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Research Article

Estimation of older adult mortality from imperfect data: A comparative review of methods using Burkina Faso censuses

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Abstract

BACKGROUND
Since the 1950s, many indirect or semi-indirect methods have been developed to either adjust mortality estimates or generate complete life tables from mortality indices in countries lacking high quality vital registration data. These methods are underused for estimating older adult mortality.

OBJECTIVE
I seek to answer the following questions: How to better estimate older adult mortality from imperfect data? Can consistent estimates be derived from indirect-based methods? If not, what could explain the possible differences?

METHODS
After adjusting population and intercensal death counts for incompleteness using death distribution methods, data from the last three censuses in Burkina Faso (1985, 1996, 2006) were fitted using Singular Value Decomposition (SVD) and Brass models, and specifically the Makeham model (MKH) for extrapolation to advanced ages where large age errors were suspected. The resulting estimates were then compared in terms of age patterns and risk of death between the ages of 50 and 80.

RESULTS
Estimates from the SVD model are higher than those from both the adjusted data and the Brass model, which are consistent, but only before age 70. Extrapolation by the MKH model reveals obvious underestimations in the adjusted data beyond age 70, but of smaller magnitude than those suggested by the SVD model. When compared with the empirical data from the Human Mortality Database (HMD), all estimates agree with the empirical data before age 70, but only the estimates from the SVD and MKH models remain consistent beyond age 70.

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CONCLUSION
When used to infer mortality in older adults, the estimates from empirical models such as the SVD model should be taken with caution. Further refinements of the model are required to better reflect the observed mortality level at older ages.

CONTRIBUTION
This study highlights issues with using empirical models indexed by child and adult mortality to infer mortality at older ages from imperfect data.

1. Introduction

In countries that have a poor vital statistics system, mortality estimates are derived from general population-based surveys. These sources suffer from a variety of age errors that are reflected in the data in different ways, including age heaping and age misstatements (Pison and Ohadike 2006; Preston, Elo, and Stewart 1999; United Nations 2018). In sub-Saharan Africa the problem is more pronounced for older adults (Randall and Coast 2016). Most of this population is illiterate and without birth certificates, and therefore people are unaware of their true age. Those birth certificates that do exist are backdated, are very often imprecise regarding the birth year, and sometimes give no indication of the month and day of birth. These issues make it difficult to know or to accurately approximate actual ages during surveys and censuses. This is even more difficult when it comes to estimating the age at death of deceased adults. In this context, how can we accurately estimate older adult mortality?

In a broad sense, adult mortality refers to the mortality of people aged 15 and over. To make a clear distinction with mortality at older ages, the concept of adult mortality is used restrictively in demographic analysis to denote the mortality of people between the ages of 15 and 50 and more generally up to 60 years old (Timaeus, Dorrington, and Hill 2013). Until now, life tables have remained the best tool for analysing and describing mortality at any age, whether through a real or a synthetic cohort. But in contexts where the data are poor, constructing life tables should involve the use of indirect or semi-indirect methods to correct the data, such as death distribution methods. The reasonableness of the resulting mortality estimates could be compromised if the assumptions underlying these methods are unrealistic. Hence, attention should be paid to the assumptions, especially those that appear unrealistic.

1.1 Methods used to correct data

In the past, death distribution methods (DDMs) have been used to assess and correct for incompleteness of death and population counts from census data. One group of DDMs is based on the Growth Balance equation of a population (Brass 1975; Gray 1986; Hill 1987). The other method, known as the Cohort Extinct method, relies on the ratio between the number of people of a certain age and older that are alive in a population and the total number of deaths expected above that age in the future (Preston et al. 1980; Preston and Hill 1980). Both methods were first developed for census data at one point in time and assume the observed population to be stable or almost stable. It was later shown that the assumption of a stable population underlying both methods can be relaxed when two censuses are available (Bennett and Horiuchi 1981, 1984; Gray 1986; Hill 1987). Other variants of these methods have been developed, but they require reliable death registration records to perform consistency checks between the enumerated population and recorded deaths at a certain advanced age (Andreev 2004; Machemedze and Dorrington 2011; Terblanche and Wilson 2015b, 2015a; Wilmoth et al. 2017). However, in many sub-Saharan African countries there is no such external accurate source of death registration records. Hence, the extended versions of the Growth Balance and the Cohort Extinct methods have become popular, termed respectively the Generalized Growth Balance (GGB) and the Synthetic Extinct Generation (SEG) methods (Dorrington 2013). They allow the assessment of the relative coverage of one census compared to the other in estimating the completeness of intercensal deaths. As a result, these methods remain suitable and among the most widely used for countries lacking vital registration systems when the underlying assumptions are checked. A detailed description of these methods can be found in Tools for Demographic Estimation, an open resource[2] developed by the International Union for the Scientific Study of Population (IUSSP).

The price for relaxing the assumption of a stable population when using the extended DDMs is to come up with a single point estimate from two censuses. Apart from this assumption, attention should be paid to three other assumptions that are less restrictive but may lead to incorrect estimates of death completeness (Adair and Lopez 2018; Dorrington 2013; Murray et al. 2010). The first is that the level of completeness is constant above a certain age limit and age is accurately reported for both population and deaths. Age heaping has been shown to have a negligible effect, unlike age misreporting, whose effects could disrupt this assumption and affect the reliability of the resulting estimates (Murray et al. 2010). However, these effects may be partly diminished by reducing the limits of the open age group of the age distribution until they correspond to the constancy condition required in the diagnostic plots when

[2] https://demographicestimation.iussp.org/

applying DDM methods. The second assumption is that the coverage of the two censuses considered when applying a method is assumed to be similar at all ages and invariable over time. The authors of the SEG method (Bennett and Horiuchi) suggest taking into account a possible differential coverage of the two censuses by correcting age-specific intercensal growth rates with a delta factor (δ) as the relative coverage of the first census compared to the second. Rather than estimating the δ factor and using it to correct intercensal growth rates as just explained, Hill and others (2004, 2009) prefer combining both methods by applying the GGB method first and then using the resulting adjusted population as input for the SEG method. The last problematic assumption underlying DDMs is that the population is closed to migration, even though these methods are quite sensitive in high migration contexts. They have therefore been improved to take this issue into account (Bhat 2002; Hill and Queiroz 2010). In the absence of reliable information about the type and age structure of recent population movements generally collected in censuses, Hill and others (2009) suggest that the minimum age for assessing the completeness of death reports be raised from 15 to 30 years or above, while Murray and colleagues (Murray et al. 2010) suggest using the GGB method for ages 40–70, the SEG method for ages 55–80, and the hybrid GGB-SEG method for ages 50–70. Following these precautionary measures does not eliminate all the errors in the data but may be helpful in improving any mortality measure based on them.

1.2 Indirect approaches to adjusting life tables

Various approaches have been developed to generate life tables from defective data. Rather than using raw data, as is done in countries with a good vital statistics system, a first approach is to correct data to compute life tables directly without any further adjustment. For example, death distribution methods could be used for that purpose (Dorrington 2013; Hill and Choi 2004). There are also variable-*r* procedures that do not require adjustment for the completeness of intercensal deaths when constructing a slightly more accurate life table. Two variants of this procedure have been used to estimate mortality in previous studies (Merli 1998; Preston et al. 1996). The procedure uses age-specific growth rates with either successive age distributions of censuses, or age distribution of intercensal deaths. When applying these methods to Vietnam, the census-based method was more sensitive to differential census coverage and residual intercensal migration than the death-based method (Merli 1998). The death-based method is derived from the cohort extinct method developed by Paul Vincent (Vincent 1951).

The idea of empirical life tables was put forward in the 1950s to overcome the scarcity of reliable data sources for mortality estimation in most developing countries (United Nations 1955). The objective was to take advantage of the experience of countries whose mortality patterns were better known in order to establish a repertoire of mortality patterns. For example, the level of child mortality observed in any population could be used to identify the overall age-specific mortality level that better describes it. This idea was later taken up and refined in various studies (Coale and Demeny 1966; Coale, Demeny, and Vaughan 1983; Ledermann 1969; United Nations 1982). The most popular empirical model life tables remain those of Coale–Demeny (CD) and the United Nations (UN). The construction of the CD model life tables was largely based on European sources. Four regional families were constructed based on seemingly similar mortality patterns and the relationships between child and adult mortality, each tabulated by sex into twenty-four levels of mortality with a minimum life expectancy at birth of 20 years for level 1.[3] The UN model tables were assembled from data from a few developing countries, but the only African data included was from Tunisia. The UN tables have also been subdivided, but into five main families. These tables and the CD model life tables have been criticized for being based on limited empirical data that are uniparametric and therefore inflexible, and, above all, for not reflecting the contemporary epidemiological experiences of many countries, particularly the HIV/AIDS crisis in some sub-Saharan countries (Murray et al. 2000).

Noting that the logits of two survivorship probabilities may be related linearly, in the 1970s Brass introduced a new model for life tables that allows for correction of the survival function from deficient data. The model generates a complete survival function using a standard survival function (Brass 1971, 1975). Its approach makes it possible to avoid generating life tables directly from an empirical age pattern of mortality. One important issue with this method is finding the appropriate standard survival function. In addition, if accurate information on child mortality is available, it allows for better adjustment of the overall mortality level compared to the standard. The Coale–Demeny model and United Nations model life tables are a good repository for choosing a standard. But, as stated before, these empirical life tables are from developed countries and do not necessarily reflect the mortality age pattern of developing countries, including those from sub-Saharan Africa. It was later shown that the assumption of linearity used in the Brass logit transformation is not satisfactory, and a modification of the model was introduced with correction factors based on the level of child and adult mortality, again with respect to a standard provided with the model (Murray et al.

[3] The four families of patterns from the CD model life table are: North (mostly from Scandinavian countries), South (Mediterranean European countries), East (Eastern European countries), and the Western pattern, which is used as the residual pattern. The model has been updated and extended to close the tables beyond age 100.

2003). Considering adult mortality contributes to a better adjustment of the overall shape of mortality and the assumption of linearity. This paved the way for the use of two input parameters – the levels of child mortality and adult mortality between 15 and 50 or 60 years of age – to generate complete life tables, including old-age mortality. Using 719 life tables from the Human Mortality Database[4] (HMD), an indirect and flexible log-quadratic (LQ) model with two input parameters was developed to estimate complete life tables based on either child mortality only, or child and adult mortality. By relating log-scale age-specific mortality rates to child mortality using a quadratic regression, the model coefficients were derived from the first term of a singular value decomposition of the matrix of the regression residuals (Wilmoth et al. 2012). The LQ model is expressed as follows:

$$\log(\mu_x) = a_x + b_x h + c_x h^2 + v_x k \qquad (1)$$

where a_x, b_x, c_x and v_x are constant age-specific coefficients related to age groups x denoted by {0, 1–4, 5–9, 10–14, …105–109, 110 +}, h is equal to $log({}_5q_0)$, and k depicts the deviation of the observed age pattern of adult mortality (${}_{45}q_{15}$) from that of a standard. Wilmoth and colleagues argue that the model performs as well as the modified logit of Brass but is preferable because of its flexibility.

It was later shown that the singular value decomposition (SVD) technique, on which the LQ model is based, has many properties and is a powerful tool for summarizing, smoothing, and modelling age-specific demographic quantities (Clark 2015). Recently, Clark (2019) used this approach to develop a general model indexed by child (${}_5q_0$) and adult (${}_{45}q_{15}$) mortality indices. In order to better capture as much variability as possible, the model was calibrated using 4,610 complete life tables for each sex from historical periods that are contained in the HMD.

1.3 Objective and research questions

In sub-Saharan Africa, where mortality beyond age 50 is less studied, the developments mentioned above open a new era to better estimate old-age mortality, at least until age

[4] "The Human Mortality Database (HMD) contains original calculations of death rates and life tables for human populations (for countries or areas), as well as the input data used to make these calculations. The input data consist of death counts from vital statistics, plus census counts, birth counts, and population estimates from various sources. […] The database is limited by design to populations where death registration and census data are virtually complete, since this type of information is required for the implementation of the standardized methodology used to reconstruct historical data series. As a result, the countries and areas included in the database are relatively wealthy and for the most part highly industrialized." See https://www.mortality.org.

70, which is considered the threshold of premature death (Norheim et al. 2015). Even up to age 80 can be considered a starting cut-off age after which frailty and decline in functional abilities occur markedly (Kafkova 2016; Kannisto 1992; Thatcher, Kannisto, and Vaupel 1998; Wilmoth and Dennis 2007). One of the few papers that tries to assess old-age mortality is by Bendavid and colleagues (2011) and uses household deaths during the last twelve months to directly derive estimates from eight country-specific household surveys. The authors argue that the sample size (around 75 deaths on average beyond age 60) is too low to draw any valuable conclusions. Apart from this, other estimates available are those derived from international agencies' databases (WHO, UNPD, IHME) or national statistical offices based on census data. In addition, reliable estimates are available for sub-populations from Health and Demographic Surveillance Systems (HDSS). Notwithstanding age errors and the risk of omission, the comparison of mortality estimates from deaths during the twelve months preceding the censuses with those of the areas covered by three HDSS in Senegal has produced fairly consistent results, even between the ages of 60 and 80 (Masquelier et al. 2016). Unfortunately, mortality levels estimated from these data may not always reflect those at the national level since these data are not representative. In addition, individuals lost to follow-up, and even probable cases of age exaggeration, could also distort observed mortality levels. Deaths within households during the year preceding a census appear to be the most suitable source for studying older adult mortality in the sub-Saharan context. They provide a higher number of deaths at older ages than surveys. Using such information from the last three censuses in Burkina Faso, our aim is to contribute to a better understanding and knowledge of older adult mortality in that country. We seek to answer the following questions: How can we better estimate older adult mortality from limited data? Although most of the models described above are based on non-African mortality patterns, can consistent estimates be derived from these methods? If not, what could explain the possible differences? Which method is preferable?

After a brief review of the data and their quality, the following sections present the analytical methods used to answer the research questions, and then present and discuss the results.

2. Data and methods

2.1 Data description

As one of the least developed countries in the world, Burkina Faso in West Africa lacks a reliable vital statistics system. Many surveys and censuses have been carried out in order to provide comprehensive information to policymakers, but censuses are the only sources that collect information on mortality for all ages. All the following analyses are based on the enumerated population and the reported deaths from the 1985, 1996, and 2006 censuses provided by the National Institute of Statistics and Demography (INSD) of Burkina Faso. The enumerated population for each census consists of a random sample of 50% of the population. Compared to the 10% samples usually available on the IPUMS platform, this is a significant sample size. Using the total sex-specific population sizes recorded in the census reports and the age distribution of the study sample, it was possible to draw the age distribution of the total population by year and sex. Deaths that occurred within households during the twelve months preceding each census were recorded, by sex, with the age at death. The analyses use 100% of the data on the reported deaths. I was able to tabulate the age distribution of the population and death counts between the ages of 0 and 98 years and over.

Table 1 below shows a general overview of the census data from Burkina Faso for both population and deaths. In the three censuses, unknown ages in resident populations never exceeded 0.5%. This is mostly due to basic techniques given to interviewers to approximate the respondents' true ages. However, about 29% of ages at death were not reported in 1996, while this proportion remained low and almost constant in 1985 and 2006. At the same time, an exceptional rise in deaths is noticeable in 1996. No mention is made of the reasons for this spike in deaths, but it may be due to a combination of the effects of meningitis and measles epidemics: about 43,000 cases of meningitis and 32,400 cases of measles were recorded in health facilities in 1996 (DGISS 2011; Nicolas 2012).

Table 1: 1985, 1996, and 2006 census data, Burkina Faso

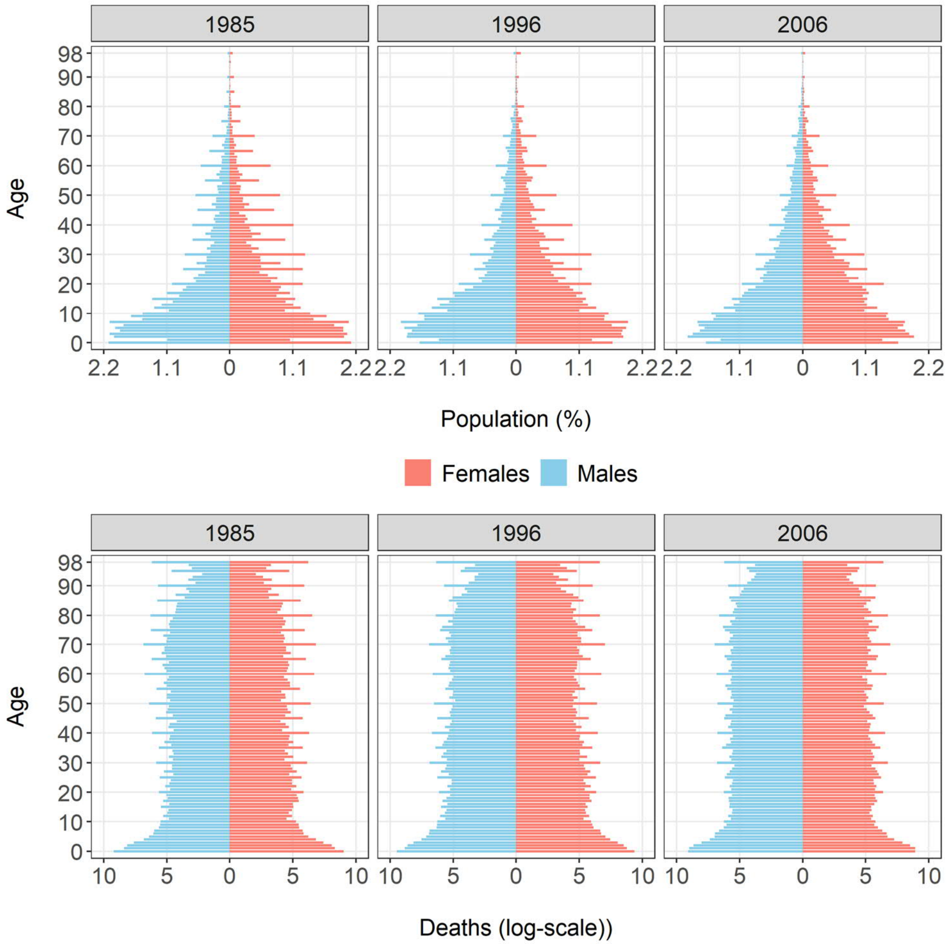
	Total size	Females (%)	Unknown ages (%)
Population			
1985	7,964,701	51.87	0.1
1996	10,312,613	51.80	0.4
2006	14,017,261	51.71	0.5
Deaths			
1985	75,634	47.00	2.8
1996	157,097	47.04	29.2
2006	116,201	45.41	3.3

Source: Author's calculations based on Burkina Faso census data provided by the INSD

These epidemics happened in conjunction with the adverse effects of the state's structural adjustment plans for disengaging from social sectors, including the health sector. In addition, the level of health service attendance gradually declined from 32% in 1986 to 18% in 1996 (INSD 2000). However, the sex-specific distribution was relatively stable, with about 52% resident females and 45% to 47% deceased females, regardless of census.

Additional problems were observed in the data when looking at age distribution through age pyramids, plotted in Figure 1 below. These pyramids were built without the unknown ages. As expected for a developing country like Burkina Faso, characterized by high fertility, the population-based pyramids of the three censuses are triangular in shape; i.e., with large bases that shrink gradually with age (INDEPTH 2003; Pison and Ohadike 2006). The population-based pyramids show age heaping at ages with terminal digits 0 and 5, with a stronger preference for 0. Another noticeable problem is the under-enumeration of children under two years and especially those under one year, regardless of gender. This phenomenon also affects 11 year olds in all censuses, as well as individuals aged 24, 34, 44, 54, and 64, particularly in the 1985 census. In general, this highlights the problem of incomplete census data. Regarding the distribution of deaths, there is a concentration of deaths in the early years of life. Except in 2006, these deaths are more concentrated at birth and then decrease gradually, regardless of gender. The exception noted in 2006 could reflect an under-reporting of newborn deaths rather than a real decrease in infant mortality. Beyond 5 years, deaths are almost uniformly distributed, with slight increases or decreases in young adults until age 80, after which the proportions start declining. As for populations, a noticeable preference for terminal digits 0 and 5 also affects the reported ages at death. The phenomenon is perceptible beyond age 15, and sometimes extends to terminal digit 6, particularly in the elderly in 1996 and adults in 2006.

Figure 1: Age distribution of population and deaths in 1985, 1996, and 2006, Burkina Faso



Source: Author's calculations from census data provided by the INSD.

2.2 Methods for correcting the data

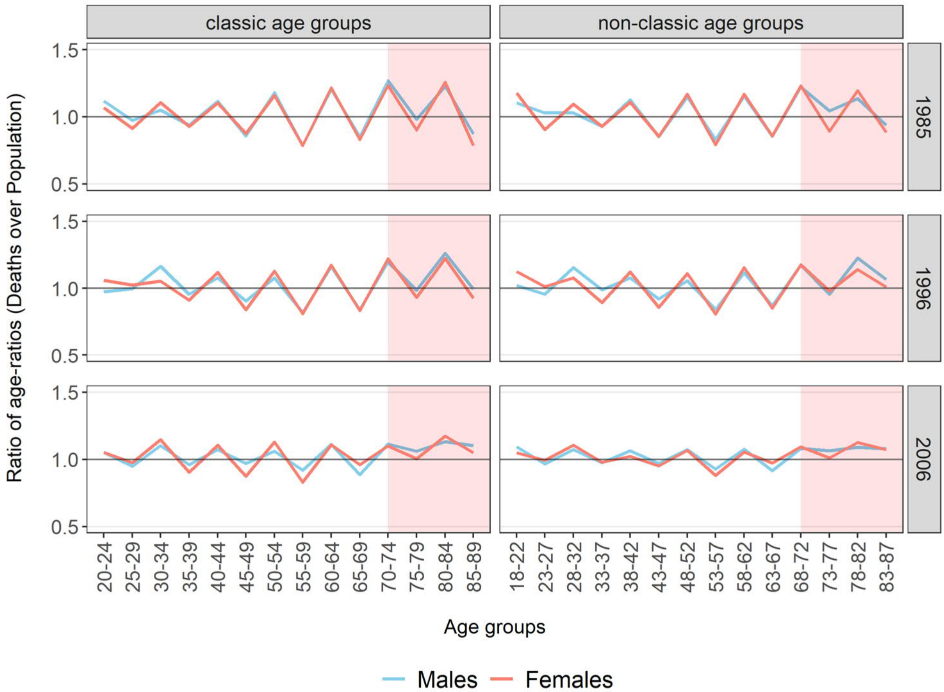
2.2.1 Age heaping

The magnitude of age heaping in the data can be assessed using age ratios (AR). Before calculating AR, demographers used to aggregate the data in 5-year age groups. Rather than using classic 5-year age groups (15–19, 20–24, 25–29, etc.), which are more sensitive to preference for terminal digits 0 and 5, Blacker, cited by Dorrington, suggests using non-classic age groups centred on ages subject to heaping (13–17, 18–22, 23–27, etc.). This approach could be a simple solution to reduce the effect of age heaping on further estimations without distorting the data as much. It also makes it possible to redistribute unknown ages without being totally absorbed by the ages subject to heaping. Without any prior knowledge of the age distribution of unknown ages, we assume they have the same age structure as individuals of known ages. As a reminder, Hobbs (2004) suggests calculating the AR for an age group i by using the formula below, which gives sufficient weight to the central age group:

$$AR_i = \frac{3 \times N_i}{N_{i-1} + N_i + N_{i+1}} \quad (2)$$

When ARs in deaths are compared to those in populations, a value close or equal to 1 would mean that age heaping is of similar magnitude in the two age structures. Figure 2 below gives no clear picture of whether age heaping is more pronounced in deaths than in populations, given the irregular fluctuations observed around 1. The only evidence is that age heaping is more pronounced in deaths at age groups that contain the terminal digit 0, and inversely in populations at age groups containing the terminal digit 5. On the other hand, the magnitude of the fluctuations increases with age but decreases with time. This shows that in the past the older people became the more they tended to round their ages – much more so than recently. Although there is no clear gender difference, in some places the phenomenon seems slightly more marked in females. In general, the above observations apply to both classic and non-classic age groups. However, non-classic age groups result in less pronounced age heaping. It should be noted that the phenomenon tends to increase in deaths beyond age 70 and 68 in classic and non-classic age groups respectively, regardless of gender and year. For example, in 2006, with non-classic age groups, age heaping was more prominent in deaths starting from around the age of 70 (centre of the 68–72 age group), but with fewer fluctuations for males than for females. Because of the potential effects of such anomalies, attention should be paid to any resulting estimates.

Figure 2: Comparison of age ratios in deaths and population in 1985, 1996, and 2006, Burkina Faso



Source: Author's calculations from census data provided by the INSD

2.2.2 Systematic age misstatements

The tendency to round ages to terminal digits 0 and 5 and the fluctuations that result from this could lead to systematic age misstatements. For example, if several 64-year-old individuals are reported to be 65, there will be a trough in the 64 year olds and a peak in the 65 year olds that could suggest under-enumeration in the former and over-enumeration in the latter. Such systematic age misstatements are generally corrected when using non-classical age groups centred on ages subject to heaping. However, not all the age misstatements are related to age heaping. Some of them are due to omissions caused by disintegrated households. These cases occur most often in single households, but in the context of Burkina Faso, where the extended family is still widespread, the number of cases of disintegrated single households may be quite small. On the other hand, omissions due to unreported deaths could be more important. Other kinds of errors such as age exaggeration may also be important in such a context, where being old confers a certain social status. For example, an individual aged 64, instead of rounding off their age to 65, could attribute to themselves an age greater than 70, or be assigned an exaggerated age if they have died. This kind of exaggeration in age declarations is difficult to detect and correct. As their amplitudes exceed 5 years, the 5-year age groupings cannot dilute them and reduce their potential effects. It is well known that age at death is more often exaggerated at older ages and usually leads to substantial downward bias in mortality rates (Booth and Gerland 2015; Murray et al. 2010; Palloni, Pinto, and Beltrán-Sánchez 2016; Preston, Elo, and Stewart 1999). Palloni and others (2016) use an age misstatement pattern from Costa Rica as a standard to correct their effects for mortality estimation in Latin America. Such a pattern does not exist in Burkina Faso, or even more broadly in West Africa, making it difficult to use this approach. An assessment and correction for data incompleteness could help to mitigate this problem.

2.2.3 Correction for census coverage and incompleteness of deaths

I used the hybrid death distribution method that combines the GGB and SEG methods. To choose the minimal age that allows controlling for migration effect, I explored information on international migration over the preceding twelve months collected in the Burkina Faso censuses. As a result, the use of out-migration data in ‘unattractive’ countries such as Burkina Faso raises questions, especially when the aim is to improve estimates. Analysis of the migration data from Burkina Faso censuses (Table 2) shows that there are irregularities that affect its reliability. However, it is known that data on international immigration are generally better captured than data on international emigration, which often suffer from important omissions and misinformation about the final destination of migrants (Dabiré 2016).

Table 2: Net migration of recent international migrants (last 12 months), Burkina Faso, from the 1985, 1996, and 2006 censuses

Ages	1985		1996		2006	
	Females	Males	Females	Males	Females	Males
< 15	6,674	6,312	379	–493	7,626	7,162
15–19	–1,077	–7,992	–1,382	–16,690	379	–7,707
20–24	246	–12,971	–493	–24,060	1,472	–10,043
25–29	789	–8,085	17	–15,650	1,926	–5,573
30–34	443	–3,557	326	–8,928	1,228	–2,626
35–39	380	–1,733	230	–4,478	882	–1,330
40–44	330	–750	154	–2,584	517	–840
45–49	220	–238	119	–1,385	360	–423
50–54	175	–3	85	–790	204	–329
55 +	331	334	144	–551	368	19
Unreported ages	4,133	4,680	–659	–3,556	108	–67
Total	12,644	–24,003	–1,080	–79,165	15,071	–21,758

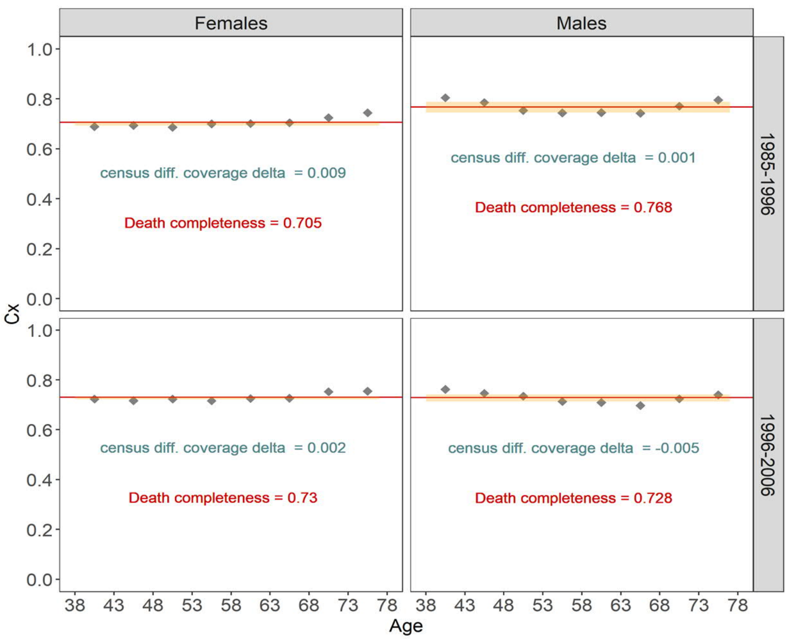
Source: INSD, extracted from the 1985, 1996, and 2006 census reports

These data show that Burkina Faso has remained a country of emigration. Regardless of the census, this emigration affects males more than females and is concentrated in the 15–39 age group. Beyond this age, international migration appears to be of a lesser magnitude and does not substantially affect population dynamics. Extensive internal migration towards urban areas and economic poles can be observed in countries such as Burkina Faso but is unlikely to affect mortality estimates at the national level.

Thereafter, I opted for using non-classical age-group data with less pronounced age heaping. To avoid the effect of under-enumeration of children observed in population age pyramids, which cannot be addressed by any death distribution method, I truncated the data from age 13. An *R* package is now available to implement death distribution methods (Riffe, Lima, and Queiroz 2017). When the minimal age is specified, the package's algorithm can automatically pick up the age range that minimizes the mean squared errors for adjusting the completeness. In the absence of reliable information on the type and age structure of population movements, and based on the age pattern of net migration observed in the table above, I assessed the completeness starting from age 38, in the same vein as suggested by Hill, You, and Choi (2009) and Hill and Choi (2009). For each sex and period, the algorithm retained this age as the lower age limit and identified 77 as the upper age limit beyond which the fit would be worse and would have resulted in a greater mean squared error. Overall, this is concordant with the magnitude of age heaping noticed previously in the 70s when comparing age ratios in deaths and population. It is also possible that other kinds of errors are present beyond these ages, such as age overstatements. Regarding the differential census coverage as shown in Figure 3 below, the second census was always over-enumerated compared to the first, except for males in 1996–2006. As for the completeness of intercensal deaths, it is about 71% and 73% for females and 77% and 73% for males in 1985–1996 and 1996–2006 respectively

When looking at the diagnostic plot, the dots are well aligned for females and the orange band representing the interquartile range of completeness levels of death is quite narrow. From the age group 68–72 onwards the dots diverge slightly upwards from the band. This is also consistent with the age-ratio analysis above and may be due to an effect of age exaggeration. On the other hand, the dots are less well aligned for males than for females. Overall, there is an acceptable alignment of points, at least until age 68.

Figure 3: Differential census coverage and incompleteness of intercensal deaths in the 1985, 1996, and 2006 censuses, Burkina Faso



Source: Author's estimations from census data provided by the INSD

2.3 Procedures for estimating older adult mortality

The focus of this analysis is not the oldest old people, defined in many studies as people aged 80 or older. Instead, the indicator of interest is the probability of death between ages 50 and 80 (${}_{30}q_{50}$). I first computed a basic estimate directly from the adjusted intercensal person-years-lived and the adjusted intercensal deaths with the age range of 50 to 80 (${}_{30}\hat{q}_{50}$), then by 10-year age intervals, mainly ${}_{10}\hat{q}_{50}$, ${}_{10}\hat{q}_{60}$, ${}_{10}\hat{q}_{70}$. Since important age heaping was noticed in deaths beyond age 70, I split ${}_{30}\hat{q}_{50}$ into ${}_{20}\hat{q}_{50}$ and ${}_{10}\hat{q}_{70}$.

In addition to life tables generated directly from the data adjusted for incompleteness of deaths, I used different model-based approaches. First, I used the Brass relational model with the regular standard age pattern from INDEPTH Network for sub-Saharan Africa. As this standard is constructed based on classical 5-year age groups, I proceeded by interpolation to determine the survivors at the boundaries of the classical age groups. Second, I used the SVD-based model from Clark (2019), which has the advantage of minimizing errors compared to the LQ model when estimating age-specific mortality rates. Since this model is indexed by ${}_{5}q_{0}$ and ${}_{45}q_{15}$, I used the interpolated number of survivors at age 15 (l_{15}) and age 60 (l_{60}) in order to estimate ${}_{45}q_{15}$ from the adjusted data tabulated using non-classical age groups. For the child mortality (${}_{5}q_{0}$) input, I used country-specific estimations of child mortality for Burkina Faso from the United-Nations Inter-agency Group for Child Mortality Estimation (UN-IGME). These estimates are based on all national data sources available for all countries, and there is consensus on the bias-reduction Bayesian B-spline model used to derive them (Alkema et al. 2014). However, the indices ${}_{5}q_{0}$ were estimated using the geometric mean of its yearly estimates over the two intercensal periods. These input parameters are summarized in Table 3 below.

Table 3: Estimated adult mortality and corresponding levels of child mortality, Burkina Faso, from the 1985, 1996, and 2006 censuses

Basic estimate	Source	Females		Males	
		1985–1996	1996–2006	1985–1996	1996–2006
${}_{45}q_{15}$	Estimated	0.335	0.296	0.401	0.412
${}_{5}q_{0}$	UN-IGME*	0.191	0.165	0.205	0.177

Note: (*) The UN-IGME estimates are interpolated over each intercensal period by using a geometric mean.

In addition to the Brass model that is calibrated with the INDEPTH African data and the SVD model that is calibrated mostly with data from developed countries, including historical data, I fitted a parametric model to the data as a final approach. Unlike mortality beyond age 80, whose functional shape is still the subject of debate in ageing societies, there seems to be a consensus on the Gompertzian nature of the age patterns of human mortality between the ages of 30 and 80, as reported in multiple studies (Horiuchi and Wilmoth 1998; Saikia and Borah 2014; Thatcher 1999; Thatcher, Kannisto, and Vaupel 1998; Vaupel 1997). For example, assuming human mortality to follow the Kannisto model (Kannisto 1992) as the simplest form of logistic model, mortality patterns before age 80 were used to fit and interpolate life tables to the oldest old ages in the Human Mortality Database (HMD) (Wilmoth et al. 2017). This approach is used to circumvent irregular fluctuations generally observable at the extreme ages of life due to either data quality, or heterogeneity and low population size (Gavrilov and Gavrilova 2011). Hence, taking advantage of the monotonic Gompertz increase of the force of mortality between ages 30–80, I used the Makeham model (Makeham 1860) as a Gompertz-based model that allows accounting for constant background mortality at younger adult ages, thus removing some of the distortion of the basic Gompertz between ages 30 and 40. The data adjusted for incompleteness of deaths is then fitted over the age range 38–42 to 68–72, which seems less impacted by age errors (as shown in the age-ratios plot and the diagnostic plot related to the death distribution method). The model parameters are then used to extrapolate a mortality pattern until age 80 and over. This approach leads to a smooth mortality curve and allows checking the consistency with the age pattern of the input data, mainly beyond age 70. Any clear deviation of the fitted age pattern from the one derived from the adjusted data used as inputs could reflect an effect of age errors. To achieve that, I used the expression of the Makeham (MKH) model provided by Horiuchi et al. (2013) as follows:

$$\mu_x = \beta e^{\beta(x-M)} + \gamma \tag{3}$$

where β, M, and γ are the parameters of the model. Each of the methods described above has advantages and disadvantages, and the main ones are summarized in Table 4 below.

Table 4: Summary of the methods used and the main advantages and disadvantages

Method	Principle	Advantages	Disadvantages
Adjusted data	Hybrid death distribution method combining GGB + SEG	Allows correction of the data for incompleteness and differential census coverage with the possibility of reducing the effects of migration and age exaggerations at older ages	Assumption of constant completeness of death
BRASS model	Relational model indexed on a standard age pattern of mortality	Allows deriving an entire life table from fragmentary or imperfect mortality data	Depends on whether the age pattern of mortality used as a standard to fit the model reflects the demographic and epidemiological experience of the population under study
SVD model	Empirical model indexed by ${}_5q_0$ and ${}_{45}q_{15}$	Indexes any available pair of parameters of ${}_5q_0$ and ${}_{45}q_{15}$ with empirical age patterns of mortality from HMD to generate full life tables	Depends on whether the age patterns of the empirical life tables used to calibrate the model reflect the demographic and epidemiological experience of the population under study. Poor prediction of age-specific mortality schedules could lead to erroneous mortality levels.
MKH model	Gompertz-based parametric model able to draw background mortality at younger ages with the monotonic linear increase of the force of mortality until at least age 80	Possibility to fit the model to an age range (65 or 70, for example), and then extrapolate to age 80	Depends on the data quality over the age range used to fit the model parameters before extrapolation, and the upper limit of this age range should not fall within the age ranges suspected of obvious and pronounced age errors

Source: Author's summary

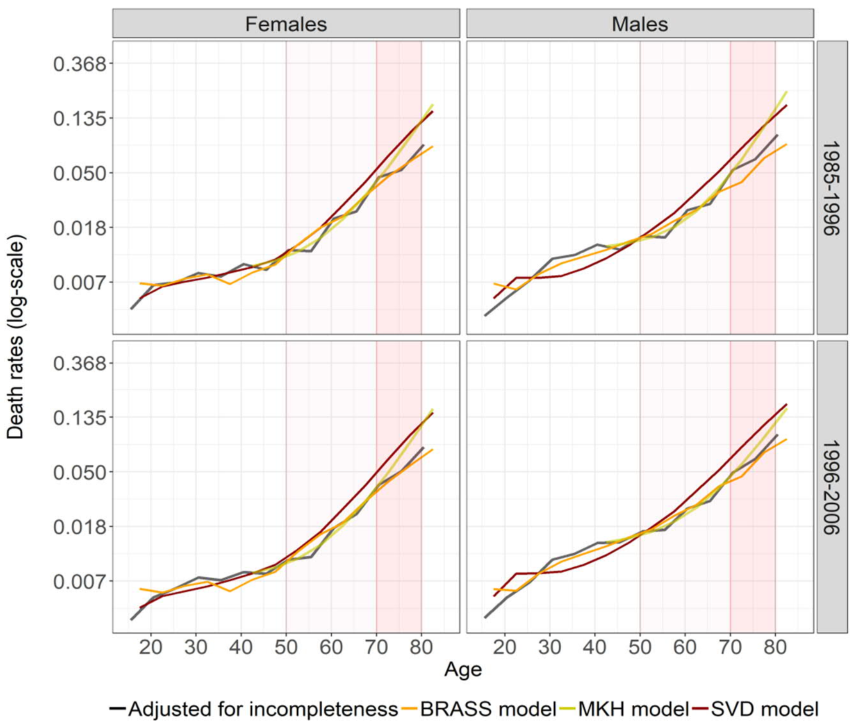
3. Results and discussion

3.1 Age pattern of older adult mortality

After adjusting the data for incompleteness, the resulting mortality curve shows some slight fluctuations, probably due to the remaining effects of age heaping, with peaks in age groups centred on ages ending in 0 and troughs for those centred on ages ending in 5 (see Figure 4 below). Before age 50 there is a mortality hump between ages 20 and 35, which is somewhat flattened in females and more apparent in males and extends to age 40. This mortality hump can be explained by several factors, including multiple risky behaviours in young adults as well as maternal mortality, the importance of which is well known in females of reproductive age (Anderson and Ray 2018; Melaku et al. 2014; Rao, Lopez, and Hemed 2006; Streatfield et al. 2014). Beyond age 50 the pace of the curve seems to define a linear trend that is not very disturbed by fluctuations. When applied to the data adjusted for incompleteness of death, the BRASS, MKH, and SVD models result in mortality age patterns that differ in some respects.

Regarding these age patterns, the BRASS model fits the data adjusted for incompleteness of death up to age 70 well, but beyond that age deviates slightly from it downwards. When the data adjusted for incompleteness of deaths are used to fit the MKH model over the age groups from 38–42 to 68–72 and then extrapolated beyond this, a clear upward deviation is evident beyond age 70. The SVD model, on the other hand, does not adequately capture the mortality hump at younger ages. Between 50 and 80 years the age pattern described by the model remains well above that described by the data adjusted for incompleteness of death, with a gap that gradually widens beyond age 70, although the former uses the same level of adult mortality ($_{45}q_{15}$) as the latter as an input.

Figure 4: Age patterns of older adult mortality using different methods, Burkina Faso, 1985, 1996, and 2006 censuses



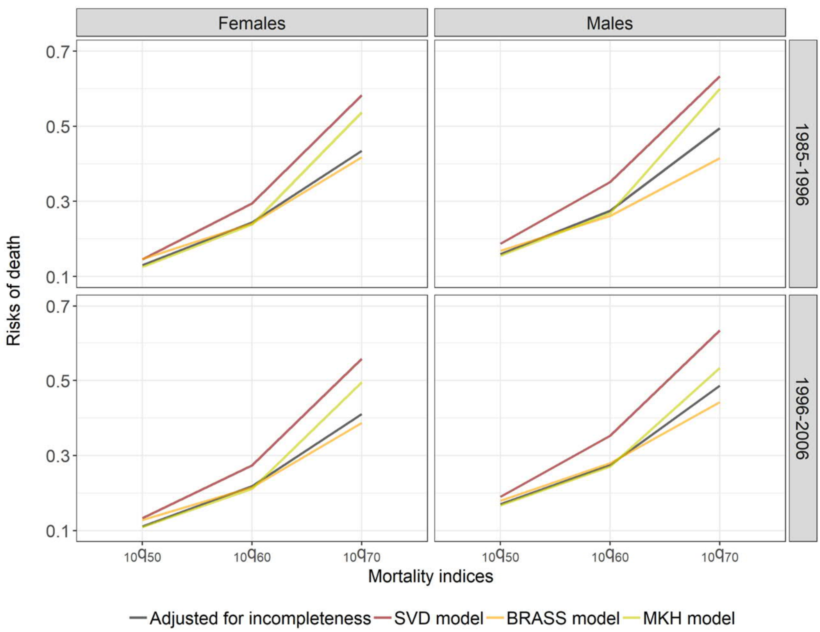
Source: Author's estimations from census data provided by the INSD

3.2 Age- and sex-specific differences between mortality indices

Following the analysis of the age schedule of mortality, Figure 5 below summarises the mortality levels derived from each method for ${}_{10}q_{50}$, ${}_{10}q_{60}$, and ${}_{10}q_{70}$. Regardless of the method and the mortality index considered, the risk of death is higher among older males than among older females. In addition, female mortality appears to have decreased slightly between the two intercensal periods, while male mortality does not seem to have improved. In the 50–80 age range the risk of death increases with age and reaches its highest levels between the ages of 70 and 80. This configuration is observed regardless of the method, sex, and intercensal period considered. This is illustrated by the steeper slopes of the curves displayed on each graph in Figure 5, showing the change from ${}_{10}q_{60}$ to ${}_{10}q_{70}$.

The aggregated indices ${}_{30}q_{50}$ estimated from the data adjusted for incompleteness of deaths are 0.628 and 0.591 for females and 0.692 and 0.691 for males over the intercensal periods 1985–1996 and 1996–2006, respectively.

Figure 5: Risks of death at older ages, by sex and period, Burkina Faso



Source: Author's estimations from census data provided by the INSD

The Brass model results in levels of ${}_{20}q_{50}$ that are consistent with the estimates from the adjusted data. However, a lower mortality between ages 70 and 80 is more noticeable in males over the two intercensal periods. Regarding the MKH model, the risks of death are, not surprisingly, identical to those derived from the adjusted data from age 50 to 70. However, the mortality predicted by extrapolation from age 70 onwards results in levels of ${}_{10}q_{70}$ that are higher than those estimated from the adjusted data, regardless of sex and period. In terms of aggregated indice ${}_{30}q_{50}$, the risks of death are 0.692 and 0.645 for females over the periods 1985–1996 and 1996–2006, respectively. For males, these risks are estimated at 0.753 and 0.717 respectively over the two intercensal periods. In accordance with Figure 4 on mortality curves, the highest mortality levels are observed with the SVD model over the entire 50–80 age interval. The risk of death is estimated at 0.749 and 0.722 for females and 0.807 and 0.808 for males over the periods 1985–1996 and 1996–2006, respectively.

The inconsistencies between the different methods in terms of differing age patterns and levels of mortality raise questions. The good fit of the Brass model to the adjusted data up to the age of 70 could mean that the age patterns of mortality before this age are not strongly affected by age errors. It also highlights the capacity of the African age-specific standard proposed by the INDEPTH network to describe age-specific mortality in countries with poor vital statistics. However, the deviation of the resulting age pattern beyond age 70 assumes either that mortality is overestimated in the data adjusted for incompleteness of death, or that the INDEPTH African age-specific standard underestimates mortality beyond age 70. The first assumption is less plausible insofar as in African contexts such as Burkina Faso the data, even when adjusted for incompleteness of death, remain marred by important age exaggerations, mainly at advanced ages that should lead to an underestimation of mortality, and not the opposite. The second assumption is more tenable, mainly because of the scarcity of deaths in the data from observations on which the INDEPTH standard is based. Indeed, these data generally consist of small numbers at advanced ages.

It may be that the various corrections made to the data (use of non-classic age groups, adjustment of completeness of death and census coverage) were effective enough to make them close to reality, at least until around 70 years ago. In that case, the age pattern described by these data beyond age 70 is obviously underestimated, irrespective of period and sex, if one considers the upward deviation observed with the extrapolation from the MKH model. However, this underestimation seems to be less pronounced in males over the period 1996–2006. It is possible that age heaping, which was clearly more prominent in male deaths than in male populations in 2006, may have contributed to lessen the effect of this underestimation. Such an underestimation could also be explained by omissions and age exaggerations at older ages, the effects of which have been discussed in many previous studies (Dechter and Preston 1991; Elo and

Preston 1994; Hill, Preston, and Rosenwaike 2000; Preston et al. 1996; Preston, Elo, and Stewart 1999). Thus, to consider the estimates from the MKH model as plausible is to assume that it is from the age of 70 onwards that age errors have a downward effect on mortality estimates. This is corroborated by the work of Bendavid and colleagues (2011). Comparing age-specific probabilities of death derived from Demographic and Health Surveys (DHS) with those estimated by the World Health Organization (WHO) and United Nations Population Division (UNPD), they find that DHS estimates noticeably underestimate mortality beyond ages 65–70.

If it is assumed that the SVD model predicts an age pattern of mortality that reflects the observed pattern of mortality, this would lead to the assumption that mortality adjusted for incompleteness deaths is underestimated even before age 70. Yet the diagnostic plots of the data correction (Figure 3), although not perfect, have produced relatively well-aligned dots that give confidence in the plausibility of the resulting estimates at least up to age 70. Even so, any underestimation is not expected to have a major effect before this age. It is probably this plausibility of the estimates derived from these data that allowed for an adequate fit up to age 70 with the Brass model using a standard age pattern derived from African data. Rather than admitting a general underestimation at older ages, one might also think that the predicted age pattern of mortality from the SVD model is not suitable to describe the age pattern of the observed mortality in Burkina Faso. One possible explanation of this discrepancy could be that this and other models that have been calibrated with empirical mortality data from mainly developed countries do not necessarily reflect the demographic and epidemiological experiences of African countries, including Burkina Faso. Indeed, like other African countries, Burkina Faso has benefited from the medical advances of developed countries with the adoption of expanded programmes of immunization and control of childhood diseases. These advances have contributed to an accelerated drop in child mortality from 0.327 to 0.135 between 1960 and 2010, i.e., a drop of about 60% in half a century (United Nations 2019). Unfortunately, child and adult mortality do not necessarily evolve in tandem, as has been the case in developed countries (Masquelier, Reniers, and Pison 2014). Adult mortality has remained high in many African countries and very little progress has been made in improving longevity among the oldest. Such epidemiological pathways may have created discrepancies with the pathways observed in developed countries that are likely to affect models for predicting age-specific patterns of mortality from those countries. Moreover, predictions made with models such as the SVD model rely on mean-age patterns from the combination of empirical life tables used, which may deviate from the detailed age-specific mortality schedule it seeks to predict, or may predict mortality at some ages better than others. In addition, for example, the fact that these models use as input an aggregated adult mortality index that ranges from age 15 to 60 may not capture detailed mortality between these two ages with good accuracy and may confound predictions beyond age 60. All these reasons can be sources of disturbance and affect the quality of the predictions. This is perhaps why reservations have been expressed in the literature about the indirect estimation of age-specific mortality schedules from the traditional model tables (Hu and Yu 2014; Murray et al. 2000).

Since there are no sampling errors, the differences observed with the SVD model seem too large to be overlooked. Before attempting to analyse these differences in depth, one could think that the redistribution of 29% of deaths with unknown ages may have led to this poor adjustment with the SVD model. As shown in Table 5 below, when comparing the levels of adult mortality (${}_{45}q_{15}$) obtained after redistribution and correction of the observed data with the United Nations (UN) estimates, they remain very close even with a 2-year lag, thus resulting in levels of ${}_{30}q_{50}$ that are quite similar. If the redistribution of unknown ages had resulted in inconsistent levels of ${}_{45}q_{15}$ compared to those of the United Nations, one would have thought that the observed differences in old age could have resulted from this redistribution. It is therefore unlikely that the differences observed with the SVD model that use ${}_{45}q_{15}$ as an input parameter are related to the redistribution of unknown ages.

Table 5: Estimated adult probabilities of death compared with the United Nations World Population Prospects (UN WPP) estimates for Burkina Faso

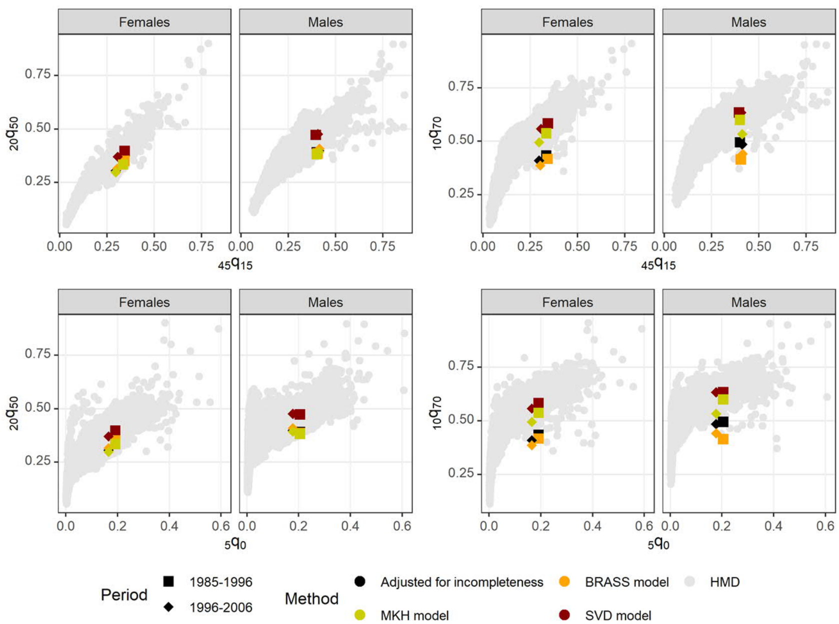
Period	Period length	Source	${}_{45}q_{15}$		${}_{30}q_{50}$	
			Females	Males	Females	Males
1985–1989	5	UN WPP	0.288	0.345	0.726	0.784
1985–1996	11	Estimated	0.335	0.401	0.749	0.807
1990–1994	5	UN WPP	0.301	0.361	0.731	0.790
1995–1999	5	UN WPP	0.302	0.374	0.730	0.795
1996–2006	10	Estimated	0.296	0.412	0.722	0.808
2000–2004	5	UN WPP	0.297	0.349	0.722	0.781

Source: Author's calculations, United Nations World Population Prospects 2019

3.3 Consistency checks with empirical mortality data

A good understanding of the differences in mortality levels resulting from all the methods used requires a comparison of the estimates for Burkina Faso with the mortality experiences of developed countries based on HMD data, as shown in Figure 6 below. Since the effects of age errors appeared to be pronounced only beyond age 70, our mortality index $_{30}q_{50}$ was split between $_{20}q_{50}$ and $_{10}q_{70}$. First, by relating $_{20}q_{50}$ to adult mortality ($_{45}q_{15}$), the estimates for Burkina Faso coincide with those of most HMD countries, regardless of the method used. On the other hand, by relating $_{10}q_{70}$ to $_{45}q_{15}$, the consistency between the estimates for Burkina Faso and those of HMD countries appears less obvious, in particular for the estimates derived from data adjusted for incompleteness of deaths and those derived from the Brass model despite the use of the INDEPTH African standard. This tends to corroborate the suspicions of mortality underestimation beyond age 70 mentioned above. Furthermore, it underlines the inadequacy of the INDEPTH African standard for adjusting mortality at older ages, particularly in males where underestimation seems more noticeable. In their paper on the log-quadratic model for indirect mortality estimation, Wilmoth and colleagues (2012) also note that the INDEPTH data are consistent with historical data, but only at younger ages. At older ages, they point out the potential downward bias that could result from misreporting of age in these data. In addition, the problem of the small size of the INDEPTH data at older ages could contribute to amplifying this effect.

Figure 6: Consistency between mortality levels observed in Burkina Faso and in empirical data from HMD



Source: Author's calculations, Human Mortality Database (www.mortality.org)

When data are extrapolated beyond 70 years using the MKH model, the resulting estimates of mortality between 70 and 80 years appear more plausible in terms of agreement with the scatterplot of historical HMD mortality experiences. However, these estimates indicate lower mortality than predicted by the SVD model, which also results in a level of mortality that is consistent with historical mortality experiences. In addition to adult mortality, the relationship of both ${}_{20}q_{50}$ and ${}_{10}q_{70}$ to child mortality (${}_{5}q_{0}$) shows a similar pattern to that described above when compared to historical data.

Overall, only the estimates from the SVD model and those extrapolated from the MKH model remain very consistent with historical data beyond age 70, but the estimates from the SVD model are always higher. This raises the question of whether the estimates extrapolated from the MKH model are optimistic, or whether it is rather the SVD model that is pessimistic in overestimating mortality at older ages. With a view to removing such ambiguity, future research on SVD-type models should consider adult mortality up to at least age 70. Thus, rather than considering adult mortality between the ages of 15 and 60, the 15 to 50 age range should be favoured. This age range encompasses the period of reproductive life for females, but also corresponds exactly to the period of youth in general and, by ricochet, to the period of risk behaviours. Such a range would better account for the mortality hump in young adults and would reduce the likelihood of death shifts from the under-50 to the over-50 age group when modelling. Incorporating an additional input that covers the 50–70 age group (or older if information is available) would allow better prediction of observed mortality while avoiding the very late age groups where age errors are large.

4. Conclusion

Estimating mortality beyond age 50 in sub-Saharan Africa remains a complex task. The data are generally affected by various age errors that need to be well understood before deriving any estimates. In the case of Burkina Faso, data from the 1985, 1996, and 2006 censuses revealed age heaping problems, possible systematic age exaggerations, and deficient completeness. This last problem was solved using the GGB-SEG hybrid death distribution method to correct census coverage and the incompleteness of intercensal deaths. Other checks identified ages at which age errors appeared to be evident. Comparing age ratios in deaths and population showed that age heaping was more pronounced in deaths than in populations beyond age 70. Regarding age exaggerations, there are some that are complex to detect, but using non-classic age groups has mitigated those that are systematic. Controlling for potential effects of migration allows deriving estimates of older adult mortality from the adjusted data over the intercensal periods, which appeared to be quite good, at least up to age 70.

When compared with estimates from data adjusted for incompleteness of deaths, estimates from the Brass model were consistent up to age 70, giving credibility to these data up to that age. However, the downward deviation observed beyond this age with this method calls into question the relevance of using the INDEPTH African standard age pattern to estimate mortality beyond age 70, at least for Burkina Faso. Moreover, fitting the MKH model to the adjusted data and its extrapolation beyond age 70 confirmed the suspicion of important age errors beyond 70 years, and their effects in terms of underestimation of mortality in the corrected data. On the other hand, the fit of the SVD model to the adjusted data resulted in higher levels of mortality before and after age 70. However, it remains unclear whether the upward deviation observed with the SVD model is due to an underestimation of mortality in the adjusted data, especially before age 70. This is particularly the case since the relationships between the estimates within the age range 50–70 from the adjusted data and both adult and child mortality are consistent with empirical data. Inconsistencies with empirical data are only apparent beyond age 70, but these are removed when considering extrapolations from the MKH model. This raises the question of whether the SVD model overestimates mortality at older ages and calls for further refinement of the model to remove any ambiguity.

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Appendix

Table A-1: Age-specific mortality risks of death at older ages, by sex, period, and method, Burkina Faso

Index	Method	Females		Males	
		1985–1996	1996–2006	1985–1996	1996–2006
${}_{10}q_{50}$	Adjusted for incompleteness	0.130	0.111	0.160	0.171
	BRASS	0.146	0.128	0.168	0.180
	SVD	0.145	0.133	0.187	0.190
	MKH	0.125	0.109	0.155	0.167
${}_{10}q_{60}$	Adjusted	0.244	0.219	0.275	0.275
	BRASS	0.241	0.215	0.261	0.278
	SVD	0.295	0.274	0.351	0.353
	MKH	0.238	0.212	0.269	0.271
${}_{10}q_{70}$	Adjusted	0.434	0.410	0.495	0.486
	BRASS	0.418	0.387	0.415	0.442
	SVD	0.583	0.558	0.634	0.633
	MKH	0.537	0.495	0.600	0.534
${}_{20}q_{50}$	Adjusted	0.342	0.306	0.391	0.398
	BRASS	0.352	0.315	0.385	0.409
	SVD	0.397	0.370	0.473	0.476
	MKH	0.334	0.298	0.382	0.393
${}_{30}q_{50}$	Adjusted	0.628	0.591	0.692	0.691
	BRASS	0.622	0.580	0.641	0.670
	SVD	0.749	0.722	0.807	0.808
	MKH	0.692	0.645	0.753	0.717

Source: Author’s calculations from census data provided by the INSD.

Table A-2: Population and deaths within households during the twelve months preceding the 1985, 1996, and 2006 censuses, by classic age group, Burkina Faso

Age group	Males			Females		
	1985	1996	2006	1985	1996	2006
Population						
<1	168,190	173,307	235,076	168,445	172,953	232,149
1–4	566,312	716,178	996,347	562,667	706,055	974,301
5–9	731,758	913,212	1,174,911	717,386	884,926	1,139,127
10–14	484,377	707,108	899,683	452,184	669,879	845,895
15–19	390,663	534,289	709,625	377,990	549,372	764,424
20–24	255,789	339,975	531,077	318,359	427,317	654,690
25–29	210,488	285,811	448,437	299,959	381,723	561,713
30–34	169,554	248,868	363,941	226,993	322,473	431,371
35–39	161,718	205,573	298,537	206,619	261,594	358,954
40–44	130,246	173,594	250,617	169,326	217,336	299,555
45–49	127,461	144,962	194,046	145,198	165,000	232,537
50–54	107,337	127,985	167,010	122,686	152,338	192,433
55–59	93,622	102,643	132,041	95,229	105,827	141,234
60–64	81,160	93,390	111,167	91,599	102,291	127,889
65–69	60,816	66,374	80,986	58,490	65,814	82,824
70–74	39,784	54,438	64,263	47,839	60,956	72,688
75–79	21,847	31,412	36,942	24,464	30,998	39,986
80–84	11,873	15,297	21,899	19,110	20,589	28,574
85–89	6,583	6,199	9,550	8,629	7,947	12,068
90+	8,963	9,520	9,162	13,219	15,842	15,483
unknown	4,696	20,745	33,416	5,077	20,498	40,621
Deaths						
<1	9,973	12,968	8,785	8,365	11,640	7,474
1–4	10,856	17,627	18,480	10,065	16,300	16,608
5–9	1,961	4,313	3,817	1,654	3,679	2,851
10–14	841	1,739	1,715	667	1,408	1,254
15–19	842	1,411	1,639	963	1,593	1,536
20–24	787	1,221	1,652	952	1,631	1,808
25–29	730	1,645	1,703	878	1,661	1,850
30–34	746	2,180	2,023	880	1,513	1,900
35–39	792	1,748	1,882	809	1,128	1,439
40–44	876	1,659	2,094	852	1,148	1,484
45–49	860	1,235	1,808	716	763	1,067
50–54	1,131	1,301	1,985	897	1,030	1,256
55–59	939	1,003	1,724	672	741	945
60–64	1,525	1,557	2,121	1,211	1,339	1,515
65–69	1,216	1,210	1,722	785	976	1,305
70–74	1,532	1,879	2,305	1,202	1,753	1,827
75–79	969	1,299	1,833	675	989	1,339
80–84	820	1,067	1,621	917	1,111	1,547
85–89	481	555	1,018	399	526	834
90+	992	1,167	1,285	1,087	1,529	1,315
unknown	1,223	24,419	2,225	907	21,437	1,608

Table A-3: Population and deaths within households during the twelve months preceding 1985, 1996, and 2006 censuses, by non-classic age group, Burkina Faso

Age group	Males			Females		
	1985	1996	2006	1985	1996	2006
Population						
<1	168,190	173,307	235,076	168,445	172,953	232,149
1–4	566,312	716,178	996,347	562,667	706,055	974,301
5–7	473,297	583,786	747,247	467,391	568,278	726,036
8–12	569,263	779,800	1,005,673	536,981	738,471	952,309
13–17	438,533	622,138	784,547	404,369	599,634	770,734
18–22	303,504	399,929	594,813	363,195	495,775	745,843
23–27	223,684	299,676	481,883	308,899	398,258	593,280
28–32	185,889	265,929	399,952	259,925	351,335	482,284
33–37	160,472	218,561	313,563	202,193	271,358	369,009
38–42	144,523	186,083	269,933	190,743	238,862	328,310
43–47	125,055	148,376	209,486	143,859	167,391	247,805
48–52	117,351	139,053	177,069	134,493	166,309	212,377
53–57	95,236	108,005	138,810	96,760	112,521	149,101
58–62	88,187	99,850	125,070	98,236	111,051	143,446
63–67	66,495	72,386	88,957	63,841	69,300	89,362
68–72	45,982	61,602	72,712	53,116	68,585	82,136
73–77	24,691	36,976	42,837	25,928	34,305	43,003
78–82	14,610	20,165	27,896	21,797	24,466	34,389
83–87	7,606	7,581	12,482	9,634	8,915	14,060
88+	9,661	10,754	10,964	13,919	17,408	17,961
unknown	4,696	20,745	33,416	5,077	20,498	40,621
Deaths						
<1	9,973	12,968	8,785	8,365	11,640	7,474
1–4	10,856	17,627	18,480	10,065	16,300	16,608
5–7	1,434	3,226	2,881	1,174	2,809	2,170
8–12	1,094	2,296	2,119	899	1,788	1,493
13–17	827	1,500	1,543	783	1,418	1,344
18–22	846	1,325	1,759	1,102	1,837	1,884
23–27	766	1,457	1,727	887	1,669	1,848
28–32	761	2,130	1,997	968	1,654	1,977
33–37	737	1,855	1,836	767	1,134	1,525
38–42	926	1,770	2,075	935	1,243	1,487
43–47	783	1,259	1,823	667	767	1,169
48–52	1,136	1,334	1,996	945	1,045	1,257
53–57	927	996	1,701	641	714	953
58–62	1,458	1,474	2,130	1,171	1,302	1,452
63–67	1,199	1,230	1,751	825	956	1,258
68–72	1,577	1,867	2,277	1,243	1,766	1,857
73–77	1,071	1,310	1,883	651	1,049	1,315
78–82	892	1,220	1,761	942	1,155	1,647
83–87	558	664	1,166	481	596	929
88+	1,048	1,276	1,522	1,135	1,616	1,507
unknown	1,223	24,419	2,225	907	21,437	1,608