An evaluation of adult death registration coverage in the Human Mortality Database and World Health Organization mortality data.

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Abstract

The Human Mortality Database (HMD) and the World Health Organization Global Health Observatory (GHO) are important mortality databases to study the evolution of mortality and health conditions around the world. The HMD is considered to be the highest quality standardized mortality database, while the GHO is as extensive mortality database of primary (unadjusted) data provided to WHO by member states. Many studies use HMD data to investigate the trends in life expectancy, distribution of age at death, and others. In addition, several studies evaluate the quality of data. GHO is not subject to any procedures to control the data quality, and one important limitation is under-registration of death counts, especially in countries with incomplete vital registration systems. Furthermore, the issue of under-registration of death counts is not discussed for HMD, as countries are selected for inclusion on the premise that vital registration is nearly complete. We use a set of formal demographic analyses, based on the Death Distribution Methods (DDM), to evaluate the quality of mortality data for all countries in these two databases. The results indicate that quality of mortality data is improving over time for most countries in the world. We also find that a series of HMD countries have low completeness of death count registration, and some countries have significant variations in data quality in specific periods, in general related to social, economic, or political instability. We also discuss limitations in the evaluation methods used are also discussed.

Introduction

The study of the pattern, level and trends in mortality are very important in understanding the population dynamics, urban planning and social policies. Appropriate decisions on public health occur only with appropriate information on health-related events; mortality, morbidity, causes of death; which require the existence of an adequate health information system. The basic pillar of this system is the correct recording of the number of deaths by age and sex in the country, but information on death and causes of death are also critical to the development of appropriate policies Good mortality records also allow analysis on the future levels and shape of mortality curves and to a better understanding of population dynamics.

In recent years there is an increase in the availability of mortality data for a series of countries. This includes more developed economies with mature vital registration system and countries with much less developed registration systems. The main goal of this paper is to evaluate the quality of mortality data in two of these databases (Human Mortality Database and World Health Organization Global Health Observatory). We use a set of formal demographic analyses, based on the Death Distribution Methods (DDM), to evaluate the quality of mortality data for all countries in these two databases. There are very few studies investigating the quality of mortality records in more developed countries (Coldran , Himes and Preston, 1991). In general, one assumes that vital records are of excellent quality or most of studies indicate high quality (Luy, 2010). This leaves most applications of death distribution methods concentrated in the experience of Latin America, Africa and Asia (Timaeus, 1991; Hill, Choi and Timaeus, 2005).

The Human Mortality Database (HMD) and the World Health Organization Global Health Observatory (GHO) are important mortality databases to study trends in mortality and health conditions around the world. The HMD is the highest quality standardized mortality database, while the GHO is an extensive mortality database of primary (unadjusted) data provided to WHO by member states. Researchers use HMD data to investigate the trends in life expectancy, distribution of age at death, and others. In addition, some studies evaluate the quality of HMD data (Barbieri, et al, 2015; Wilmoth, et al, 2007; Wilmoth, Queiroz nd You, 2004). GHO is not subject to any procedures to control the data quality, and one important limitation is under-registration of death counts, especially in countries with incomplete vital registration systems. The issue of under-registration of death counts is not discussed much in the HMD Methods Protocol [cite], as countries are selected for inclusion on the premise that vital registration is nearly complete.

The results indicate that quality of mortality data is improving over time for most countries in the world, specially more developed ones. Despite the fact that data is generally considered of good quality, we also find that a series of HMD countries have low completeness of death counts registration, especially in the past, and some countries have significant variations in data quality in specific periods, in general related to social, economic or political instability.

Data and Methods

Data Sources

We use data from two major mortality databases that are public available, highly used in demographic research and fully documented: Human Mortality Database and World Health Organization Database.

Human Mortality Database (www.mortality.org) was created to provide detailed mortality and population data to researchers, students, journalists, policy analysts, and others interested in the history of human longevity. The project began as an outgrowth of earlier projects in the Department of Demography at the University of California, Berkeley, USA, and at the Max Planck Institute for Demographic Research in Rostock, Germany. Currently, HMD includes data from 38 countries ranging from 1751 (Sweden) to 2014 (for most of the other countries. For each country series of data, we select population estimates from census years, and deaths for the intercensal period, both in 5-year age groups. Deaths are summed within age groups over the intercensal period.

World Health Organization Database available the http://www.who.int/healthinfo/mortality_data/en/ is a compilation of mortality data by age, sex and cause of death, as reported annually by Member States from their civil registration systems. Data is available for all member states starting in 1950. For this paper, we concentrated our analysis for countries already using ICD-10 and with information on both deaths and population counts available in the database. In the end, we concentrated our analysis on more developed countries and information from mid-1990s on. This limits our analysis to more developed economies, but also makes possible to compare and contrast results from HMD to GHO. We are working on producing estimates for all countries available in the GHO database. This will allow to a more in depth investigation of quality of mortality data across different levels of development. In the World Health Organization Data we study countries with death counts and population counts available for all years in mid-1990s. So, we estimate completeness for each pair of years and average death counts in the mid-period.

<u>Evaluation of Data Quality</u>

In addition to estimating mortality record coverage, which corrects only the level of mortality, an important analysis to obtain good quality mortality measures is to assess the age distribution of specific mortality rates. For this, it is necessary to analyze the quality of the stated age in the data sources (population and deaths). Studies indicate that errors, such as exaggeration at reported age, are common in advanced ages and directly affect mortality measures (Lee and Lam 1983, Kannisto, 1988, Condran, Himes and Preston, 1991; and Preston, 1991, Garson, 1991, Meslé and Vallin, 2002, Gomes and Turra, 2009). In order to measure the quality of the data sources, in relation to the declared age, some indicators, especially preferably digits (United Nations, 1955; Shryock and Siegel, 1973; Zhdanov et al., 2008) and others indicating an exaggeration in the (Coale and Kisker, 1986; Zhdanov et al., 2008*)*.

Jdanov et al. used, as criteria for for identifying possible exaggerations in reported age, the ratio between deaths in very advanced ages (D105 + / D100 + and D110 + / D105 +). If there is a trend of exaggeration in the reported age in the death registry, the number of deaths reported in advanced ages (above 105 or 110 years, numerator of the ratio) will be high in relation to the total number of deaths of people aged 100 or 105 years (denominator). In this paper, the ratio between the number of deaths of people aged 70 years and over, of sexes, and of people aged 60 years and over, of the same sexes (D70 +, s / D60 +, s) will be used. The number of deaths of persons aged 90 years and over and persons aged 60 and over, by sex (D90 +, s / D60 +, s), and the ratio of the number of deaths of persons aged 90 years and over and persons of 60 years or more, for each sex s

(D90 +, s / D60 +, s). To verify a trend of exaggeration in the age reported in the death register, the number of deaths observed in advanced ages (above 70, 80 or 90 years) will be high in relation to the total number of deaths of the elderly (60 years or more).

Wilmoth, You and Queiroz (2004) performed similar analysis for a different group of countries and find that, overall, there is no strong evidence for widespread age misreporting and that countries in the HMD, that they investigate, have good age statement at older ages during most of the XXth century.

Death Distribution Methods

To evaluate the quality of mortality data, we use classical indirect demographic methods called Death Distribution Methods. These methods evaluate coverage of deaths counts relative to population (Hill, You and Choi, 2009). Death distribution methods treat the mortality structure as the objective, that is, the profile of age-specific mortality rates, by estimating the coverage of the death registration relative to population stocks in order to correct the level of mortality. When mortality rates are corrected by rescaling according to the degree of under-registration, more correct mortality measures are obtained than those that have not been corrected.

These methods compare the age distribution of deaths with the age distribution of the population and provide the age pattern of mortality for a defined period of time. It should be noted that the method compares the age distribution of the deaths to the intercensal population change; thus, strictly speaking, it estimates the completeness of recording between censuses, not at the beginning or end of the intercensal period. There are three main methods that we discuss briefly: General Growth Balance (GGB), proposed by Hill (1987), the Synthetic Extinct Generations method (SEG) proposed by Bennett and Horiuchi (1981), and the adjusted Synthetic Extinct Generations method (SEG-adj) proposed by Hill, You and Choi (2009). All three of these methods have strong assumptions: a closed population, constant death coverage and population enumeration over age, and ages of population and death are declared without major or systematic errors. The advantage of these three methods over previous formulations by Brass (1975) and Preston, et al. (1980) is the relaxation of the stable population assumption.

The GGB method is derived from the basic demographic balancing equation, which expresses the identity that the growth rate of the population is equal to the difference between its entry rate and exit rate. This identity holds for open-ended age segments x+, and in a closed population the only entries are through birthdays at age x. The entry rate x+ minus the growth rate x+ thus provides a residual estimate of the death rate x+. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using the recorded deaths, the completeness of death recording relative to population recording can be estimated (Hill, 1987; Hill, Choi & Timeaus, 2005; Hill, You & Choi, 2009).

The method is derived from the basic demographic balancing equation, which expresses the identity that the growth rate of a population is equal to the difference between its entry rate and exit rate. Equation 1 shows the basic relations of the method

$$\frac{N'(x)}{N(x+)} - r'(x+) = \frac{1}{t}\ln\left(\frac{k_1}{k_2}\right) + \frac{(k_1 k_2)^{1/2}}{C}\left(\frac{D'(x+)}{N(x+)}\right) \quad (1)$$

Where N’(x) is the number of persons who reach the exact age x in the period, N(x+) is the number of persons at exact age x and over, r(x+) is the population growth rate, k1 and k2 are the relative coverage of the enumerated population in two censuses, C is the degree of completeness of death records over the period, D’(x+) is the observed number of deaths of people with x or more years of age and t is the interval corresponding to the intercensal period

This identity holds for open-ended age segments x+, and in a closed population the only entries are through birthdays at age x. The “birth” rate x+ minus the growth rate x+ thus provides a residual estimate of the death rate x+. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using the recorded deaths, the completeness of death recording relative to population recording can be estimated. The method has a few strong and key assumptions: the population is closed to migration; the completeness of recording of deaths is constant by age; the completeness of recording of the population is constant by age; and ages of the living and dead are reported without error.

The death distribution method has also an important limitation. Since they compare a distribution of deaths to an intercensal population, they estimate intercensal completeness of mortality estimates, and not the completeness at the beginning or end of the intercensal period. This matter is of particular importance when a distribution of deaths comes from data from the latest census or when vital registration is available for recent years,. The assumption of the GGB method that the population is closed to migration is also of importance to Brazil and its regions. The GGB method uses information on deaths and growth rates cumulated above a series of ages x. If there is some age x above which net migration is negligible, the performance of the methods above that age will be unaffected. The intercept and slope of the GGB method were obtained by orthogonal regression to points for the ages 35+ to 75+.

The Bennett and Horiuchi method, SEG, uses specific growth rates by age for converting an age distribution of deaths into an age distribution of a population. Once the observed deaths from a given age x in a population is equal to the population of age x, adjusted by the rate of population growth by age range, we have the deaths of a population of age x+ that provide an estimate of the population on that age x. The extent of death registration coverage is given by the ratio of deaths estimated by the population above the age x and the observed population above the age x. Equation 2 presents the mathematical formalization of the method

$$N'(x) = \sum_{a=x}^{\omega} D(a) e^{[r(a-r)]} \quad (2)$$

Where N’(x) is the number of people who reach the exact age x in a population with growth rate r, and D(x) is the number of deaths at age x. In this case, the estimate of deaths under-registration in the period is given by the ratio between the estimated number of people aged x (N’(x)) and the observed number of people aged x (N(x)). The diagnostic plot in this case should present a straight line across age, showing constant completeness. A change in the slope over the age groups indicates possible coverage problems of population censuses, problems in the age statement of the living and dead or variation in the quality of the registration / listing of deaths by age group

Hill and colleagues suggest that the combination of GGB and SEG methods may be more robust than the application of the two methods separately. The adjusted method consists of applying GGB to obtain estimates of the change in the population enumeration (k1/k2), and use this ratio to adjust the coverage of both census, and then apply the SEG method using the adjusted population for the coverage of mortality data.

To evaluate quality of data for a series of countries and long period of time, we use an R package developed by the authors. The package is available, https://CRAN.R-project.org/package=DDM. The DDM package selects the age trimming for each year of data in a flexible way, using an automatic fitting method that mimics the more commonly used graphical analysis. The package generates a single age interval based the smallest difference between the observed versus estimated death rates, given by the root-mean-square-error statistic. Thus, the age-range for each set of estimates is not necessarily the same. For simplicity, we present only the GGB results for males.

The assumption of both the SEG and GGB methods that the population is closed to migration is also of importance for countries that have experienced net emigration or immigration in recent decades. Both the SEG and GGB methods use information on deaths and growth rates accumulated above a series of ages x. If there is some age x above which net migration is negligible, the performance of the methods above that age will be unaffected or less affected. Visual diagnostics often reveal such patterns and may suggest optimal age ranges from which to obtain estimates. It is therefore important to evaluate diagnostic plots and try to identify potential problems when applying these methods. This might be a more relevant issue when one is investigating the quality of mortality data for small areas or sub-population groups for which migration is a larger component of population change. The approach we propose here does not correct directly for migration, but provides some alternatives based on the selection of age ranges to mitigate distortions in estimates that are possible due to net migration.

Results

Overview of Age Declaration

Figure 1 shows the analysis of right tail of death counts. We used ratio of death counts at older ages to investigate the quality of information gives an overview and possible suggestions of older ages overstatements. Since we are working with a long time series and a set of heterogeneous countries we used the ratio between ages 90+ and 70+ and ages 70+ to ages 60+. As a control check, we assume that it would not be reasonable to find values for the ratios that were much higher than for Sweden

We show results for 4 countries, representing one of each of the groups we discuss in the completeness of death counts analysis: Belarus, Israel, Portugal and Japan. One criteria we used to verify the quality of information is to compare the results for each country to the estimates for Sweden, as Jdanov etal (2008) used.. In our analysis, all countries, for both set of estimates, were under the ratios calculated for Sweden using the Human Mortality Database. We find that for Israel, Portugal and Japan there is no evidence of poor quality of information in older ages after 1950s. Similar results are observed for most of countries in Western, Southern and Northern Europe.

In some countries in Eastern Europe, for instance in Belarus, we find a very different pattern, especially in recent years, with large fluctuations in the ratio of death counts at older ages. As in other countries, the ratios were increasing steadily overtime, indicating that deaths were concentrating at older ages. However, we find significant drops for the 70+/60+ ratio in the 1990s and to the 90+/60+ ratio around 2000. Human Mortality Database indicates that Belarus data has some limitations in until the 1970s what could result in overestimation of life expectancy and of mortality at ages 80 and above (Grigoriev, 2008). Murray and Bodadilla (1997) suggest that data quality in Eastern European countries are of high quality. The evidence we present here indicates that we should analyze results with caution and further studies would be important for the former Soviet Republics.

Human Mortality Database

The main finding is that from 1950 on, most countries in the HMD show complete coverage of death counts or very close to 100% completeness. However, we find some cases where completeness is below 100%, indicating that not all deaths are registered adequately. Table 1 shows summary results for all three methods over the period of analysis. The three methods show very similar results despite of differences in the sensitivy of the methods to data problems (Hill, You and Choi, 2009). The results also indicate that the methods perform quite well and that they are still a good alternative to evaluate data quality in less developed parts of the world.

Table 1 – Summary Statistics, Completeness of Death Counts Coverage, Human Mortality Database, 1950-2015

Variable	Obs	Mean	St. Dev	Min	Max
GGB	244	1.00	0.030	0.90	1.17
SEG	244	1.02	0.065	0.90	1.50
GGBSEG	244	1.00	0.038	0.91	1.28

Source: Human Mortality Database

We also split the sample in two series. One going up to 1970 and the second one going from 1971 to the most recent year. On average, we find that completeness of death counts coverage in the first period is about 101%, which can be considered full completeness, and in the second period about 99%. The main difference is that in the most recent period we observe a much smaller variation across countries (standard deviation changes from 0.042 (in the first period) to 0.033 in the second period. We also looked at different dispersion measures and the results are very consistent for all periods and methods.

Figure 2 shows the estimates, over time, for a series of countries in the Human Mortality Database. We focus our analysis on information available from 1940 on and organize countries by their greater regional location. We divided the European countries in 6 regions (Northern, Southern, Eastern, Western and two Central parts) and the other countries separately in two groups. As pointed before, the main picture is that overtime the quality of death counts registration is very high for most (or all) countries in the HMD. But, we observed some fluctuations across 100% coverage for some countries in some periods of time.

For example, , Hungary in the decade of 1950, Italy in the 1960s, and in more recent years Luxembourg, the USA and Canada, all show GGB registration levels near or approaching 90%. The method detects over-registration of about 10% in 1950s Portugal, in 2000s Iceland, and recent decades in Lithuania. The impact of a 10% under-registration indicates that adult mortality, 45q15, would be 10% higher. The impact of this change is a difference from 1 to 2 years in the life expectancy at birth, for countries ranging e0 between 60 and 80.

In general, values so far from unity could also be due to violations of the GGB assumptions: migration, abrupt changes in age structure, or biases or changes in census coverage can also produce such anomalies. The other methods (SEG and SEG-adj) also reveal some limitations for some countries in specific periods of time. However, applying the three methods with different age ranges improve the quality of estimates and give some additional robustness to the evaluation of the two databases.

World Health Organization Database

Table 2 shows summary results for all three methods over the period of analysis. The three methods show very similar results despite of differences in the sensitivy of the methods to data problems (Hill, You and Choi, 2009). The results also indicate that the methods perform quite well and that they are still a good alternative to evaluate data quality in less developed parts of the world. In the World Health Organization we have a more heterogeneous sample, so we find countries with lower data quality and the variation in data quality (measured by completeness of death counts) is much greater than when one studies countries in the HMD.

The results however, indicate, that for more developed economies and those that are also included in the HMD the quality of information is very high and we find that death counts registration is very close to 100% for the countries. It is interesting to note that, several countries that are not included in the HMD also have very high quality in the level of information for the most recent periods of time.

Table 2 – Summary Statistics, Completeness of Death Counts Coverage, World Health Organization Database, 1994-2014

Variable	**Obs**	**Mean**	**St. Dev**	**Min**	**Max**
GGB	1302	0.96	0.235	0.23	3.17
SEG	1302	1.04	0.265	0.06	2.95
GGBSEG	1302	0.97	0.213	0.30	2.70

Source: World Health Organization Mortality Database

We selected 12 countries from the World Health Organization Database to analyze in more detailed the quality of the information. We divided the countries in three groups. The first one is the less developed economies: Armenia, Cyprus, Egypt and Jordan. The second group are the countries in Eastern Europe: Bulgaria, Poland, Czech Republic and Hungary. And the third group composed by Australia, Germany, France and Austria.

For the more developed economies, as observed in the HMD countries, we find very high level of completeness of death counts coverage. The four countries depicted in the figure have level of completeness very close to 100%. We find small variations in the estimates, but they are all very close to 100%.

For the countries in Eastern Europe, we observe that data quality in the more recent periods is one very high quality. We find, as observed in the HMD, a decline in the quality in the mortality data for Hungary in the 2000s, but more recent years are showing sign of improvement. Thus, one should be careful when estimating mortality measures for the country and analyzing trends, since variation in data quality might affect estimates and trends.

Finally, we look at the less developed economies. Death Distribution Methods were first developed to deal with data issue from countries with less mature vital records systems. Also, there is a lot of interest in understanding the evolution of mortality in those countries and one should first evaluate the quality of information. For the countries selected, we find that the quality of information is lower compared to the other two groups. However, the level of completeness it is not very far from 80%, indicating that after correction the data could be used to estimate and study mortality. More worrisome is the information from in 2010 showing a over-registration of death counts of 100%, that is, the methods suggest that Egypt is recording twice the number of deaths that are happening in the country. This could be an issue of data – for both mortality and population – and also the application of the methods. In any case, further studies are necessary.

Conclusions

In this paper we evaluate the quality of mortality data from two major databases public available for researchers. The Human Mortality Database and the World Health Organization Database. We provide a systematic evaluation of the quality of age declaration and completeness of death counts using traditional demographic methods.

Results, for the majority of countries in HMD indicate that quality and completeness of death count registration is very high. We observe very few countries departing from complete coverage of death counts and when we find otherwise they occur in very particular periods of time for a few countries.

Regarding the death distribution methods, it should be noted that since there is no gold standard to be adopted and the different methods might present different results due to violation of their assumptions and other problems. In the case of this article, an important limitation refers to the assumption of population closed to migration. We did not use any to proposed alternatives to avoid the possible impacts of migration flows on the estimates, and some of the results – in recent years – might be related to that (Hill and Queiroz, 2010; Bhat, 2002). However, when we apply the different variations of death distribution methods using different age groups as an adjustment, seeking to minimize the effects of international migration and errors in the age declaration, we believe that our results are more robust than others available to estimate mortality in the parents.

The results also indicate that model assumption violations affect the three methods differently. Researchers might average estimates from the three methods to produce a more robust result and also point to the importance of developing new methods or alternative methods to test the quality of mortality data for less developed economies or countries where a mature vital registration system is in place.

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Apendix: Figures

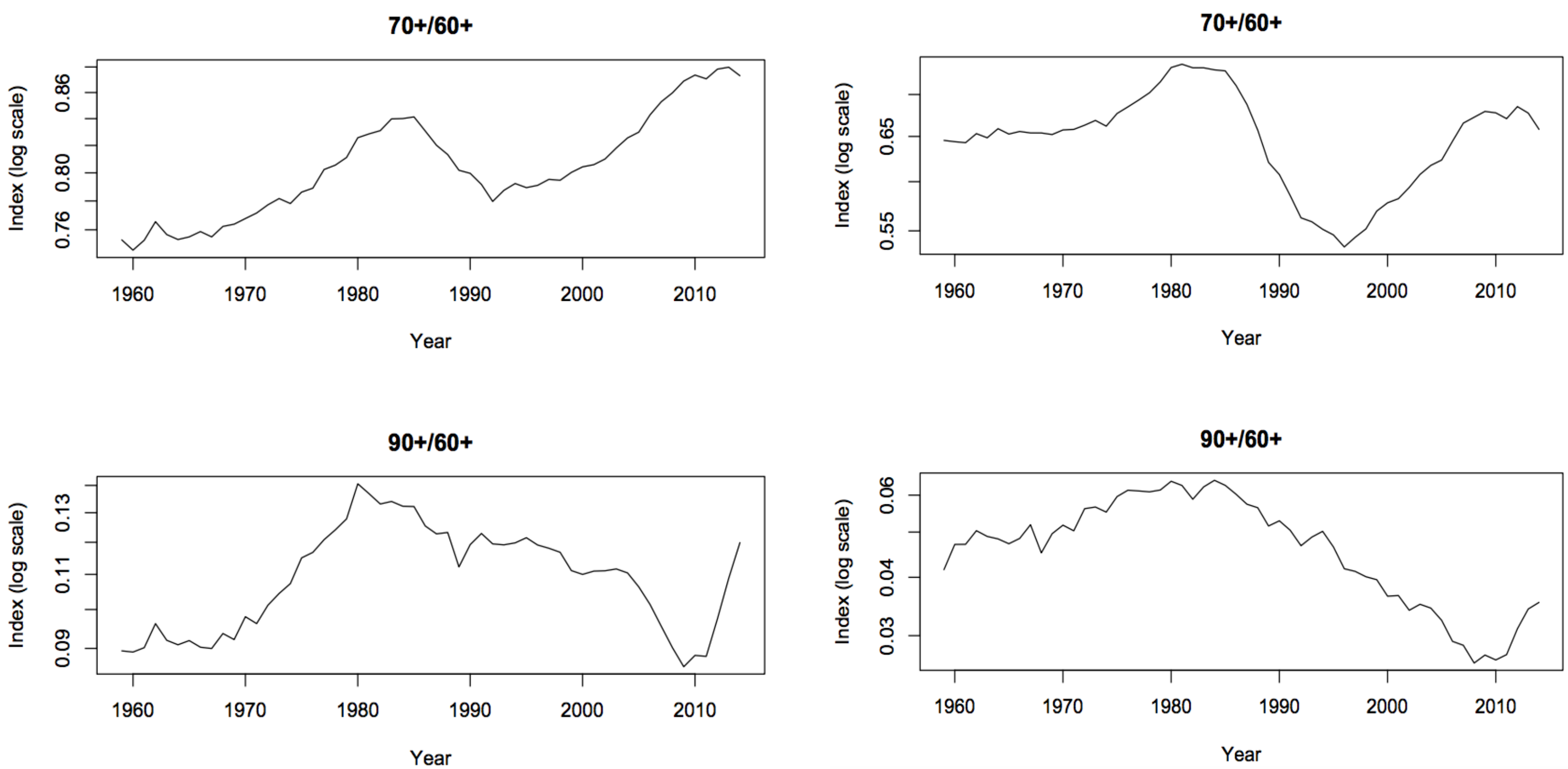
1. **Death Counts Ratios**
2. **Completeness of Death Counts, HMD**
3. **Completeness of Death Counts, WHO**

Figure 1: Ratio of Death Counts, Ages 70+ to 60+ and Ages 90+ to 60+, Males and Females, selected countries from HMD, 1950-2015

a. Belarus

Females

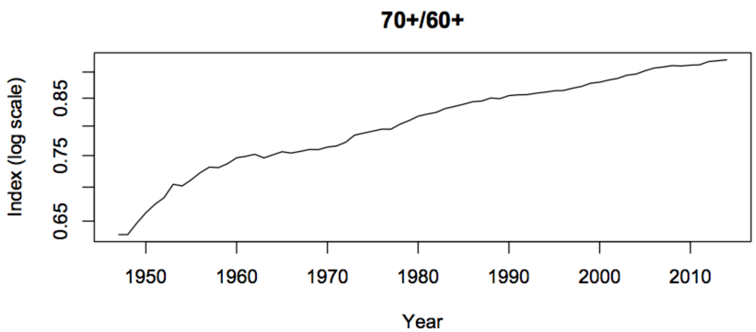
Males

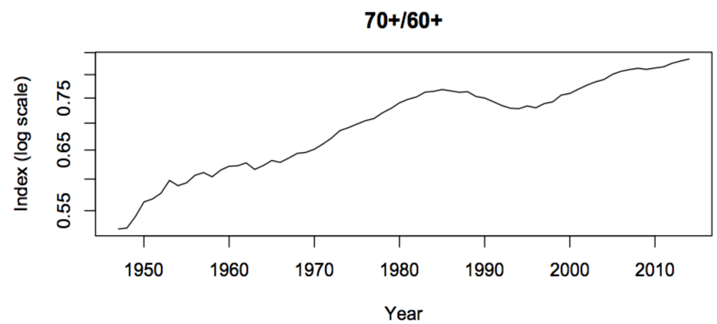


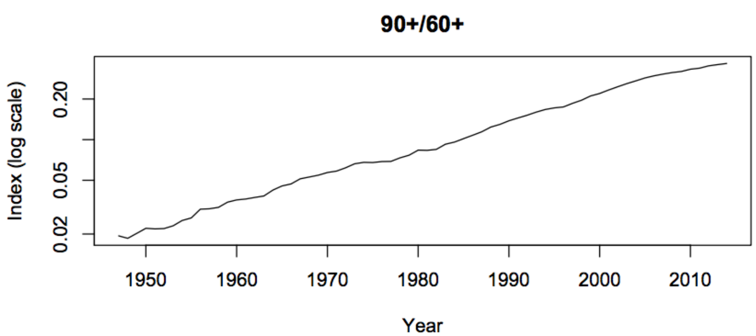
b. Japan

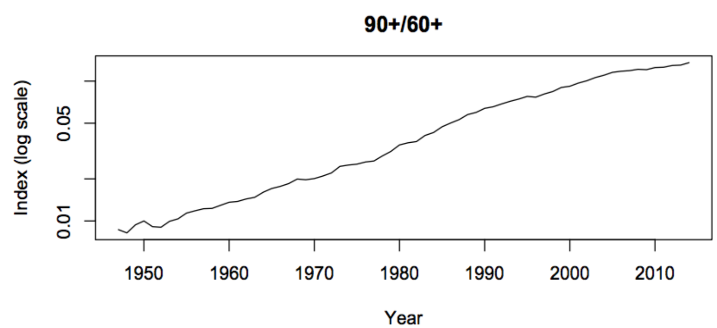
Females

Males



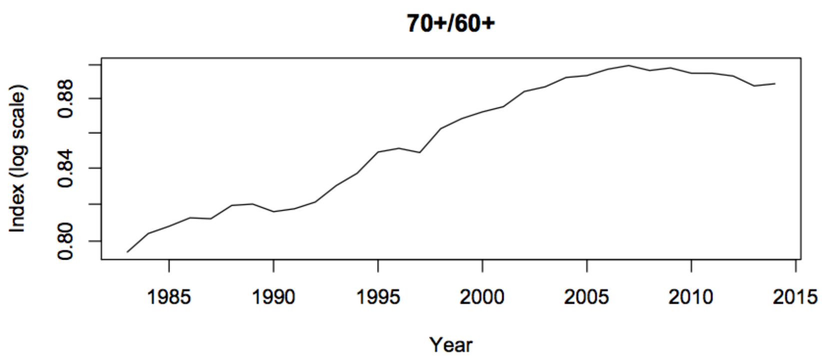


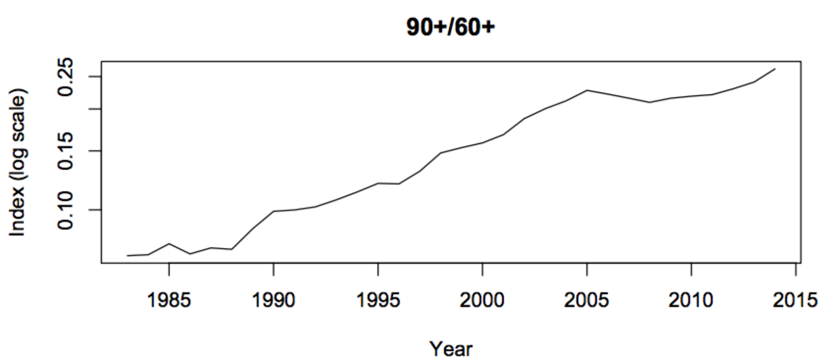




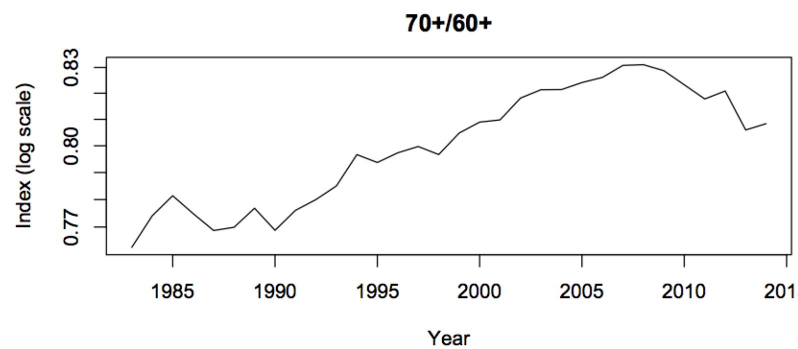
c. Israel

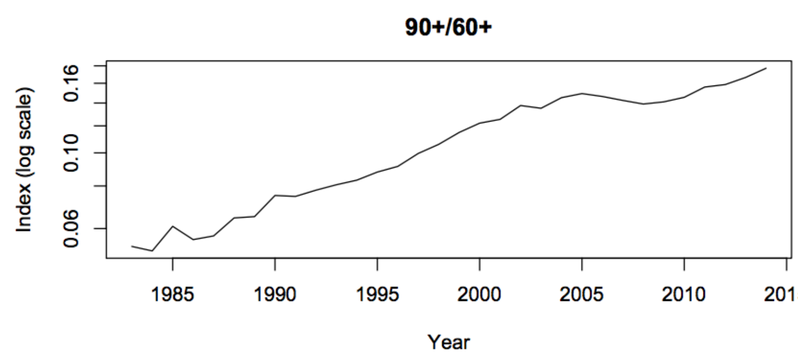
Females





Males





d. Portugal

Females

Males

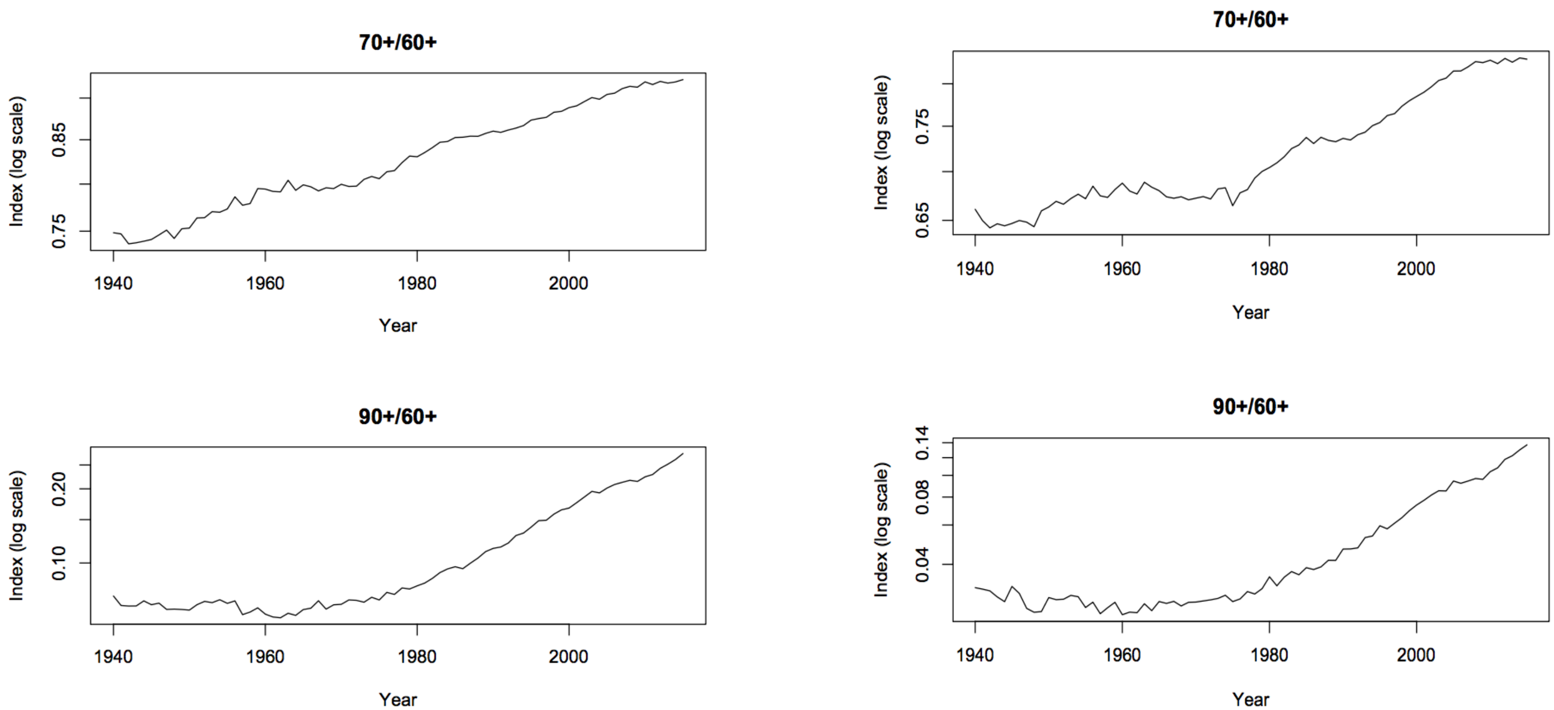
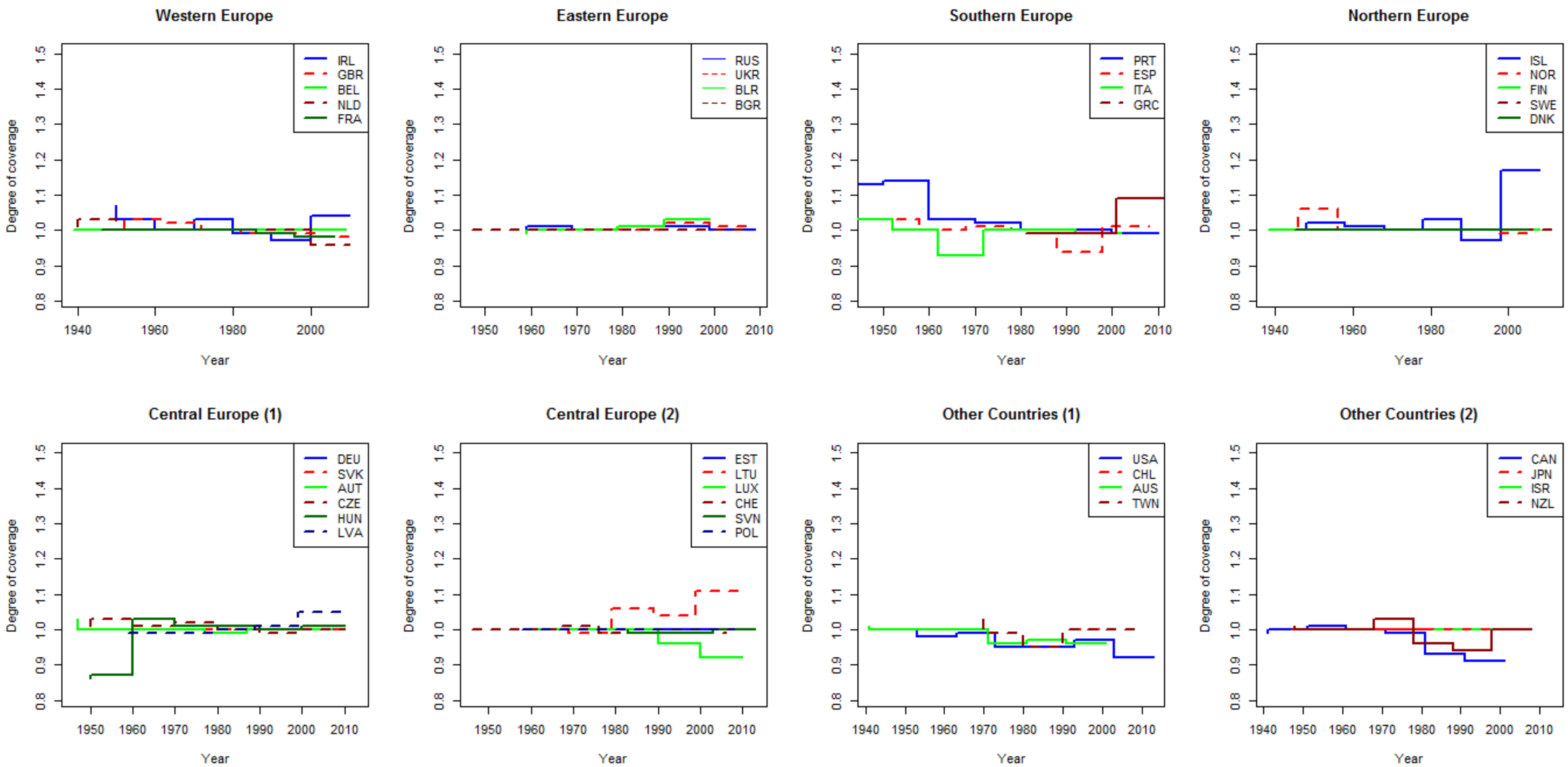
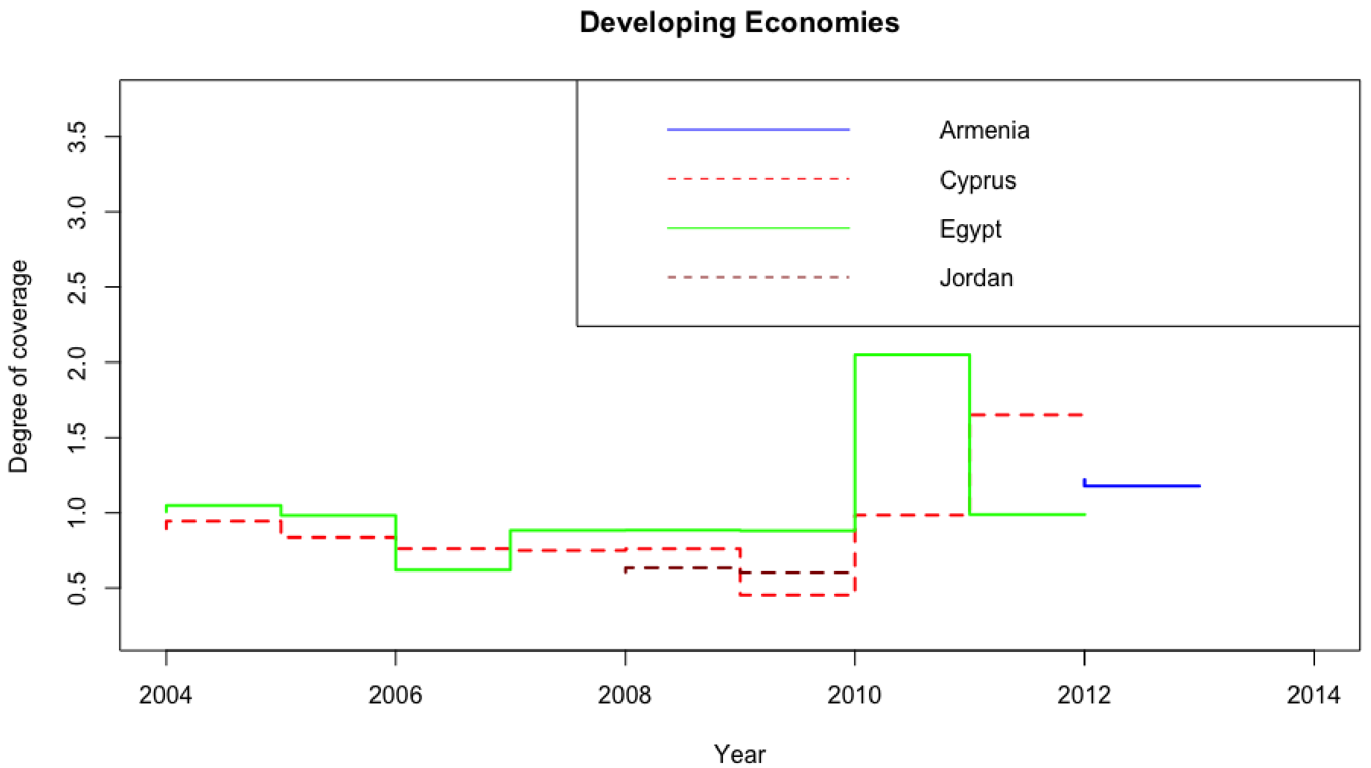


Figure 2: Completeness of death counts according to countries regions. Human Mortality Database, 2016. Males.



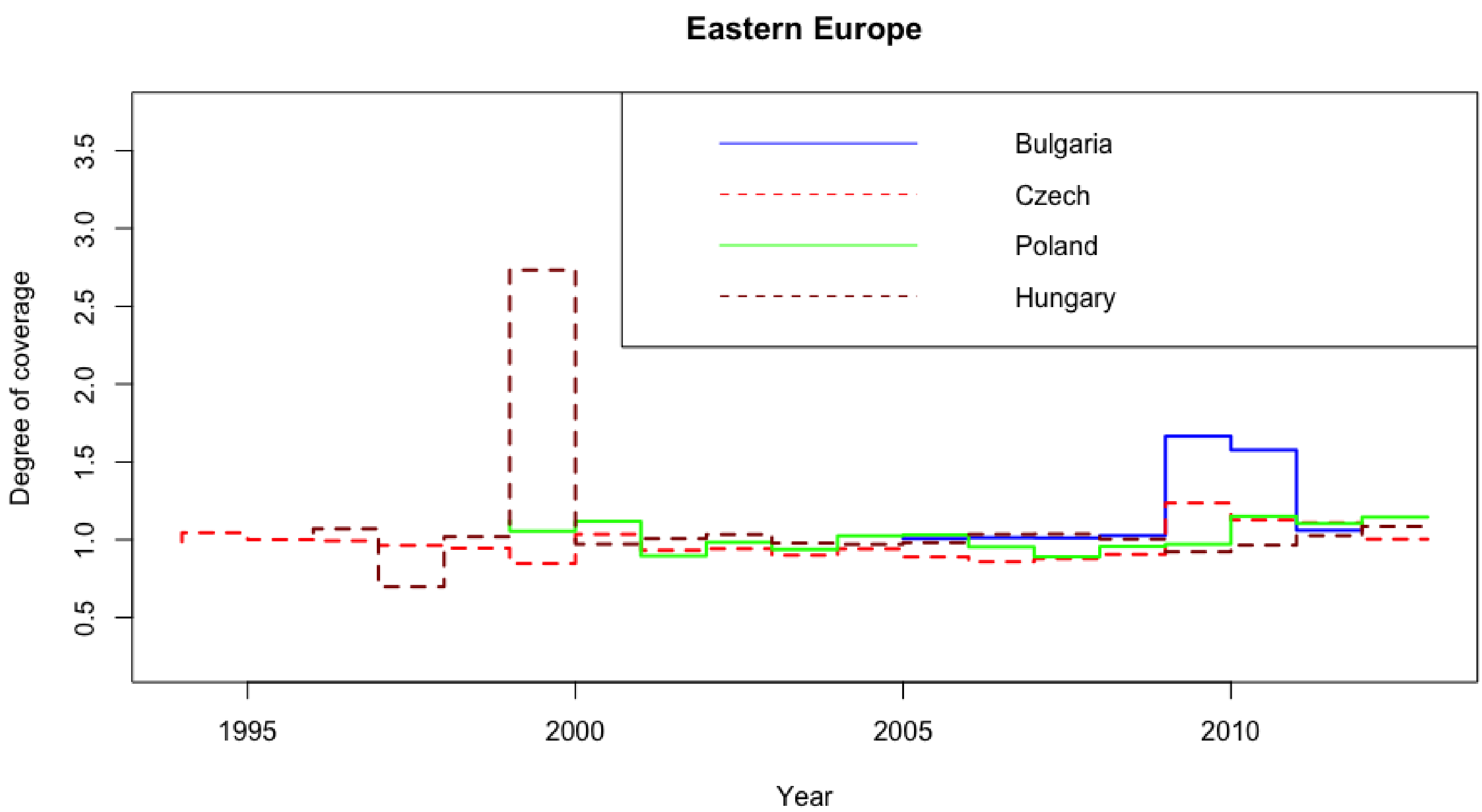
Source: Human Mortality Database, 2016

Figure 3a: Completeness of death counts according to countries regions. World Health Organization Database, 2016. Males.



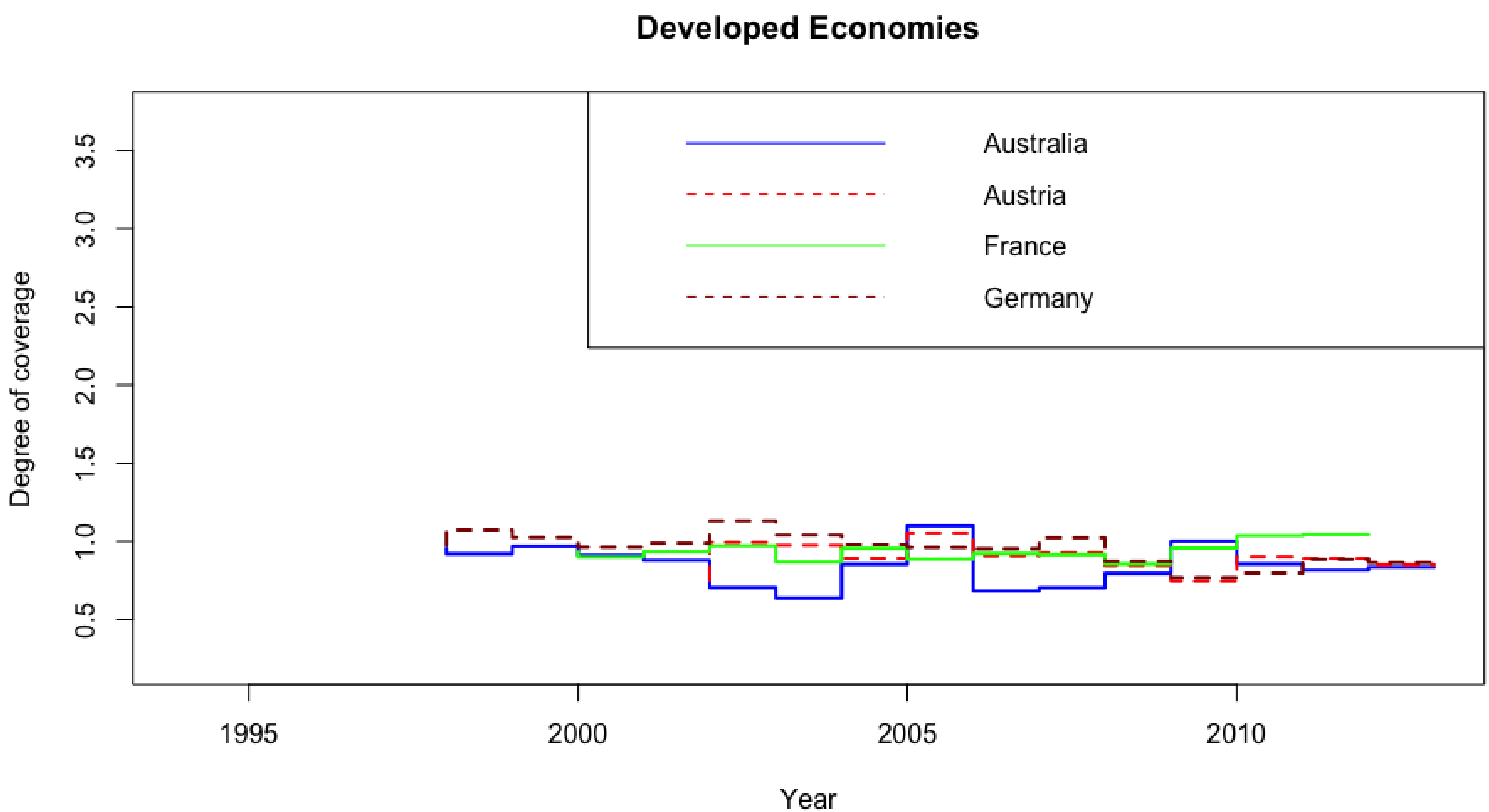
Source: World Health Organization Database, 2017

Figure 3b: Completeness of death counts according to countries regions. World Health Organization Database, 2016. Males.



Source: World Health Organization Database, 2016

Figure 3c: Completeness of death counts according to countries regions. World Health Organization Database, 2016. Males.



Source: World Health Organization Database, 2016