forth.

The procedure for constructing the new United Nations model life tables, however, was not to begin with the Gompertz formula and develop a new law of mortality. The procedure was one of statistical and demographic analysis. The relation between the models produced and historical attempts at the development of mortality laws was noted after the fact. Nevertheless, it provided reassurance to discover a theoretical actuarial/demographic basis for the statistical model.

Collection and evaluation of the data

As the new United Nations model life tables were to be empirically based, the initial stage of the project was that of data collection. This was undertaken for the United Nations by the Development Centre of the Organisation for Economic Co-operation and Development (OECD).[5] The OECD was able to provide the United Nations with an invaluable annotated file of census and vital registration data for developing countries. This file was updated at the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat, and augmented whenever possible with survey data and the tabulations necessary for indirect estimation.

Approximately 150 sets of death rates from about 60 developing countries were collected by OECD for evaluation at the United Nations. On a country-by-country basis each set of death rates was analysed using standard demographic techniques. The evaluation of data was frustrating at times and often tedious. Approximately 14 professional man-months were spent on evaluation. The goal was to gather together a refined data set for which there was reasonable certainty that the observed age patterns of mortality were indicative of actual mortality patterns rather than of data errors. The underlying philosophy was that the model life tables could only be as accurate as the life tables upon which they are based. Although it was known ahead of time that this approach might necessitate the basing of the model life-table system on a relatively small number of empirical tables, it was deemed preferable to a looser approach of accepting less reliable tables.

The data were evaluated by carrying out tests of both internal and external consistency. As a rule, a set of mortality rates was accepted for inclusion in the refined data set only if there was agreement among the various tests that the data were of high quality or the tests provided similar conclusions concerning adjustments necessary to the data and the extent of these adjustments. Exclusion of a set of death rates from the refined data set therefore does not necessarily indicate that the data were of low quality; it may simply indicate that there were inconsistencies between test results or a lack of certain information necessary to evaluate the data.

Various tests of internal consistency were made. Age-sex distributions of the population and age-specific sex ratios were evaluated to determine the extent of systematic age misstatement. If age misstatement were extensive, the data could not be relied on to produce accurate age patterns of mortality. Age-specific death rates were graphed to ensure that the resulting age patterns followed the normal pattern of high mortality at the youngest ages, falling to a trough around age 10 and then monotonically rising to the oldest ages. Through the use of Gompertz and Makeham curves it was also possible to investigate the death rates at the older ages to check for differential omission of deaths or overstatement of age, a problem not uncommon in developing countries.[6] These tests were of great value for data evaluation and the location of data errors, but generally were not helpful for determining how to adjust the data. Two variations of what have now become known as "death-distribution" methods proved very valuable in this regard, however. Developed by Brass and by Preston, these methods provide estimates of completeness of the recording of adult deaths (from either registration systems or surveys) under the assumption of non-differential omission of deaths by age.[7]

Tests for external consistency were essentially comparisons with other data sources. These tests were usually of three kinds: (1) comparisons of levels and age patterns of mortality from available surveys and vital registration systems; (2) estimates of completeness of death registration from matching surveys (i.e., surveys which match, on a case-by-case basis, deaths reported in a survey with those recorded in a vital registration system; and (3) comparison of levels and age patterns of mortality with those implied by application of indirect estimation techniques to survey or census data on children ever born and children surviving. These external tests often provided estimates of completeness of death registration within specific age segments and as such could be used to adjust the data.

In this way 72 input life tables (36 male and 36 female) were constructed for 22 developing countries. The set of life tables consists of 16 male-female pairs from 10 Latin American countries, 19 pairs from 11 Asian countries, and 1 pair from the African continent. Of the 72 life

[5] The base data collected by OECD are described in Organisation for Economic Co-operation and Development, *Mortality Project, Annotated Bibliography on the Sources of Demographic Data*, vols. 1–3 (Paris, 1979).

[6] See S. Horiuchi and A. J. Coale, "A simple equation for estimating the expectation of life at old ages" (Princeton University, mimeographed).

[7] See S. Preston and others, "Estimating the completeness of reporting of adult deaths in populations that are approximately stable", *Population Index*, vol. 46, No. 2 (Summer, 1980), pp. 179–202; and S. Preston and K. Hill, "Estimating the completeness of death registration", *Population Studies*, vol. 34, No. 2 (July 1980), pp. 349–366.

tables, 10 exhibited life expectancies at birth of under 50 years, and 10 of 70 years or older. Table 1 presents a list of the refined data bases upon which the new United Nations model life tables were based and their distribution by life expectancy at birth and sex.

We note, for comparative purposes, that in the Coale and Demeny system, the West region was constructed from 130 life tables for 21 countries; the North region from 9 life tables for 3 countries; the East region from 31 life tables for 4 countries; and the South region from 22 life tables for 5 countries. The United Nations sample was 36 life tables for 22 countries.

TABLE 1. DESCRIPTION OF LIFE TABLES CONSTRUCTED FOR THE UNITED NATIONS MODEL LIFE TABLE PROJECT

Country	Year	*Life expectancy at birth (years)* Male	Female
Africa			
Tunisia	1968–1969	52.7	52.5
Latin America			
Caribbean:			
Trinidad and Tobago	1920–1922	37.6	40.1
	1945–1947	53.0	55.8
	1959–1961	62.4	66.6
Middle America:			
Costa Rica	1962–1964	60.9	63.7
	1972–1974	67.5	71.2
El Salvador	1970–1972	54.9	60.1
Guatemala	1963–1965	46.8	48.0
Honduras	1960–1962	40.6	44.1
	1973–1975	50.1	54.3
Mexico	1969–1971	58.8	62.9
Temperate South America:			
Chile	1951–1953	51.6	55.6
	1959–1961	54.7	60.1
	1969–1971	58.9	64.9
Tropical South America:			
Colombia	1963–1965	57.7	59.7
Guyana	1959–1961	59.5	63.7
Peru	1969–1971	53.3	57.3
East Asia			
Other East Asia:			
Hong Kong	1960–1962	63.7	71.1
	1970–1972	67.6	75.2
	1976	69.6	76.6
Republic of Korea	1971–1975	59.3	66.1
South Asia			
Eastern South Asia:			
Philippines	1969–1971	58.7	64.0
Singapore	1969–1971	65.9	72.2
Thailand	1969–1971	56.5	60.8
Middle South Asia:			
Metlab (Bangladesh)	1974 and 1976 (average)	52.6	52.8
India	1970–1972	49.1	46.2
Iran	1973–1976	57.2	56.6
Sri Lanka	1945–1947	44.8	43.1
	1952–1954	58.4	57.3
	1962–1964	62.1	62.6
	1970–1972	63.8	66.7
Western South Asia:			
Arab countries			
Kuwait	1974–1976	65.9	70.3
Non-Arab countries			
Israel			
Jewish population	1948–1949	65.1	67.6
	1960–1962	70.8	72.6
	1971–1973	70.5	73.5
Non-Jewish population	1971–1973	66.6	69.9

METHODOLOGY OF MODEL LIFE TABLE CONSTRUCTION

Before choosing a method for construction of model life tables, various approaches were tested. This task was performed by Le Bras of the *Institut national d'études démographiques* in consultation with the Population Division of the Department of International Economic and Social Affairs, United Nations Secretariat.

The testing involved re-analysis of the data base used by Coale and Demeny in constructing their model life tables. Three procedures of constructing model life tables were examined: that used by Coale and Demeny,[8] the regression approach used by Ledermann,[9] and principal components analysis. Coale and Demeny, in their approach, brought together 326 life tables for developed and developing countries from the 19th and 20th centuries. For each of these life tables they drew graphs of the absolute deviations of q_x values from an average set of q_x values and studied these deviations. For quality control they removed from their data set all life tables whose deviations appeared to be extremely large and inexplicable. This essentially removed from their data set nearly all of the developing country life tables, leaving a final data set of 192 tables. Of these 192 tables, two thirds had no consistent pattern of deviations and were clustered into one group, called the West region because they were mainly from West European stock. Because of consistent patterns of deviation, 9 life tables from 3 countries were clustered into the North region, 31 tables from 4 countries into the East region, and 22 tables from 5 countries into the South region. Within each of these regions regression equations of the forms

$$\ln q_x = a_x + b_x e_{10}$$

and

$$q_x = a'_x + b'_x e_{10}$$

were estimated. The equations were fitted by standard regression techniques, one equation to be used when mortality was high, one when mortality was low and an average at middle levels. The statistical technique was not particularly aesthetic and sample sizes in all regions but the West were quite small. However, the tables have been extremely valuable for demographic analysis in developing countries and have been continually useful under circumstances in which they might not have been expected to be. For example, some Asian mortality patterns have similarities to the South region and some sub-Saharan African patterns to the North region.

The Ledermann tables began with the set of input life tables first used by the United Nations in constructing their original set in 1955. Under the assumption that the mortality patterns of these life tables did not cluster but instead formed a continuum, Ledermann did not do any initial clustering, as Coale and Demeny did, but instead used multiple regression techniques to estimate a series of equations of the form

$$_nq_x = A_x + \sum_{i=1}^{k} b_{xi} Q_i$$

where Q_i are chosen independent variables, equal to life expectancy at birth or mortality at a given age. Model life tables were generated based on both one independent

[8] A. J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations* (Princeton, Princeton University Press, 1966).

[9] S. Ledermann, *Nouvelles tables-types de mortalité* (Paris, Institut national d'études démographiques, Travaux et Documents, 1969), cahier no. 53.

variable ($k = 1$) and 2 independent variables ($k = 2$), and various alternatives of independent variables.

For classical principal components analysis, all input life tables would be included in one data set and an equation estimated of the form

$$f_x = U_{ox} + \sum_{i=1}^{k} a_i U_{ix},$$

or in vector notation

$$\begin{bmatrix} f_0 \\ f_1 \\ f_5 \\ , \\ , \\ , \\ , \\ f_{85} \end{bmatrix} = \begin{bmatrix} U_{0,0} \\ U_{0,1} \\ U_{0,5} \\ , \\ , \\ , \\ , \\ U_{0,85} \end{bmatrix} + \sum_{i=1}^{k} a_i \begin{bmatrix} U_{i,0} \\ U_{i,1} \\ U_{i,5} \\ , \\ , \\ , \\ , \\ U_{i,85} \end{bmatrix}$$

where f_x is a chosen life table function at age x, the U_{ox} vector represents the average of this life table function at each age over the entire set of input life tables, U_{1x} represents first order deviations from this average pattern, U_{2x} second order deviations, and so on. The principal components model is similar to more usual linear regression procedures in that the values of parameters are found which minimize sums of squared deviations. Distances between actual and predicted values are measured as perpendicular (orthogonal) distances from the line rather than vertical.

The three methods outlined above were tested by applying each to the original 192 tables of Coale and Demeny and comparing each of the 192 tables to that predicted on the basis of the model. Results of this work clearly pointed to principal components analysis as the best of the three methods for summarizing age patterns of mortality, and this approach was therefore adopted. The principal components analysis showed best fit when logit $({}_nq_x)$ or $\ln {}_nq_x$ was the dependent variable. The logit function was chosen because it limited predicted ${}_nq_x$ values to be in the range of (0,1). The principal components model we chose was therefore:

$$\text{logit } ({}_nq_x) = U_{ox} + \sum_{i=1}^{k} a_i U_{ix}$$

Before actually applying the model to the refined data set (i.e., the 36 male and 36 female developing country life tables), the expectation was that all these U_{ix} vectors would have clear demographic meaning. The vector U_{ox} would indicate the average age pattern of mortality in our data set. We expected U_{1x} to indicate the age pattern of mortality change and correspondingly a_1 to the amount of change, or level of mortality. These meanings were necessary to allow generation of a series of model life tables at various life expectancies at birth for publication purposes. We expected the additional U_{ix} vectors to indicate important deviations between actual and predicted life tables even after adjustment for level using the first component U_{1x}. For example, there might be a component indicating high mortality under age 5 and, possibly Asian life tables would have high weights on this component, and we could use that knowledge to build an Asian pattern by rewriting the principal components equation in the form

$$\text{logit } ({}_nq_x) = \underbrace{(U_{ox} + a_2 U_{2x})}_{\text{average pattern for Asia}} + \underbrace{a_1 U_{1x}}_{\text{generates different life expectancies}}$$

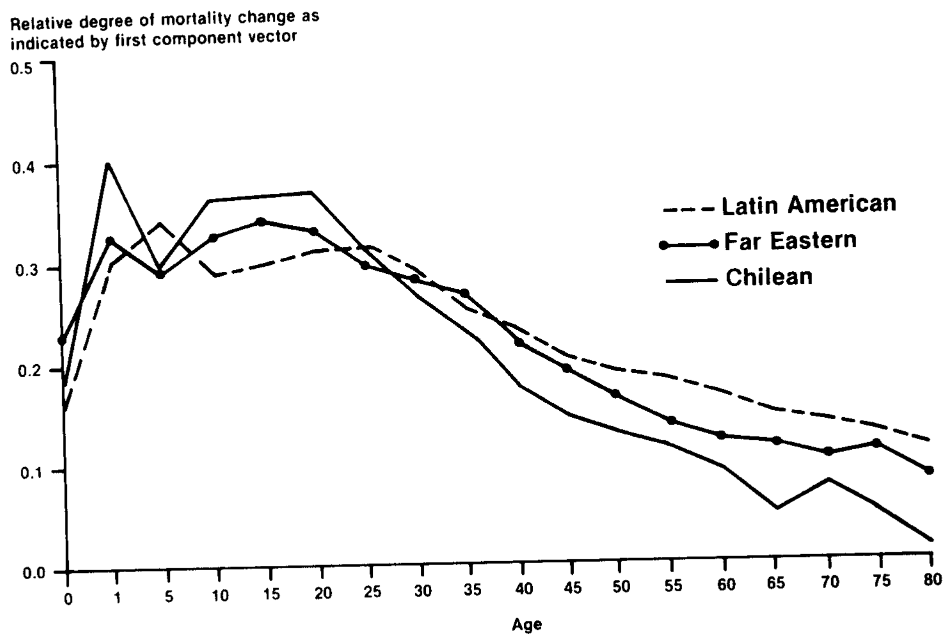
However, when the principal components model was applied to our data set, these demographic interpretations could not be made. Specifically, the first component did not represent the age pattern of mortality change. The reason appeared to be related to the clustering of age patterns on a more or less geographical basis.

There were four clear pattern groups and a few life tables which did not fit together well or easily into any other groups. The four pattern groups or clusters were as follows. The first cluster contained the life tables from the Latin American countries of Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico and Peru, as well as the non-American countries of the Philippines, Sri Lanka and Thailand. The second cluster was the very distinctive pattern of the Chilean life tables. The third pattern group was made up of tables from India, the Matlab Thana area of Bangladesh, Iran and Tunisia. The fourth cluster consisted of the tables from Hong Kong, Singapore, the Republic of Korea, Guyana and Trinidad and Tobago among the male populations, and Singapore, Guyana and Trinidad and Tobago among the female populations. These four patterns have been labelled respectively, the Latin American pattern, Chilean pattern, South Asian pattern and Far Eastern pattern, according to the geographical region which is predominant within each pattern group. Life tables from Israel and Kuwait, as well as from the female populations of Hong Kong and the Republic of Korea, did not cohere into any cluster and were therefore omitted from the principal components analysis and included only in construction of the "general pattern" of mortality described later.

As a first approach, principal components analysis was applied separately within each cluster. This was done with some scepticism, since sample sizes within each cluster were very small. The Latin American pattern consisted of 15 life tables from 10 countries; the Chilean pattern, 3 life tables from 1 country; the South Asian pattern, 4 life tables from 4 countries; and the Far Eastern pattern, 9 life tables from 5 countries. To our surprise the results were very good and very reasonable, except for the South Asian pattern, which because there was very little variation in mortality level among the included countries, presented component vectors with no demographic meaning. We were able to solve this problem by taking advantage of an empirical observation: the first component vector was nearly identical for the Latin American pattern, the Chilean pattern and the Far Eastern pattern. That is, in spite of quite different age patterns of mortality among clusters, the age pattern of mortality change was nearly identical. Figure I presents graphically the values of the first component vector for each of the three clusters for females. The comparison for males is similar. As can be seen, the first component for each cluster has essentially the same shape. The differences are well within expected sampling errors. We took advantage of this finding to make a slight variation on the principal components formula. Our new formula was

$$\text{logit } ({}_nq_x) = U_{ox}^c + \sum_{i=1}^{k} a_i U_{ix},$$

Figure I. Age pattern of mortality change for Latin American and Far Eastern countries and for Chile, as indicated by the first component vector (females)



where U^c_{ox} is the average pattern of mortality within each cluster. That is, we allowed the average pattern of mortality (the U_{ox} vector) to vary according to cluster, but the first and higher component vectors (U_{1x}, U_{2x}, . . .) were the same for each cluster.

DESCRIPTION OF MORTALITY AGE PATTERNS

Figure II presents graphically the resulting age patterns, of mortality by presenting the ratios q_x/q^w_x as a function of age x, where q_x is the mortality rate at age x for the given model and q^w_x is the mortality rate at age x in the Coale and Demeny West region model life table with the same expectation of life at age 10. The graphs show the ratios for life expectancy at birth of 40, 55 and 70 years. The graphs are presented for females only; males show similar deviations.

The first model, designated the Latin American pattern, is based on the life tables of Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico and Peru, as well as the non-American countries of the Philippines, Sri Lanka and Thailand, which were shown to have similar patterns of mortality. Compared to historical Western European experience, as described by the Coale-Demeny West region, this pattern shows high mortality during the infant and childhood years, high mortality again during young adult years and relatively low mortality during the older years. These deviations are rather small when mortality is high but increase as mortality declines, presumably reflecting the growing importance, relative to Western European experience, of diarrhoeal and parasitic disease during childhood and accidental deaths (mainly motor vehicle) during the prime ages, and the relatively low levels of cardiovascular diseases at the older ages. Tests have shown that Brazil and Argentina also seem to have similar patterns.

The second pattern of mortality presented in Figures I and II has been labelled the Chilean pattern. The Chilean pattern was estimated from Chilean life tables for the 1949–1951, 1959–1961 and 1969–1971 periods. It has some similarities to the Far Eastern pattern except for an extremely high infant mortality rate due presumably to deaths from respiratory diseases.[10] This pattern was unique in the sample of reliable life tables but is included because it may appear in areas where accurate evidence of age patterns of mortality is not yet available.

A third pattern delineated is the South Asian pattern of mortality. This pattern shows, relative to the West region tables, very high rates under age 15 and high rates again at the older ages, with correspondingly lower mortality for the prime age groups. Life tables for India, the Matlab-Thana area of Bangladesh, Iran and Tunisia all show this pattern. Similar patterns appear in less reliable life tables constructed for Pakistan, Nepal, Bangladesh and Turkey. Life tables constructed for Indonesia and China also show such a pattern, with the exception of remarkably low mortality under age 5. Cause of death data are nearly non-existent for these populations, but it can be surmised that the South Asian pattern is related to high incidences of infectious, parasitic and diarrhoeal diseases at the younger ages and high mortality from diarrhoeal and respiratory diseases at the oldest ages. It is interesting to note that the deviations in these life tables are very similar to those of the Coale-Demeny South region, except that the South region deviations are somewhat less extreme.

A fourth identified age pattern of mortality has been labelled the Far Eastern pattern. Goldman recently noted the existence of a distinctive pattern of mortality in selected Far Eastern populations.[11] This pattern is char-

[10] See World Health Organization, *World Health Statistics Annual, 1979*, vol. 1, *Vital Statistics and Causes of Death* (Geneva, 1979), table 9. The Chilean rate is especially high for pneumonia (A91–92). It has also been suggested that early weaning may be responsible for Chile's high infant mortality rate. See S. J. Plank and M. L. Milanesi, "Infant feeding and infant mortality in rural Chile", *Bulletin of the World Health Organization*, vol. 48, No. 2 (1973), pp. 203–210.

[11] N. Goldman, "Far Eastern patterns of mortality", *Population Studies*, vol. 34, No. 1 (1980), pp. 5–19.

Figure II. Deviations of developing country patterns from the Coale-Demeny West region (females)

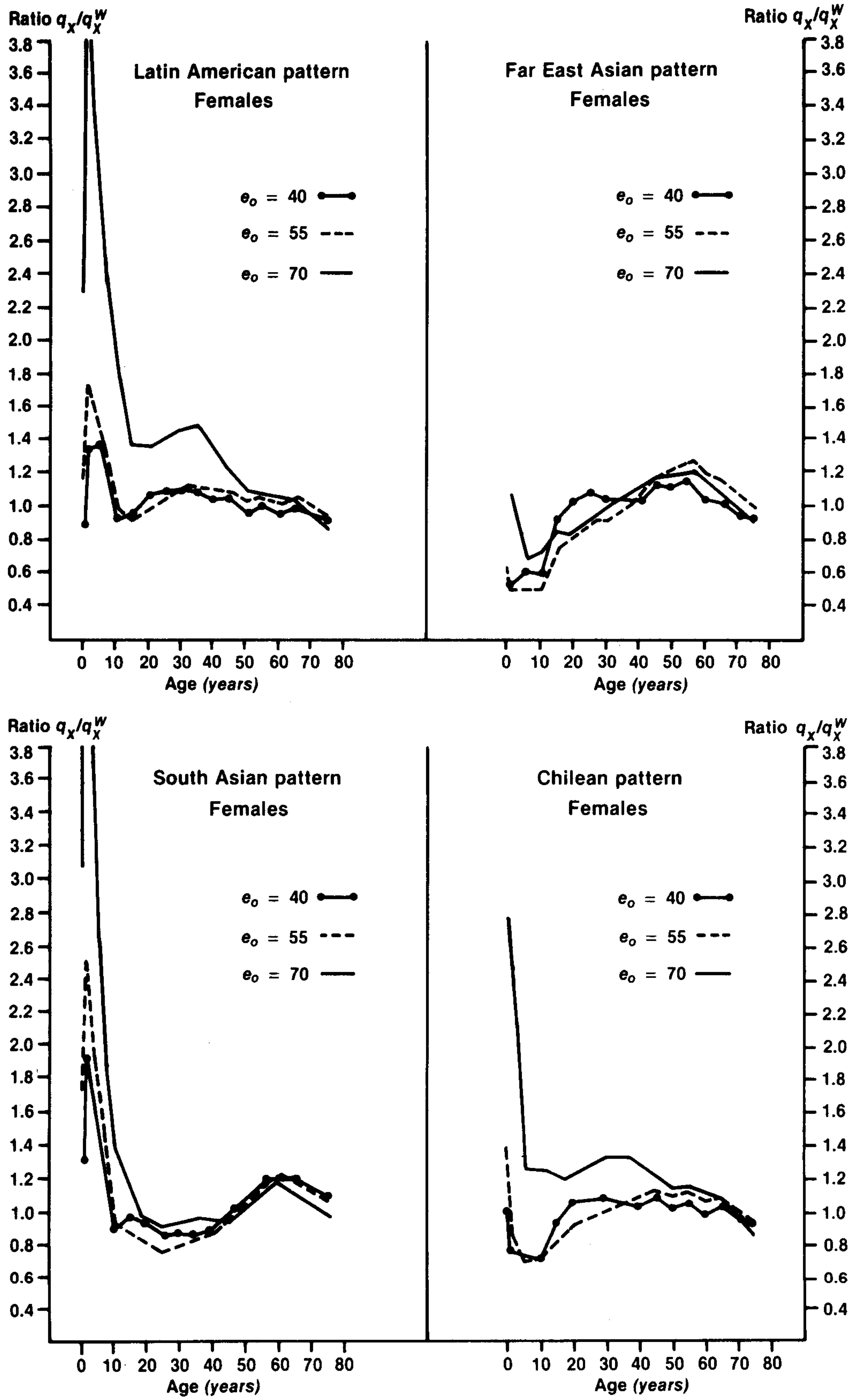


TABLE 2. FIRST THREE PRINCIPAL COMPONENTS

Age x	Males: 1st component U_{1x}	Males: 2nd component U_{2x}	Males: 3rd component U_{3x}	Females: 1st component U_{1x}	Females: 2nd component U_{2x}	Females: 3rd component U_{3x}
0........	.23686	−.46007	.09331	.18289	−.51009	.23944
1........	.36077	−.68813	−.29269	.31406	−.52241	−.11117
5........	.33445	.06414	−.47139	.31716	.08947	.07566
10........	.30540	.12479	−.17403	.30941	.03525	.06268
15........	.28931	.24384	.10715	.32317	.03132	−.26708
20........	.28678	.10713	.28842	.32626	.07843	−.39053
25........	.27950	.06507	.33620	.30801	.06762	−.28237
30........	.28023	.03339	.33692	.29047	.00482	−.14277
35........	.26073	.02833	.21354	.25933	−.01409	−.05923
40........	.23626	.06473	.15269	.22187	−.02178	.18909
45........	.20794	.08705	.06569	.19241	.01870	.24773
50........	.17804	.10620	.00045	.17244	.04427	.33679
55........	.15136	.11305	−.03731	.15729	.08201	.34121
60........	.13217	.09467	−.10636	.14282	.08061	.38290
65........	.12243	.10809	−.11214	.12711	.15756	.26731
70........	.11457	.14738	−.22258	.11815	.24236	.14442
75........	.10445	.21037	−.19631	.11591	.30138	.09697
80........	.08878	.30918	−.38123	.09772	.50530	−.13377

acterized by high male death rates at older ages relative to their death rates at younger ages and very high sex ratios of mortality at the older ages. Goldman found some evidence that this pattern may be related to a high incidence of tuberculosis in the past which is still evident among adult males in these populations. Research at the United Nations has duplicated Goldman's findings for these populations but has also found a similar pattern of high adult mortality relative to younger age mortality in Guyana and Trinidad and Tobago. However, in these latter two populations females also show relatively high mortality at the adult ages so that large sex differentials in mortality at these ages do not appear. A recent life table constructed for Peninsular Malaysia at the United States Bureau of the Census also shows this latter characteristic.[12] The term "Far Eastern pattern" is generalized here to include age patterns characterized by high older age death rates relative to younger age death rates, irrespective of sex differentials. Among populations so far identified as having this pattern are the male populations of Hong Kong, Singapore, the Republic of Korea, Peninsular Malaysia, Guyana and Trinidad and Tobago; and the female populations of Singapore, Malaysia, Guyana and Trinidad and Tobago.

The fifth pattern, the general pattern (graph not shown), is constructed as an average of all the life tables in the refined data set, without consideration of cluster. This average pattern appears very similar to that of the Coale and Demeny West region. The countries included in the West region will of course portray patterns similar to that of the general pattern.

The first three principal component vectors are presented in table 2.

As expected, the first principal component models the age pattern of mortality change. According to this component, as mortality declines, change is greatest during the childhood years and lessens as age increases. Declines during the infancy are somewhat smaller than those during childhood, similar to those that take place during the later middle years of life. Pattern of mortality change, as used here, is defined as change in the logit $({}_nq_x)$ function of the life table. Since, except when ${}_nq_x$ values are quite high, the logit $({}_nq_x)$ is very close to one half of $1n\,{}_nq_x$ values, it is possible to think of elements of the first component as representing proportional change in ${}_nq_x$ values.

The second component appears to account mainly for characteristic differences among life tables in mortality under age 5. These would be characteristics that were not fully accounted for by either the initial clustering of the mortality patterns into four groups or by the age pattern of mortality change described by the first component. The third component appears to affect mortality during the childbearing age for females and at various ages for males; if only ages 10 and over are considered, it seems also to allow for a twisting of the logit $({}_nq_x)$ curve around age 50 for males and 35 for females.

Table 3 presents in abbreviated fashion the set of model life tables that appear in the forthcoming United Nations publication. These are one-component models, based on the five average patterns (the four distinct pattern groups and the overall general pattern) and the age pattern of mortality change defined by the first principal component.

ADDITIONAL MODELS COMPLEMENTARY TO THE MODEL LIFE TABLES

The major output of the United Nations model life table project is the abridged life tables themselves. However, for estimating demographic parameters from deficient data and for carrying out population projections additional models can be useful. Therefore complementary to the abridged model life tables themselves, the United Nations is producing and publishing model age patterns of mortality under age 5, models of sex differentials in mortality, interpolated unabridged model life tables and model stable populations.

Model age patterns of mortality under age 5

One of the most powerful techniques developed by demographers for estimating levels and trends in mortality is that developed by Brass, with later modifications by

[12]United States of America, Department of Commerce, Bureau of the Census, *Country Demographic Profiles: Malaysia*, by G. S. Finch and A. Sweetser (Washington, D.C., 1979), table 5, p. 8.

TABLE 3. UNITED NATIONS MODEL LIFE TABLES

	Latin American pattern					
	e_0^o = 35 years		e_0^o = 55 years		e_0^o = 75 years	
Age	$_nq_x$	e_x^o	$_nq_x$	e_x^o	$_nq_x$	e_x^o
			Males			
0..........	.20429	35.00	.10144	55.00	.02499	75.00
1..........	.16631	42.90	.05399	60.17	.00593	75.92
5..........	.04790	47.19	.01553	59.53	.00194	72.36
10..........	.02522	44.44	.00889	55.43	.00132	67.50
15..........	.03427	40.52	.01284	50.90	.00212	62.58
20..........	.05051	36.87	.01930	46.53	.00326	57.71
25..........	.05679	33.69	.02232	42.40	.00395	52.89
30..........	.06449	30.57	.02542	38.30	.00449	48.09
35..........	.07363	27.50	.03117	34.24	.00625	43.30
40..........	.08418	24.48	.03893	30.26	.00914	38.55
45..........	.09948	21.50	.05096	26.38	.01440	33.88
50..........	.11849	18.60	.06758	22.65	.02323	29.34
55..........	.14939	15.76	.09411	19.11	.03872	24.97
60..........	.19205	13.08	.13065	15.82	.06165	20.87
65..........	.26327	10.58	.18943	12.81	.09795	17.07
70..........	.35208	8.47	.26750	10.20	.15128	13.63
75..........	.45210	6.73	.36482	8.00	.22999	10.59
80..........	.56382	5.31	.48718	6.18	.35272	7.98
85..........	1.00000	4.21	1.00000	4.78	1.00000	5.96
			Females			
0..........	.16750	35.00	.09415	55.00	.03209	75.00
1..........	.18826	40.97	.06942	59.68	.01038	76.48
5..........	.05672	46.16	.01877	60.03	.00263	73.27
10..........	.02923	43.78	.00975	56.13	.00142	68.45
15..........	.04140	40.03	.01327	51.66	.00178	63.55
20..........	.05832	36.64	.01871	47.32	.00248	58.66
25..........	.06576	33.75	.02262	43.17	.00337	53.80
30..........	.07340	30.95	.02700	39.11	.00450	48.97
35..........	.07842	28.20	.03228	35.12	.00656	44.18
40..........	.07871	25.39	.03692	31.21	.00949	39.45
45..........	.08642	22.35	.04509	27.31	.01399	34.80
50..........	.10329	19.22	.05819	23.48	.02060	30.26
55..........	.13620	16.14	.08201	19.77	.03236	25.84
60..........	.18414	13.28	.11874	16.30	.05231	21.62
65..........	.25438	10.70	.17734	13.14	.08878	17.66
70..........	.34558	8.49	.25631	10.42	.14143	14.12
75..........	.45425	6.67	.35385	8.13	.20976	11.01
80..........	.56938	5.24	.48161	6.22	.33533	8.25
85..........	1.00000	4.12	1.00000	4.78	1.00000	6.12

	Chilean pattern					
	e_0^o = 35 years		e_0^o = 55 years		e_0^o = 75 years	
Age	$_nq_x$	e_x^o	$_nq_x$	e_x^o	$_nq_x$	e_x^o
			Males			
0..........	.23869	35.00	.11128	55.00	.02374	75.00
1..........	.09829	44.87	.02623	60.84	.00221	75.82
5..........	.02850	45.61	.00796	58.45	.00079	71.99
10..........	.02094	41.88	.00651	53.90	.00079	67.04
15..........	.03395	37.72	.01132	49.23	.00155	62.09
20..........	.05094	33.95	.01736	44.77	.00242	57.18
25..........	.06206	30.64	.02191	40.51	.00323	52.32
30..........	.07819	27.49	.02784	36.36	.00410	47.48
35..........	.09072	24.61	.03505	32.33	.00595	42.66
40..........	.10738	21.81	.04594	28.41	.00930	37.90
45..........	.12612	19.13	.06057	24.65	.01507	33.23
50..........	.14981	16.53	.08121	21.07	.02514	28.70
55..........	.18555	14.00	.11247	17.70	.04258	24.37
60..........	.23837	11.61	.15792	14.62	.06990	20.33
65..........	.31412	9.46	.22177	11.88	.10885	16.66
70..........	.40388	7.66	.30294	9.53	.16438	13.37
75..........	.49748	6.21	.39775	7.59	.24278	10.49
80..........	.59232	5.05	.50738	6.00	.35783	8.03
85..........	1.00000	4.12	1.00000	4.76	1.00000	6.11

TABLE 3 (*continued*)

Age	*Chilean pattern* $e_0^o = 35$ *years* $_nq_x$	e_x^o	$e_0^o = 55$ *years* $_nq_x$	e_x^o	$e_0^o = 75$ *years* $_nq_x$	e_x^o
			Females			
0..........	.21832	35.00	.11998	55.00	.03895	75.00
1..........	.12215	43.68	.03903	61.45	.00503	77.03
5..........	.03375	45.57	.00997	59.89	.00123	73.42
10..........	.02588	42.07	.00783	55.47	.00101	68.50
15..........	.04509	38.12	.01312	50.89	.00156	63.57
20..........	.06489	34.80	.01894	46.53	.00221	58.66
25..........	.07236	32.03	.02278	42.38	.00301	53.79
30..........	.08069	29.33	.02733	38.30	.00407	48.94
35..........	.08508	26.69	.03255	34.31	.00599	44.13
40..........	.08856	23.94	.03912	30.38	.00926	39.38
45..........	.09932	21.02	.04930	26.51	.01427	34.72
50..........	.11943	18.06	.06453	22.75	.02150	30.19
55..........	.15667	15.17	.09113	19.14	.03411	25.79
60..........	.20708	12.51	.12982	15.80	.05468	21.61
65..........	.28316	10.11	.19353	12.76	.09360	17.70
70..........	.36964	8.12	.26953	10.20	.14421	14.26
75..........	.47913	6.44	.36865	8.04	.21300	11.22
80..........	.57678	5.20	.48161	6.30	.32699	8.55
85..........	1.00000	4.18	1.00000	4.94	1.00000	6.48

Age	*South Asian pattern* $e_0^o = 35$ *years* $_nq_x$	e_x^o	$e_0^o = 55$ *years* $_nq_x$	e_x^o	$e_0^o = 75$ *years* $_nq_x$	e_x^o
			Males			
0..........	.22680	35.00	.11375	55.00	.02713	75.00
1..........	.20238	44.17	.06721	61.02	.00699	76.09
5..........	.04734	51.03	.01523	61.32	.00179	72.61
10..........	.01901	48.44	.00663	57.22	.00093	67.74
15..........	.02154	44.33	.00796	52.59	.00124	62.80
20..........	.02520	40.26	.00941	47.99	.00149	57.87
25..........	.03005	36.23	.01155	43.42	.00192	52.96
30..........	.03718	32.27	.01431	38.90	.00238	48.05
35..........	.04758	28.42	.01971	34.43	.00373	43.16
40..........	.06325	24.71	.02875	30.07	.00642	38.31
45..........	.08465	21.20	.04284	25.88	.01158	33.54
50..........	.11706	17.92	.06649	21.92	.02211	28.90
55..........	.15488	14.96	.09753	18.29	.03914	24.50
60..........	.21659	12.23	.14844	14.98	.06922	20.38
65..........	.29286	9.90	.21269	12.14	.10930	16.70
70..........	.38910	7.97	.29925	9.73	.16948	13.42
75..........	.48246	6.50	.39301	7.81	.24827	10.63
80..........	.56743	5.37	.49039	6.29	.35190	8.29
85..........	1.00000	4.45	1.00000	5.08	1.00000	6.44
			Females			
0..........	.20275	35.00	.11372	55.00	.03664	75.00
1..........	.20976	42.81	.07578	61.01	.01006	76.85
5..........	.05278	49.82	.01673	61.90	.00206	73.61
10..........	.02254	47.45	.00720	57.91	.00093	68.76
15..........	.03321	43.49	.01015	53.32	.00119	63.82
20..........	.04043	39.89	.01228	48.84	.00142	58.89
25..........	.04178	36.47	.01359	44.41	.00177	53.97
30..........	.04697	32.95	.01636	39.99	.00240	49.06
35..........	.05044	29.45	.01974	35.81	.00358	44.18
40..........	.05583	25.88	.02514	31.28	.00586	39.33
45..........	.06743	22.26	.03401	27.02	.00970	34.54
50..........	.09613	18.68	.05285	22.87	.01742	29.85
55..........	.13962	15.39	.08266	19.00	.03069	25.33
60..........	.20267	12.46	.12967	15.47	.05450	21.05
65..........	.27633	9.98	.19183	12.39	.09251	17.11
70..........	.37868	7.82	.28149	9.71	.15153	13.58
75..........	.50317	6.09	.39631	7.52	.23298	10.53
80..........	.60457	4.88	.51475	5.85	.35647	7.94
85..........	1.00000	3.89	1.00000	4.54	1.00000	5.94

TABLE 3 (*continued*)

Age	Far Eastern pattern					
	e_0^o – 35 years		e_0^o – 55 years		e_0^o – 75 years	
	$_nq_x$	e_x^o	$_nq_x$	e_x^o	$_nq_x$	e_x^o
			Males			
0..........	.16455	35.00	.06760	55.00	.00990	75.00
1..........	.10907	40.83	.02602	57.97	.00131	74.75
5..........	.03958	41.66	.00995	55.48	.00061	70.84
10..........	.03032	38.28	.00855	51.01	.00067	65.89
15..........	.04386	34.39	.01335	46.43	.00120	60.93
20..........	.06222	30.85	.01940	42.02	.00180	56.00
25..........	.06908	27.73	.02231	37.80	.00220	51.10
30..........	.08271	24.60	.02690	33.61	.00265	46.20
35..........	.10044	21.59	.03583	29.46	.00418	41.32
40..........	.12743	18.71	.05114	25.46	.00742	36.48
45..........	.15653	16.07	.07165	21.69	.01338	31.73
50..........	.20190	13.58	.10662	18.16	.02623	27.13
55..........	.24364	11.39	.14536	15.02	.04578	22.78
60..........	.32370	9.25	.21509	12.14	.08319	18.74
65..........	.41407	7.49	.29655	9.76	.13152	15.20
70..........	.50972	6.09	.39066	7.82	.19741	12.10
75..........	.59841	5.01	.48953	6.27	.28592	9.44
80..........	.67982	4.17	.59347	5.03	.40997	7.21
85..........	1.00000	3.49	1.00000	4.08	1.00000	5.50
			Females			
0..........	.14593	35.00	.07498	55.00	.02110	75.00
1..........	.11498	39.92	.03485	58.44	.00370	75.62
5..........	.03800	40.93	.01072	56.50	.00109	71.89
10..........	.02862	37.45	.00827	52.08	.00089	66.97
15..........	.06039	33.48	.01692	47.49	.00165	62.02
20..........	.08444	30.46	.02380	43.26	.00229	57.12
25..........	.09619	28.03	.02942	39.26	.00352	52.25
30..........	.10268	25.74	.03382	35.37	.00425	47.41
35..........	.10837	23.41	.04051	31.52	.00642	42.60
40..........	.11250	20.95	.04880	27.74	.01018	37.86
45..........	.12985	18.29	.06375	24.03	.01663	33.22
50..........	.16150	15.64	.08705	20.49	.02663	28.74
55..........	.20707	13.17	.12089	17.20	.04217	24.45
60..........	.26347	10.95	.16654	14.20	.06633	20.41
65..........	.33175	8.98	.22819	11.53	.10537	16.67
70..........	.42131	7.22	.31021	9.19	.16048	13.32
75..........	.52993	5.72	.41272	7.20	.23289	10.36
80..........	.63508	4.56	.53882	5.54	.36540	7.72
85..........	1.00000	3.63	1.00000	4.29	1.00000	5.73

Age	General pattern					
	e_0^o – 35 years		e_0^o – 55 years		e_0^o – 75 years	
	$_nq_x$	e_x^o	$_nq_x$	e_x^o	$_nq_x$	e_x^o
			Males			
0..........	.20001	35.00	.09376	55.00	.01937	75.00
1..........	.14156	42.67	.04124	59.66	.00344	75.48
5..........	.04457	45.48	.01324	58.16	.00129	71.73
10..........	.02643	42.49	.00863	53.91	.00103	66.82
15..........	.03695	38.57	.01289	49.36	.00172	61.89
20..........	.05159	34.95	.01835	44.97	.00251	56.99
25..........	.05702	31.71	.02090	40.76	.00302	52.13
30..........	.06760	28.48	.02489	36.58	.00358	47.28
35..........	.07932	25.36	.03159	32.44	.00524	42.44
40..........	.09513	22.32	.04178	28.42	.00829	37.65
45..........	.11582	19.40	.05694	24.54	.01391	32.94
50..........	.14367	16.61	.07956	20.87	.02429	28.37
55..........	.18046	13.97	.11135	17.45	.04167	24.01
60..........	.23679	11.49	.15940	14.31	.06999	19.93
65..........	.31732	9.28	.22755	11.53	.11123	16.23
70..........	.41352	7.43	.31513	9.17	.17118	12.93
75..........	.51359	5.97	.41709	7.24	.25635	10.06
80..........	.61162	4.83	.53082	5.69	.37816	7.64
85..........	1.00000	3.92	1.00000	4.50	1.00000	5.77

TABLE 3 (continued)

Age	General pattern e_0^o = 35 years $_nq_x$	e_x^o	e_0^o = 55 years $_nq_x$	e_x^o	e_0^o = 75 years $_nq_x$	e_x^o
			Females			
0..........	.16449	35.00	.08977	55.00	.02804	75.00
1..........	.15856	40.82	.05438	59.39	.00692	76.16
5..........	.05244	44.26	.01642	58.73	.00198	72.68
10..........	.03107	41.57	.00986	54.67	.00124	67.82
15..........	.04917	37.82	.01502	50.19	.00173	62.90
20..........	.06735	34.64	.02061	45.91	.00234	58.00
25..........	.07348	31.96	.02416	41.82	.00311	53.13
30..........	.08069	29.29	.02845	37.80	.00414	48.29
35..........	.08369	26.65	.03314	33.83	.00596	43.48
40..........	.08569	23.85	.03894	29.90	.00904	38.73
45..........	.09667	20.86	.04917	26.01	.01399	34.06
50..........	.12076	17.82	.06680	22.22	.02196	29.50
55..........	.15897	14.91	.09446	18.62	.03497	25.10
60..........	.21214	12.25	.13565	15.29	.05668	20.92
65..........	.28340	9.86	.19654	12.28	.09428	17.01
70..........	.38157	7.77	.28304	9.66	.15140	13.50
75..........	.50256	6.05	.39465	7.47	.23023	10.44
80..........	.61176	4.78	.52134	5.73	.36089	7.79
85..........	1.00000	3.77	1.00000	4.40	1.00000	5.76

Sullivan and Trussell.[13] The technique uses data on children ever born and children surviving tabulated by either age of mother or duration of marriage to provide quite robust estimates of the probability of a child dying before age 2, 3 and 5. Model life tables are used to provide corresponding estimates of the more common demographic parameters, the infant mortality rate and life expectancy at birth. This procedure requires estimates therefore of single-year mortality under age 5.

The method chosen to generate estimates of single-year mortality under age 5 was application of the three-parameter interpolation formula

$$\ln(-\ln {_1q_x}) = \ln t_1 + t_3 \ln(x + t_2)$$

where x is age and t_1, t_2 and t_3 are chosen so that the interpolation equation is consistent with given values of $_1q_0$, $_4q_1$, and $_5q_5$.

The equation was chosen after observation that in a wide range of countries, $\ln(-\ln {_1q_x})$ values were linearly related to $\ln x$ for ages 1 through 7 or 8 years. The simple addition of the parameter t_2 brought infant mortality in line with the linear relationship.

Model sex differentials of mortality

Some estimation techniques such as the children ever born/children surviving approach referred to previously often provide estimates for both sexes combined only, because the requisite tabulations are often not prepared separately for each sex. Other indirect techniques, such as the orphanhood approach for estimating adult mortality, appear to provide robust estimates of females mortality only.

As a result, it is often useful to have estimates of model sex differentials in mortality. Analysis of differences in male and female life expectancy for the input data set indicated three different patterns of sex differentials in mortality and that the grouping of countries by pattern of sex differentials was not identical to the grouping by age patterns described earlier. Generally, in comparison to the average differentials from the entire data set, the Asian countries, excluding those from the Far East, had relatively high mortality for a given level of female mortality; the Latin American countries had relatively low female mortality; and the Far East Asian countries, extremely low female mortality relative to male mortality. Different from the age pattern clustering, the sex differentials for the Caribbean countries grouped with the Latin American pattern rather than with the Far East Asian countries and Sri Lanka; Thailand and the Philippines grouped with the other Asian countries, rather than with Latin America.

Table 4 presents average sex differentials for different life expectancies at birth for the various regions, as estimated by orthogonal regression lines. Sex differentials for each of the four regions in the Coale and Demeny system are also presented for comparison purposes.

TABLE 4. FEMALE MINUS MALE LIFE EXPECTANCY AT BIRTH (IN YEARS)

Region	Life expectancy at birth (both sexes combined) 40 years	50 years	60 years	70 years
Latin America..........	2.1	3.3	4.0	4.6
Asia (excluding Far East)..........	−2.9	−0.8	1.4	3.5
Far East Asia..........	x	x	6.8	7.1
Above three regions combined..........	0.8	2.0	3.3	4.6
West region..........	2.7	2.9	3.6	4.0
North region..........	3.1	3.4	3.7	3.7
East region..........	2.9	3.4	4.1	4.7
South region..........	1.7	2.8	3.8	3.9

Interpolated unabridged model life tables

The projection of a population by age and sex has been a valuable tool to demographers and national planners for understanding the consequences of various trends of

[13] Various approaches now exist for estimating early age mortality from tabulations of children ever born and children surviving. For a description of these approaches, see *Manual X: Indirect Techniques for Demographic Estimation* (United Nations publication, forthcoming).

mortality, fertility and migration on a country's demographic and social future. In the past, population projections for developing countries have generally been five-year projections. But as fertility has begun to decline, often quite rapidly, in many countries there has been an increasing need for single-year population projections. These single-year projections require unabridged, single-year life tables. Unabridged model life tables corresponding to the abridged model life tables have been constructed at the United Nations by use of an eight-parameter formula for the age curve of mortality.

$$ {}_1q_x = A^{(x+B)^C} + D^{-E(\ln x - \ln F)^2} + \frac{GH^x}{1+GH^x} $$

developed by Heligman and Pollard.[14] The equations were fit to the ${}_nq_x$ values of the abridged model life tables by least squares procedures and produced single-year tables very consistent with the abridged model tables.

Model stable populations

Model stable populations have also been constructed corresponding to the new model life tables. The stable populations have been constructed corresponding to growth rates ranging from 0.0 per cent to 4.0 per cent at intervals of 0.5.

FINAL OBSERVATIONS AND SUMMARY

The first effort at construction of model life tables was that made by the United Nations with the publication in 1955 of *Age and Sex Patterns of Mortality: Model Life-Tables for Under-Developed Countries.*[15] These life tables and the later families of model life tables constructed by Coale and Demeny have formed an important basis for demographic estimation in developing countries. The early United Nations tables were based on a large sample of observed mortality patterns for both developing and developed countries. However, the quality of the data for these recorded life tables was very uneven. In construction of their model life tables, Coale and Demeny removed from their data set of empirical mortality patterns life tables which appeared to be of questionable quality. As a result the Coale and Demeny models are based almost entirely on recorded mortality patterns of populations of European stock. As model life tables are used mainly for demographic analysis in currently developing countries, it is necessary when using these tables to assume that these countries exhibited age patterns similar to the historical European experience.

Recently, owing to improvements in both quantity and quality of mortality and population data in less developed countries, as well as the development of various techniques for evaluating the quality of such data, it has become possible to consider constructing model life tables based on mortality patterns actually observed for developing countries.

The new United Nations model life tables are based on observed age patterns of mortality for developing countries. On a country-by-country basis, age-sex specific death rates were calculated and carefully evaluated. When data was proven to be of high quality or when reliable adjustments could be made, the set of age-sex specific death rates were included as part of the final data set. In this way 36 male life tables and 36 female life tables were chosen as the basis for construction of model life tables. A list of these life tables is given in table 1.

Analysis of the life tables in this refined data set indicated four major age patterns of mortality. These patterns have been labelled the Latin American pattern, the Chilean pattern, the South Asian pattern and the Far Eastern pattern, according to the geographical region predominant in each pattern. The characteristics of these patterns are displayed in figure II.

After testing various methodologies, a variant of classical principal components analysis was used to actually construct the model life tables. This approach took advantage of the observation that age patterns of mortality change for countries appeared to be similar enough, in spite of different actual age patterns of mortality that were present in the data set, to permit all countries to be treated together as one data set (reducing sample size problems), while ensuring that the principal component vectors had clear demographic meaning.

The first three principal component vectors are presented in table 2. The first principal component vector models the age pattern of mortality change. When combined with each of the five mortality patterns, five model patterns of mortality result and these are presented, in abreviated form, in table 3.

The second and third components add flexibility to the model life table system. The second component models characteristic differences in mortality under age 5. The third component affects mortality during the childbearing ages for females and at various ages for males. These two additional components can be used to adjust the published one-component models to more closely resemble special characteristics of actual mortality patterns under study. In this way the new model system has flexibility similar to that of the Brass logit system.

In addition to publication of the model life tables themselves, the United Nations model life tables project has also produced corresponding models of single-year mortality under age 5, sex differentials, interpolated unabridged model life tables, and model stable populations. A manual of computer programs which facilitate use of the model life table system is also in preparation.

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[14]L. Heligman and J. H. Pollard, "The age pattern of mortality", *The Journal of the Institute of Actuaries,* vol. 107, part 1, No. 434 (June 1980), pp. 49-80.

[15]United Nations publication, Sales No. E.55.XIII.9.

A NOTE ON ESTIMATING THE CAUSE OF DEATH STRUCTURE IN HIGH MORTALITY POPULATIONS

A. D. Lopez and T. H. Hull***

SUMMARY

Strategies for reducing mortality should be based on an informed assessment of the underlying structure of causes of death. In the absence of an adequate vital registration scheme, cause of death information is generally derived from fragmentary data which are often limited to specific sectors of the population. Using the previous mortality experience of industrialized countries at higher levels of mortality and the cause of death returns of contemporary developing societies with reasonably accurate and complete mortality data, a linear model has been developed to estimate the cause-structure of mortality in a population from knowledge of the crude death rate alone. Through an appropriate weighting of age-cause-specific mortality rates, emphasis is placed on those causes of death likely to be of greatest concern in high mortality populations.

Using the model parameters derived in this fashion, the technique is applied to estimate the cause-structure of mortality in Java. The resulting distribution of deaths differs markedly from that suggested by an older age-standard and is much more in accord with epidemiological opinion about likely causes of death based on rural health surveys, hospital records and other health data. Regression parameters for estimating the cause of death structure during infancy and early childhood are also shown and may be used independently of the all-age regression estimates.

With the widespread adoption of new indirect methods to estimate demographic parameters from limited data, much more has been learned about the level and trend of mortality in a number of developing countries. At the same time, systems for the collection of cause of death data, such as lay reporting schemes, have generally failed to provide a more reliable account of the underlying cause of death structure in these populations. Consequently, health policies designed to reduce overall levels of mortality continue to be based on fragmentary and often highly questionable evidence about the relative impact of certain causes of death.

The possibility exists, however, that the cause structure of mortality can be estimated with some confidence through an appropriate model relationship depending on a single parameter such as the general level of mortality prevailing in the population. Hull and Rohde (1978), for example, in their study of mortality in Java in the early 1970s, employed a series of linear relationships of the form

$$M_i = a_i + b(M)$$

to estimate the cause-specific death rate (M_i) from the overall crude death rate (M). The set of coefficients (a_i, b_i) used to define the model were originally derived by Preston (1976, p. 18) from the recorded mortality experience of 165 populations at various stages of development using the age-standardized death rate as a summary index of the mortality schedule.[1]

An important consideration in the formulation of the model is the choice of weights to be applied to the respective age and age-cause-specific death rates. In deriving his set of functional relationships, Preston chose as a standard the West female stable population age structure defined by an expectation of life of 65 years and an annual growth rate of 1 per cent. As a result, the standardized mortality rates, and hence the coefficients (a_i, b_i), are more representative of mortality patterns at the older ages than of the cause of death structure in a typical developing country. Clearly, if inferences are to be drawn about the relationship between M_i and M in a population with a comparatively high growth rate, they

TABLE 1. PERCENTAGE DISTRIBUTION OF STANDARD POPULATIONS BY BROAD AGE GROUPS

Age last birthday	West female stable population with: $e_0^o = 45.0$, $r = 0.02$ (younger standard)	$e_0^o = 65.0$, $r = 0.01$ (older standard)
0–4	15.4	10.0
5–14	24.3	18.2
15–44	43.8	43.1
45–64	12.8	19.4
65+	3.7	9.3

Source: Coale and Demeny (1966).

*Division of Health Statistics, World Health Organization, Geneva, Switzerland.
**Department of Demography, Australian National University, Canberra, Australia.

[1]For a description of the populations comprising the basic data set, see Preston (1976), pp. 3 and 4.

TABLE 2. COEFFICIENTS FROM THE REGRESSION OF AGE-STANDARDIZED CAUSE-SPECIFIC MORTALITY RATES (M_i) ON THE AGE-STANDARDIZED DEATH RATE FOR ALL CAUSES COMBINED (M)

	Regression coefficients from the simple linear regression $M_i = a_i + b_i \cdot M$ (standard error of b_i given in parentheses) for death rates[a] based on the West female stable population with:									
	$e^o_0 = 45.0, r = 0.02$						$e^o_0 = 65.0, r = 0.01$			
	Males		*Females*		*Both sexes*		*Males*		*Females*	
Cause of death category (i)	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
Respiratory tuberculosis	−0.00040	0.09350 (0.00426)	−0.00029	0.09264 (0.00452)	−0.00034	0.09254 (0.00307)	−0.0011	0.1188 (0.0054)	−0.0007	0.1059 (0.0049)
Other infectious and parasitic diseases	−0.00094	0.16661 (0.00610)	−0.00065	0.16272 (0.00583)	−0.00076	0.16153 (0.00432)	−0.0015	0.1458 (0.0062)	−0.0011	0.1398 (0.0052)
Neoplasms	0.00104	−0.02633 (0.00230)	0.00079	−0.01039 (0.00167)	0.00091	−0.01770 (0.00147)	0.0024	−0.0569 (0.0050)	0.0016	−0.0245 (0.0035)
Cardiovascular diseases	0.00187	0.00622 (0.00682)	0.00126	0.03384 (0.00543)	0.00152	0.02331 (0.00460)	0.0048	−0.0316 (0.0160)	0.0033	0.0179 (0.0123)
Influenza/pneumonia/bronchitis	−0.00126	0.25028 (0.00768)	−0.00080	0.22841 (0.00760)	−0.00100	0.23696 (0.00546)	−0.0026	0.2831 (0.0082)	−0.0016	0.2434 (0.0078)
Diarrhoeal diseases	−0.00062	0.12598 (0.00723)	−0.00042	0.12538 (0.00707)	−0.00050	0.12361 (0.00507)	−0.0010	0.1050 (0.0066)	−0.0007	0.1041 (0.0060)
Certain degenerative diseases	0.00022	0.01269 (0.00245)	0.00017	0.01164 (0.00224)	0.00019	0.01276 (0.00167)	0.0003	0.0206 (0.0050)	0.0003	0.0165 (0.0043)
Complications of pregnancy[b]	—	—	0.00004	0.01854 (0.00071)	−0.00001	0.00734 (0.00086)	—	—	−0.0001	0.0197 (0.0008)
Certain diseases of infancy	0.00022	0.07457 (0.00468)	0.00020	0.06976 (0.00429)	0.00020	0.07323 (0.00317)	−0.0001	0.0447 (0.0033)	0.0000	0.0422 (0.0028)
Violence[c]	0.00058	0.02370 (0.00453)	0.00021	0.00826 (0.00134)	0.00034	0.02242 (0.00335)	0.0006	0.0232 (0.0041)	0.0003	0.0041 (0.0014)
All other and unknown causes (residual)	−0.00072	0.27315 (0.00879)	−0.00041	0.25952 (0.00813)	−0.00055	0.26442 (0.00598)	−0.0020	0.3475 (0.0153)	−0.0013	0.3307 (0.0131)
TOTAL[d]	−0.00001	1.00037	0.00002	1.00032	0.00000	1.00042	0.0002	1.0002	0.0000	0.9998

[a]Based on death rates expressed as annual deaths per person.
[b]Coefficients are only meaningful for the female population.
[c]Including motor vehicle accidents.
[d]The coefficients a_i should sum to zero and the b_i should sum to one. Differences are due to rounding.

Source: Computed from data given in Preston, Keyfitz and Schoen (1972). Coefficients shown in right-hand panels are taken from Preston (1976, p. 18).

TABLE 3. ESTIMATED PERCENTAGE DISTRIBUTION OF DEATHS BY CAUSE FOR TWO STANDARD AGE STRUCTURES, JAVA, 1972

Cause of death category (i)	Percentage of all deaths attributable to ith cause under the West female stable population with: $e_o^o = 45.0, r = 0.02$			$e_o^o = 65.0, r = 0.01$		
	Males	Females	Total	Males	Females	Total[a]
Respiratory tuberculosis	6.7	7.1	6.8	4.7	5.3	5.0
Other infectious and parasitic diseases	10.5	11.3	10.8	4.7	5.7	5.2
Neoplasms	4.2	4.9	4.6	10.3	9.6	10.0
Cardiovascular diseases	13.1	12.8	13.0	28.9	26.7	27.9
Influenza/pneumonia/bronchitis	16.7	16.8	16.7	11.3	12.3	11.7
Diarrhoeal diseases	8.5	9.4	8.9	3.9	5.1	4.5
Certain degenerative diseases	2.7	2.4	2.6	4.1	3.9	4.0
Complications of pregnancy	—	1.6	0.7	—	1.2	0.6
Certain diseases of infancy	8.9	8.5	8.8	3.9	4.2	4.0
Violence	6.2	2.4	4.6	6.4	2.7	4.6
All other and unknown causes (residual)	22.5	22.8	22.5	21.8	23.3	22.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0
Crude death rate	15.1	13.3	14.2	15.1	13.3	14.2

[a]Calculated as a weighted average of proportions for males and females.

should rather be based on a model of mortality which better reflects the impact of a younger age structure.[2]

In constructing their mortality tables, Preston, Keyfitz and Schoen (1972) also computed age-standardized death rates based on a younger age-standard, the West female stable population with $e_o^o = 45.0$ and $r = 0.02$. A summary of the two age structures is given in table 1. Of particular interest is the difference in the proportion of children aged less than 5 years, a reflection of the differential growth rate of the two populations. Since approximately one half of all deaths occurring annually in populations with a life expectancy of less than 50 years or so can be expected to occur at these ages, the greater weighting assigned to them in the compilation of the mortality index by the younger age standard should lead to a more representative description of the overall pattern of causes of death.[3]

Table 2 presents the schedule of coefficients (a_i, b_i) which define the set of linear relationships between cause-specific age-standardized death rates (M_i) and the overall level of mortality using the younger age structure as the standard. The model relationships have been estimated for males and females separately, as well as for both sexes combined. For comparative purposes, the coefficients determined by Preston on the basis of the older age standard are shown in the right-hand panels of the table.

The new set of b_i's, which measure the proportionate contribution, on average, of each cause of death category to total mortality decline, serve to reinforce Preston's (1976, pp. 19 and 20) conclusions about the relative importance of the various communicable diseases in reducing overall death rates. Only for the "residual" category of diseases do the b_i's differ by more than 0.05 (i.e., a 5 per cent difference in the estimated average contribution of the residual group). The lower proportionate impact (25 per cent) of these conditions under the younger age standard is to be expected, however, since the majority of deaths in this category occurred at the older ages where a precise diagnosis would often have been extremely difficult given the limited knowledge about the pathology of disease and without modern diagnostic aids. Irrespective of which weighting system is used, sex differences in the b_i's are relatively small, reflecting the roughly equivalent proportionate role of the various causes of death in reducing overall mortality levels for both males and females.

On the other hand, when the two sets of coefficients are used to estimate the cause of death structure at relatively high levels of mortality, markedly different patterns emerge. This is illustrated in table 3, which shows the estimated proportion of all deaths (expressed as a percentage) assigned to each cause category based on crude death rates of 15.1, 13.3 and 14.2 per thousand males, females and total population, respectively, as estimated for Java in 1972.[4] It is immediately obvious that the distribution derived from mortality rates based on the younger age standard is much more consistent with the expected cause structure in a youthful, high mortality population. Specifically, the relative impact of diseases of infancy, the diarrhoeal diseases and other infectious and parasitic conditions is approximately twice as great under the new standard, each now claiming an estimated 10 per cent or so of all deaths. The class of specific respiratory ailments also accounts for a higher proportion of deaths, claiming one in six victims, compared to an estimated one

[2]This is clear from the composition of the total mortality rate. Thus the age-standardized mortality rate for a given population can be $M^s = \Sigma\, m_x \cdot p_x^s$ where $\{m_x\}$ is the schedule of age-specific death rates and p_x^s the proportion of the standard population aged x years. The crude death rate can similarly be viewed as a weighted average of age-specific death rates ($M = \Sigma_x m_x \cdot p_x$), the weights $\{p_x\}$ in this case being the actual population composition. Obviously, the closer the agreement between the two sets of weights $\{p_x\}$ and $\{p_x^s\}$, the more appropriate will be the regression coefficients (a_i, b_i) for estimating the cause of death structure.

[3]See, for example, the appropriate national tables in Preston, Keyfitz and Schoen (1972) or the model schedules as estimated by Coale and Demeny (1966).

[4]The cause of death distributions shown in the table were derived from the crude death rate according to the linear model described earlier. The coefficients (a_i, b_i) in the equation are taken from table 3. In this way one can estimate the crude cause-specific death rate (M_i) for each cause of death from knowledge of the crude death rate (M) alone. Since the cause-specific death rates must sum to the overall crude death rate, the proportionate distribution of cause-specific mortality follows.

TABLE 4. REGRESSION PARAMETERS AND IMPLIED CAUSE OF DEATH DISTRIBUTIONS DURING INFANCY AND EARLY CHILDHOOD

	Age 0			*Age 1-4*		
	Coefficients from the simple linear regression of death rates for both sexes combined		*Percentage of deaths attributable to ith cause*[a]	*Coefficients from the simple linear regression of death rates for both sexes combined*		*Percentage of deaths attributable to ith cause*[a]
Cause of death category (i)	a_i	b_i		a_i	b_i	
Respiratory tuberculosis	−0.00016	0.00572	0.4	−0.00002	0.02113	2.0
Other infectious and parasitic diseases	−0.00274	0.11703	9.6	−0.00022	0.27130	26.1
Neoplasms	0.00010	−0.00010	0.1	0.00010	−0.00181	0.3
Cardiovascular diseases	−0.00084	0.01948	1.3	0.00002	0.01096	1.2
Influenza/pneumonia/bronchitis	−0.00217	0.20369	18.7	−0.00007	0.24409	24.1
Diarrhoeal diseases	−0.00255	0.18998	17.0	−0.00017	0.19509	18.8
Certain degenerative diseases	0.00002	0.00151	0.2	0.00003	0.00695	0.8
Certain diseases of infancy	0.01029	0.20779	28.8	—	—	
Violence	0.00032	0.00800	1.0	0.00039	0.01050	2.9
All other and unknown causes (residual)	−0.00226	0.24690	22.9	−0.00006	0.24128	23.8
TOTAL	0.00001	1.00000	100.0	0.00000	0.99949	100.0

[a]As estimated for Java in 1972 assuming an infant mortality rate (both sexes combined) of 128 per thousand live births and a childhood mortality rate of 21.5 per thousand population aged 1-4 years.

in nine under the old standard. Conversely, the collective impact of the major chronic diseases (neoplasms, cardiovascular diseases and certain other degenerative diseases) has been more than halved, accounting for roughly one in five deaths rather than an improbable 42 per cent as suggested by the older standard.

The regression procedure could, of course, be further refined by estimating separate regression equations for broad age groups chosen so as to delineate between stages of life when the composition of the leading causes of death is likely to change. By aggregating the results one could then obtain an estimated cause of death distribution for the total population.[5] As the basic data set is presented according to conventional age groupings (0-1, 1-5, 5-10, 10-15, etc. . . .), specific regression equations can at least be estimated for two ages which at the same time account for a substantial proportion of all deaths—namely, infancy and early childhood (1-4 years).[6] The two sets of regression coefficients derived from the 165 populations are shown in table 4, along with the estimated cause of death structure which they would imply given the level of mortality thought to prevail in Java in 1972 (this distribution is obtained in an identical manner to that for the total population as shown in table 3).

The estimated cause-specific distributions which result are largely consistent with what one might expect in a high mortality population. During infancy, three cause of death groups predominate, one of which, the class of disorders peculiar to the first four weeks of life, accounts for almost 30 per cent of all infant deaths. This category essentially comprises the various constitutional maladies which are often present among the newborn together with such conditions as umbilical sepsis and including deaths due to injuries sustained during parturition. Diarrhoeal and respiratory diseases each claim a further 15 to 20 per cent of infant deaths, most of which could be expected to occur during the post-neonatal period when the malnutrition-respiratory-diarrhoeal triad emerges as the leading threat to infant survival. Much the same mechanism continues to operate throughout early childhood, with an additional substantial contribution (around one quarter of all deaths) due to the other infectious and parasitic diseases, such as measles and diphtheria, which are particularly common at these ages. Interestingly, some 10 per cent of infant deaths at this level of mortality are also estimated to have occurred from this class of diseases, a considerable proportion of which may well be due to neonatal tetanus. One may also note from the relative magnitude of the b_i coefficients that these same causes are largely responsible for effecting declines in mortality at these ages.

The fact that the results are roughly in accord with the cause structure of mortality expected to prevail in a population in the early stages of the epidemiological transition does not, of course, detract from the inherent weaknesses of this type of estimation procedure. To begin with, the empirical evidence used to derive the model relationships was largely drawn from the experience of the industrialized countries at various stages of development and what developing countries were included were almost exclusively from Central and Southern America. It is obviously highly contentious to suppose that similar structural relations exist in contemporary developing societies, given their particular climatic and environmental conditions and the diffusion of modern medical technology. Moreover, the cause of death categories employed are undoubtedly too broad to provide an adequate basis for formulating public health policy, a restriction necessarily imposed in order to improve the comparability of the basic data set. None the less, in countries where knowledge about the cause structure of mortality is extremely limited, these model relationships can at least indicate the order of magnitude of common fatal health concerns, which, in conjunction with simple epidemiological observation, should help to avoid the misappropriation of already scarce national health resources.

[5]Wherever possible, the structure estimated by such indirect methods should be reconciled with available epidemiological and clinical evidence of suitable reliability in order to ensure that the final estimates are roughly in accord with known mortality experience. For an example of this approach, see Hull, Lopez and Rohde (1981).

[6]For the remaining ages (5 years and over), age-standardized cause-specific death rates may be computed, for selected age-segments or for the entire age-span, using the data set of Preston, Keyfitz and Schoen. This procedure, in association with the estimates derived for infants and young children in this article, could be expected to lead to a more realistic appraisal of the underlying overall cause of death pattern in the population. Unfortunately, because the Preston-Keyfitz-Schoen data set was not available to the authors in machine-readable form, it has not been possible to carry out a more complete age-disaggregation in this analysis.

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