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ADULT MORTALITY IN THE DEVELOPING WORLD; WHAT WE KNOW AND HOW WE KNOW IT *

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** Johns Hopkins University, Baltimore, MD. This paper draws extensively on results generated by the Adult Mortality in the Developing World (AMDC) project, funded by National Institute on Aging grant # 1 P01 AG17625, and involving, in addition to the author, co-PI John Wilmoth (University of California, Berkeley), Advisory Board members Mari Bhat (Institute of Economic Growth, Delhi), Hoda Rashad (American University of Cairo), Arodys Robles (University of Costa Rica), and Ian Timæus (London School of Hygiene and Tropical Medicine), and Core Working Group members Yoonjoung Choi (Johns Hopkins), Bernardo Queiroz (Berkeley), Piedad Urdinola (Berkeley) and Danzhen You (Berkeley). The views expressed in the paper do not imply the expression of any opinion on the part of the United Nations Secretariat.

A. INTRODUCTION

Accurate knowledge of adult mortality levels and trends in the developing world is hampered by a widespread lack of complete vital registration systems. Although knowledge of infant and child mortality once faced similar barriers, survey-based techniques – indirect methods and birth histories – have been more successful at measuring child than adult mortality, and we know correspondingly less about the latter than the former.

A relatively small number – and smaller share by population -- of developing countries do have close to complete registration of adult deaths and population censuses of high quality. A larger number of countries have national or sample vital registration systems that are complete enough to be promising candidates for methodologies that assess completeness of registration relative to census counts. An increasing number of countries lacking even that level of registration coverage have included questions in censuses (or very large sample household surveys) concerning household deaths by age and sex in some period (most often one year) prior to the census; completeness of reporting can then be assessed. A number of countries have conducted small sample household surveys (most often under the umbrella of the Demographic and Health Surveys programme) that have included sibling histories that ask each respondent about the survival or otherwise of each sibling. A number of countries have sought to measure adult mortality by including questions in censuses and surveys concerning the survival or otherwise of each respondent's mother or father. Attempts have also been made to use the age distributions from successive censuses to arrive at measures of adult survival.

The ordering of approaches in the above paragraph reflects my own view of their ordering in terms of producing valid estimates of adult mortality, and countries will be classified according to their highest level of information. However, beyond the first methodology – accurate death registration -- , any estimation procedure is no better than its assumptions and the quality of the data on which it is based. There is thus a margin of uncertainty, largely unquantifiable, about most of the results that will be presented here. The HIV/AIDS epidemic, that has created highly abnormal age patterns of adult mortality and undermined assumptions about steady trends, has substantially increased this uncertainty and reduced the value of so-called "indirect" methods.

This paper does not attempt to produce estimates of adult mortality for all developing countries, nor to produce estimates of adult mortality for world regions. Rather, it focuses on the experience of countries for which the data appear to be of adequate quality to provide (after adjustment or analysis as necessary) satisfactory estimates for the recent past and, for a subset of cases, of trends over the last three or four decades.

B. METHODOLOGY

This section will only summarize the main estimation approaches available for adult mortality. A manual recently published by the United Nations (2002) describes the methodologies and their applications in detail. Here I will summarize the main characteristics of the methods, the assumptions underlying them, and their suitability for tracking adult mortality in the era of AIDS.

Methods using the Distribution of Deaths by Age

A group of methods have been developed and refined that seek to measure the completeness of recorded deaths (whether by a vital registration system or by retrospective questions in a census or survey about household deaths) relative to population counts. The early methods (Brass, 1975; Preston et al., 1980) relied on the strong assumption that the underlying population was demographically stable. Later methods relaxed this assumption to require only that the population be closed to migration or that age-specific migration rates be known (Bennett and Horiuchi, 1984; Hill, 1987). These methods use mathematical models of population age distributions to relate the age pattern of deaths to the age pattern of the population in such a way that the completeness of death registration can be estimated. The key assumption underlying these methods is that recording of deaths (after childhood) should not vary with age.

The Brass (1975) and Hill (1987) methods estimate the completeness of age recording by comparing an observed death rate for the population aged x and over to a residual estimate obtained by subtracting the growth rate of the population aged x and over from an estimate of the entry rate into the population aged x and over, both obtained from the population age distribution. I refer to these methods as "Growth Balance" (GB) methods. The more flexible Hill method (which uses data from two censuses and does not assume that the population is stable) estimates both the completeness of coverage of deaths relative to population enumerations and the possible change in coverage between two census enumerations. The Preston et al. (1980) and Bennett and Horiuchi (1984) methods use population growth rates above age x to expand recorded deaths over age x to estimate the number of deaths over age x in the corresponding stationary population; completeness of death recording is then estimated by comparing the population aged x to the sum of stationary population deaths above age x. I will refer to these methods as "Synthetic Extinct Generations" (SEG) methods. The more flexible Bennett and Horiuchi method (which also uses data from two censuses and does not assume that the underlying population is stable) estimates the completeness of coverage of deaths relative to the populations, but is sensitive to changes in census coverage.

Hill (2001) uses simulations to show that the GB methods are more sensitive to possible errors in age reporting than the SEG methods, whereas the SEG methods are much more sensitive to any changes in census coverage. He suggests a two-stage process, by which the GB method is applied first to estimate any change in census coverage, and the SEG method is then applied to data after adjusting the census numbers for possible coverage change.

Sibling Survival

Analogous to the use of a birth history to measure infant and child mortality is the use of a sibling history (essentially the birth history of the respondent's mother) to measure adult mortality. Such a history has been asked in a considerable number of DHSs, particularly in sub-Saharan Africa, originally with the intent of estimating maternal mortality (Rutenberg and Sullivan, 1991). A respondent is asked about every sibling born of the same mother: the age of surviving siblings, and the year of birth and date of death of siblings who have died. The data provide deaths and exposure time by age, sex and time period, from which age-specific mortality rates can be calculated directly. Key assumptions of the method are that surviving siblings and siblings who have died are equally likely to be reported, and that the data are not affected by substantial selection bias. Comparisons with other sources suggest that sibling survival tends to underestimate adult mortality (Stanton et al., 1997).

Survival of Parents

The proportion of respondents of a given age with a surviving parent is clearly an indicator of adult mortality – the higher the proportion, the lower the mortality, other things being equal – but the first person to formalize a methodology that allowed for the other things was Brass (Brass and Hill, 1973). The major factor affecting the relationship between the proportion with a surviving mother (or father) and a standard indicator of mortality is the age distribution of the parents at the time of the births of the respondents: the younger the parents, the lower the proportion dead for a given level of mortality. The original methods have been refined and improved by Timæus (1991, 1992) among others. Apart from issues of completeness of recording of parents who have died (the proportion of young children with dead parents is generally implausibly low, for example), the main problem with these methods is that the deaths occur, and hence represent mortality, over a long period, the age of the respondent. Thus although the estimates tend to refer to a time period somewhat more recent than the mid-point of the respondents' age (because the mortality risk of a parent increases with age) if trends are regular, there is no way to estimate a reference point if trends are irregular, as will be the case in countries affected by HIV. The methodology also assumes that the experience of parents (weighted by their number of surviving children) is representative of the population at large.

Intercensal Survival Methods

Two censuses conducted five or ten years apart provide information about intercensal cohort survival. For example, the population aged 50-54 at a second census represent the survivors (in a closed population) of the population aged 40-44 at a first census ten years earlier. The ratio of the second to the first population can be interpreted as a life table survivorship ratio, and such ratios can be combined across age groups to provide a summary measure of adult mortality. For censuses exactly five or 10 years apart, the analysis presents no problems; for other intervals, generalized equations for non-stable populations have been used to obtain summary measures (Preston and Bennett, 1983). Apart from the assumption that the population is closed to migration, such methods are very sensitive to changes in census coverage (coverage improving from one census to the next appears to imply fewer intercensal deaths and hence lower mortality) and to age exaggeration.

C. MEASURES

For the purpose of mortality studies, adulthood may reasonably be defined as starting at age 15, about the inflection point at which declining mortality risks in childhood are replaced by rising risks in adulthood. The primary measure of adult mortality used in this paper is the probability of dying between the ages of 15 and 60, ${}_{45}q_{15}$. This measure covers a substantial age range, but avoids the problems inherent in the measurement of old age mortality. Mortality rates specific for five year age groups are used to examine age patterns of mortality. Another widely used measure of post-childhood mortality, the expectation of life at age 10, e_{10}, is not used because of its sensitivity to old age mortality.

D. DATA SOURCES BY REGION

The data upon which estimates of adult mortality can be based vary widely by region. Table 1 shows by region the primary data source used to derive estimates of life expectancy for countries with populations of 5 million or more in the United Nations (2001) World Population Prospects 2000 Revision, in terms of the percent of the regional population covered by each source. Latin America has far and away the highest proportion of population covered by accurate or potentially adjustable vital statistics data, though it should be noted that the vital registration data were only regarded as adequate without adjustment for four countries representing 15 percent of the regional population. For none of the populations of sub-Saharan Africa and South-Central Asia are the estimates of life expectancy based on vital registration. In sub-Saharan Africa, and to a lesser extent in North Africa and West Asia, the predominant basis for estimates of life expectancy is an estimate of child mortality and the assumption of an age pattern of mortality from a family of model life tables. In South Central Asia, the predominant basis is sample vital registration systems, used in Bangladesh, India, and Pakistan. The predominant basis for countries of East and South-East Asia is information from a population census on household deaths in a reference period before the enumeration. Estimates of life expectancy are inferred from information for a neighboring country only in sub-Saharan Africa, and only for four percent of the regional population, but for some countries of that region and North Africa and West Asia, as well as South-Central Asia, no information more recent than 1980 is available. For developing countries as a whole, household deaths from a census and sample vital registration are the most common bases for U.N. estimates, largely because these two approaches are used in the two largest populations, China and India. The third most common basis, for 20 percent of the population of the developing world, is the combination of child mortality and an assumed age pattern of mortality from a model life table.

TABLE 1: SOURCES OF ESTIMATES OF LIFE EXPECTANCY FOR COUNTRIES (POPULATION 5 MILLION OR MORE) OF THE DEVELOPING WORLD USED BY THE UNITED NATIONS WORLD POPULATION PROSPECTS 2000 REVISION

Source of Estimate	*Sub-Saharan Africa*	*North Africa and West Asia*	*South-Central Asia*	*East and South-East Asia*	*Latin America*	*Total*
Vital Registration	0	23	0	6	96	14
Official National Life Table	0	12	5	3	0	3
Sample Vital Registration	0	0	88	0	0	27
Household Deaths from Census	4	0	5	72	3	31
Estimates of Child Mortality	77	56	2	15	2	20
Other	6	3	0	5	0	3
Inferred from Neighboring Country	4	0	0	0	0	<1
No Information Since 1980	9	7	2	0	0	2
Total Population (‘000)	579	335	1,468	1,868	494	4,744

Source: United Nations (2001).

E. ESTIMATES OF ADULT MORTALITY

This section presents estimates produced to date by the Adult Mortality in Developing Countries Project for 27 countries and a range of time periods. Appendix 1 lists the countries and the time periods. Although the countries included cover over two-thirds of the population of the less developed world, the representation of particular regions varies, from very high for Latin America to very low for sub-Saharan Africa. Timeliness also varies – for three of the 27 countries, the most recent estimate has a reference date in the 1970s, and for only 15 of the 27 is the reference date in the 1990s. A consequence of this low representation of sub-Saharan Africa and lack of recency is the small numbers of countries represented that are severely affected by the HIV epidemic. Mortality increases resulting from HIV have mainly occurred since the early 1990s; the methodology we rely upon basically measures mortality for an intercensal period; to examine short-term changes requires assumptions about constant coverage of death registration that we have not made.

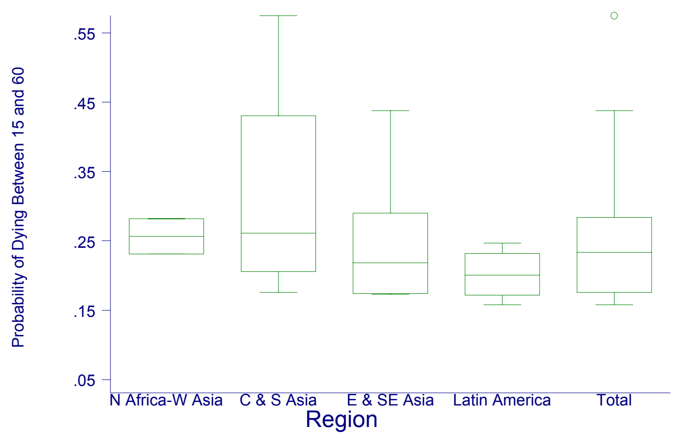
The methodology relied upon by the AMDC Project is the two-step process combining Growth Balance and Synthetic Extinct Generations methods described in section B.2. For countries with two or more census age distributions and some information on the age distribution of deaths for the intervening period, the Hill (1987) General Growth Balance method is applied first to estimate any change in census coverage, one census or the other is adjusted for the coverage change, and then the Bennett-Horiuchi (1984) method is applied. Simulations suggest that this two-stage approach is more robust to typical data errors or departures from assumptions (age misreporting, change in census coverage, migration) than either method alone. Estimates based on other methods are not presented, primarily because we are unsure about their robustness (sibling survival) or because they do not estimate age-specific mortality patterns (parental survival).

Levels

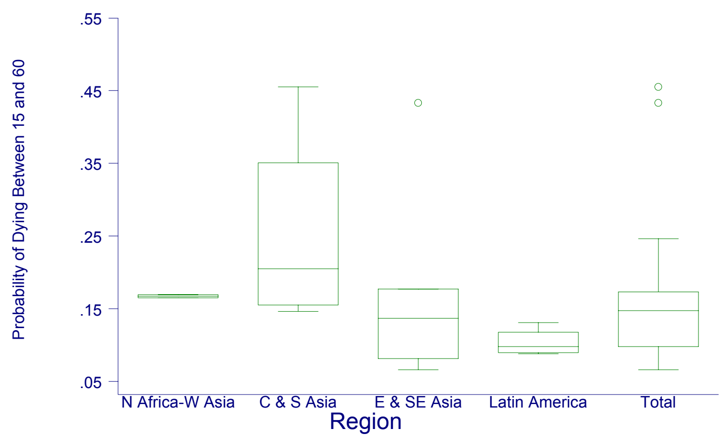
Adult mortality level is summarized by the probability of dying between the ages of 15 and 60, or ${}_{45}q_{15}$ in standard life table notation. Figure I summarizes estimates for the 1990s by sex and region in the form of box plots. The range of values is wide, from a minimum of 66 per 1,000 for females in the

Republic of Korea to a maximum of 575 per 1,000 for males in Mongolia. The corresponding expectations of life at age 10, e , are 70.3 and 42.8 years respectively.

Figure I. Estimates of the Probability of Dying between Ages 15 and 60 by Sex and Region; 15 AMDC Project Countries with Estimates for the 1990s



Males



Females

Sex Differences

Figure II plots female ${}_{45}q_{15}$'s against male ${}_{45}q_{15}$'s for the most recent estimate for all 27 countries. Note that some of these estimates are for the 1970s. Females have a lower probability of dying in all 27 populations, though the differences are very small in two populations, Laos and Pakistan. There does not seem to be any clear association between the sex differential in absolute terms and mortality level (as indicated by the male ${}_{45}q_{15}$), nor with region, although the female advantage may be somewhat below average in South and Central Asia. The lack of a clear association between male and female risks in absolute terms suggests that relative female advantage increases as mortality falls, following the same pattern as in the developed world.

Age Patterns

One of the major advantages of basing estimates of adult mortality on adjusted registered deaths (or deaths in a defined reference period recorded by a census) is that the estimates include information about the age pattern of mortality. Sibling histories (as implemented by the Demographic and Health Surveys program) provide information only up to age 50, survival of parents provides no indication of age patterns of mortality, and intercensal survival techniques are typically so affected by age exaggeration as to provide little useful information. This section compares AMDC estimates of age-specific mortality rates for individual countries with the patterns expected by matching the observed $_{45}q_{15}$ with that of a model in the appropriate family of the U.N. *Model Life Tables for Developing Countries* (UN; 1982). Given problems with age misreporting, the comparisons are presented only for the subset of 9 populations for which the AMDC estimation procedure was judged (on the basis of goodness of fit) to have worked well or very well.

Figure II. Sex Differences in Adult Mortality: Most Recent Estimates of Female $_{45}q_{15}$ Against Male $_{45}q_{15}$ for 27 Countries

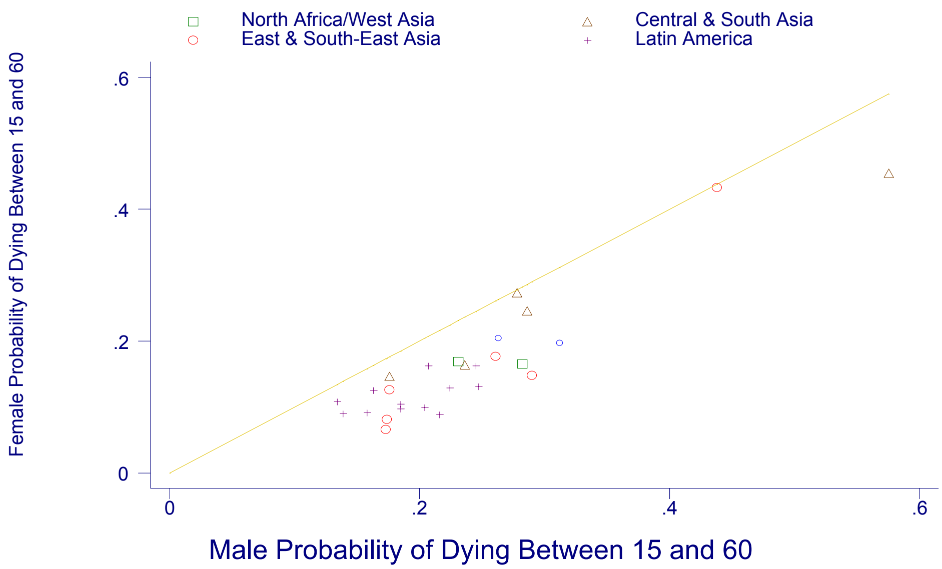
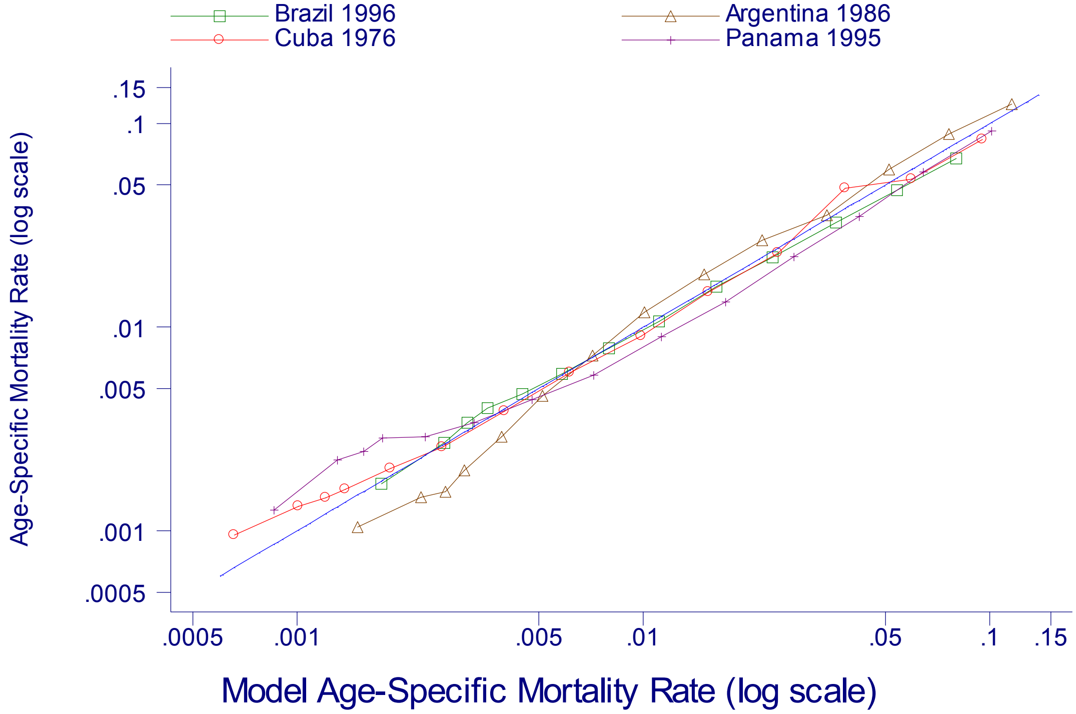


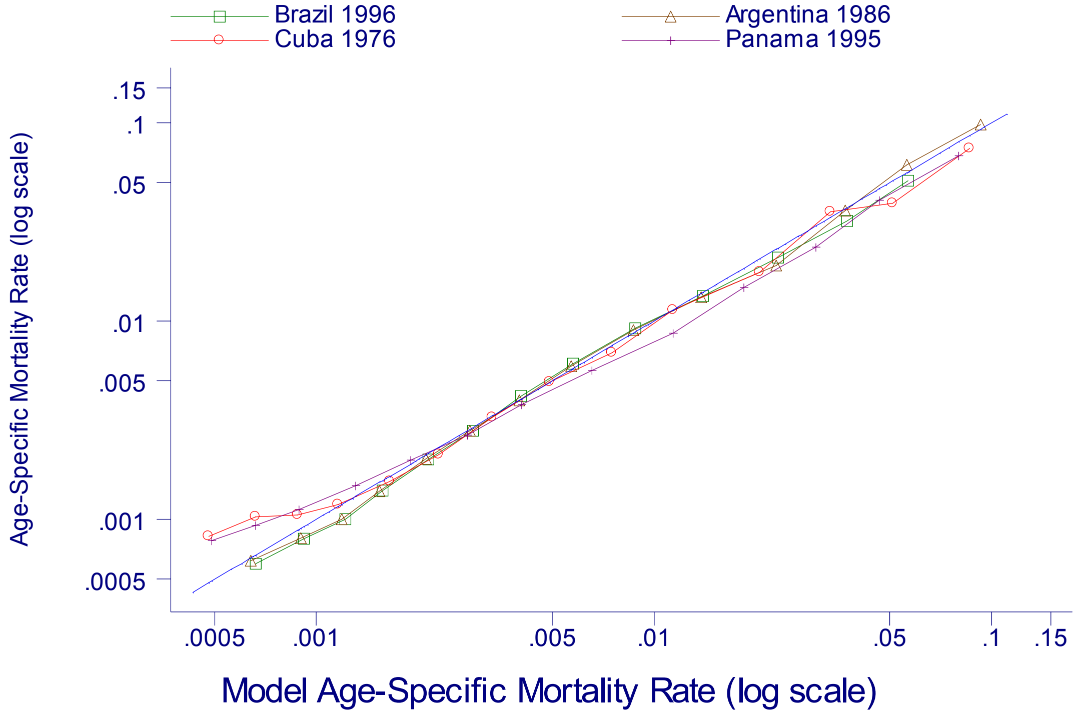
Figure III plots (by family of UN models and separately for males and females) the observed age-specific mortality rates for age groups 15-19 to 80-84 (except for Brazil, with a highest age group of 75-79, and Mongolia, with a highest age group of 65-69) against the expected mortality rate for that age group given the observed value of $_{45}q_{15}$ matched with the $_{45}q_{15}$ in the appropriate model family. If the model fits the observed age pattern well, the points will lie along the diagonal; scatter around the diagonal suggests random errors, whereas curvature or a systematic divergence from the diagonal suggests that the model does not fit the data well.

Figure III. Age-Specific Mortality Rates Plotted Against Corresponding Value from UN Model Life Tables with Same 45q15

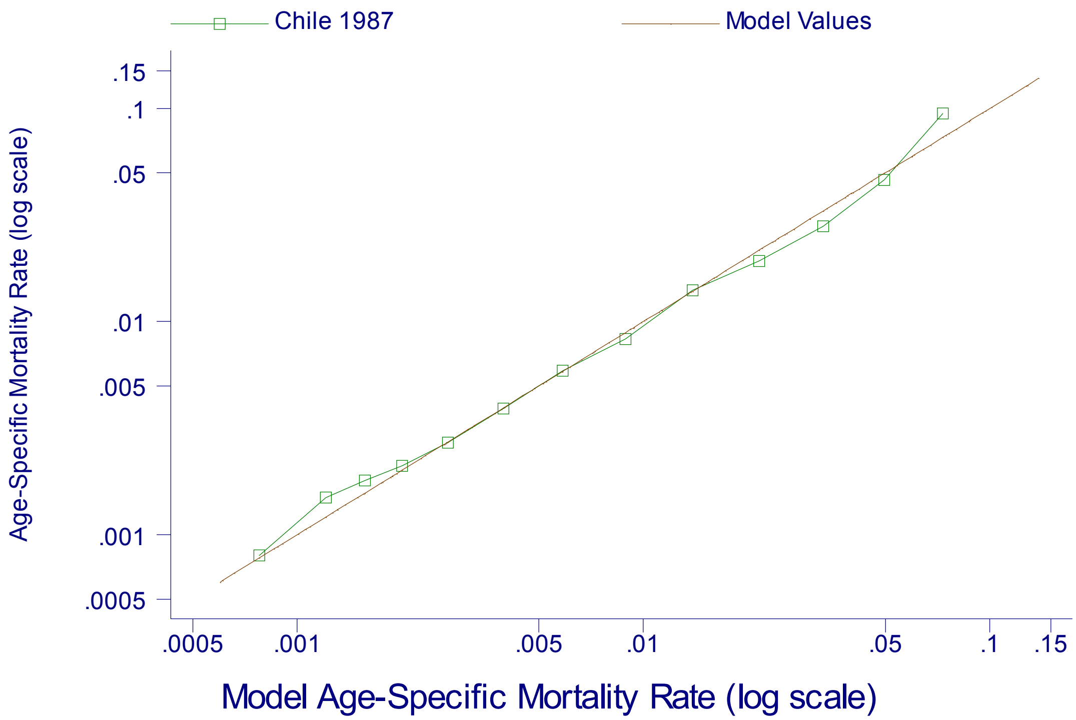
a) Males, Latin American Standard



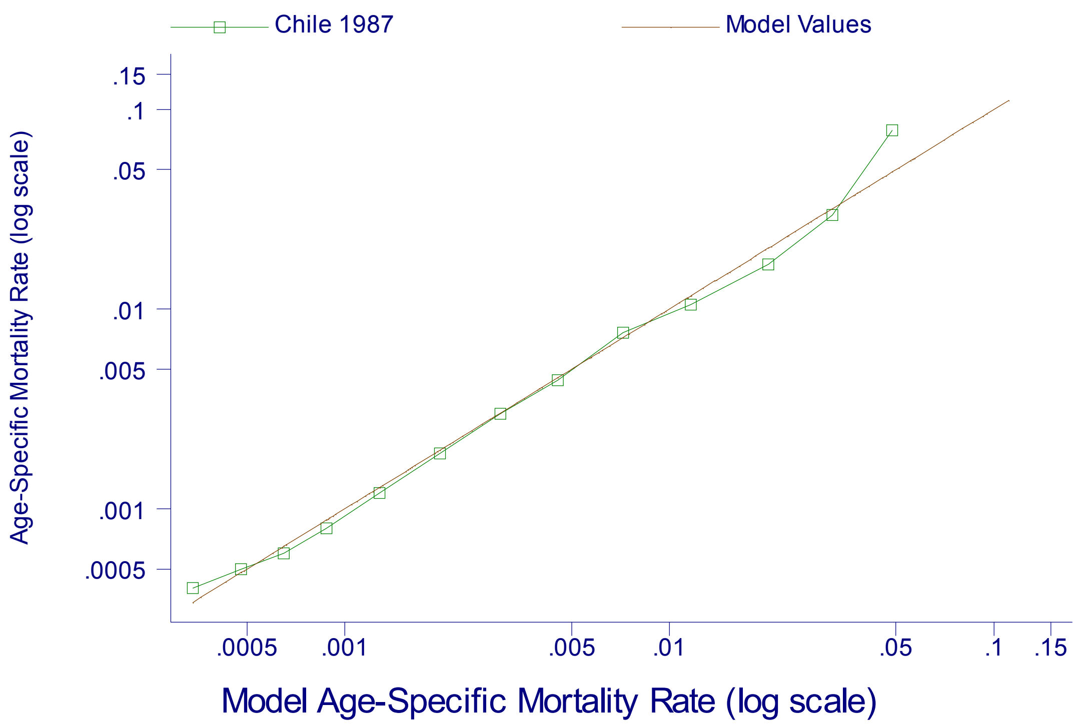
b) Females, Latin American Standard



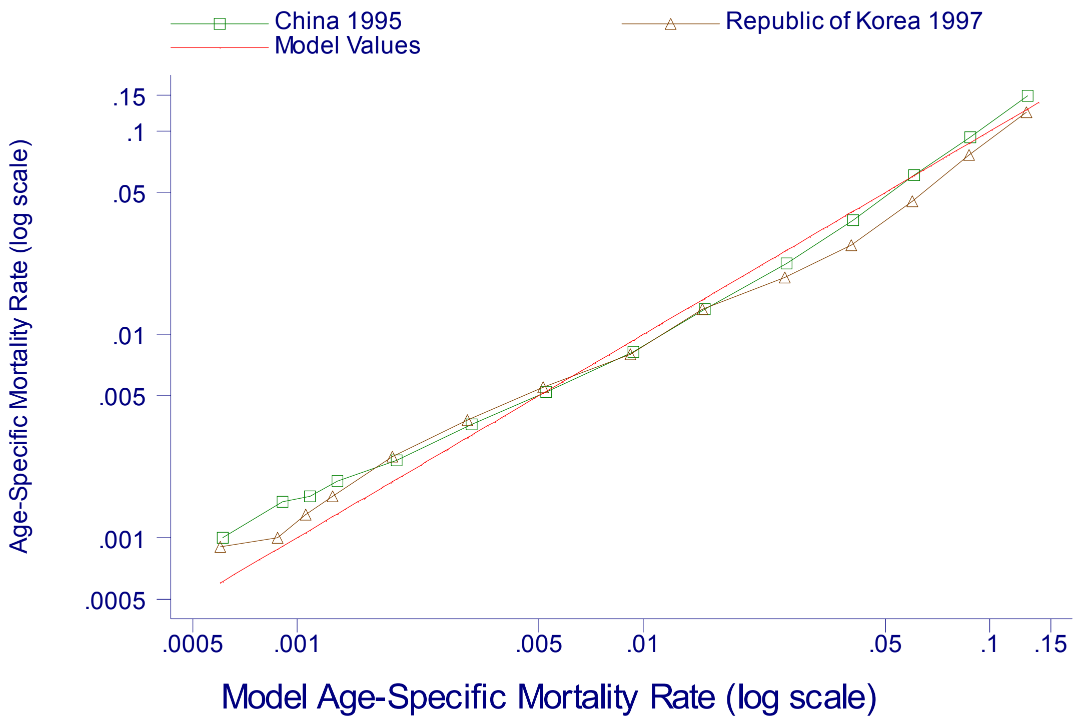
c) Males, Chilean Standard



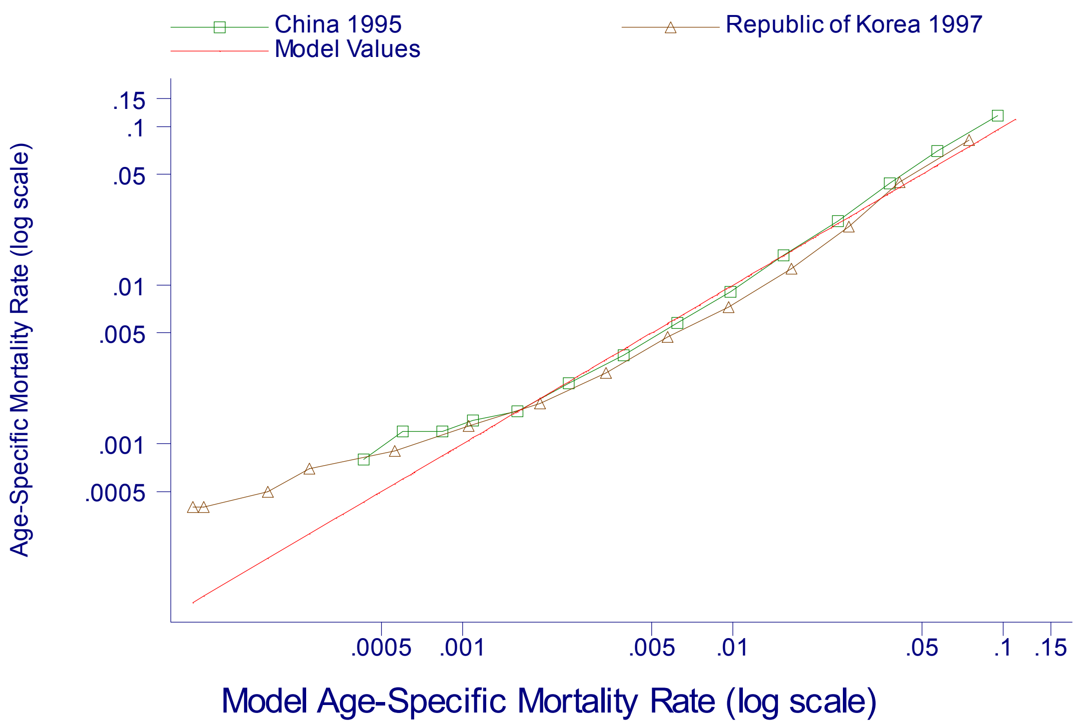
d) Females, Chilean Standard



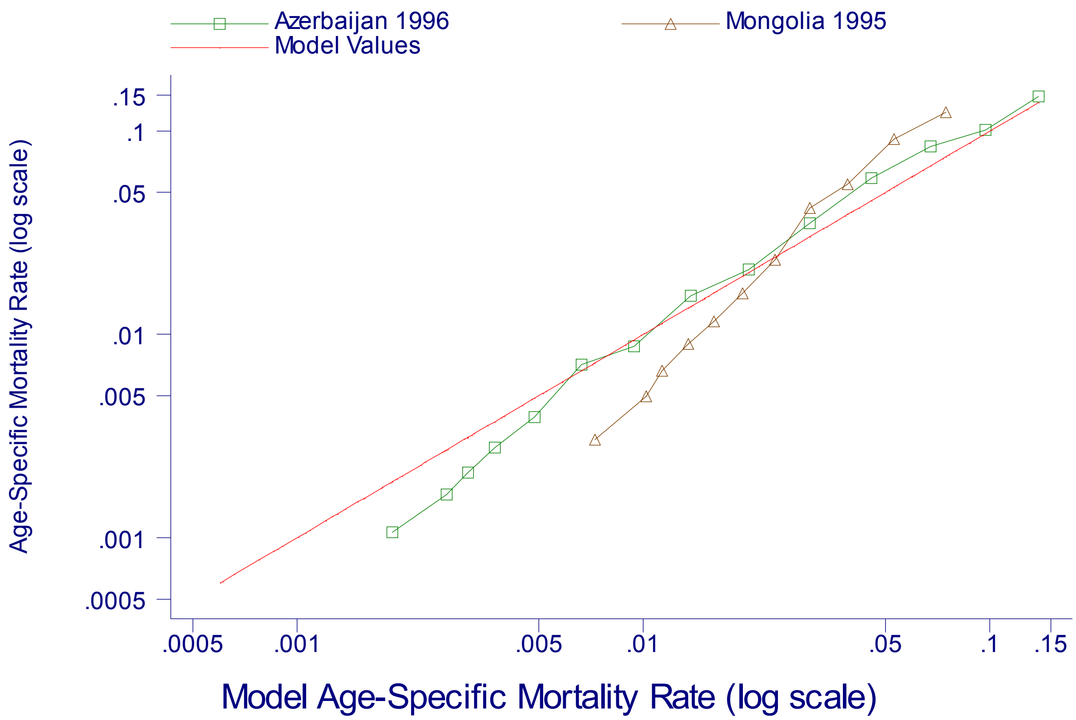
e) Males, Far Eastern Standard



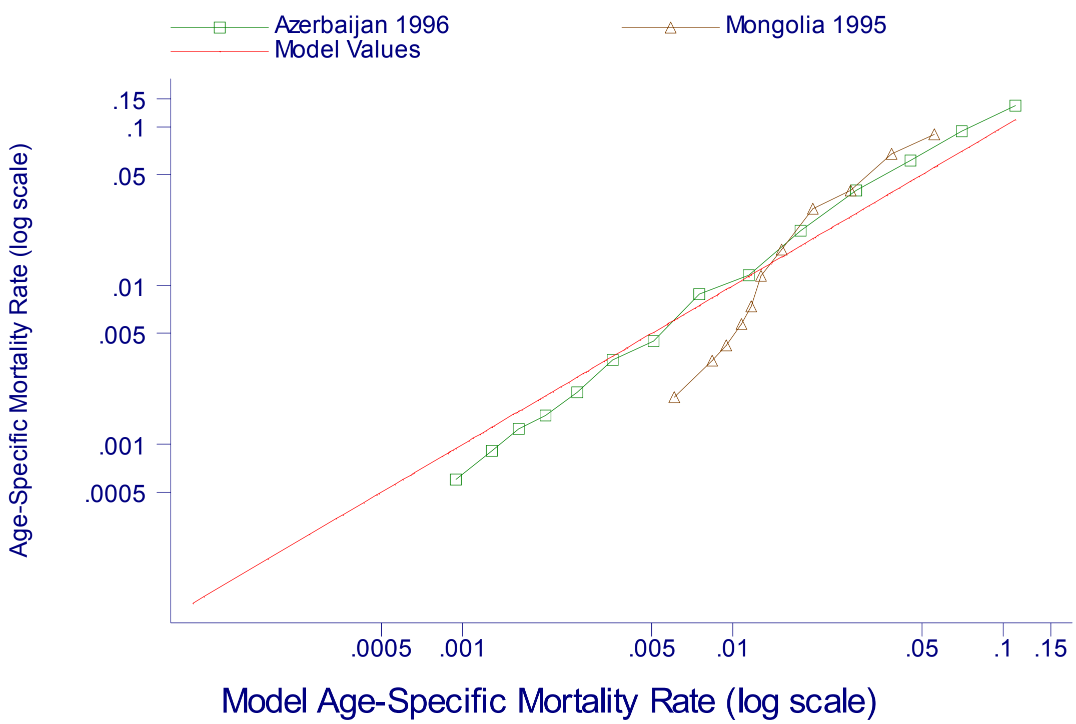
f) Females, Far Eastern Standard



g) Males, General Standard



h) Females, General Standard

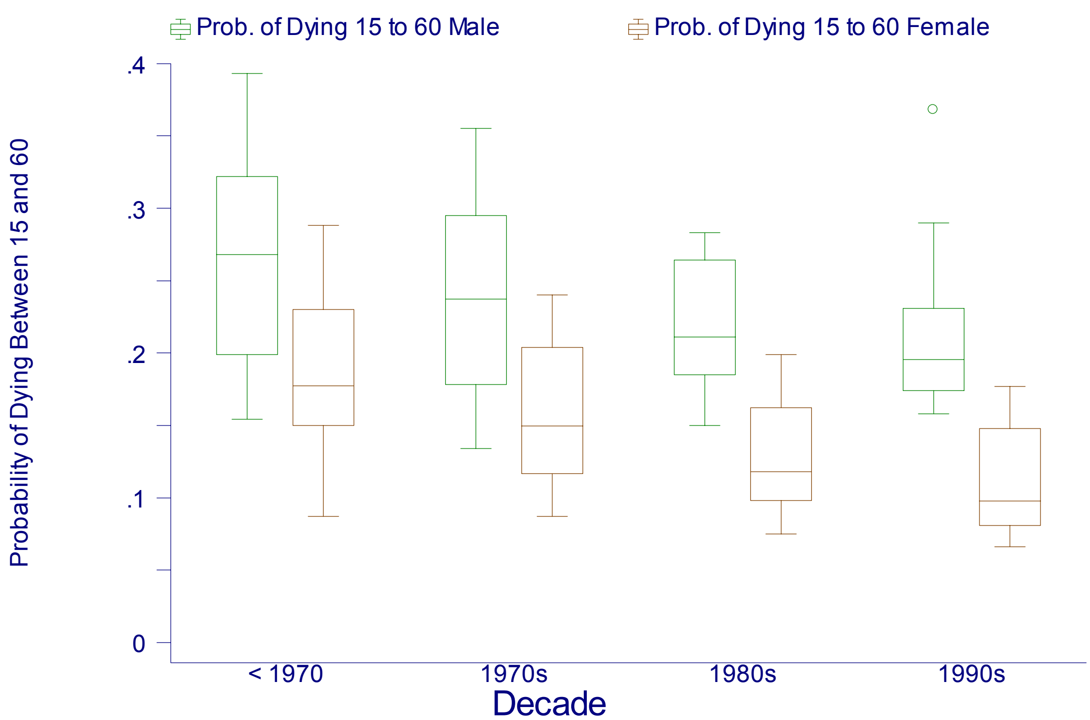


By and large, the observed patterns are reasonably well fitted by the models. The Latin American model fits the data for Brazil and Argentina females very well, and the Chilean family fits the Chilean data very well. The largest relative differences are typically for younger adults: Cuba and Panama both have higher mortality under the ages of 30 (females) or 35 (males) than the Latin American family would predict, and both males and females in China and the Republic of Korea have higher mortality under age 40 than the Far Eastern model would suggest, with correspondingly lower mortality between 40 and 75. The worst fits are clearly for the two populations of the former Soviet Union, Azerbaijan and Mongolia, fitted for want of a better alternative by the General Standard: mortality rates are lower than the models would suggest under age 35 or 40, and higher above.

Trends

For 16 of the 27 countries examined, estimates are available for two or more time periods, allowing examination of trends. Figure IV shows the probabilities of dying between the ages of 15 and 60 by sex and decade for countries with multiple observations. There is a steady downward trend over time for both males and females, the median ${}_{45}q_{15}$ dropping from 0.268 before 1970 to 0.196 in the 1990s for males, and from 0.178 before 1970 to 0.098 for females. Regression of ${}_{45}q_{15}$ on reference date using a country fixed effects model indicates an annual rate of decline of one percent per annum for males and two percent per annum for females (corresponding rates of decline for the Under-Five Mortality Rate, U5MR, are approximately four percent per annum (Hill et al., 1999)). Rates of decline have not differed significantly by decade.

Figure IV. Estimates of ${}_{45}q_{15}$ by Sex and Decade, 1950s to 1990s



Effects of HIV/AIDS on Adult Mortality

The inclusion of only two countries from sub-Saharan Africa among the 27 countries for which data are presented in this paper greatly reduces the timeliness of the results for studying the effects of the HIV/AIDS epidemic. There can be no doubt, however, that the epidemic has had dramatic effects on adult mortality in certain populations. Timæus (2003) has used regression models with data on survival of siblings from Demographic and Health Surveys to document very large increases in adult mortality in a number of African populations. The only country included in the data base used in this paper that has a generalized HIV epidemic and data recent enough to show an effect is Thailand. Figure V shows unadjusted male and female age-specific mortality rates for selected years from the late 1980s to the late 1990s for Thailand. For males, mortality rates in 1997 are higher than in 1988 for ages between 15 and 50; mortality is somewhat higher even in 1991 than in 1988, but the big increase is from 1991 to 1994. The age-specific mortality rate for the age group 25 to 29 is two and a half times higher in 1997 than in 1988. The pattern for females is also clear, though somewhat different: the mortality increase is largely limited to ages 20 to 35, the big increase was between 1994 and 1997, and the maximum increase from 1988 to 1997, for the age group 25 to 29, was somewhat smaller than for males at a factor of two. Male and female mortality rates at other ages appear to have declined between 1988 and 1997.

F. CONCLUSIONS

Estimates of adult mortality for the developing world are less satisfactory than estimates of child mortality for two main reasons: no equivalent of the birth history for estimating child mortality from household surveys has been developed for adult mortality, and indirect estimation techniques do not seem to be as robust as indirect estimates of childhood mortality based on summary birth histories. As a result, much of what we know about adult mortality in the developing world is based on vital registration data (or household deaths recorded by a population census) evaluated (and if necessary adjusted) using death distribution methods. Although such data cover over two-thirds of the population of the developing world, we know very little about adult mortality in sub-Saharan Africa. In the era of HIV/AIDS, with adult mortality acquiring a new salience, action is needed to increase the number of countries for which death distribution methods are applicable. The most effective way of achieving this goal seems likely to be by encouraging the inclusion in population censuses of questions on household deaths by age and sex.

Twenty-seven countries have so far been studied by the Adult Mortality in Developing Countries project. On the basis of these countries, the following conclusions are drawn:

1. There is very wide variability in levels of adult mortality in the developing world even between populations little affected by HIV/AIDS.

2. Female adult mortality is lower than male in all the populations studied, but the female advantage varies substantially and seems to increase in relative terms as adult mortality falls.

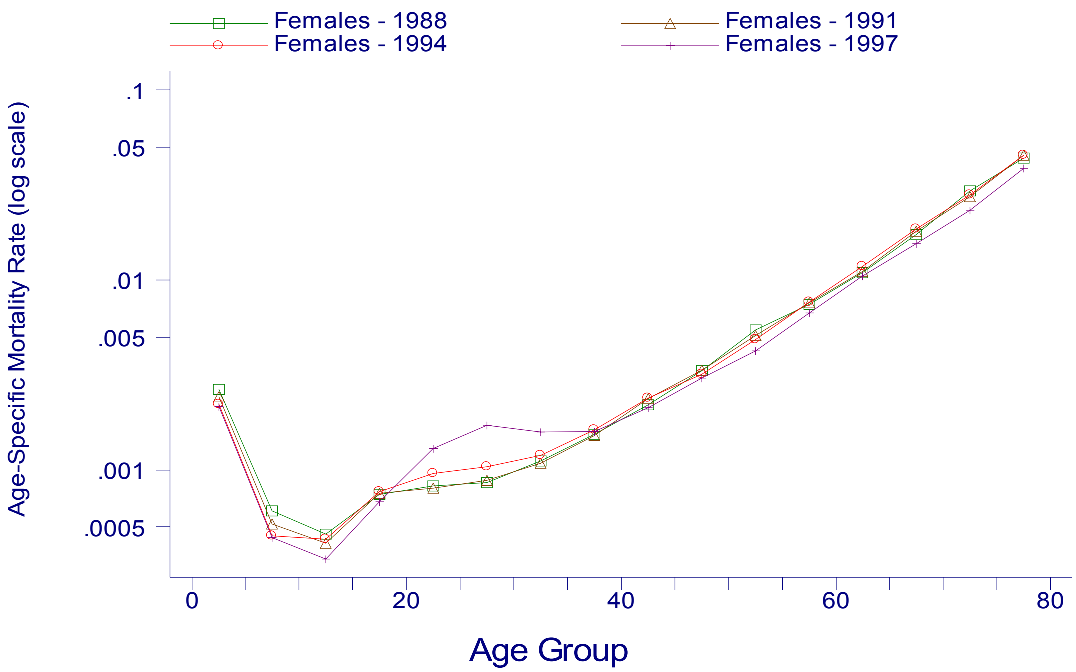
3. The United Nations families of model life tables generally fit the age patterns of mortality reasonably well, though they tend to underestimate young adult male mortality in most populations, cannot capture the age-specific mortality patterns of populations of the former Soviet Union (very high mortality after age 50) and cannot represent the age patterns associated with the HIV/AIDS epidemic.

4. Adult mortality appears to have been falling throughout the developing world from the 1960s to the 1990s, on average by about one percent per annum for males and two percent per annum for females, though the HIV/AIDS epidemic undoubtedly will reverse these gains in countries that are substantially affected. Even Thailand, touted for having controlled the epidemic, has seen age-specific rates for persons in their 20s and early 30s more than double.

Figure V. Unadjusted Age-Specific Mortality Rates for Selected Years: Thailand

a) Males

b) Females



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Appendix. Countries and Time Periods Covered by AMDC Project Estimates

Country	Time Periods
Argentina	1947-1960, 1960-1970, 1970-1980, 1980-1991
Azerbaijan	1991-2001
Bangladesh	1991-2001
Benin	1979-1992
Brazil	1980-1991, 1991-2000
Chile	1952-1960, 1960-1970, 1970-1982, 1982-1992
China	1964-1982, 1982-1990, 1990-2000
Colombia	1951-1964, 1964-1973, 1973-1985, 1985-1993
Costa Rica	1951-1963, 1963-1973, 1973-1984
Cuba	1953-1970, 1970-1981
Dominican Republic	1950-1960, 1960-1970, 1970-1981
Egypt	1947-1960, 1960-1976, 1976-1986, 1986-1996
Guatemala	1950-1964, 1964-1973, 1973-1981, 1981-1994
India	1992-1998
Iran	1986-1996
Laos	1985-1995
Mexico	1950-1960, 1960-1970, 1970-1980, 1980-1990, 1990-2000
Mongolia	1989-1999
Pakistan	1981-1998
Panama	1950-1960, 1960-1970, 1970-1980, 1980-1990, 1990-2000
Peru	1961-1972, 1972-1981, 1981-1993
Philippines	1948-1960, 1960-1970, 1970-1980, 1980-1990, 1990-1995
Puerto Rico	1960-1970, 1970-1980, 1980-1990, 1990-2000
Republic of Korea	1955-1960, 1960-1965, 1965-1970, 1970-1975, 1975-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000
Taiwan	1956-1966, 1966-1970, 1970-1975, 1975-1980, 1980-1990, 1990-2000
Thailand	1960-1970, 1970-1980, 1980-1990, 1990-2000
Zimbabwe	1982-1992