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Understanding uncertainty in ANACONDA results due to small numbers of deaths: Guidance for users

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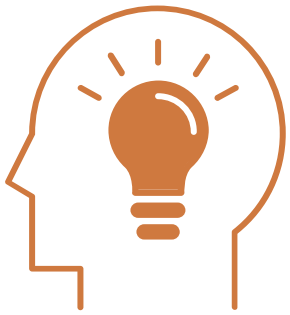

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Melbourne School of Population and Global Health
Building 379
207 Bouverie Street
Carlton, VIC 3053
Australia

CRVS-info@unimelb.edu.au
www.mspgh.unimelb.edu.au/dataforhealth

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Understanding uncertainty in ANACONDA results due to small numbers of deaths: Guidance for users

This document provides guidance to ANACONDA users to help inform decisions on the appropriate number of deaths necessary to have confidence in ANACONDA results for a population or sub-population. For more resources relating to ANACONDA, visit the CRVS Knowledge Gateway: crvsgateway.info

Introduction

A common question from users of the electronic mortality data quality assessment tool ANACONDA (Analysis of Causes of National Death for Action)[1] is the extent to which its results are biased by small numbers of deaths. In any mortality analysis, uncertainty from random fluctuation in death numbers – known as *stochastic uncertainty* – is greater at smaller, compared with larger, numbers of deaths. At small numbers of deaths, true patterns and trends in mortality data can be difficult to distinguish from random fluctuation. This is a significant issue in ANACONDA for two main reasons:

1. ANACONDA is commonly used for subnational populations, or countries with small populations (i.e. less than two million).
2. Some of the steps in ANACONDA analyse deaths for sub-groups of the population (two sexes, 19 age groups, and numerous causes of death) so low numbers of deaths for some categories can be common, even in large populations.

This document provides guidance to ANACONDA users[2] of the extent of uncertainty in its key outputs at different numbers of total deaths (that is, deaths for both sexes and all ages used in the input data), helping to guide users to make a decision on the appropriate number of deaths necessary to use ANACONDA for a population or sub-population. The document uses a range of examples of countries or groups of countries, each with typical levels of mortality and data quality, to demonstrate the impact of small numbers of deaths on uncertainty in ANACONDA results (**Table 1**).

How to use this guide

Users should choose a country from **Table 1** whose mortality and data quality characteristics most closely match their own country, and refer to the uncertainty results presented for that country example throughout this document. The one exception is for leading causes of death, where users can choose from three different groupings of countries - guidance for users is provided in that specific section.

While this document provides guidance to users about the extent of uncertainty in ANACONDA outputs, ultimately it is the decision of the user about how much uncertainty is tolerated. This will be influenced by different factors, including the purposes the data are used for in their country, which ANACONDA output(s) the user is interested in, and whether there is a decision to be made about the appropriate number of deaths to use because of a small population (which may influence whether to aggregate different populations or years).

1 ANACONDA is an electronic tool for users to assess the quality of mortality data. Further information about ANACONDA can be found here: https://crvsgateway.info/file/10084/56

2 This document is also intended for those who have or are currently receiving training in ANACONDA, or are already very familiar with the tool.

A useful way to interpret this document is to assess the trade-off in uncertainty and numbers of deaths, by examining how much uncertainty reduces as the number of deaths increases. This can inform a decision about the appropriate number of deaths necessary to use ANACONDA (taking into account the tolerance of uncertainty of the user and the specific outputs they are interested in). The conclusion of this document summarises some of the key findings from the information presented to assist users in understanding how best to understand uncertainty in ANACONDA outputs.

Box 1: Useful definitions

5q0: Otherwise known as the under-five mortality rate. The probability of dying between birth and age five years (per 1000 live births).

Completeness: Completeness is the percentage of actual deaths in a population that are reported in the data source being used (Step 2.2 in ANACONDA).

Garbage Codes: Any code that cannot or should not be an underlying cause of death[3] (Steps 6 and 7 in ANACONDA).

VSPI(Q): The Vital Statistics Performance Index (VSPI) is overall summary index of mortality data quality, originally developed by Phillips et al (2014).[4] The VSPI(Q) is a version of the VSPI that focuses on the quality of the input data, that measures quality of based on the completeness, fraction of deaths that are garbage codes, length of cause list, quality of age and sex data, and extent of biologically implausible causes reported (Step 10 in ANACONDA).

Cause-specific mortality fraction (CSMF): The percentage of all deaths that are due to a specific cause. This is normally reported as a percentage (Step 9.2 in ANACONDA).

Age-specific mortality rate (ASMR): The number of deaths in an age group divided by the population of the age group. This is normally reported per 1000 population (Step 3.1 in ANACONDA).

Relative ASMR error: Average error in ASMR divided by the actual ASMR calculated from the ANACONDA input data.

Total number of deaths: The number of total deaths for both sexes and all ages used in ANACONDA input data. This definition of total number of deaths remains even where the indicators are presented separately for males and females.

Uncertainty interval: A range of values, within which the true level of an indicator is 95% likely to be located.

3 https://crvsgateway.info/file/14581/276 Phillips, D. et al, 2014, A composite metric for assessing data on mortality and causes of death: the vital statistics performance index, Population Health Metrics, 12: 14

4 Phillips, D. et al, 2014, A composite metric for assessing data on mortality and causes of death: the vital statistics performance index, Population Health Metrics, 12: 14

Table 1: 16 country examples[5] of typical mortality patterns and data quality[6]

Characteristics			Country/year example	5q0 (per 1000)	Completeness (%)	Garbage (%)	VSPI(Q)
Mortality level	Completeness	Garbage					
Low	High	Low	Australia 2015	4	100	22	82
Medium	High	Low	Mongolia 2016	18	93	11	80
Low	High	Medium	Turkey 2016	13	98	33	75
Medium	High	High	Jamaica 2014	16	98	41	74
Low	High	High	Greece 2015	4	100	46	69
Medium	Medium	Medium	Ecuador 2015	22	77	36	62
Medium	High	High	El Salvador 2014	16	93	54	59
Medium	High	High	Thailand 2016	12	90	52	58
Medium	Medium	Medium	Jordan 2012	20	75	38	54
Medium	High	High	Egypt 2012	27	95	65	52
Medium	Medium	High	Iraq 2016	31	74	53	50
High	Medium	High	Azerbaijan 2007	46	72	62	44
Low	Medium	High	Oman 2014	11	78	68	43
High	Low	High	Tajikistan 2016	43	59	51	35
Low	Low	High	Tunisia 2013	15	46	52	34
Medium	Low	High	Morocco 2012	31	35	70	20

Assessment of uncertainty

In each country example shown in **Table 1**, uncertainty[7] is assessed for each of the following total deaths in the population (deaths for all ages and both sexes[8]): 500, 1000, 2000, 3000 and 5000.

This guidance document assesses uncertainty for the following ANACONDA outputs:

1. **All-age results:** Uncertainty is measured using 95 per cent uncertainty intervals (a range within which the true level of an indicator is 95 per cent likely to be located).
   a. VSPI(Q)[9], completeness[10] (per cent) by sex, and garbage (per cent)
   b. Leading 10 cause-specific mortality fractions (CSMFs) by sex (per cent) according to the Global Burden of Disease (GBD) cause list (used in Step 9.2 in ANACONDA). The CSMF examples are taken from countries in the GBD Social-Demographic Index's (SDI) highest, middle and lowest quintiles. These three examples present a range of typical levels of CSMFs at each top 10 ranking. Users can check the uncertainty for each level of CSMF in their own data and for each number of cases.

5 The true numbers of deaths in the countries used as examples vary greatly (e.g. Australia has 160 000 deaths per year). To enable assessment of each country example at each number of total deaths, all characteristics of each country's mortality data are held constant (e.g. mortality rates, completeness, garbage), but adjusted so that the total number of deaths equals the respective level (e.g. Australia has 160 000 deaths per year, so for the 1000 deaths example all its death numbers are divided by 160).

6 Source: ANACONDA input data - mortality data: WHO Mortality Database; population data: WHO Mortality Database, GBD. 5q0, completeness, garbage and VSPI(Q) are all calculated using ANACONDA.

7 Uncertainty is assessed by assuming that death numbers have a Poisson distribution and the garbage and CSMF per cent has a binomial distribution. Uncertainty is calculated by running 1000 simulations on each value.

8 The total number of deaths presented in each table is for both sexes, even when the tables present uncertainty in indicators separately for males and females.

9 The uncertainty in the VSPI(Q) is different to its individual components.

10 Uncertainty in completeness, which is measured using the empirical completeness method, occurs due to uncertainty in the inputs of the registered crude mortality rate and the registered under-five mortality rate (which is influenced by the age distribution of deaths in the population). Additional uncertainty occurs due to the true under-five mortality rate, but this is not measured here so as not to obscure the impact of uncertainty from small death numbers.

2. **Age-specific results:** Relative age-specific mortality rate (ASMR) error (average error[11] in ASMR divided by the actual ASMR calculated from the ANACONDA input data). The age-specific results will be subject to more uncertainty than the all-age results because there are smaller numbers of deaths in each specific age group.

All-age results

Tables 2-4 show the 95 per cent uncertainty intervals of the VSPI(Q), completeness percentage by sex and garbage percentage for all ages, at each total number of deaths. Each result is colour-coded to show the level of uncertainty in percentage points (refer to Legend). As an example, at 1000 deaths, a population with Thailand's mortality and data quality characteristics would have a VSPI(Q) of 58 that is 95 per cent likely to be within a range of 55 to 61. This is coloured light green to show the error is within plus or minus three percentage points. It should be noted that these colour categories are used as a guide as to how uncertainty differs at each number of changes; light green does not necessarily mean that uncertainty is acceptable, as the degree of acceptability is at the discretion of the user.

VSPI(Q) (all-age results)

VSPI(Q) exhibits relatively low levels of uncertainty compared with garbage and completeness, largely because it is a composite indicator and uncertainty in each component tends to offset each other (**Table 2**). Uncertainty is highest in populations where completeness uncertainty is highest, such as Thailand and Oman. Reductions in uncertainty due to increases in total deaths from 1000 to 2000 are minor. This is especially apparent in countries with high levels of completeness, such as Australia and Egypt, where uncertainty in VSPI(Q) does not increase above 1000 deaths. Only in countries with the largest uncertainty at 500 deaths, is there a noticeable reduction in uncertainty by progressing to higher numbers of deaths.

Table 2: VSPI(Q) and 95% uncertainty interval, by total number of deaths, both sexes

Country example	VSPI(Q)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Australia	82	79-84	79-83	80-83	80-82	80-82
Mongolia	80	76-83	77-82	78-82	78-82	70-82
Turkey	75	73-78	73-77	74-77	75-77	75-77
Jamaica	74	71-77	72-76	73-76	73-75	73-75
Greece	69	65-72	67-71	67-71	68-71	68-71
Ecuador	62	56-66	57-65	58-64	59-63	60-63
El Salvador	59	55-63	57-62	57-61	58-61	58-61
Thailand	58	52-62	54-61	55-61	56-61	56-60
Jordan	54	49-58	50-57	51-56	52-56	52-55
Egypt	52	49-56	51-54	51-54	51-54	51-54
Iraq	50	46-54	48-54	49-53	49-53	49-52
Azerbaijan	44	40-48	41-47	42-46	43-46	43-45
Oman	43	38-47	40-46	40-45	41-44	41-44
Tajikistan	35	31-38	33-38	34-37	34-37	34-36
Tunisia	34	30-39	31-37	32-37	33-36	33-36
Morocco	20	18-23	18-22	19-22	19-21	19-21

11 Error is the difference between the reported ASMR in a simulation and the actual ASMR calculated from the ANACONDA input data. Average error is calculated from 1000 simulations of ASMRs, and is reported as a per cent by dividing by the reported ASMR.

Legend for Tables 2, 3 and 4

95% uncertainty interval:
Plus or minus less than 1.0 percentage point
Plus or minus 1.0-3.9 percentage points
Plus or minus 4.0-7.9 percentage points
Plus or minus 8.0 or more percentage points

Note: The classification of each cell is based on the average of the percentage points of the interval above and below the CSMF.

Completeness (all-age results)

Completeness, while also measured for all ages, is subject to more uncertainty than the VSPI(Q) or garbage due to:

a) The input data of the registered under-five mortality rate where there are low numbers of deaths at ages 0 and 1-4 years, especially in low-mortality settings

b) The model parameters, which have a greater impact at lower levels of completeness than higher levels

c) The smaller number of deaths when measured by sex.

At 500 deaths, countries with high levels of uncertainty in completeness (plus or minus eight percentage points) include those with low or medium mortality and low or medium completeness, such as Oman, Tunisia and Ecuador (**Table 3**). For example, at 500 deaths the 95 per cent uncertainty interval of completeness for Oman males is 63-86 per cent. In Thailand, although completeness is high, the low number of deaths at young ages means higher uncertainty in the registered under-five mortality rate, and therefore higher uncertainty in overall completeness.

For some countries with lower completeness uncertainty, there are very limited reductions in uncertainty when progressing from 1000 to 2000 deaths. However, for countries with higher uncertainty, these reductions are quite substantial, and are even noticeable at 2000 to 3000 deaths in some countries. It should be noted that completeness uncertainty would be even higher if uncertainty in the true under-five mortality rate were included in this calculation.

Table 3: Completeness at all ages (%) and 95% uncertainty interval, by sex and total number of deaths

Country example	Completeness (%)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Males						
Australia	100	93-100	96-100	97-100	98-100	98-100
Mongolia	92	86-96	88-95	89-95	90-94	90-94
Turkey	98	93-99	94-99	96-99	96-99	96-98
Jamaica	97	91-99	94-99	95-99	95-98	96-98
Greece	99	92-100	93-100	96-100	97-100	98-100
Ecuador	75	64-85	67-81	70-80	71-79	72-78
El Salvador	93	86-97	89-96	90-96	91-95	91-95
Thailand	91	76-98	82-97	85-95	86-95	87-94
Jordan	75	65-83	68-81	70-79	71-79	72-78
Egypt	94	89-97	91-96	92-96	92-95	93-95
Iraq	75	66-82	68-80	70-79	71-78	72-77
Azerbaijan	70	59-79	63-76	65-74	66-73	67-73
Oman	76	63-86	67-84	69-81	71-81	72-80
Tajikistan	58	50-66	52-63	54-62	54-61	55-60
Tunisia	44	37-53	39-50	41-48	42-48	42-47
Morocco	40	34-45	36-44	37-43	37-42	38-42
Females						
Australia	100	91-100	94-100	96-100	97-100	97-100
Mongolia	93	85-98	88-97	90-96	91-96	91-95
Turkey	98	93-100	95-99	96-99	97-99	97-99
Jamaica	98	91-100	95-99	96-99	96-99	97-99
Greece	100	93-100	94-100	95-100	97-100	98-100
Ecuador	79	67-88	71-85	73-84	74-83	75-82
El Salvador	92	82-97	85-96	88-95	88-94	89-94
Thailand	90	68-98	77-96	81-95	83-95	84-94
Jordan	75	64-84	68-81	71-80	71-79	72-79
Egypt	95	91-98	92-97	93-97	94-96	94-96
Iraq	73	63-82	67-80	69-78	69-77	70-76
Azerbaijan	75	65-83	67-81	69-79	70-79	72-78
Oman	80	67-91	71-88	73-86	75-85	76-84
Tajikistan	61	52-69	55-67	56-65	57-64	58-63
Tunisia	48	40-59	42-55	43-52	44-52	45-50
Morocco	27	23-33	24-31	25-30	25-29	26-29

Garbage (all-age results)

Uncertainty in garbage percentage is somewhat higher than for the VSPI(Q) (**Table 4**). At 500 deaths, all country examples have 95 per cent uncertainty intervals of at least plus or minus four percentage points (except Mongolia which has a very low reported garbage level). At 1000 deaths, four countries with high garbage levels still have 95 per cent confidence intervals of at least plus or minus four percentage points, but relative to their level of garbage this uncertainty is less concerning. Hence, reductions in uncertainty are apparent from 500 to 1000 deaths but are very minor when progressing to 2000 (or more) deaths.

Table 4: Garbage at all ages (%) and 95% uncertainty interval, by total number of deaths, both sexes

Country example	Garbage (%)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Australia	22	18-26	20-25	20-24	21-24	21-23
Mongolia	11	8-14	9-13	10-13	10-12	10-12
Turkey	33	29-38	30-36	31-36	31-35	32-35
Jamaica	41	35-46	37-44	38-43	39-43	39-42
Greece	46	40-51	42-49	43-48	44-48	44-47
Ecuador	36	31-40	32-39	33-38	34-37	34-37
El Salvador	54	49-59	51-58	51-57	52-56	52-56
Thailand	52	47-57	49-56	50-55	50-54	51-54
Jordan	38	33-43	35-42	36-41	36-40	37-40
Egypt	65	60-70	62-68	62-68	63-67	63-67
Iraq	53	48-58	49-57	50-55	51-55	51-55
Azerbaijan	62	57-67	58-66	59-64	60-64	60-64
Oman	68	63-73	65-71	66-71	66-70	67-70
Tajikistan	51	46-57	48-55	49-54	49-54	50-53
Tunisia	52	47-57	48-56	50-55	50-54	51-54
Morocco	70	65-75	66-74	68-73	68-72	68-72

Leading 10 CSMFs (all-age results)

The uncertainty of the leading 10 CSMFs is presented in **Table 5** for three examples of different cause rankings (based on high, medium and low SDI groupings). Only these examples are presented because the uncertainty is solely influenced by the size of the CMSF, not the type of cause (e.g. whether the leading causes are non-communicable or communicable diseases). The three examples show a range of CSMF levels for each rank of leading causes. Users are advised to compare the uncertainty of CSMFs that are closest to those of their leading causes. The extent to which there is uncertainty in the ranking of causes will depend on the closeness of each neighbouring CSMF and their respective uncertainty.

At 500 deaths, there is quite considerable uncertainty in CSMFs of leading causes; for example, for a CSMF of 13.5 per cent the 95 per cent uncertainty interval is 10.7-16.9 per cent. This uncertainty reduces to be 12.0-15.1 per cent at 2000 total deaths and 12.6-14.5 per cent at 5000 total deaths. The table shows that, high levels of CSMF uncertainty (95 per cent uncertainty plus or minus at least three percentage points) only occur for the highest CSMFs at 500 total deaths, and are non-existent at 1000 total deaths. Moderately high uncertainty (95 per cent uncertainty plus or minus 2.0-2.9 percentage points) occurs for close to half of the top 10 causes at 500 deaths, but only occurs in a minority of top 10 causes at 1000 total deaths. The gains from increasing the number of deaths results in greater reductions in uncertainty up to 2000 deaths, than above 3000 deaths. When interpreting the shaded cells, it should be kept in mind that these measure the uncertainty interval in percentage points and, at the same number of total deaths, will be smaller for a low compared with high CSMF.

It should also be noted that if only the leading causes of deaths under the age of 70 years are shown in Step 9.2, then uncertainty will be larger than presented here.

Table 5: Ten leading CSMFs at all ages (%) and 95% uncertainty interval, by sex and total number of deaths

High SDI

Rank	CSMF (%)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Males						
1	16.9	13.8-20.6	14.7-19.5	15.4-18.7	15.7-18.4	16-18.1
2	7.7	5.6-10.5	6.2-9.6	6.7-9.1	6.8-8.8	7.1-8.6
3	7.0	4.9-9.6	5.6-8.9	6.0-8.3	6.1-8.0	6.3-7.8
4	6.3	4.4-8.9	5.0-8.1	5.4-7.6	5.6-7.4	5.8-7.1
5	4.9	3.3-7.3	3.7-6.5	4.1-6.0	4.2-5.8	4.4-5.7
6	4.0	2.6-6.3	3.0-5.5	3.3-5.1	3.4-4.9	3.6-4.7
7	3.5	2.1-5.6	2.5-4.9	2.8-4.5	3.0-4.3	3.1-4.2
8	2.9	1.7-4.9	2.0-4.1	2.3-3.8	2.4-3.6	2.5-3.4
9	2.4	1.2-4.2	1.6-3.7	1.8-3.2	1.9-3.1	2.0-2.9
10	2.3	1.2-4.2	1.5-3.6	1.8-3.2	1.9-3.0	2.0-2.9
Females						
1	16.3	13.1-19.7	14.0-18.6	14.6-17.8	14.9-17.5	15.1-17.2
2	14.1	11.3-17.6	12.1-16.5	12.7-15.8	13.0-15.5	13.3-15.2
3	9.0	6.6-11.9	7.4-11.1	7.8-10.4	8.1-10.2	8.3-9.9
4	4.6	2.9-6.8	3.4-6.1	3.7-5.6	3.9-5.4	4.0-5.2
5	4.3	2.8-6.6	3.2-5.9	3.5-5.4	3.7-5.2	3.8-5.0
6	3.8	2.5-6.1	2.8-5.3	3.1-4.8	3.2-4.7	3.4-4.5
7	3.5	2.1-5.6	2.5-4.9	2.8-4.5	2.9-4.3	3.1-4.1
8	3.2	1.8-5.1	2.2-4.5	2.5-4.1	2.6-3.9	2.7-3.7
9	2.5	1.2-4.2	1.6-3.7	1.9-3.3	2.0-3.1	2.1-2.9
10	1.9	1.0-3.6	1.2-3.1	1.4-2.7	1.5-2.5	1.6-2.4

Middle SDI

Rank	CSMF (%)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Males						
1	13.5	10.7-16.9	11.4-15.8	12.0-15.1	12.3-14.8	12.6-14.5
2	10.8	8.2-13.9	8.9-12.9	9.5-12.2	9.7-12.0	10.0-11.7
3	7.1	5.1-9.8	5.7-9.0	6.1-8.4	6.2-8.1	6.4-7.9
4	4.4	2.8-6.6	3.3-6.0	3.6-5.5	3.8-5.3	3.9-5.1
5	3.6	2.1-5.6	2.5-4.9	2.8-4.5	3.0-4.3	3.1-4.2
6	3.2	1.8-5.1	2.2-4.5	2.5-4.1	2.6-3.9	2.7-3.7
7	3.1	1.8-5.1	2.2-4.5	2.5-4.1	2.6-3.9	2.7-3.7
8	2.7	1.5-4.7	1.9-4.0	2.1-3.6	2.2-3.5	2.4-3.3
9	2.8	1.5-4.7	1.9-4.0	2.1-3.6	2.2-3.5	2.4-3.3
10	2.6	1.5-4.7	1.8-3.9	2.1-3.6	2.2-3.4	2.3-3.2
Females						
1	13.5	10.7-16.9	11.4-15.8	12.0-15.1	12.3-14.8	12.6-14.5
2	11.9	9.3-15.3	10.0-14.1	10.5-13.4	10.8-13.1	11.1-12.8
3	6.5	4.6-9.1	5.1-8.2	5.5-7.7	5.6-7.4	5.9-7.2
4	5.7	3.9-8.2	4.3-7.3	4.7-6.8	4.9-6.6	5.1-6.4
5	3.9	2.5-6.1	3.0-5.5	3.2-5.0	3.4-4.8	3.5-4.6
6	3.6	2.3-5.9	2.6-5.1	2.9-4.6	3.1-4.4	3.2-4.3
7	3.1	1.8-5.1	2.2-4.5	2.5-4.1	2.6-3.9	2.7-3.7
8	2.6	1.4-4.4	1.8-3.9	2.0-3.5	2.1-3.3	2.2-3.1
9	2.3	1.2-4.2	1.5-3.6	1.8-3.2	1.9-3.0	2.0-2.9
10	2.2	1.2-4.2	1.5-3.4	1.7-3.1	1.8-2.9	1.9-2.8

Low SDI

Rank	CSMF (%)	95% uncertainty interval by total number of deaths				
		500	1000	2000	3000	5000
Males						
1	9.4	7.0-12.3	7.7-11.4	8.2-10.8	8.4-10.5	8.6-10.3
2	8.6	6.5-11.6	7.1-10.7	7.5-10.1	7.8-9.8	8.0-9.6
3	7.1	5.1-9.8	5.7-9.0	6.1-8.4	6.3-8.2	6.5-8.0
4	7.1	5.1-9.8	5.7-9.0	6.1-8.4	6.3-8.1	6.5-7.9
5	6.0	4.1-8.5	4.7-7.8	5.1-7.2	5.2-7.0	5.4-6.8
6	5.8	3.9-8.2	4.5-7.5	4.9-7.0	5.1-6.8	5.2-6.6
7	5.7	3.9-8.2	4.4-7.4	4.8-6.9	5.0-6.7	5.1-6.5
8	3.8	2.3-5.9	2.7-5.2	3.1-4.8	3.2-4.6	3.3-4.4
9	3.1	1.8-5.1	2.2-4.5	2.5-4.1	2.6-3.9	2.7-3.7
10	2.6	1.4-4.4	1.8-3.9	2.0-3.5	2.1-3.3	2.3-3.2
Females						
1	8.5	6.1-11.2	6.8-10.4	7.3-9.8	7.5-9.5	7.7-9.3
2	8.1	5.9-11.0	6.5-10.0	7.0-9.4	7.2-9.2	7.4-8.9
3	7.7	5.6-10.5	6.1-9.5	6.6-9.0	6.8-8.7	7.0-8.5
4	7.3	5.4-10.3	5.9-9.3	6.4-8.8	6.6-8.5	6.8-8.3
5	6.5	4.6-9.1	5.1-8.3	5.6-7.8	5.8-7.6	5.9-7.3
6	5.8	4.1-8.5	4.5-7.5	5.0-7.1	5.1-6.8	5.3-6.6
7	4.5	2.9-6.8	3.3-6.0	3.6-5.5	3.8-5.3	3.9-5.1
8	3.9	2.5-6.1	2.9-5.4	3.2-5.0	3.3-4.8	3.5-4.6
9	3.2	1.8-5.1	2.1-4.4	2.4-4.0	2.5-3.8	2.7-3.7
10	2.4	1.4-4.4	1.6-3.7	1.9-3.3	2.0-3.1	2.1-3.0

Legend for Tables 5

95% uncertainty interval:
Plus or minus less than 1.0 percentage point
Plus or minus 1.0-1.9 percentage points
Plus or minus 2.0-2.9 percentage points
Plus or minus 3.0 or more percentage points

Note: The classification of each cell is based on the average of the percentage points of the interval above and below the CSMF.

Age-specific results

Age-specific results show more uncertainty than all-age results, as expected. The figures in **Appendix 1** show measures of uncertainty using the relative ASMR error for each number of total deaths[12], which is the average error (from 1000 simulations) divided by the actual ASMR from ANACONDA. For example, for Australian males the relative ASMR error at age zero years for 500 deaths is 60 per cent; that is, on average the reported ASMR is 60 per cent higher or lower than the actual ASMR due to uncertainty that occurs when there are only 500 total deaths. The relative ASMR error is highest at ages five to 14 years where mortality is lowest, and gradually declines with older ages where mortality is highest.

12 Total deaths at all ages and for both sexes combined

Decline in the relative ASMR error is greatest when transitioning from 500 to 1000 total deaths and 1000 to 2000 total deaths, than from 2000 to 3000 total deaths and 3000 to 5000 total deaths. For example, for Ecuadorian males, the relative ASMR error at ages 40-44 is 19 per cent for 1000 total deaths, 13 per cent for 2000 deaths, 11 per cent for 3000 total deaths and nine per cent for 5000 total deaths. Increasing total deaths from 1000 to 2000 provides a much greater reduction in uncertainty of results than increasing from 2000 to 3000 total deaths. In most country examples the relative ASMR error is less than 10 per cent at the oldest ages where there are at least 2000 total deaths.

It is also noticeable that relative ASMR error at ages five to 19 years is highest for a low mortality setting such as Australia (where it reaches 170 per cent for females aged five to nine years), because low mortality populations have a lower percentage of deaths at those ages compared with other countries. Relative ASMR error is also slightly higher for females, because of their lower mortality rates than males.

Appendix 2 shows an example of how relative ASMR error would affect the log ASMR chart in Step 3 of ANACONDA, using the example of Tajikistan. This demonstrates that stability in the log ASMR line is most apparent at 2000 deaths compared to 1000 deaths. Note that the extent of errors at lower numbers of deaths is masked somewhat by use of the log scale – the actual extent of errors is greater than it spears on the graph.

The uncertainty of age-specific results also impacts the sex ratio of ASMRs (Step 3.2 in ANACONDA). The error in the sex ratio of ASMRs tends to follow the same age pattern as for ASMRs (especially in the five to 19 years age group), being highest at younger ages and then declining with older age.

Summary – deciding on an appropriate number of deaths to have confidence in ANACONDA results

The primary purpose of this document is to show different examples of how the number of deaths influences the uncertainty of different key outputs of ANACONDA. The decision of a user about the appropriate number of deaths for which to have confidence in ANACONDA results will depend both on the mortality and data quality characteristics of the population, the specific outputs of interest and the extent of uncertainty the user is willing to tolerate.

A number of conclusions from this guide can be made for different ANACONDA outputs. Typically, 1000 deaths should result in relatively low uncertainty for all-age results, but more may be required for populations with low-medium completeness and low-medium mortality. In order to have reasonable certainty for age-specific results, however, 2000 deaths (or more) are necessary.

Conclusions for specific indicators are outlined below:

- **VSPI(Q):** 500 deaths can provide a reliable VSPI(Q) for countries with high completeness, while 1000 deaths should lead to reliable results for the vast majority of populations. Increases in deaths above 1000 leads to only limited reductions in uncertainty.
- **Completeness:** For many populations, 1000 deaths should be sufficient to provide reliable sex-specific completeness. 1000 deaths significantly reduces uncertainty compared with 500 deaths. For other populations, especially those with low to medium mortality and low to medium completeness, it is likely that 2000 deaths are necessary to have confidence in completeness results. For populations with lower completeness uncertainty, there are very limited reductions in uncertainty when progressing from 1000 to 2000 deaths. However, reductions are much larger for countries with higher completeness uncertainty, and are still significant moving from 2000 to 3000 deaths.
- **Garbage:** 1000 deaths provide reliable garbage levels for most countries, although uncertainty in percentage points is higher where garbage is higher. There are limited reductions in uncertainty to 2000 deaths.
- **CSMFs:** A decision of the sufficient number of deaths is largely at the discretion of the user and may depend on the CSMF level of the cause(s) of interest. At 1000 deaths, there is only moderately small uncertainty at most CSMF levels, although at higher CSMFs there is considerable uncertainty above 12 per cent even at 2000 deaths. However, this level of uncertainty may be tolerable for the user depending on the importance placed on these CSMF results.

- **Age-specific results:** The substantial reduction in relative average error, especially at younger ages, due to moving from 1000 to 2000 deaths indicates that at least 2000 deaths (at least) are needed to have confidence in age-specific results from ANACONDA – for both the age-specific mortality rates and sex ratio of deaths.

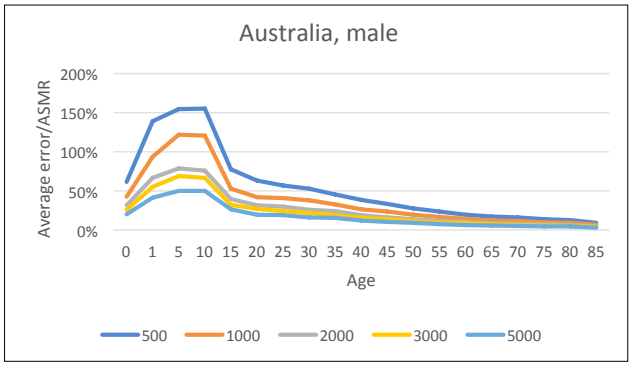
The guidance provided in this document will further enhance the utility of ANACONDA as a tool to assess the quality of routine mortality data.

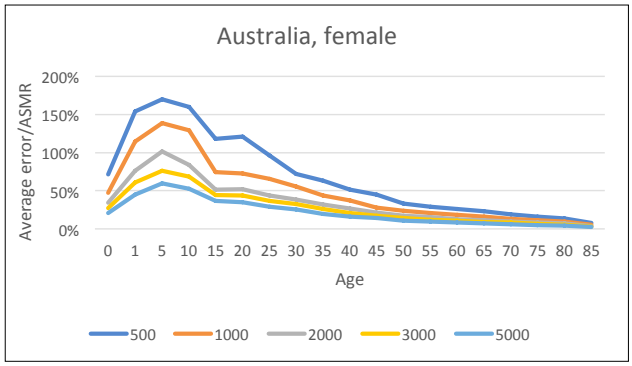
Key messages

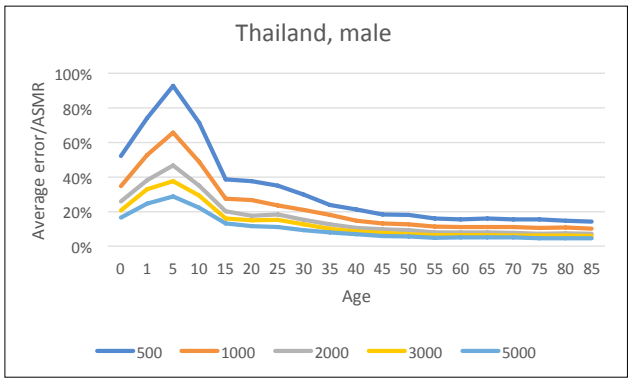
1000 deaths in ANACONDA input data are likely to be sufficient to provide tolerable levels of uncertainty of the key ANACONDA outputs; that is, VSPI(Q), completeness (unless the population has low to medium mortality and low to medium completeness), garbage, and leading causes of death.

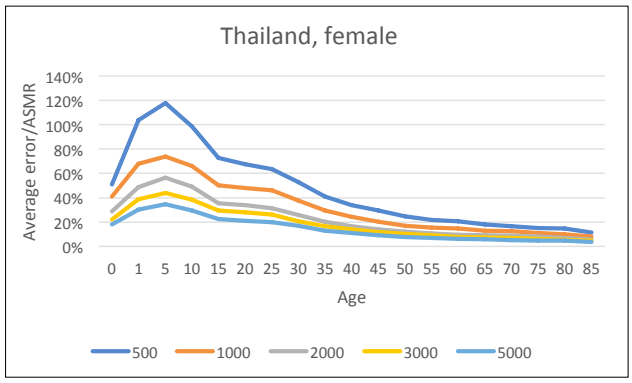
2000 or more deaths in ANACONDA input data are necessary to provide tolerable levels of uncertainty in age-specific results (such as the age-specific mortality rates and sex ratio of deaths), as well as completeness in populations with low to medium mortality and low to medium completeness

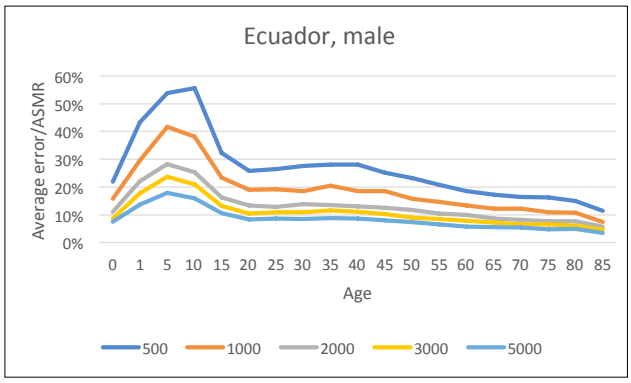
Appendix 1: Average error of ASMR (% of actual ASMR), country examples, males and females, by age and numbers of total deaths

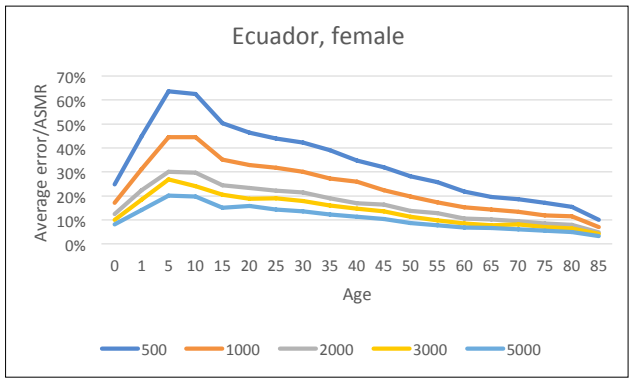


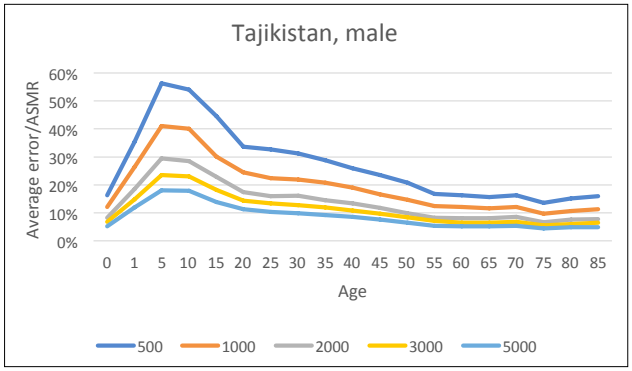


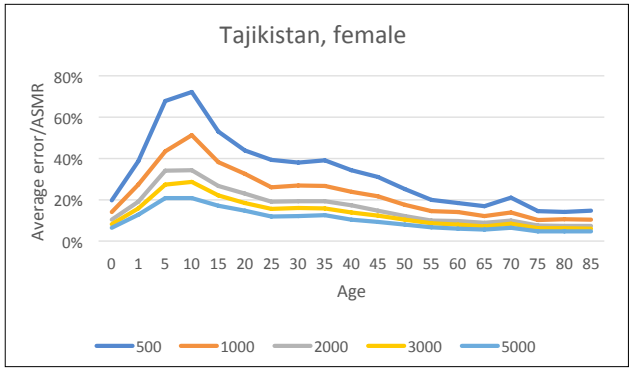


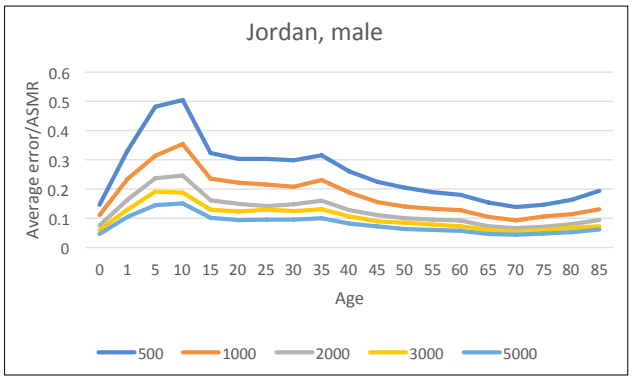


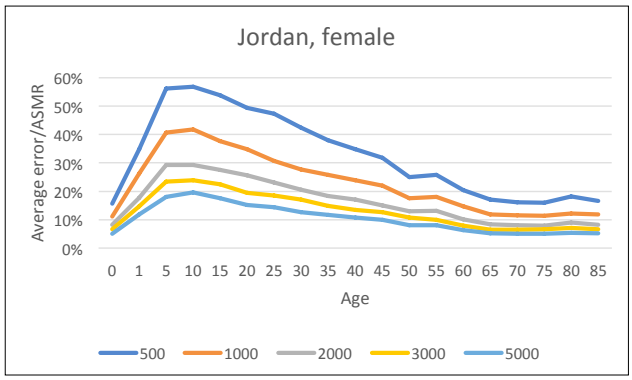


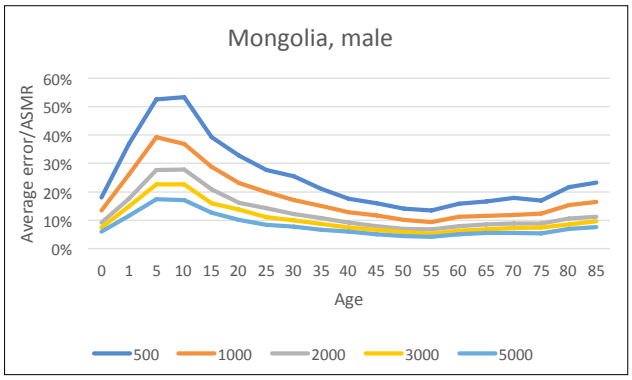


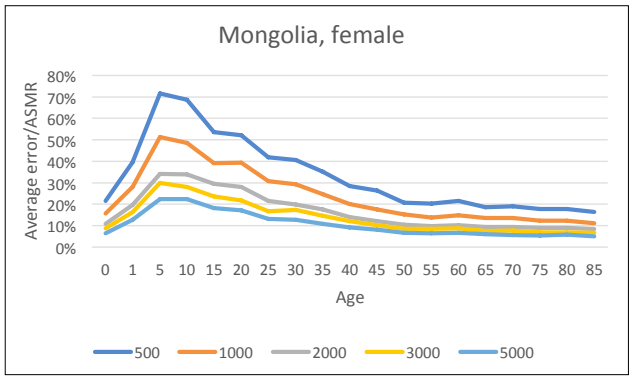

Tajikistan, male
Average error/ASMR
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

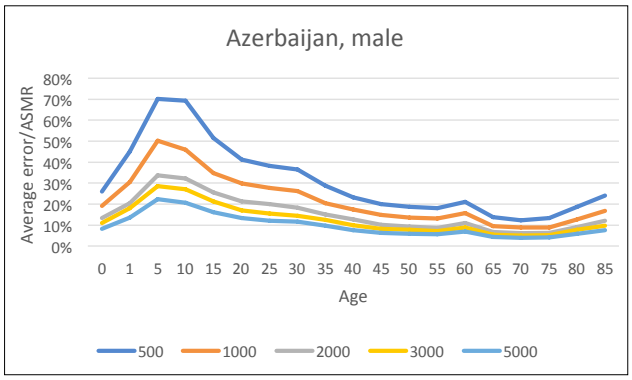

Tajikistan, female
Average error/ASMR
80%
60%
40%
20%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

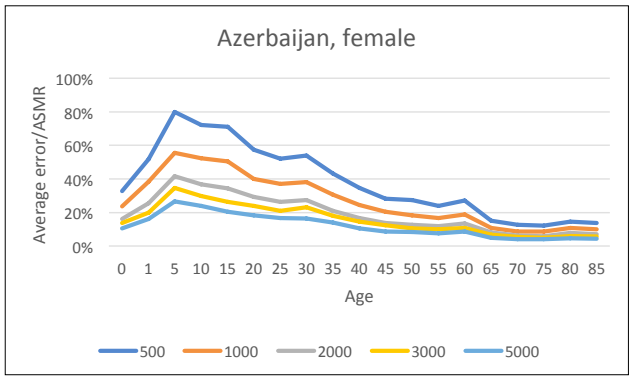

Jordan, male
Average error/ASMR
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

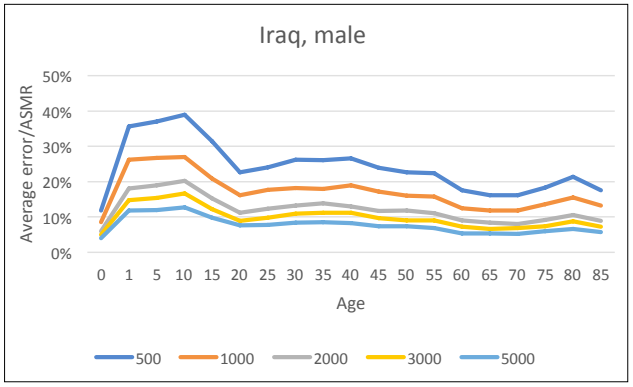

Jordan, female
Average error/ASMR
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

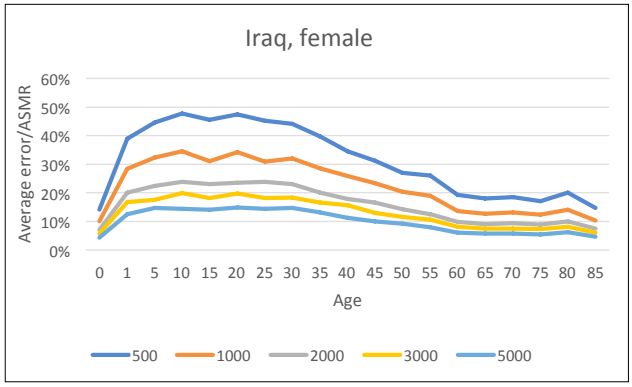

Mongolia, male
Average error/ASMR
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

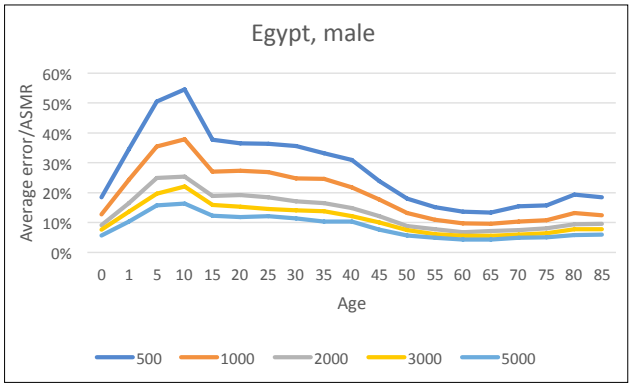

Mongolia, female
Average error/ASMR
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

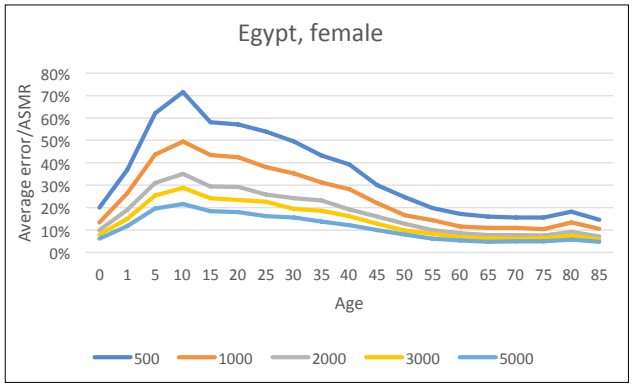

Azerbaijan, male
Average error/ASMR
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

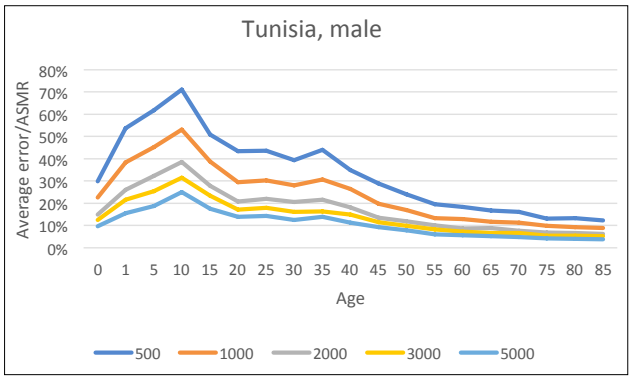

Azerbaijan, female
Average error/ASMR
100%
80%
60%
40%
20%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

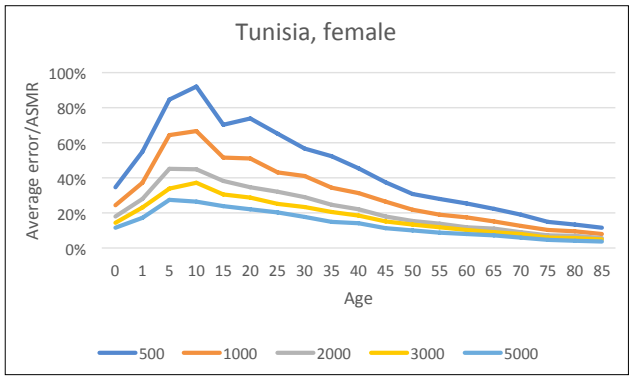

Iraq, male
Average error/ASMR
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

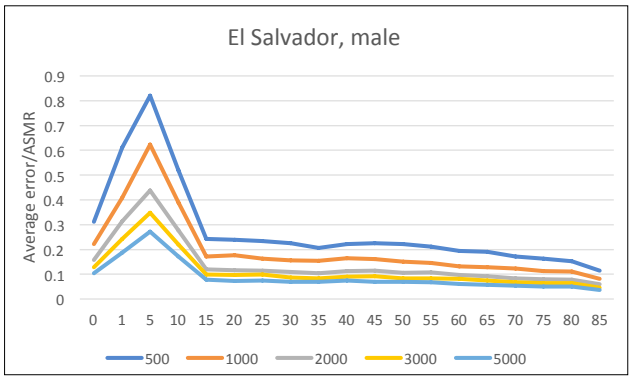

Iraq, female
Average error/ASMR
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

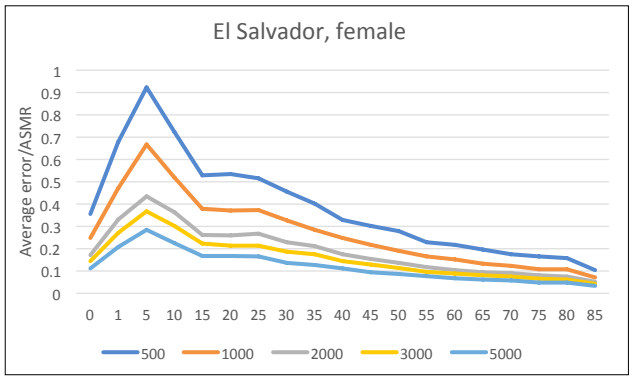

Egypt, male
Average error/ASMR
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

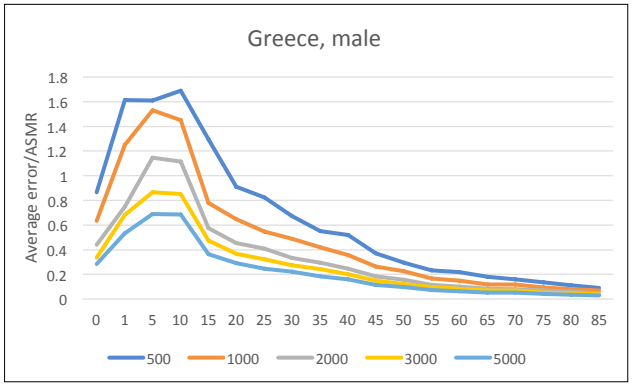

Egypt, female
Average error/ASMR
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

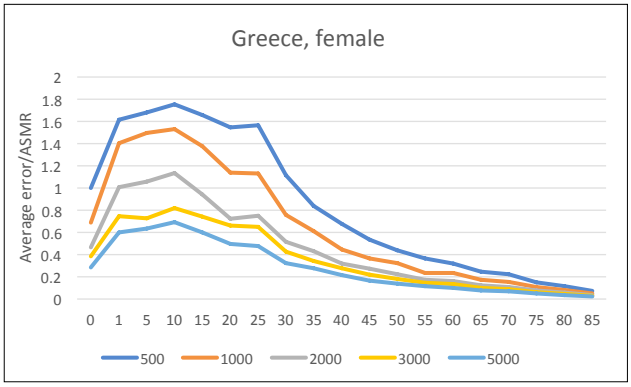

Tunisia, male
Average error/ASMR
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

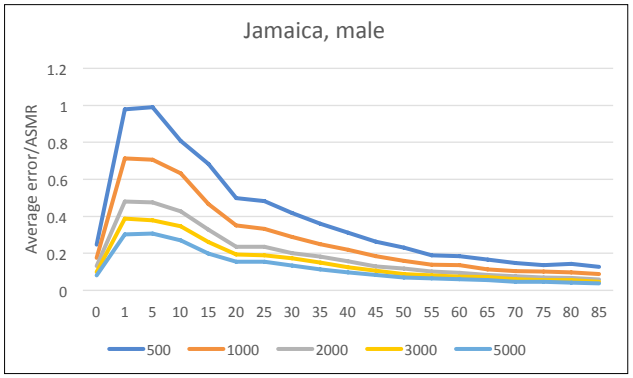

Tunisia, female
Average error/ASMR
100%
80%
60%
40%
20%
0%
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age
500 1000 2000 3000 5000

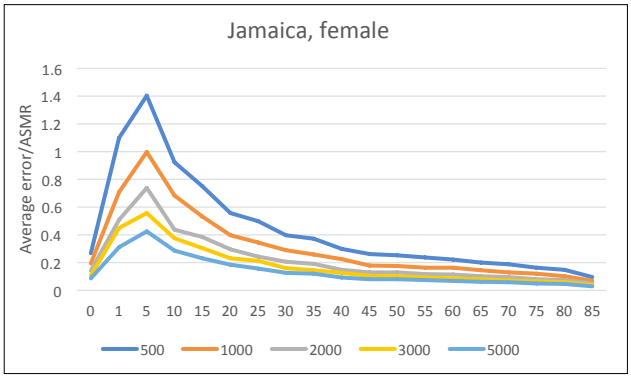

El Salvador, male
Average error/ASMR
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

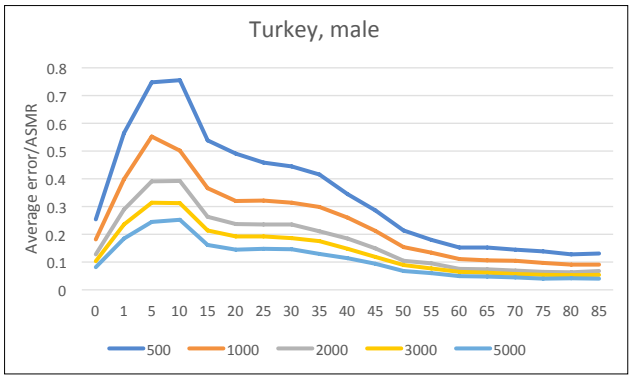

El Salvador, female
Average error/ASMR
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

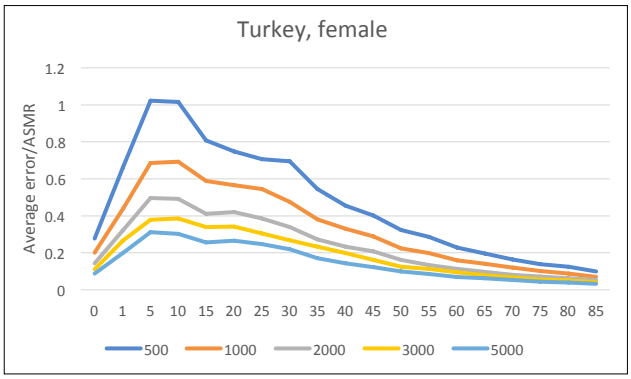

Greece, male
Average error/ASMR
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

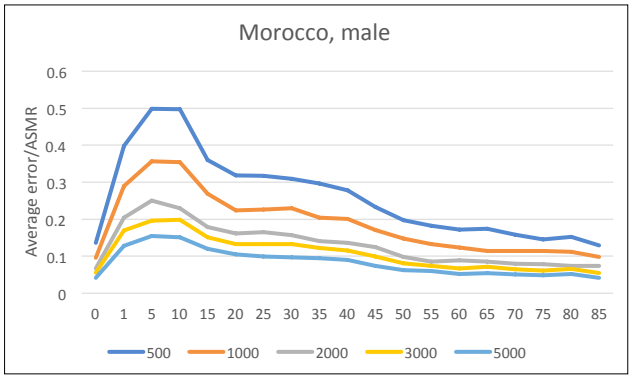

Greece, female
Average error/ASMR
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

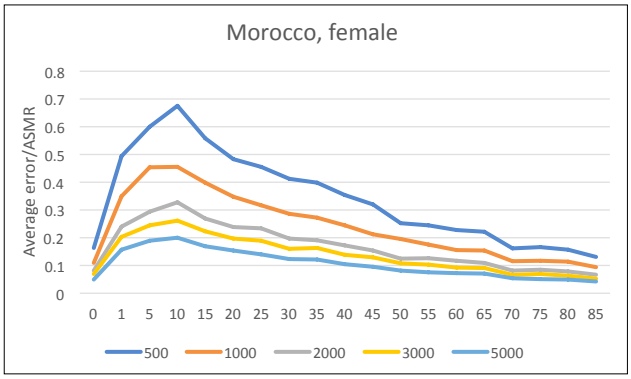

Jamaica, male
Average error/ASMR
1.2
1
0.8
0.6
0.4
0.2
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

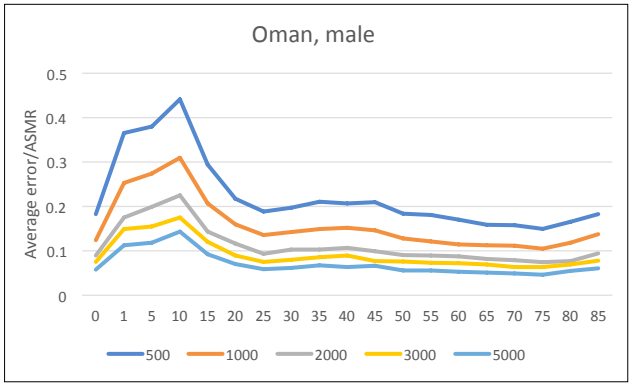

Jamaica, female
Average error/ASMR
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

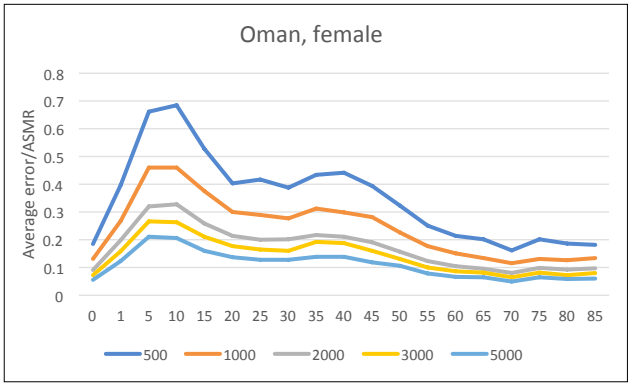

Turkey, male
Average error/ASMR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000


Turkey, female
Average error/ASMR
1.2
1
0.8
0.6
0.4
0.2
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000


Morocco, male
Average error/ASMR
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000


Morocco, female
Average error/ASMR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000


Oman, male
Average error/ASMR
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000


Oman, female
Average error/ASMR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
500 1000 2000 3000 5000

Appendix 2: Comparison of average error chart and log age-specific mortality rate chart for each number of deaths, Tajikistan, males and females

Figure A2.1: Average error of ASMR (% of actual ASMR), country examples, males and females, by age and numbers of total deaths

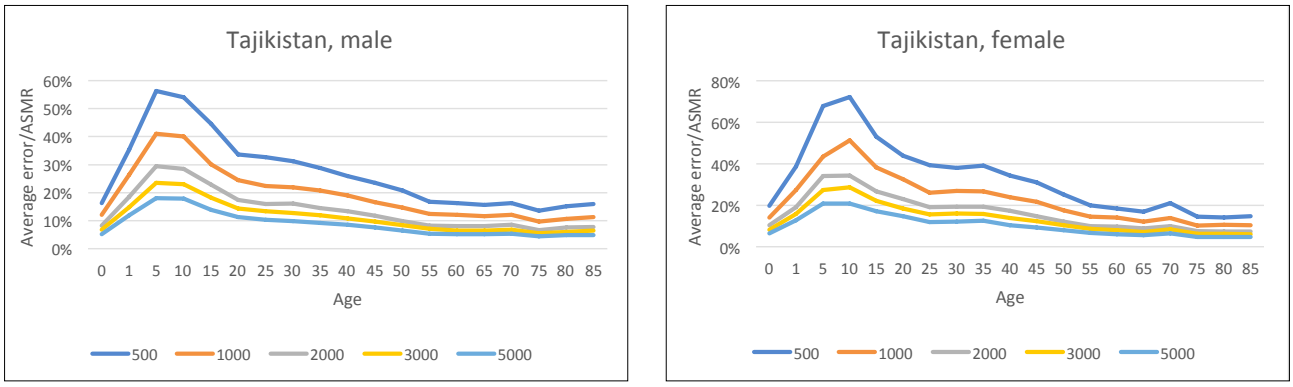
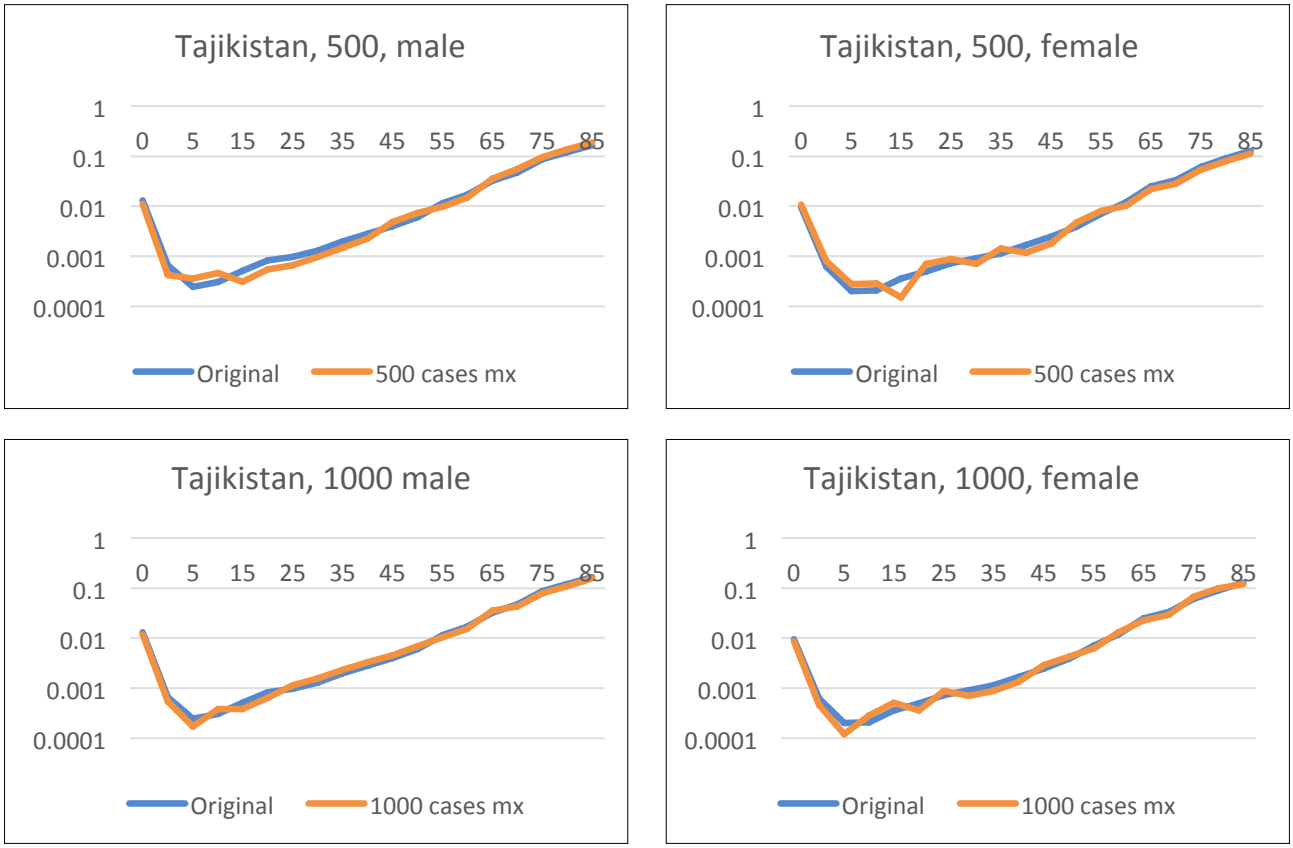
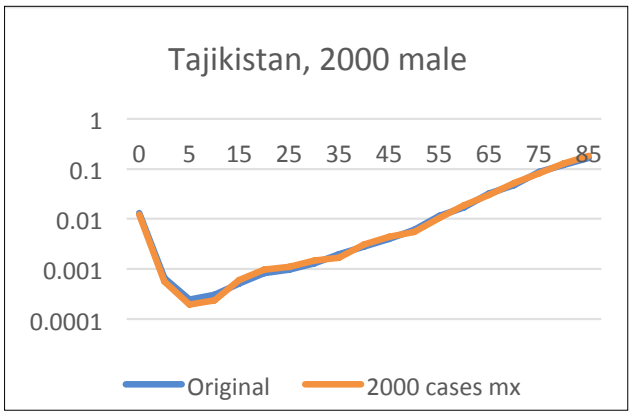
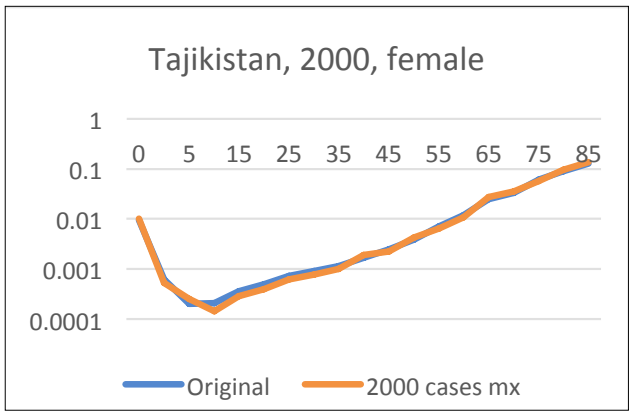
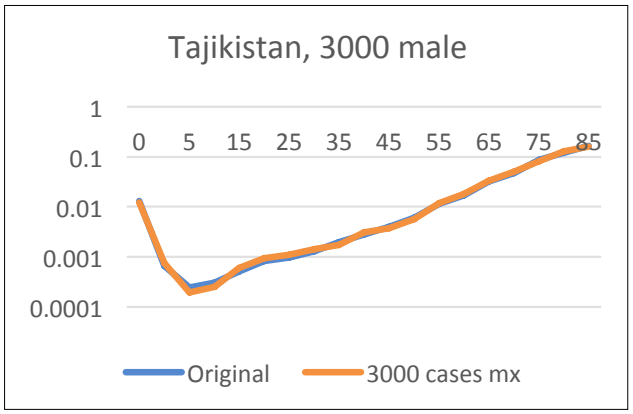


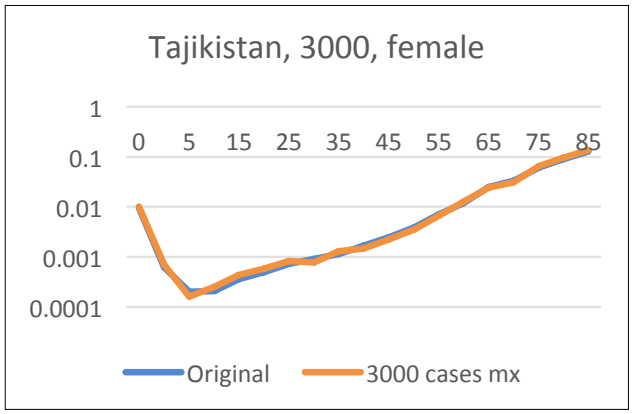
Figure A2.2: Tajikistan, log age-specific mortality rates by sex and numbers of deaths

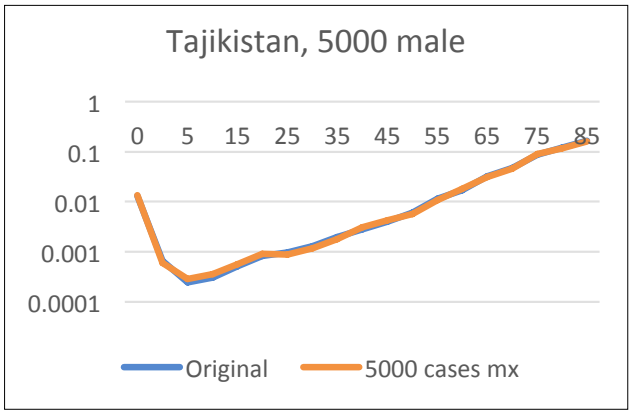


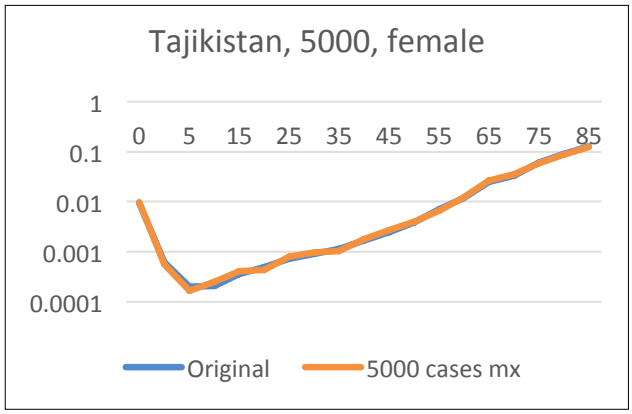

Tajikistan, 2000 male
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
2000 cases mx


Tajikistan, 2000, female
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
2000 cases mx


Tajikistan, 3000 male
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
3000 cases mx


Tajikistan, 3000, female
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
3000 cases mx


Tajikistan, 5000 male
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
5000 cases mx


Tajikistan, 5000, female
1
0.1
0.01
0.001
0.0001
0 5 15 25 35 45 55 65 75 85
Original
5000 cases mx

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For more information contact:

CRVS-info@unimelb.edu.au
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