Adult Mortality in East Asia: Trends and Patterns

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INTRODUCTION

East Asian countries have experienced rapid demographic transitions (Lee, 2000). Compared to the developed world, East Asian countries have been able to take on the medical and the industrial technologies all at once and, as a result, mortality – especially childhood mortality – decreased sharply. In addition, socioeconomic development, changes in parental attitude towards child health and education, and highly effective family planning programs contributed to fast fertility decline (Lee, 2000; Peng, 1991). Especially, the demographic transition in this region - in particular the fertility transition - has been studied extensively related with the rapid economic development (Bloom, 1998; Poston, 2000).

However, compared to fertility and child mortality, adult mortality in this region has been relatively less explored. Studies of adult mortality in less developed countries are often challenged by difficulties in data collection. Incomplete vital registration, inaccurate censuses, and age misreporting in both death and population reporting are often reported challenges (Mari Bhat, 1990; United Nations, 1983). Nevertheless, it is increasingly important to understand adult mortality better in order to respond to emerging issues regarding rapid population aging in the developing world. Changes in the burden of disease among the population and social security policy are of particular interest.

The purpose of this paper is to identify trends and patterns of adult mortality in East Asia, using data from China, South Korea, and Taiwan, covering long time periods. Specific aims include: (1) to assess adult mortality data quality in the three countries; (2) to estimate levels and trends of mortality; and (3) to study changes in age and sex patterns of mortality over time.

DATA AND METHODS

Data

Population age distribution data come from censuses. A total of four (covering a period between 1964 and 2000), ten (covering 1955-2000), and twelve (covering 1905-2000) censuses were obtained from China, South Korea, and Taiwan, respectively. For each inter-censal period, the average annual number of deaths by age and sex was obtained from various sources including vital registration records, household deaths from censuses, and a special surveillance system. In addition, data from Japan were included in order to compare changes in mortality patterns by age and sex. A total of 10 censuses (covering a period between 1950 and 2000) and annual number of deaths by age and sex for the corresponding period were obtained. More information regarding data sources is listed in Appendix 1.

Methods

For adult mortality estimation in a non-stable population, death distribution methods are widely used. They compare the distribution of deaths by age with the age distribution of the living and provide age pattern of mortality in a defined reference period. There are two major approaches: (1) the General Growth Balance method and (2) the Synthetic Extinct Generation method.

Brass (1975) first pioneered the Growth Balance method, describing that, for any open-ended age segment ***a+*** of a closed population, the entry rate into the segment is equal to the growth rate of the segment plus the exit rate of the segment. In a stable population, the growth rate is constant for all segments and, therefore, the entry rate and the death rate must be linearly related. The entry rate is calculated from a population age distribution alone and any coverage error assumed to be invariant with age cancels out. On the other hand, the death rate is calculated from both deaths and population by age and is affected by any coverage difference between population and deaths. The completeness of population recording relative to death recording is estimated from the slope of the line relating the entry rate to the death rate and provides an adjustment factor for deaths (Hill, 2001).

The method was later generalized to non-stable populations using segment-specific growth rates from two censuses (Hill, 1987). The Generalized Growth Balance method explains,

$$e(a+) - r(a+) = d(a+) \qquad (1)$$

where $e(a+)$ is the entry rate of the population $a+$, $N(a)/N(a+)$; $r(a+)$ is the growth rate of the segment; and $d(a+)$ is the death rate of the segment, $D(a+)/N(a+)$. The difference between $e(a+)$ and $r(a+)$ provides a consistency check for $d(a+)$. Typical data errors include incomplete death recording and changes in coverage from one census to another. If deaths are registered with age invariant completeness c,

$$D(a+) = \{1/c\}D^{o}(a+) \qquad (2)$$[1]

And, assuming exponential growth between two censuses,

$$r(a+) = \{1/t\} \ln\{N2(a+)/N1(a+)\} \qquad (3)$$

Then, if coverage of the second census differs from that of the first by an age invariant factor k,

$$r(a+) = \{1/t\} \ln\{[N2^{o}(a+)/N1^{o}(a+)]*[1/k]\} = r^{o}(a+) - \{1/t\}\ln(k) \qquad (4)$$

Replacing true values with observed values,

$$\frac{N(a)}{N(a+)} - r^{o}(a+) = \frac{1}{t}\ln(k) + \frac{1}{c} * \frac{D^{o}(a+)}{N(a+)} \qquad (5)$$

[1] Superscript O (^{o}) refers to an observed value.

Thus the residual estimate of the death rate in each open-ended age group should be linearly related to the observed death rate in the age group. The slope is the reciprocal of completeness of death recording *c* and the intercept is a function of any change in completeness of population recording and the length of the interval (Hill, 2001).

Alternatively, the Synthetic Extinct Generation method is based on the idea that, with perfect recording of deaths, the population age *a* at time *t* could be estimated by accumulating the deaths to that cohort after time *t* until the cohort was *extinct*.

$$\ell(a) = \sum_{x=a}^{\varpi} {}_1d_x \qquad (6)$$

Bennett and Horiuchi (1981;1984) generalized the method to non-stable closed populations by using the age-specific growth rate. The population at age *a* can be estimated from the deaths above that age *a* by applying summed age-specific growth rates to allow for the demographic history of the population.

$$N(a) = \int_a^{\varpi} D(x) e^{\int_a^x r(y)dy} dx \qquad (7)$$

The ratio of the population age *a* estimated in this way from the deaths to the observed population age *a* calculates the completeness of death recording relative to census coverage.

However, both methods require numerous assumptions about the population. The General Growth Balance method requires (1) a closed population, (2) invariant coverage of population and deaths by age, and (3) accurate recording of age for both population and deaths. The Synthetic Extinct Generation method imposes invariant coverage of population across time, in addition to three required in the General Growth Balance method. A study examined the effects of violated assumptions in these methods such as migration, age misreporting in population and deaths, age-varying coverage of population and death, and changing coverage of censuses (Hill, 2003). As implied in assumptions, the Synthetic Extinct Generation method was very sensitive to coverage change in censuses. It was also reported that the General Growth Balance method is more sensitive to typical age misreporting errors[2], whereas the Synthetic Extinct Generation is more sensitive to migration. As a result of 44 simulated cases, it was suggested that a strategy combining these two methods - Synthetic Extinct Generation method adjusted to the census coverage change based on General Growth Balance results – was more robust to typical error patterns than either individually.

In our analysis, therefore, we used a strategy combining these two methods. In order to assess data quality, the completeness of death recording relative to that of censuses was estimated for each five-year age group. Age-specific mortality rates and, as a measure of overall adult mortality, the probability of dying between 15 and 59 years of age, 45q15, were calculated. As a measure of trends, annual rates of change in 45q15 and age-specific mortality rates were examined across sex and time. In addition, in order to examine the age pattern of mortality, age-specific levels were estimated using the Coale-Demeny West Model life tables (Goldman, 1980).

[2] The author used transition probabilities of age misreporting estimated by Mari Bhat (1990).

RESULTS

Data quality: completeness of death recording

Death recording completeness relative to population recording improved in China and South Korea over time (Table 1). In China, death recording completeness was about 80% of population recording during the 1964-1982 period but increased to 85-90% in the 1990's. In South Korea, vital registration had less than 50% completeness compared to censuses in the 1950's but it substantially improved to the level of census completeness in the 1990's. On the other hand, Taiwan has had death recording completeness comparable to census coverage since the beginning of the 20th century, except the 1940-1956 period when vital registration completeness was about 75 % compared to population recoding.

Levels and trends of adult mortality

All three countries have experienced remarkable reductions in adult mortality (Figure 1). In China, 45q15 (the probability of dying between 15 and 59) declined from 0.246 and 0.212 during the 1964-1982 period to 0.176 and 0.126 during the 1990-2000 period for males and females, respectively. In South Korea, for males and females respectively, 45q15 decreased from 0.438 and 0.302 during the 1955-1960 period to 0.173 and 0.066 during the 1995-2000 period. Finally, in Taiwan, it reduced from 0.786 and 0.634 during the 1905-1915 period to 0.174 and 0.081 during the 1990-2000 period for males and females, respectively.

Importantly, each country experienced fairly constant reduction rate over time. Average annual per cent decline of 45q15 was estimated for males and females to be about 1.5% and 2.4%, 2.1% and 4.0%, and 2.0% and 2.7 % in China, South Korea, and Taiwan, respectively. Females had faster mortality decline in all countries. Furthermore, bivariate log-linear regressions suggested that more than 90 % of variance in 45q15 was explained by time alone in all populations (Table 2). Nevertheless, some exceptional periods were observed as shown in Figure 1. Both males and females in South Korea experienced slightly increased 45q15 between 1966-1970 and 1970-1975 periods. In addition, reduction in 45q15 among Taiwanese men slowed down significantly during the 1980's and 1990's whereas women have experienced by and large constant decline since the 1960's.

In terms of trends in the age-specific mortality rate, females had faster mortality decline than males in all age groups. Especially, the gap appeared to be particularly bigger for age groups between 20-24 to 40-44 in all countries. Annual reduction rates in the age-specific mortality rate were on average about 30 to 50 % smaller for males than for females in these age groups (Figure 2)[3]. In addition, mortality reduction was faster for younger adults in South Korea, whereas it was relatively similar across age groups in China and Taiwan.

Changes in patterns of adult mortality by age and sex

In South Korea and Taiwan, the Far Eastern mortality pattern (Goldman, 1980) was observed only until the 1980's and the mid 1960's, respectively. Since then, the apparent excess mortality of older men compared to men at younger ages was not detected and large sex difference in mortality among the older age group has decreased over time (Figure 3). On the other hand, China did not appear to experience the typical Far Eastern mortality pattern during the time observed. During the 1964-1982 period, excess mortality of older age compared to the younger was observed in both men and women and, consequently, there was only a fairly small sex difference among older age groups. In the 1980's and 1990's, West levels were estimated to be relatively comparable across age in both males and females.

In addition, male-to-female ratios of the age-specific mortality rate were examined (Figure 4). in all three countries, there is evidence of female mortality disadvantage among young women in earlier periods, perhaps due to maternal mortality risk. However, excess male mortality increased over time in all countries. Especially in South Korea and Taiwan, the ratios illustrated that excess male mortality has dramatically expanded to young adults since the 1980's, whereas it was more concentrated in older age groups before then. China, however, had relatively low and steady excess male mortality risks across all age groups.

The age pattern of excess male mortality during the 1980's and 1990's in South Korea and Taiwan was compared to equivalent levels of the West model life tables. Based on the probability of dying between 15 and 59, West levels ranging from 18.2 to 22.0 and from 21.7 to 24.2 were implied for males and females, respectively (Table 3). Figure 5 presents male-to-female ratios of the age-specific mortality rate for the West levels from 18 to 25. The ratios increase substantially among younger age groups, especially between 15 and 24, as the overall mortality level decreases. However, the ratios change little for age groups in their 40's.

It was further compared to data from Japan. Japanese adult mortality between 1950 and 1995 generally covers the range of adult mortality observed in South Korea and Taiwan during the 1980's and 1990's (Table 4). Figure 6 illustrates changes in male-to-female ratios of the age-specific mortality rate over time. The ratios between ages 15 and 24 increased significantly as

[3] For the comparison purpose, early periods until 1956 were excluded in Taiwan.

observed in South Korea, Taiwan, and the West model life tables. However, ratios between 30 and 39 have not changed considerably since 1965. The overall age pattern of excess male mortality appears to follow rather closely that of the West model life tables than those observed in South Korea and Taiwan.

DISCUSSION

Completeness of death recording improved remarkably in China and South Korea. In particular, household death recording from the latest two censuses in China indicated over 90 % of coverage relative to population recording. In resource limited settings, census questions on deaths in a reference period are considered to be a satisfactory substitute for registered deaths in estimating adult mortality. In addition, the probability of dying between 15 and 59 declined significantly in all three countries with annual reduction rates ranging from 1.5 % to 2.1 % for males and 2.4 % to 4.0 % for females.

Goldman (1980) identified a unique pattern of adult mortality in East Asia by comparing Far Eastern mortality schedules with those in the West model life tables. Excess mortality of older men compared to men at younger ages and women was characterized. Respiratory tuberculosis was suggested to be most strongly associated with the existence and later attenuation of this pattern (Goldman, 1980; Gragnolati, 1999). In our analysis, the Far Eastern mortality pattern was observed in South Korea and Taiwan until the 1980's and the 1960's, respectively. The pattern has disappeared progressively since then. We did not observe the Far Eastern mortality pattern in China. However, adult mortality in China during the earliest period observed (1964-1982) was lower than adult mortality levels in South Korea and Taiwan during the periods when the pattern was prominent. Therefore, it is possible that we simply included periods only after the pattern had become attenuated.

The age pattern of sex differentials in mortality was also examined by using male-to-female ratios of the age-specific mortality rate. Excess male mortality seems to be relatively constant across age in China and the magnitude is considerably smaller compared to Japan, South Korea, and Taiwan. In South Korea and Taiwan, excess male mortality increased significantly in all age groups between 15 and 59 during the recent two decades. In particular, high excess mortality of men in their 30's and 40's appears to be distinctive in comparison with Japan and the West model life tables with similar levels of overall adult morality.

Changes in the age pattern of sex differentials in South Korea and Taiwan need to be further studied with cause of death information as well as social factors. In addition, we limited our analysis to ages between 15 and 59 partially because of varying open age intervals by country and period. However, measures including older age mortality also should be investigated.

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APPENDIX 1. Source of Data by Country

	Data Sources	
	Population	Deaths
China	- 1964 census - 1982 census - 1990 census - 2000 census	- Special Cancer Surveillance (1973-1975) [2] - 1982 census [3] - 1990 census [4] - 2000 census [3]
South Korea	- 1955 census - 1960 census - 1966 census - 1970 census - 1975 census - 1980 census - 1985 census - 1990 census - 1995 census - 2000 census	- 1957-1960 vital registration - 1962-1964 vital registration - 1967 vital registration - 1970-1971 vital registration - 1974-2000 vital registration
Taiwan	- 1905 census [1] - 1915 census [1] - 1920 census [1] - 1925 census [1] - 1930 census - 1935 census - 1940 census - 1956 census - 1966 census - 1980 census - 1990 census - 2000 census	- 1906-1926 vital registration [1] - 1927-1943 vital registration - 1950-2000 vital registration
Japan	- 1950 census - 1955 census - 1960 census - 1965 census - 1970 census - 1975 census - 1980 census - 1985 census - 1990 census - 1995 census	- 1950-1995 vital registration

1. Age was recorded in Chinese age and was adjusted to western age.
2. Age-specific mortality rates were obtained.
3. The number of deaths during 12 months prior to the census
4. The number of deaths during 18 months prior to the census

Table 1. Data quality indicators by sex

Country	Census 1	Census 2	Relative Completeness: Census 1 to Census 2 [a]		Relative Completeness: deaths to population [b]	
			Male	Female	Male	Female
China	1964	1982	0.98	0.99	0.80	0.79
	1982	1990	1.00	0.99	0.87	0.86
	1990	2000	0.98	0.98	0.91	0.92
South Korea	1955	1960	0.98	1.00	0.46	0.46
	1960	1966	0.98	0.99	0.61	0.55
	1966	1970	1.00	1.00	0.85	0.72
	1970	1975	0.99	1.00	0.94	0.81
	1975	1980	1.00	1.00	1.07	1.00
	1980	1985	0.99	0.99	1.06	1.16
	1985	1990	0.97	0.99	0.99	1.08
	1990	1995	1.02	1.03	1.06	0.97
	1995	2000	1.02	1.02	1.06	0.94
Taiwan	1905	1915	0.99	0.99	0.94	0.98
	1915	1920	1.00	1.00	0.95	0.97
	1920	1925	1.00	1.00	0.97	0.99
	1925	1930	0.98	0.98	0.99	1.08
	1930	1935	1.00	1.01	1.00	0.98
	1935	1940	0.99	0.99	0.95	1.03
	1940	1956	0.73	0.85	0.73	1.02
	1956	1966	0.85	1.00	0.92	0.98
	1966	1980	0.96	0.98	1.12	0.99
	1980	1990	1.01	1.02	1.02	0.96
	1990	2000	1.00	0.99	0.99	1.05

[a] Values are estimated from the General Growth Balance method and applied to the Synthetic Extinct Generation method.
[b] Average relative completeness between age groups 15+ to 55+

Figure 1. Trends of the probability of dying between 15 and 59 by sex

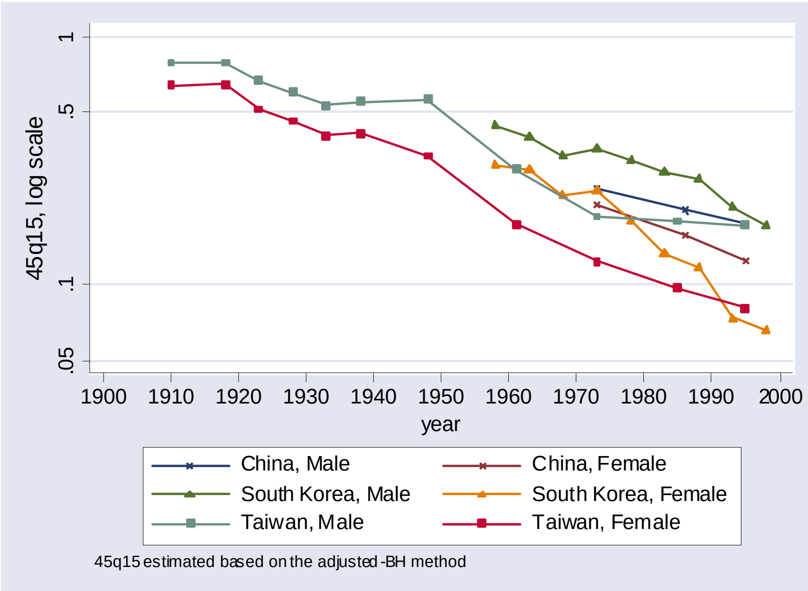


Table 2. Linear regression analyses of ln(45q15) on calendar year [a]

Country	Period	Male				Female			
		Coeff.	t	R^2	N	Coeff.	t	R^2	N
China	1964-2000	-0.015	-40.0	0.999	3	-0.024	-47.7	0.999	3
South Korea	1955-2000	-0.021	-9.8	0.931	8	-0.040	-11.5	0.949	8
Taiwan	1905-2000	-0.020	-14.7	0.941	11	-0.027	-25.7	0.980	11
	1905-1940	-0.016	-5.5	0.881	6	-0.019	-5.8	0.887	6
	1956-2000	-0.014	-2.7	0.758	4	-0.023	-14.6	0.990	4

[a] Robust standard error estimates.

Figure 2. Average annual rates of reduction in the age-specific mortality rate by sex

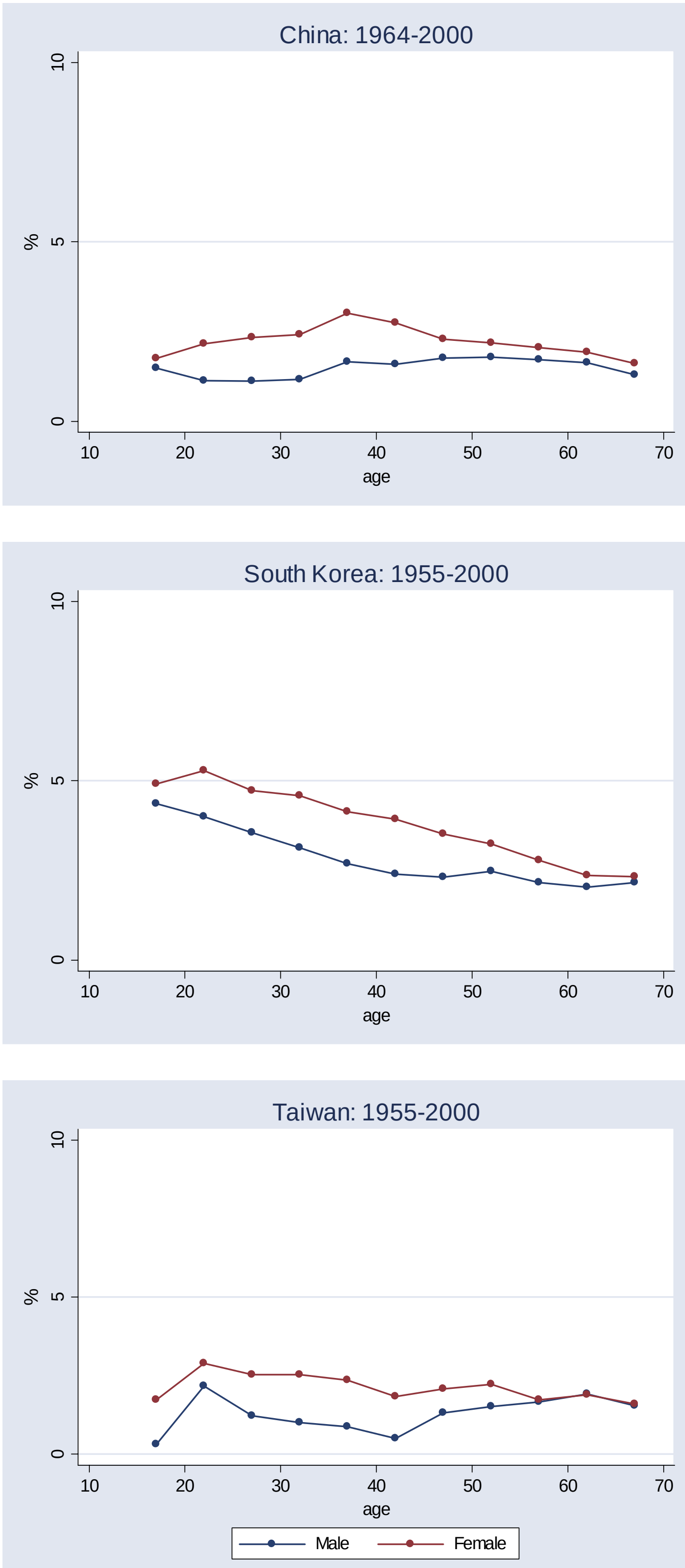


Figure 3. West levels of mortality implied by age-specific mortality rates, for selected years

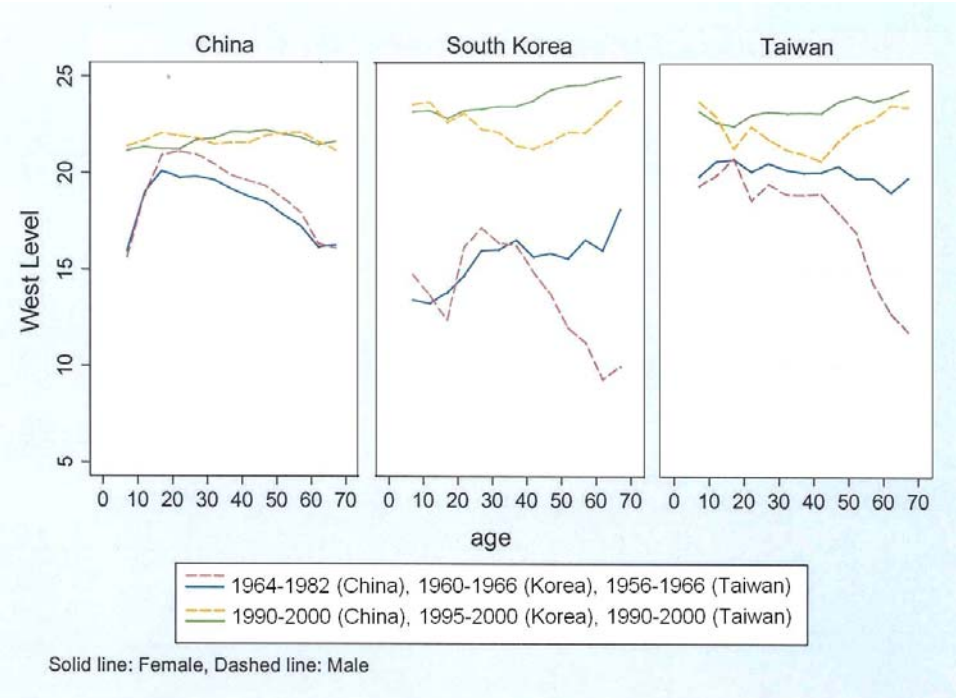
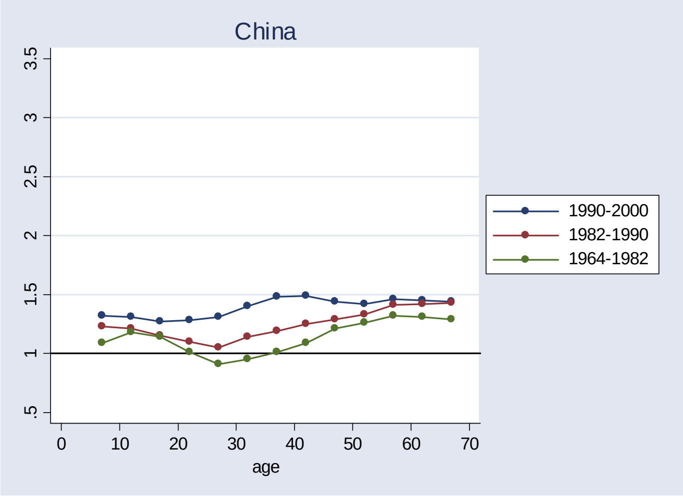
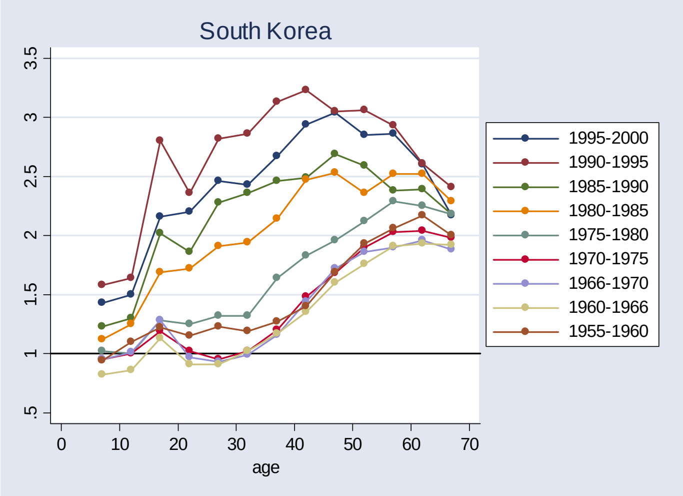


Figure 4. Male-to-female ratios of the age-specific mortality rate





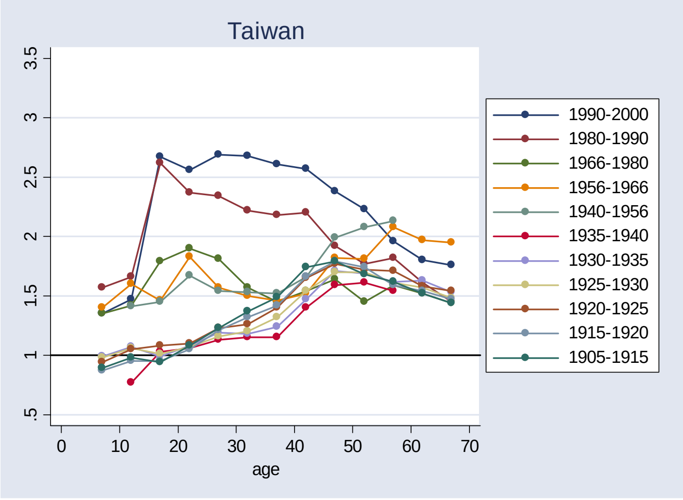


Table 3. West levels implied by the probability of dying between 15 and 59: for selected periods in South Korea and Taiwan

Country	Period	Male		Female	
		45q15	Implied West Level	45q15	Implied West Level
South Korea	1980-1985	0.283	18.2	0.133	21.7
	1985-1990	0.264	18.8	0.118	22.2
	1990-1995	0.206	21.0	0.074	23.8
	1995-2000	0.173	22.0	0.066	24.2
Taiwan	1980-1990	0.180	21.8	0.097	23.0
	1990-2000	0.174	22.0	0.081	23.6

Figure 5. Male-to-female ratios of the age-specific mortality rate: selected levels from the West model life tables

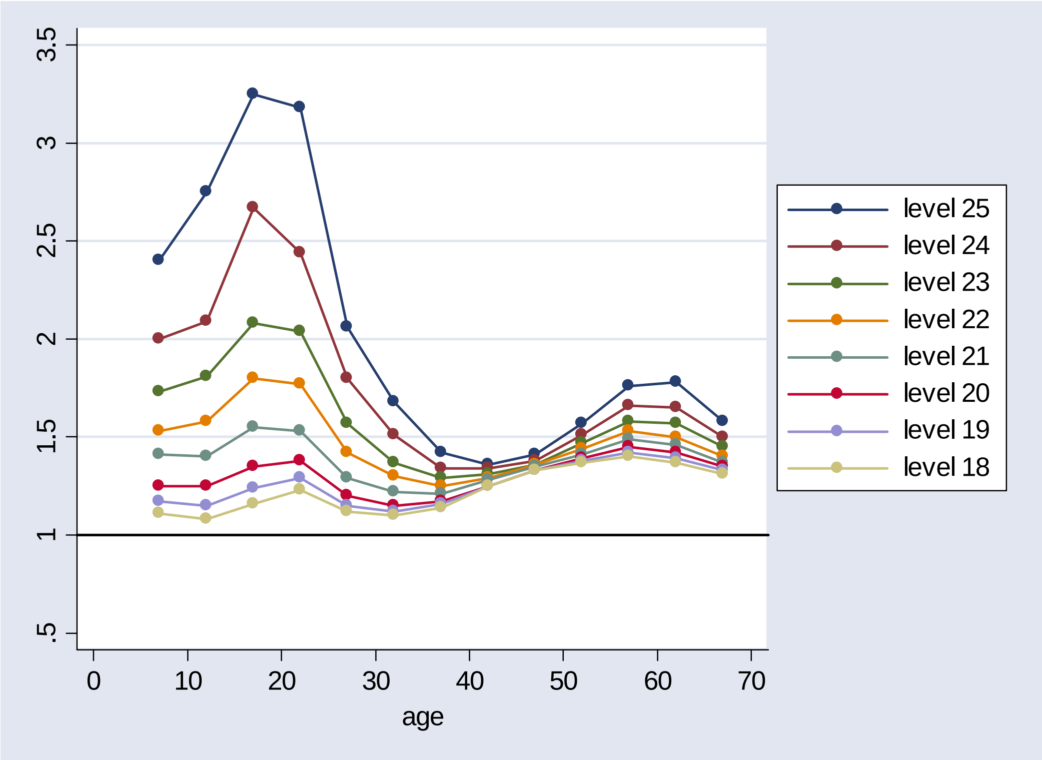


Table 4. Probabilities of dying between 15 and 59 and implied West levels: Japan, 1950-1995

Period	Male		Female	
	45q15	Implied West Level	45q15	Implied West Level
1950-1955	0.262	18.9	0.208	18.9
1955-1960	0.223	20.4	0.161	20.7
1960-1965	0.203	21.1	0.135	21.6
1965-1970	0.178	21.9	0.109	22.5
1970-1975	0.158	22.5	0.088	23.3
1975-1980	0.135	23.2	0.074	23.8
1980-1985	0.126	23.4	0.064	24.2
1985-1990	0.112	23.9	0.057	24.5
1990-1995	0.105	24.1	0.055	24.6

Figure 6. Male-to-female ratios of the age-specific mortality rate: Japan 1950-1995