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Adult mortality in the developing world:

New findings

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This paper presents 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 authors, 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 Bernardo Queiroz (Berkeley), Piedad Urdinola (Berkeley) and Danzhen You (Berkeley).

ABSTRACT

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. The Adult Mortality in Developing Countries (AMDC) of the Global Burden of Disease 2000 in Aging Populations was intended to meet this need first by exploring methodological issues, second by compiling necessary data for as many (large) countries as possible, and finally applying the "best" methodology to the compiled data to arrive at estimates of adult mortality levels, patterns by age and sex, and trends for as much of the developing world as possible.

Based on results for 30 countries spanning five decades using methodology to evaluate reporting of deaths by comparison with age distributions, a very wide range of adult mortality risks is found. In Mongolia, over half of the males who survive to 15 die before 60, whereas the corresponding risk for females in the Republic of Korea is only seven percent. In all countries except one, female probabilities of dying between the ages of 15 and 60 are lower than for males. Adult mortality has been declining in the developing countries included in this study at about the same rate as observed in England and Wales in the 20th century. However, it is important to note that the representation of countries in the data set, even though it covers countries including some 80 percent of the population of the developing world, covers only a miniscule fraction of the population of sub-Saharan Africa, where the impact of the HIV epidemic has been far and away most severe.

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.

At its inception four years ago, the Global Burden of Disease 2000 in Aging Populations program project identified accurate measurement of adult mortality as a key area of research needed to improve global disease burden measures. Project 1, Adult Mortality in Developing Countries (AMDC), of the program project was intended to meet this need first by exploring methodological issues, second by compiling necessary data for as many (large) countries as possible, and finally applying the "best" methodology to the compiled data to arrive at estimates of adult mortality levels, patterns by age and sex, and trends for as much of the developing world as possible.

This paper summarizes substantive results from Project 1. It 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. The earliest estimates included are for the 1950s.

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. Of developing regions, 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 by Percent of Population by Region (Countries with populations 5 million or more) of the Developing World Used by the United Nations World Population Prospects 2000 Revision

Percents

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: Compiled from United Nations (2001)

METHODOLOGY

Methodological work early in the project determined that the most satisfactory basis for estimating adult mortality is the evaluation of age patterns of death (as recorded by a (sample) vital registration system or census or survey questions on household deaths by age in some recent, defined period) by comparison with two or more census age distributions. A group of methods have been developed and refined that seek to measure the completeness of recorded 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. The more flexible General Growth Balance (GGB) method proposed by Hill (which uses data from two censuses to provide age-range –specific growth rates 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. The more flexible Synthetic Extinct Generations (SEG) method proposed by Bennett and Horiuchi (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.

The adult mortality estimates presented in this paper come exclusively from the application of GGB and SEG methods to data on age distributions of deaths and population. Data for only 31 countries are available (see

Appendix Table 1 for a list of countries by region and time periods) but, because the countries have very large populations, they cover 80 percent of the 2000 population of the developing world. However, as noted above, the availability of appropriate data varies widely by region. Only three countries from sub-Saharan Africa, Benin, Senegal and Zimbabwe, are included here. The methodology applied to these compiled data has been guided by an evaluation of available methods carried out as part of this project. Hill and Choi (2004) use simulations to explore the performance of these methods, and show that the GGB method is more sensitive to possible errors in age reporting than the SEG method, whereas the SEG method is much more sensitive to any changes in census coverage. They suggests a two-stage process, by which the GGB 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. Results in this paper are based on this two stage approach, though two-stage estimates differ little from estimates based on GGB alone.

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.

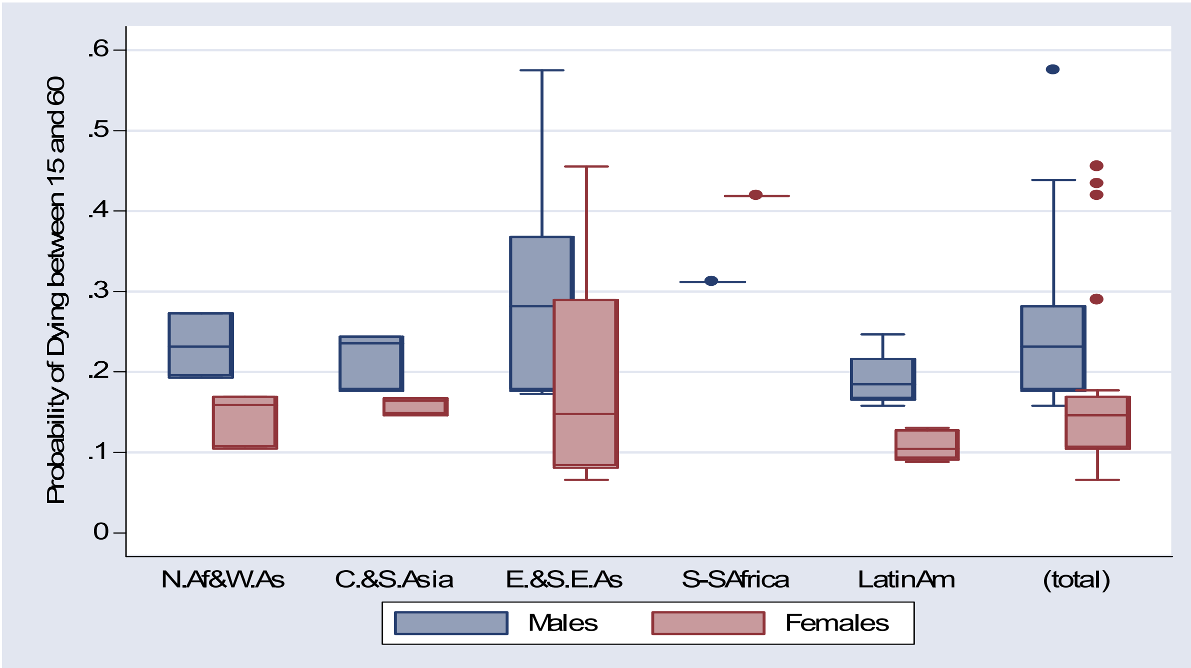
ESTIMATES OF ADULT MORTALITY

This section presents estimates produced by the Adult Mortality in Developing Countries Project for 31 countries and a range of time periods. Appendix 1 lists the countries, reference dates (midpoints of intercensal intervals), and basic estimates with an impressionistic indication of data quality. Although the countries included cover 80 percent 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 two of the 31 countries, the most recent estimate has a reference date in the 1970s, and for only 21 of the 31 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 average mortality for an intercensal period; to examine short-term changes would require assumptions that we have not made about changes or otherwise in coverage of death registration within intercensal intervals. The quality of estimates has also been assessed on the basis of a visual assessment of the GGB and SEG diagnostic plots. Applications are categorized on the basis of the linearity of the plots as good, moderate or poor, coded as 1, 2 or 3 respectively in Appendix Table 1. The analyses below are based on estimates categorized as “good” or “moderate” unless otherwise noted.

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 1 summarizes estimates with reference dates in 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_{10}, are 70.3 and 42.8 years respectively.

Figure 1: Estimates of the Probability of Dying between Ages 15 and 60 by Sex and Region; 18 AMDC Project Countries with Estimates for the 1990s



Sex Differences

Figure 2 plots female $_{45}q_{15}$'s against male $_{45}q_{15}$'s for estimates with a reference date (mid-point of the intercensal interval) of 1985 or later. The diagonal line represents equal male and female risks, whereas the lower continuous line shows the sex differences in $_{45}q_{15}$ from England and Wales from 1901 to 1995. Females have a lower probability of dying in all but one (Indonesia) of the 27 populations with estimates assessed as "good" or "moderate" quality, though the differences are very small in two additional 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. The sex differences for England and Wales (at comparable levels of mortality) are by and large similar to those for the developing countries, though perhaps the developing countries have slightly higher female advantages on average.

Figure 3 repeats Figure 2, but for estimates covering the period from 1950 to 1984. The overall pattern is very similar to that for the more recent period, and again shows no clear pattern with mortality level nor substantial difference from the historical patterns in England and Wales.

Figure 2: Sex Differences in Adult Mortality: Estimates of Female $_{45}q_{15}$ Against Male $_{45}q_{15}$ for 27 Countries with Estimates for 1985 or later.

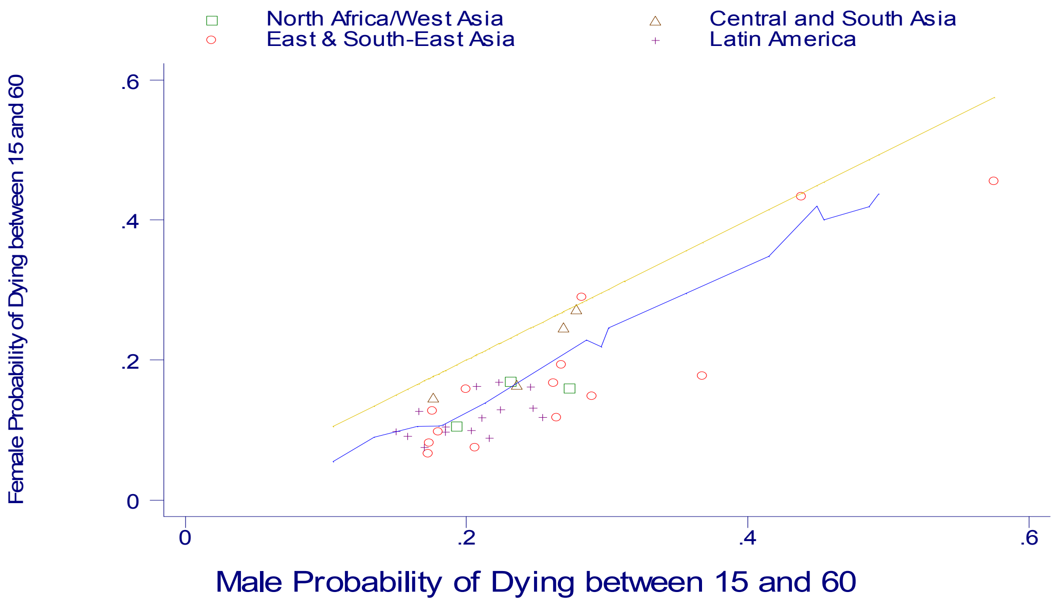
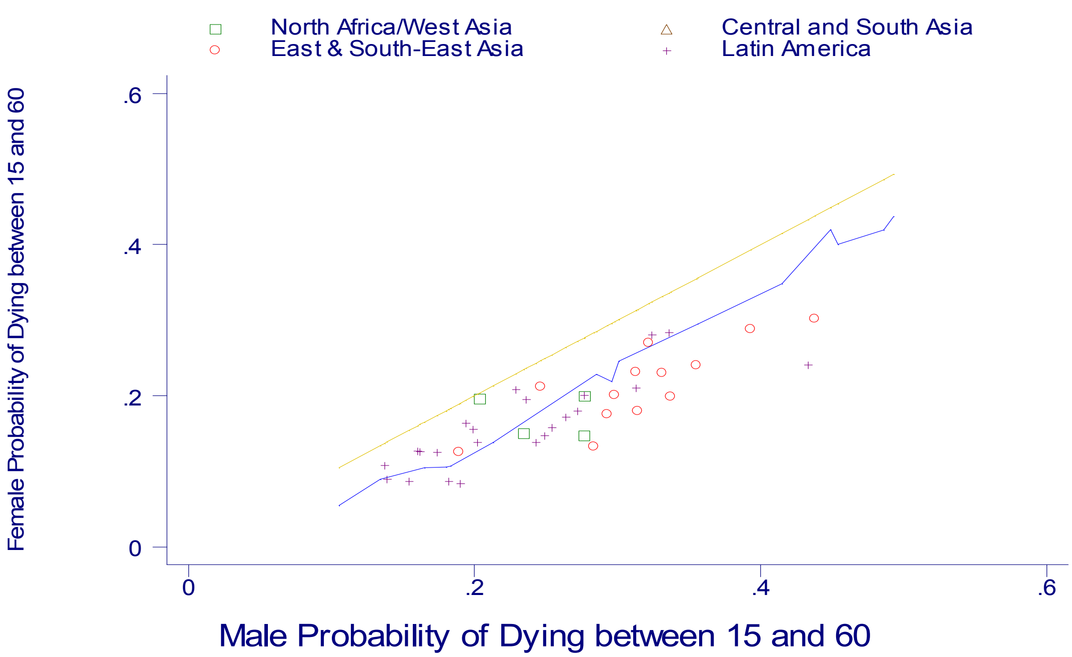


Figure 3: Sex Differences in Adult Mortality: Estimates of Female $_{45}q_{15}$ Against Male $_{45}q_{15}$ for 27 Countries with Estimates prior to 1985.



Age Patterns

This section compares AMDC adjusted 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.

Figure 4 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.

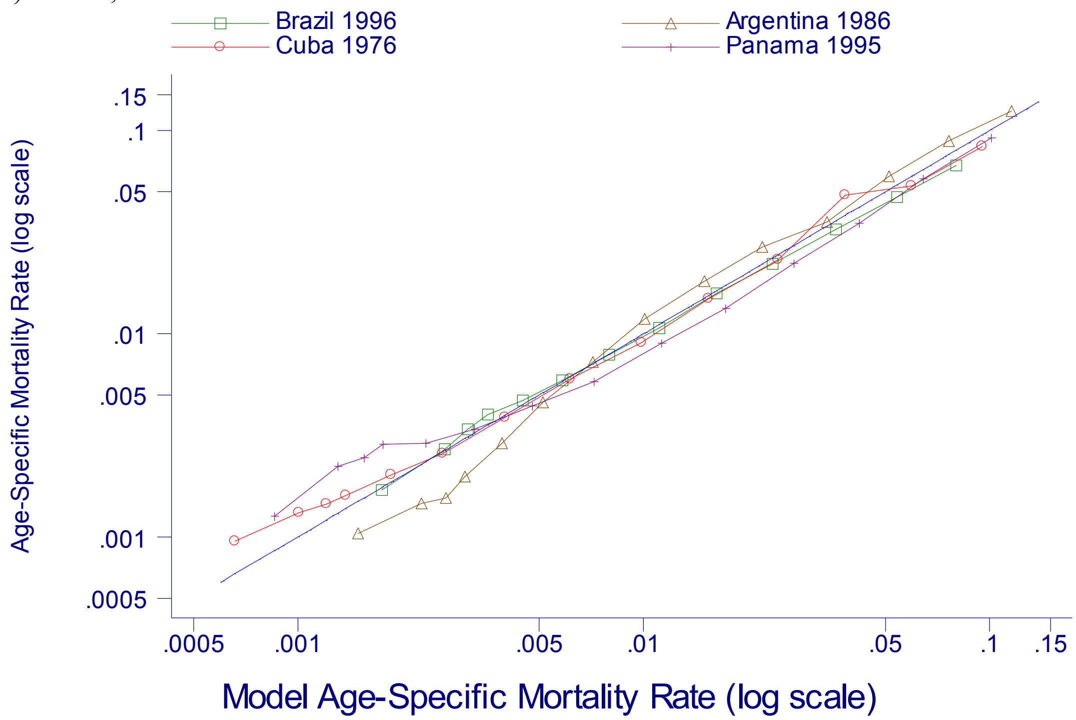
By and large, the observed patterns are reasonably well fitted by the models. The Latin American model fits the data for Brazil and Argentina females very well, and the Chilean family fits the Chilean data very well. The largest relative differences are typically for younger adults: Cuba and Panama both 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

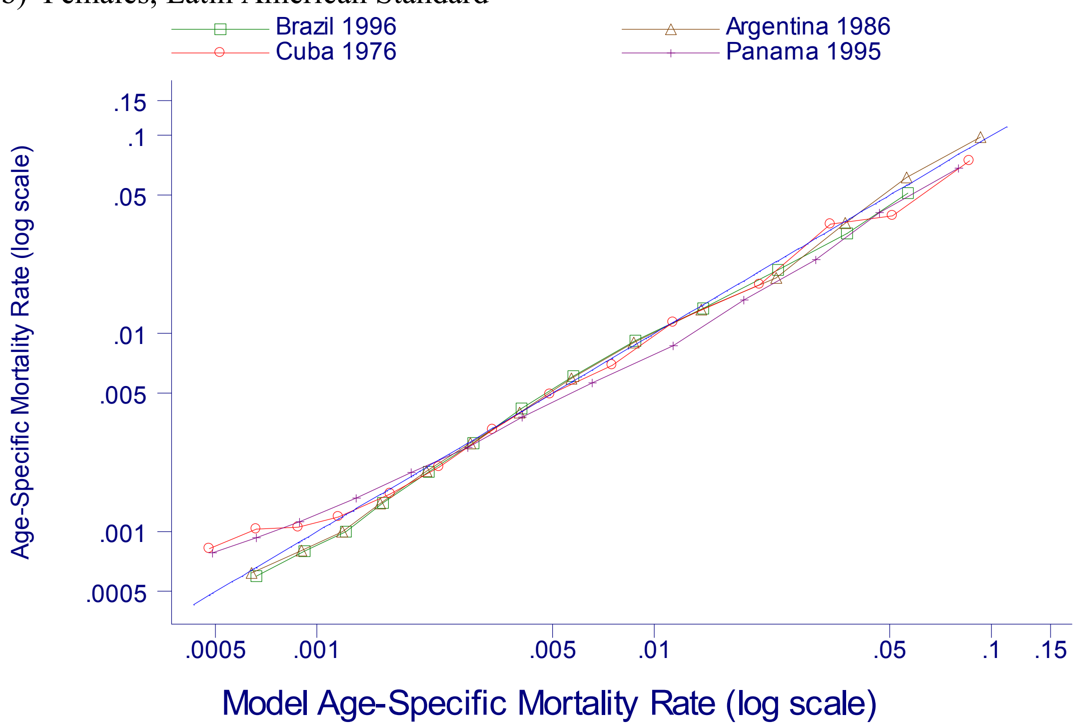
For 22 of the 31 countries examined, estimates of good or reasonable quality are available for two or more time periods, allowing examination of trends. Figure 5 shows the probabilities of dying between the ages of 15 and 60 by sex by decade for countries with multiple observations. There is a downward trend in the median value over time for both males and females, the median ${}_{45}q_{15}$ dropping from 0.277 before 1970 to 0.206 in the 1990s for males, and from 0.195 before 1970 to 0.127 for females. Regression of ${}_{45}q_{15}$ on reference date using a country fixed effects model indicates an annual rate of decline of 0.9 percent per annum for males and 1.8 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)). Figure 5 appears to indicate that improvement has slowed in the recent past. However, including a dummy variable for pre-1985 versus 1985 and later estimates indicates that rates of decline have not differed significantly by time period. By comparison, the annual decline of ${}_{45}q_{15}$ in England and Wales from 1901 to 1995 was 1.4 percent for males and 1.8 percent for females. Thus it appears that adult mortality has been declining in the developing world over the last three or four decades, and that the decline has been faster for females than for males. The declines for females have been at a pace comparable to historical declines in England and Wales, whereas declines for males appear to have been somewhat slower than the historical average.

Figure 4: Age-Specific Mortality Rates Plotted Against Corresponding Value from UN Model Life Tables with Same 45q15

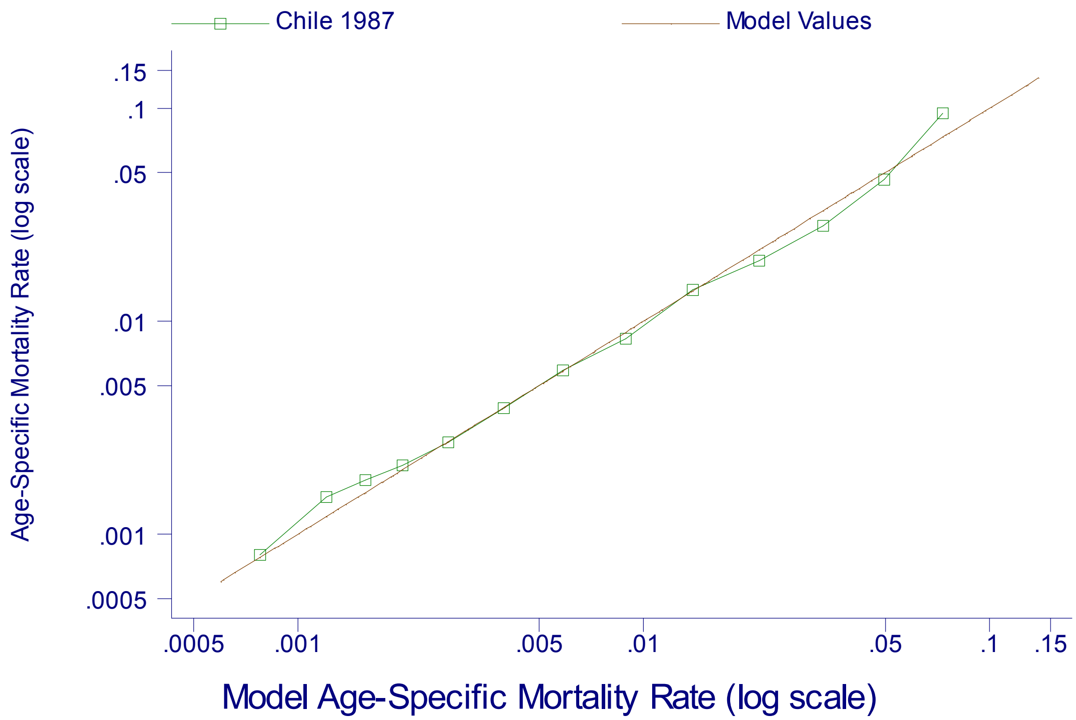
a) Males, Latin American Standard



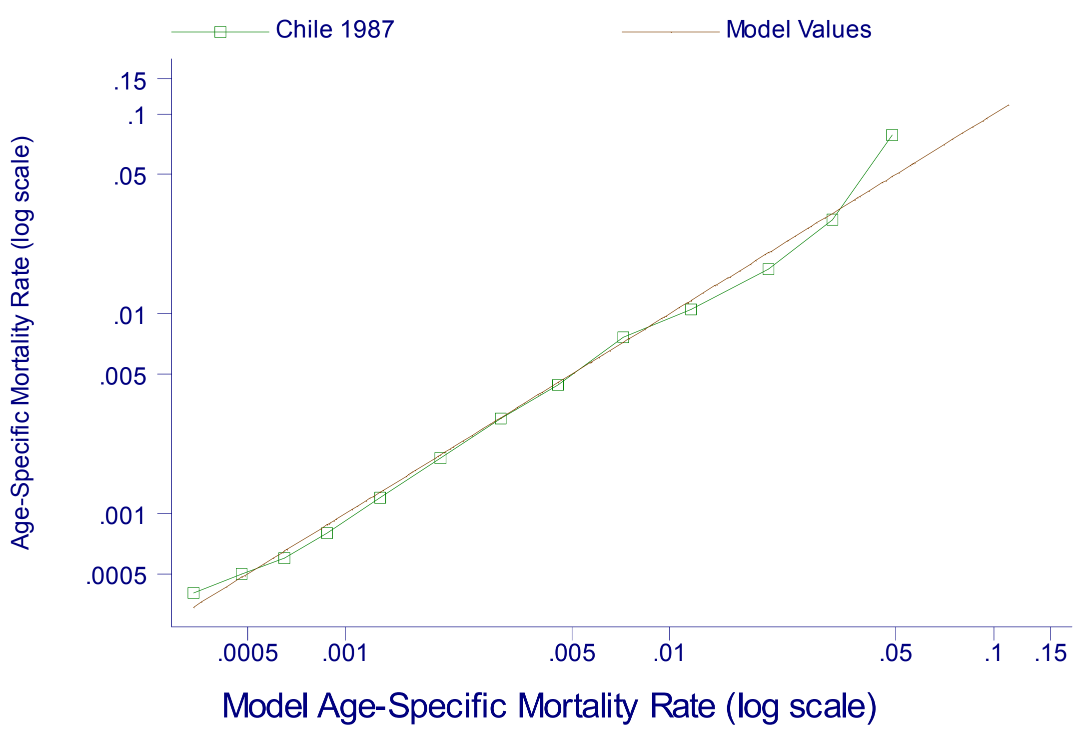
b) Females, Latin American Standard



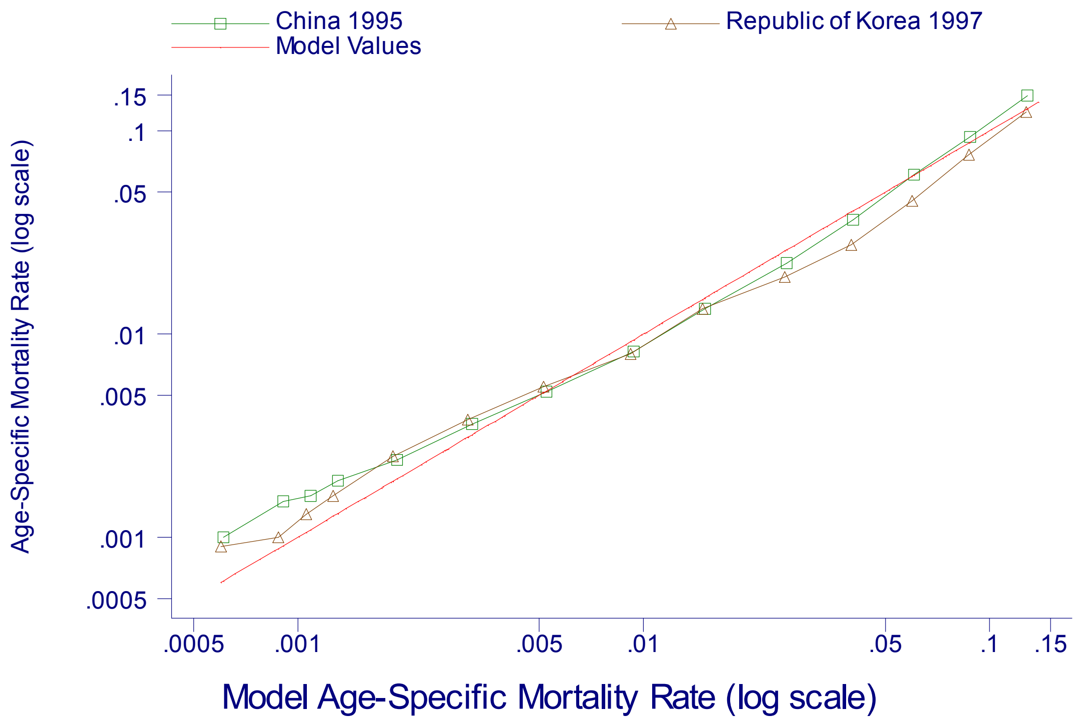
c) Males, Chilean Standard



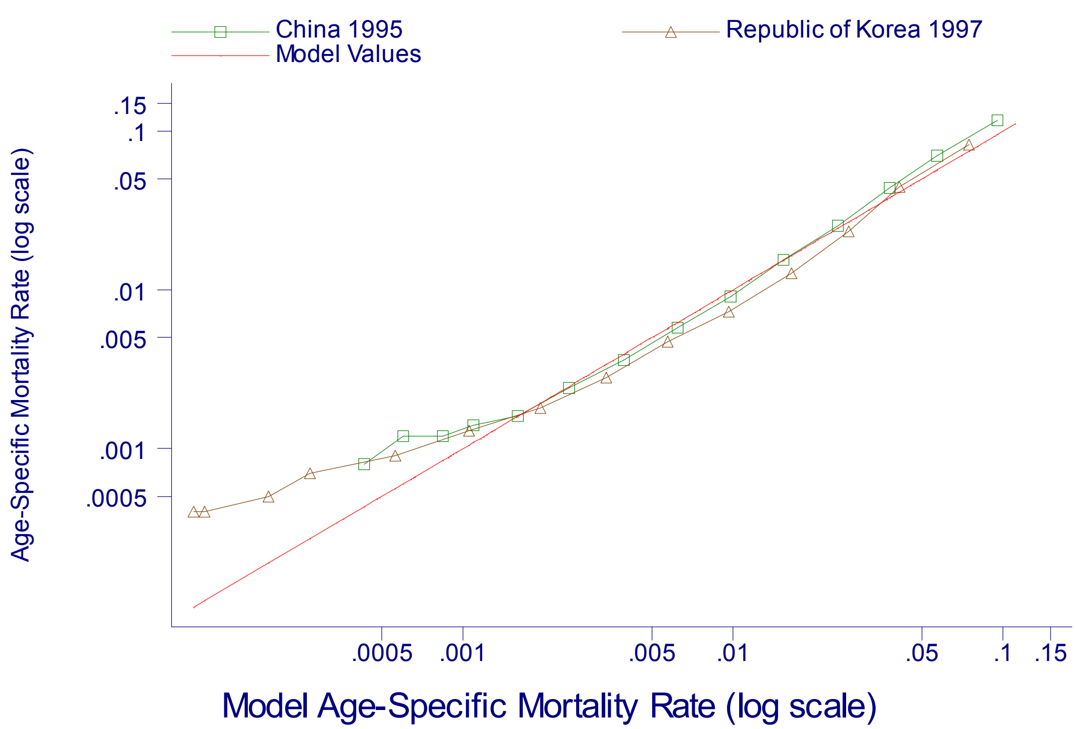
d) Females, Chilean Standard



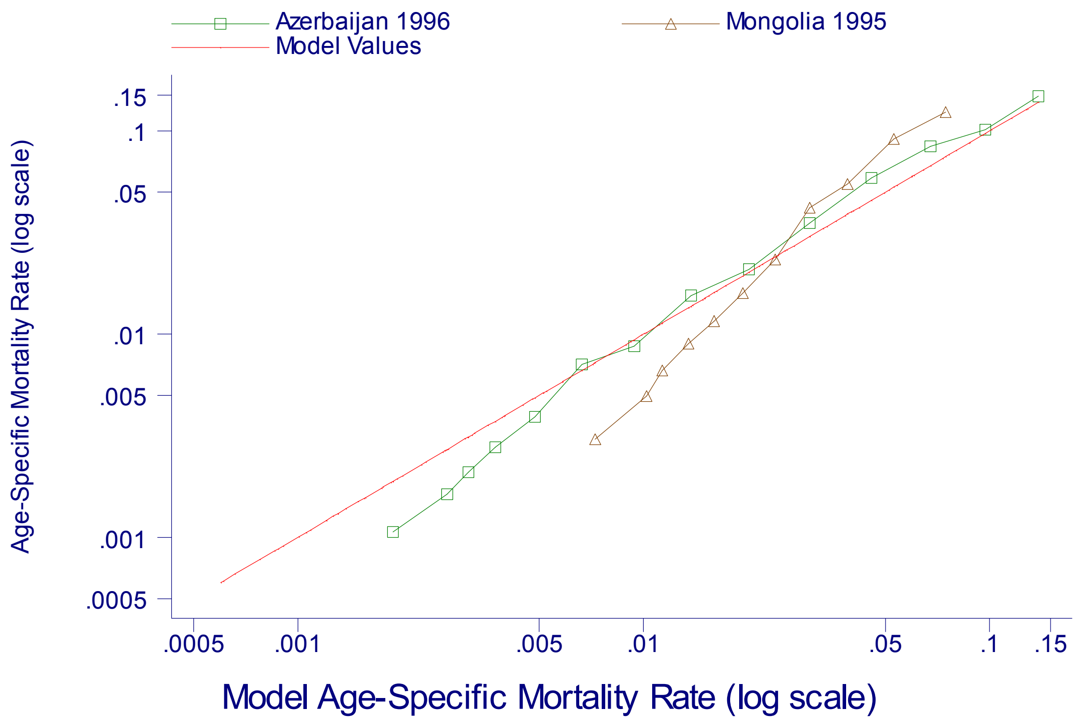
e) Males, Far Eastern Standard



f) Females, Far Eastern Standard



g) Males, General Standard



h) Females, General Standard

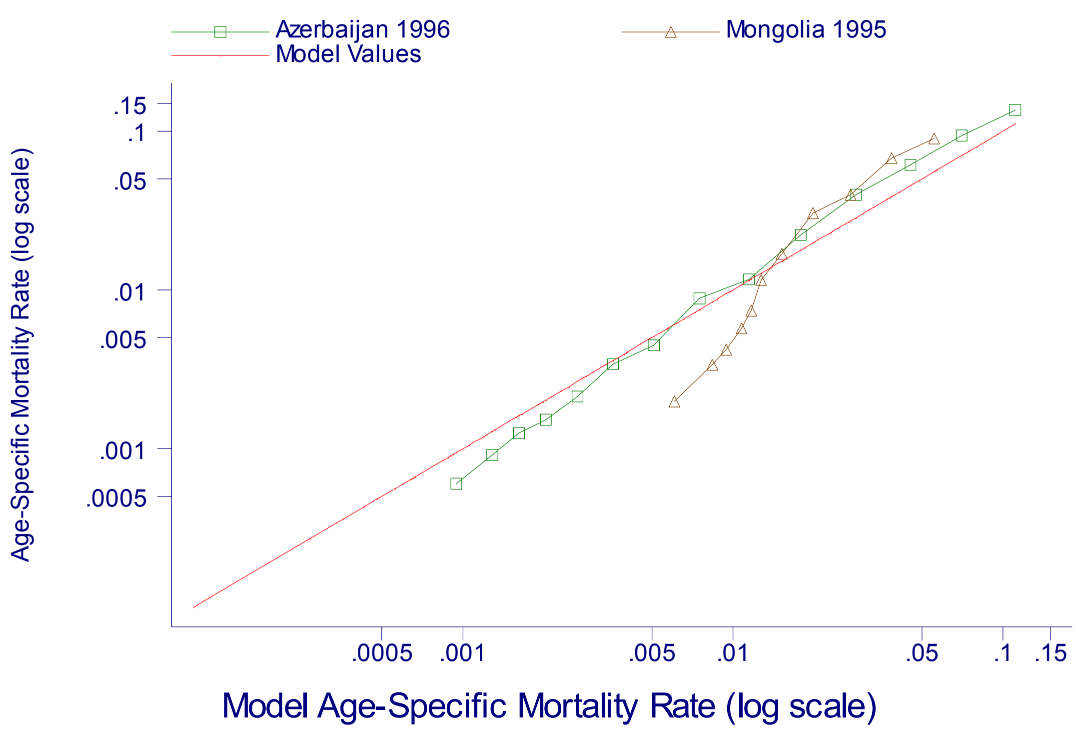
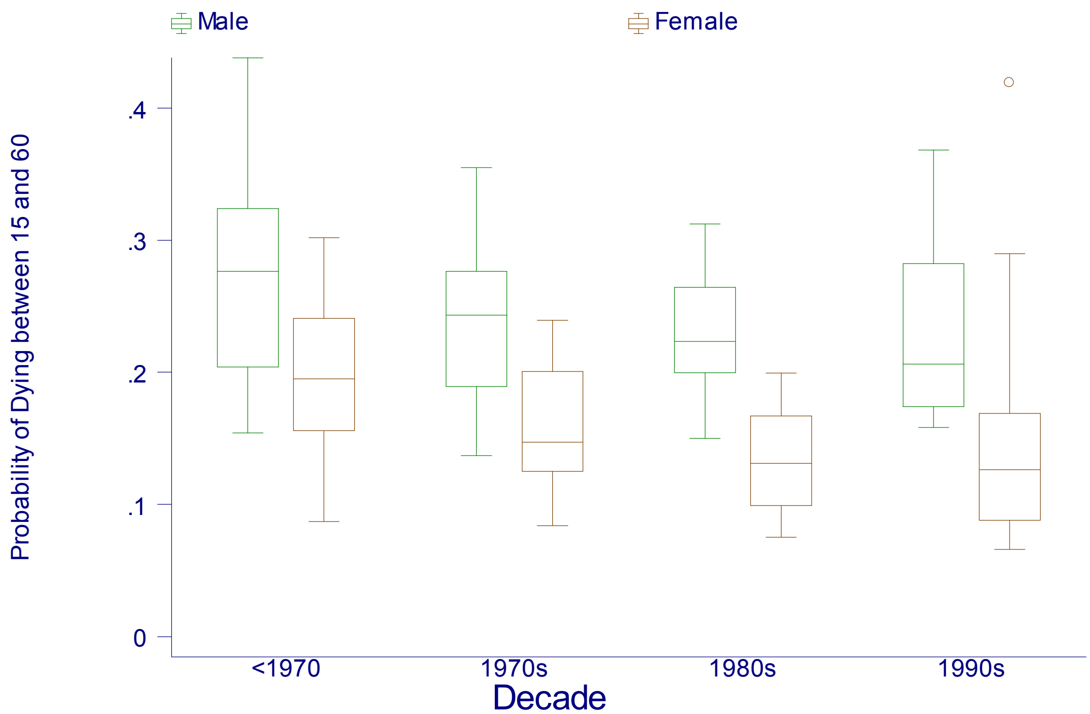


Figure 5: Estimates of ${}_{45}q_{15}$ by Sex and Decade, 1950s to 1990s



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 80 percent of the population of the developing world, we know very little from this source 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.

Thirty-one countries making up 80 percent of the population of the developing world have 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 but one the populations studied (and in that one the female disadvantage was trivial), but the female advantage varies substantially and seems to increase in relative terms as adult mortality falls. The female advantage appears to be comparable to, or slightly greater than, the historical female advantage in England and Wales.

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 Central Asian 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 close to one percent per annum for males and two percent per annum for females, though the HIV/AIDS epidemic undoubtedly has reversed these gains in countries that are substantially affected. Rates of improvement in the developing countries studied are broadly comparable to those seen for England and Wales from 1901 to 1995.

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Appendix 1: Countries, Time Periods and AMDC Project Estimates

Region	Country	Midpoint	Males		Females	
			$_{45}q_{15}$	Quality	$_{45}q_{15}$	Quality
N.Africa/W.Asia	Azerbaijan	1994	0.273	1	0.159	1
N.Africa/W.Asia	Egypt	1953	0.2345	2	0.1496	2
N.Africa/W.Asia	Egypt	1968	0.2765	2	0.1471	2
N.Africa/W.Asia	Egypt	1981	0.2772	1	0.1991	1
N.Africa/W.Asia	Egypt	1991	0.2314	1	0.169	1
N.Africa/W.Asia	Morocco	1988	0.2012	2	0.2724	3
N.Africa/W.Asia	Turkey	1968	0.2037	2	0.1958	2
N.Africa/W.Asia	Turkey	1995	0.193	1	0.1051	1
Cent&S.Asia	Bangladesh	1999	0.1764	1	0.1462	1
Cent&S.Asia	India	1986	0.274	1	0.248	2
Cent&S.Asia	India	1996	0.244	1	0.167	1
Cent&S.Asia	Iran	1991	0.2355	1	0.1643	1
Cent&S.Asia	Pakistan	1989	0.2778	2	0.2729	2
E.&S.E.Asia	China	1973	0.2465	1	0.2117	1
E.&S.E.Asia	China	1986	0.1999	1	0.158	1
E.&S.E.Asia	China	1995	0.176	1	0.1265	1
E.&S.E.Asia	Indonesia	1966	0.5126	3	0.3292	3
E.&S.E.Asia	Indonesia	1995	0.2821	1	0.2896	1
E.&S.E.Asia	Laos	1990	0.4383	2	0.4332	2
E.&S.E.Asia	Mongolia	1995	0.575	1	0.455	1
E.&S.E.Asia	Philippines	1954	0.298	2	0.2005	2
E.&S.E.Asia	Philippines	1965	0.1874	3	0.0989	3
E.&S.E.Asia	Philippines	1975	0.337	2	0.1987	2
E.&S.E.Asia	Philippines	1985	0.2675	1	0.193	2
E.&S.E.Asia	Philippines	1992	0.2895	1	0.1478	1
E.&S.E.Asia	South Korea	1958	0.438	1	0.3017	1
E.&S.E.Asia	South Korea	1963	0.3931	1	0.2875	1
E.&S.E.Asia	South Korea	1968	0.3314	1	0.2298	1
E.&S.E.Asia	South Korea	1973	0.3549	1	0.2396	1
E.&S.E.Asia	South Korea	1978	0.3142	1	0.1796	1
E.&S.E.Asia	South Korea	1983	0.2833	1	0.1327	1
E.&S.E.Asia	South Korea	1988	0.2644	1	0.1175	1
E.&S.E.Asia	South Korea	1993	0.2062	1	0.0744	1
E.&S.E.Asia	South Korea	1998	0.1731	1	0.0657	1
E.&S.E.Asia	Taiwan	1961	0.293	1	0.175	1
E.&S.E.Asia	Taiwan	1973	0.189	1	0.125	1
E.&S.E.Asia	Taiwan	1985	0.18	1	0.097	1
E.&S.E.Asia	Taiwan	1995	0.174	1	0.081	1
E.&S.E.Asia	Thailand	1965	0.3216	2	0.2699	2
E.&S.E.Asia	Thailand	1975	0.3128	1	0.2313	1
E.&S.E.Asia	Thailand	1985	0.2623	1	0.1669	1
E.&S.E.Asia	Thailand	1995	0.368	1	0.177	1
SSAfrica	Benin	1985	0.2629	2	0.2043	2
SSAfrica	Benin	1997	0.317	2	0.406	3
SSAfrica	Senegal	1982	0.249	2	0.215	2

SSAfrica	Zimbabwe	1987	0.3124	1	0.1966	1
SSAfrica	Zimbabwe	1994	0.3122	2	0.4191	2
LatAmerica	Argentina	1965	0.433	1	0.241	1
LatAmerica	Argentina	1975	0.19	1	0.084	1
LatAmerica	Argentina	1986	0.224	1	0.129	1
LatAmerica	Brazil	1965	0.313	1	0.21	1
LatAmerica	Brazil	1975	0.249	1	0.147	1
LatAmerica	Brazil	1986	0.254	1	0.118	1
LatAmerica	Brazil	1996	0.247	1	0.131	1
LatAmerica	Chile	1965	0.264	1	0.172	1
LatAmerica	Chile	1976	0.243	1	0.138	1
LatAmerica	Chile	1987	0.185	1	0.097	1
LatAmerica	Colombia	1969	0.236	1	0.195	1
LatAmerica	Colombia	1979	0.202	1	0.138	1
LatAmerica	Colombia	1989	0.203	1	0.099	1
LatAmerica	Costa Rica	1968	0.16	2	0.127	2
LatAmerica	Costa Rica	1978	0.139	1	0.09	1
LatAmerica	Cuba	1961	0.162	1	0.126	1
LatAmerica	Cuba	1975	0.137	1	0.108	1
LatAmerica	Dominican Republic	1985	0.223	1	0.168	1
LatAmerica	Dominican Republic	1995	0.166	1	0.127	1
LatAmerica	Guatemala	1957	0.336	1	0.2836	1
LatAmerica	Guatemala	1968	0.3238	1	0.2806	1
LatAmerica	Guatemala	1977	0.2765	1	0.2005	1
LatAmerica	Guatemala	1987	0.2455	1	0.1617	1
LatAmerica	Mexico	1965	0.272	1	0.18	2
LatAmerica	Mexico	1975	0.254	1	0.158	1
LatAmerica	Mexico	1985	0.211	1	0.117	1
LatAmerica	Mexico	1995	0.185	1	0.104	1
LatAmerica	Panama	1965	0.194	1	0.164	1
LatAmerica	Panama	1975	0.174	1	0.125	1
LatAmerica	Panama	1985	0.15	1	0.098	1
LatAmerica	Panama	1995	0.158	1	0.091	1
LatAmerica	Peru	1966	0.199	1	0.156	1
LatAmerica	Peru	1976	0.229	2	0.208	2
LatAmerica	Peru	1987	0.207	2	0.162	2
LatAmerica	Puerto Rico	1965	0.154	1	0.087	1
LatAmerica	Puerto Rico	1975	0.182	1	0.087	1
LatAmerica	Puerto Rico	1985	0.17	1	0.075	1
LatAmerica	Puerto Rico	1995	0.216	1	0.088	1