

Global Child Mortality: Estimates of Levels and Causes for 2000-2010

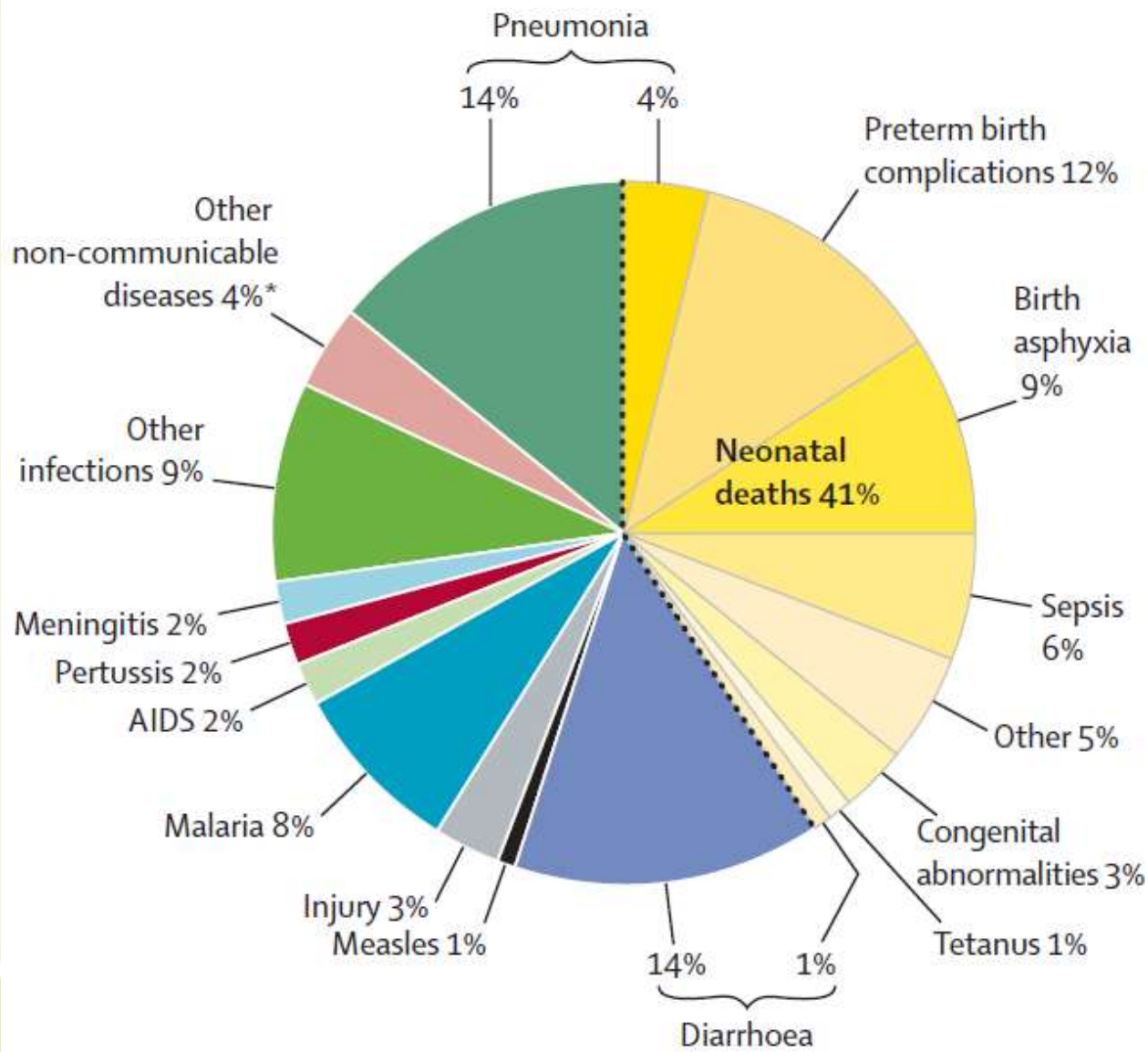
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Background and Introduction

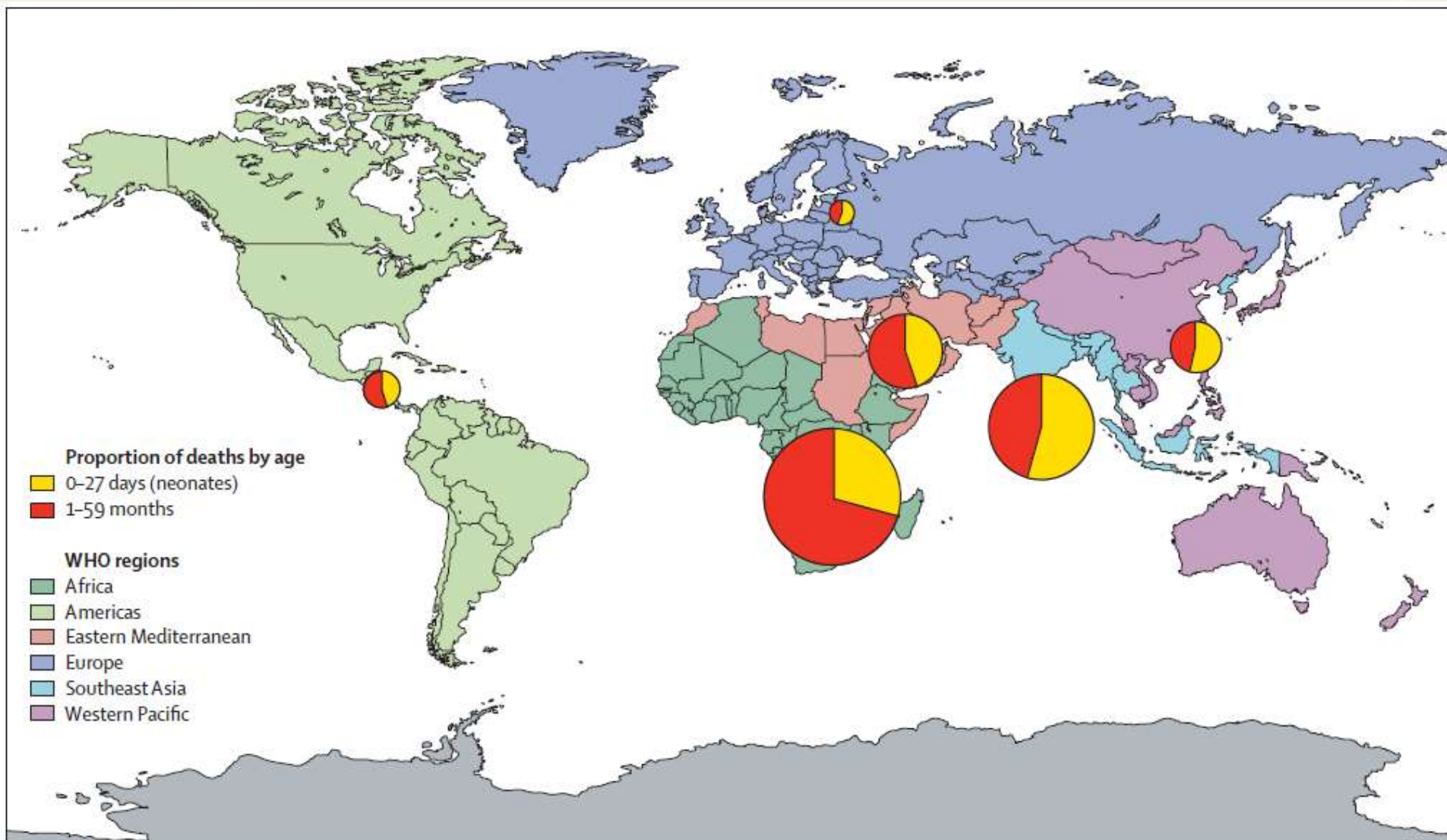
- Despite declining child mortality, 7.6 million children under 5 years old died in 2010.
- MDG 4 seeks to reduce under-five mortality by two-thirds between 1990 and 2015.
- Many countries are not on track to meet this goal.
- Accelerated mortality decline is possible with expansion of targeted interventions.
- Frequently updated national data on causes of death (COD) can guide national & global priorities.

Review of published estimates for year 2008

Global Distribution of Causes of Child Deaths: 2008



Regional Distribution of Causes of Child Deaths: 2008



Additional Details Available in Black et al, 2010

Global, regional, and national causes of child mortality in 2008: a systematic analysis



Robert E Black, Simon Cousens, Hope L Johnson, Joy E Lawn, Igor Rudan, Diego G Bassani, Prabhat Jha, Harry Campbell, Christa Fischer Walker, Richard Cibulskis, Thomas Eisele, Li Liu, Colin Mathers, for the Child Health Epidemiology Reference Group of WHO and UNICEF*

Summary

Background Up-to-date information on the causes of child deaths is crucial to guide global efforts to improve child survival. We report new estimates for 2008 of the major causes of death in children younger than 5 years.

Methods We used multicausal proportionate mortality models to estimate deaths in neonates aged 0–27 days and children aged 1–59 months, and selected single-cause disease models and analysis of vital registration data when available to estimate causes of child deaths. New data from China and India permitted national data to be used for these countries instead of predictions based on global statistical models, as was done previously. We estimated proportional causes of death for 193 countries, and by application of these proportions to the country-specific mortality rates in children younger than 5 years and birth rates, the numbers of deaths by cause were calculated for countries, regions, and the world.

Lancet 2010; 375: 1969–87

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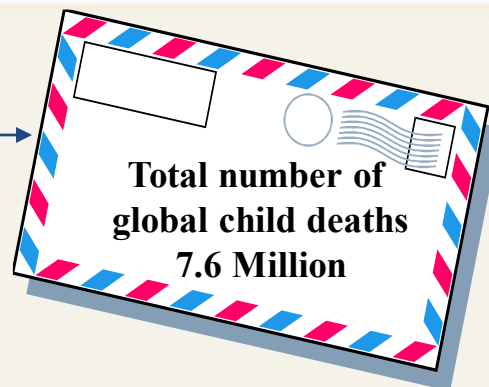
*Members listed at end of paper

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Estimation methods for 2000-2010:

Child Mortality “Envelopes”

**Under 5 deaths
(all causes)**



**Neonatal deaths
(all causes)**

All-Cause Child Mortality Rate

- Since 2004, **the UN Interagency Group for Child Mortality Estimation– IGME** (mainly UNICEF, the World Bank, UN Population Division and WHO), has been working closely to harmonize country-specific under-5 mortality and infant mortality rates
- In 2008, an independent Technical Advisory Group (TAG) was created to advise IGME on specific methodological issues.
- Annual update of estimates occur end of July, published in State of the World's Children late in the year, WHO country consultation Oct-Nov, published by WHO in May the following year.

Data for Estimating U5MR

- **Vital registration** provides annual series of neonatal, infant and under 5 mortality rates
- **Birth histories** (mainly DHS surveys) provide “direct” estimates of neonatal, infant mortality rates and under-five mortality rate (U5MR), typically for periods 0-4, 5-9 and 10-14 years before survey
- **Summary birth histories** (DHS surveys, other household surveys such as UNICEF’s MICS, and population censuses) provide “indirect” estimates of U5MR for time points covering roughly the period 2-12 years before the survey

Neonatal Mortality Rate

- Database compiled with 3551 country-years of information across 193 countries and all WHO regions
- Estimation:
 - For 38 countries with adequate **civil registration, or surveillance system data** - used directly
 - **Statistical models** used for estimation for countries with **household survey** data ($n=138$) or **no national data** ($n=17$)
 - Model predicts Neonatal Mortality Rate using under 5 mortality rate
- More details available at Oestergaard et al, PLoS Med, 2011

Levels & Trends in
**Child
Mortality**

Report 2011

Estimates Developed by the
UN Inter-agency Group for
Child Mortality Estimation



Examples of Mortality Trend Analysis

FIGURE 2 Source data and estimate line for the under-five mortality rate, Mali, 1960–2010

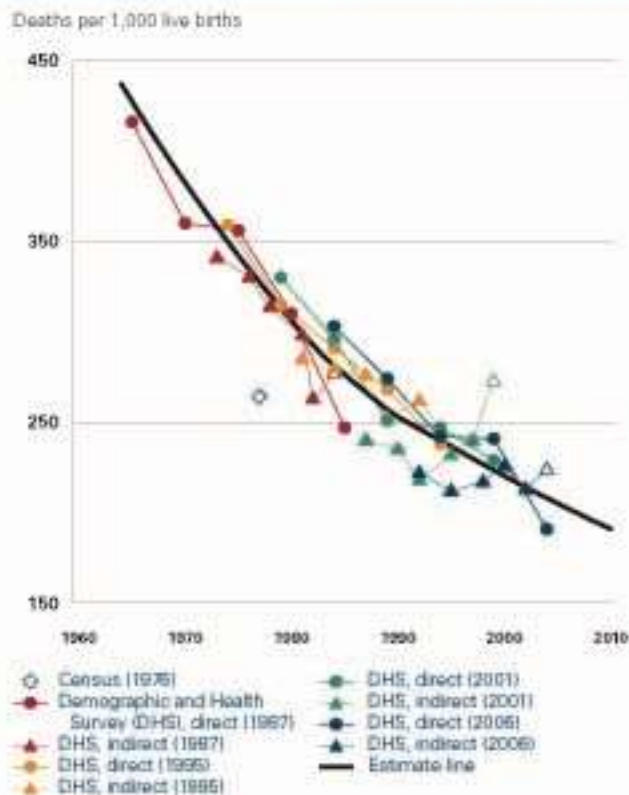
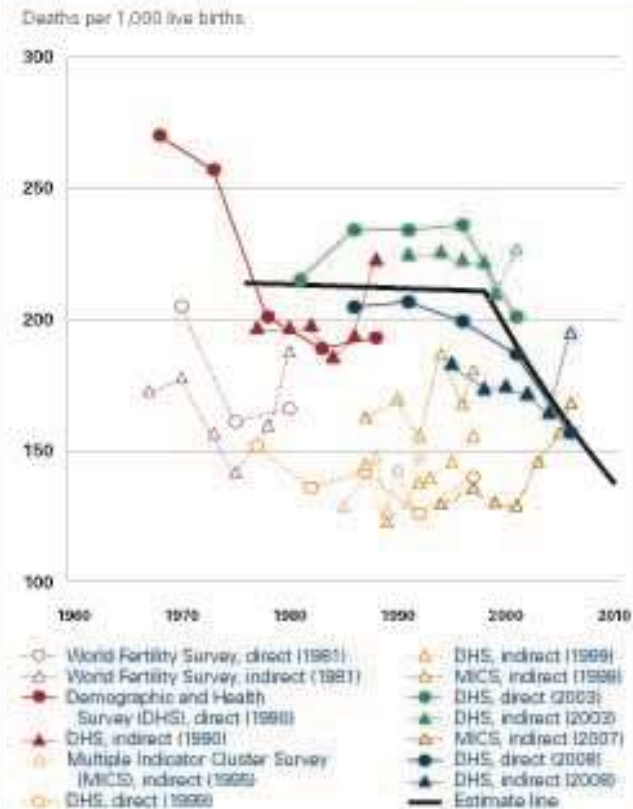
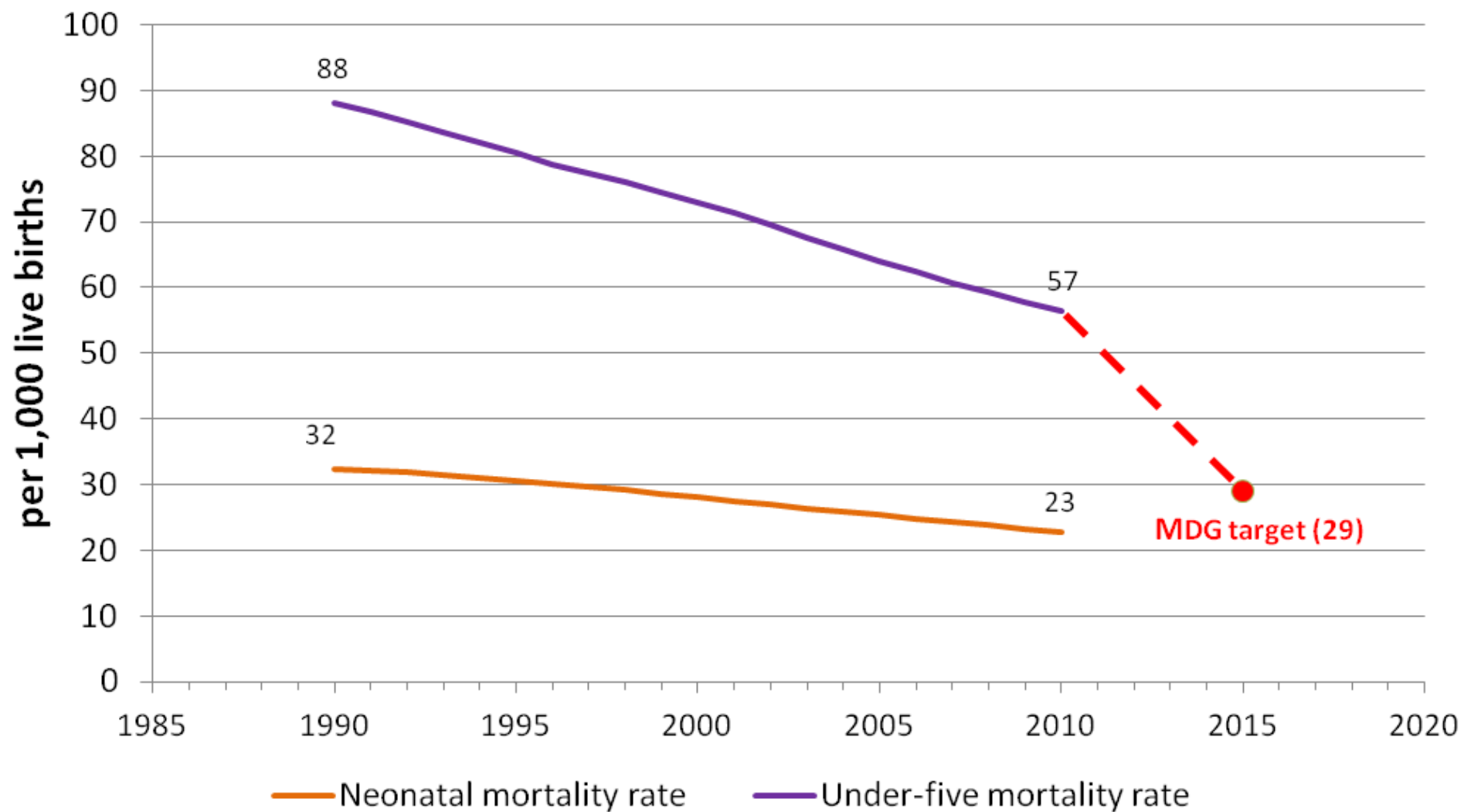


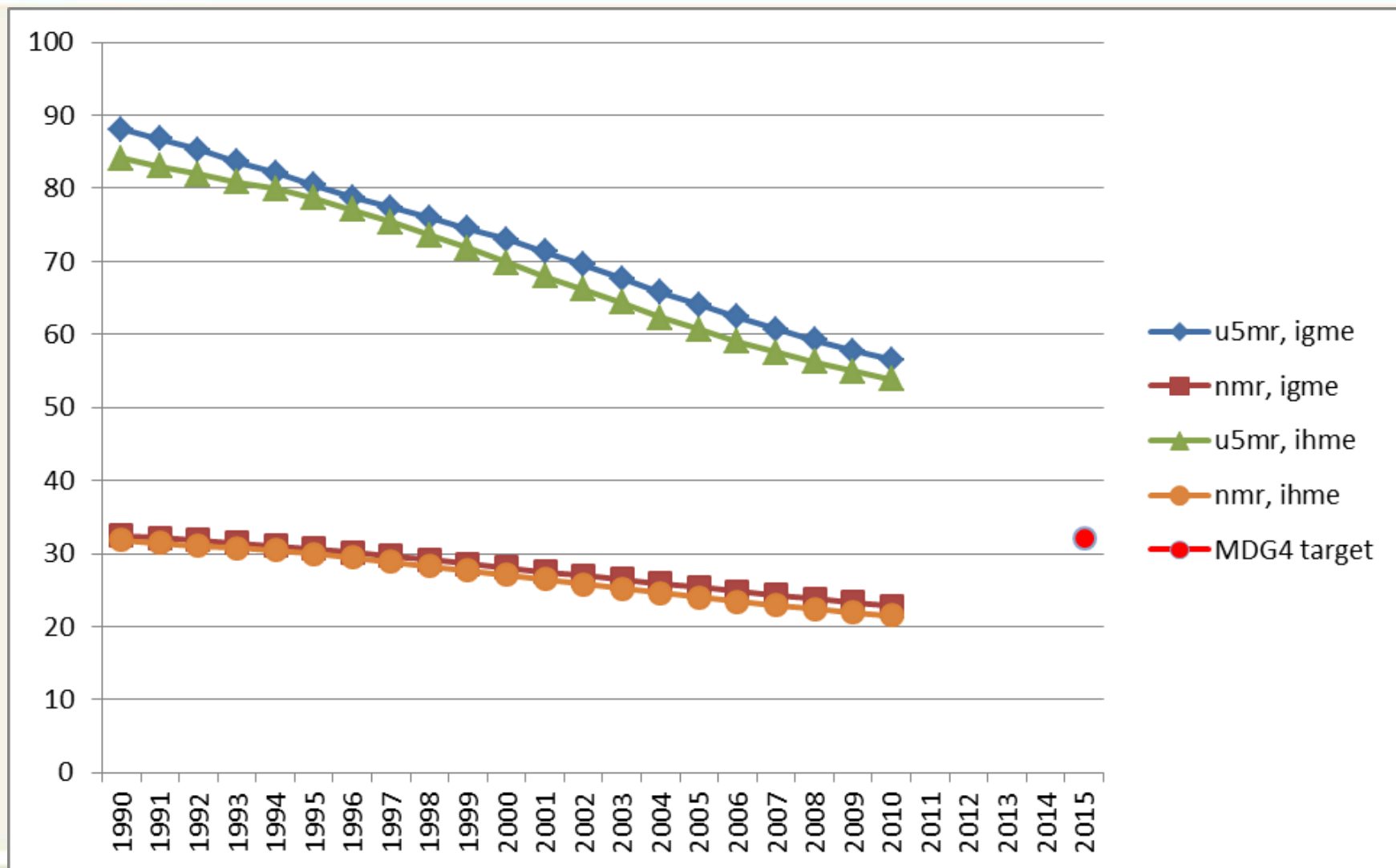
FIGURE 3 Source data and estimate line for the under-five mortality rate, Nigeria, 1960–2010



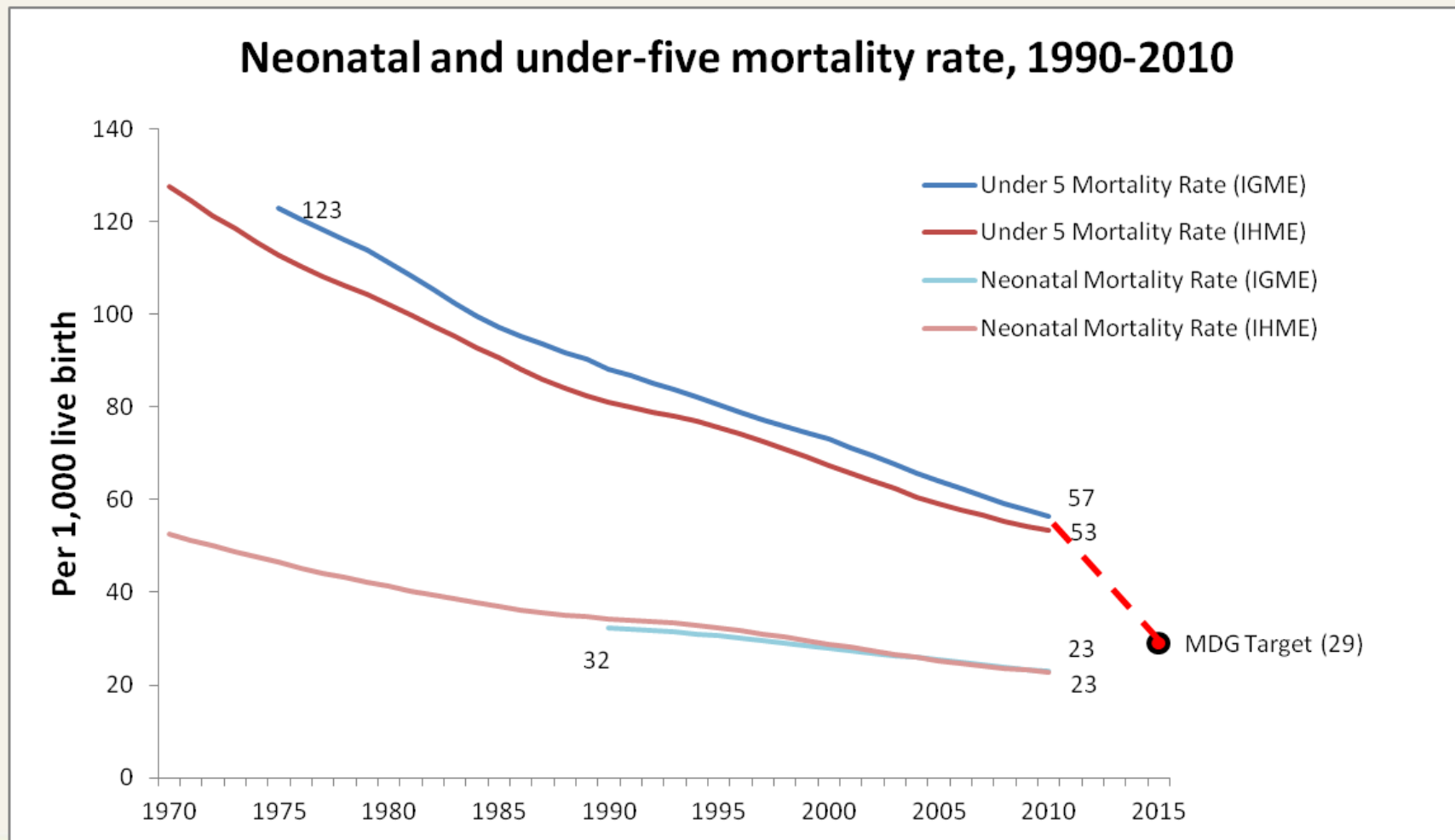
Neonatal and Under-Five Mortality Rates, 1990-2010



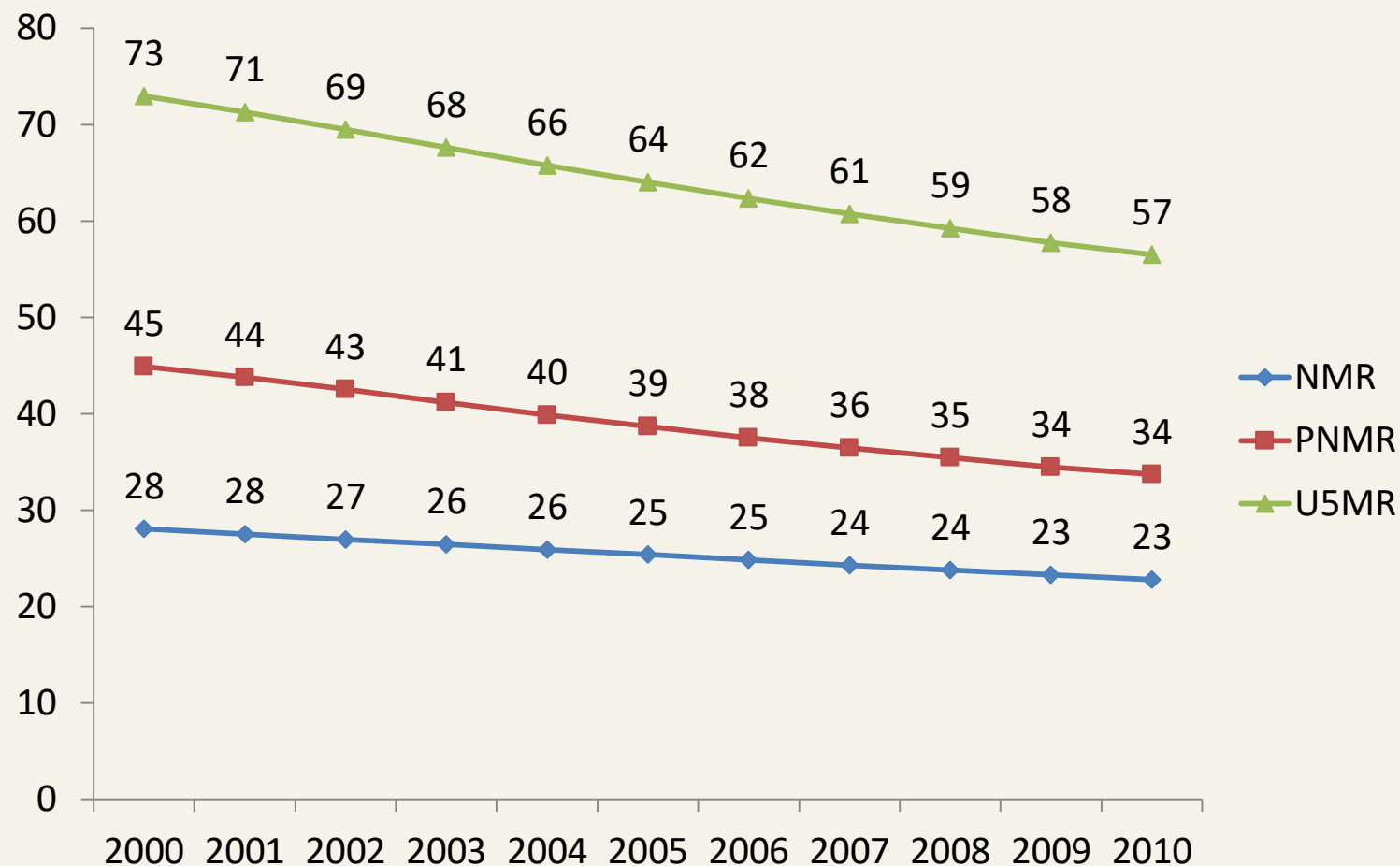
Global Progress to MDG 4



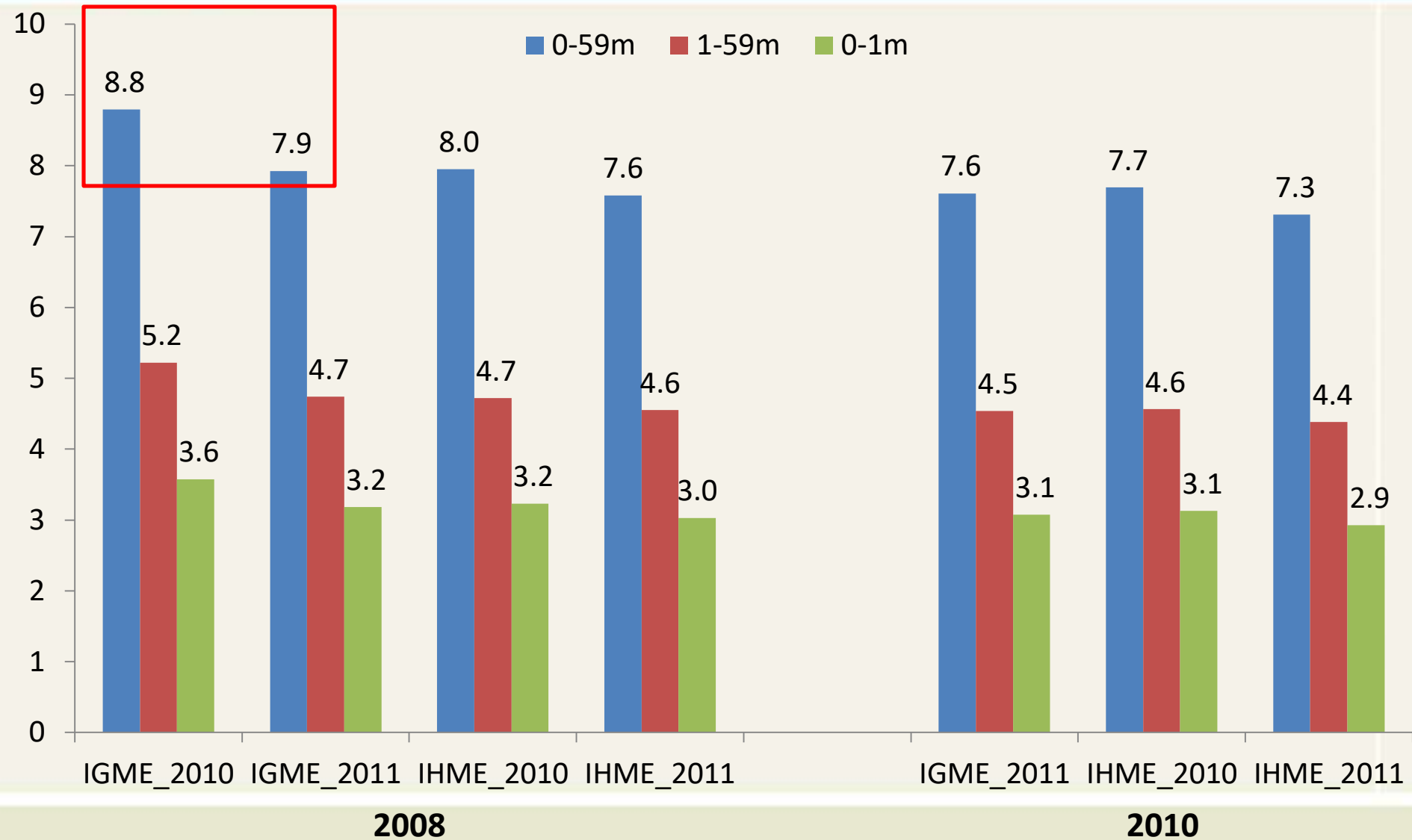
Global Progress to MDG 4



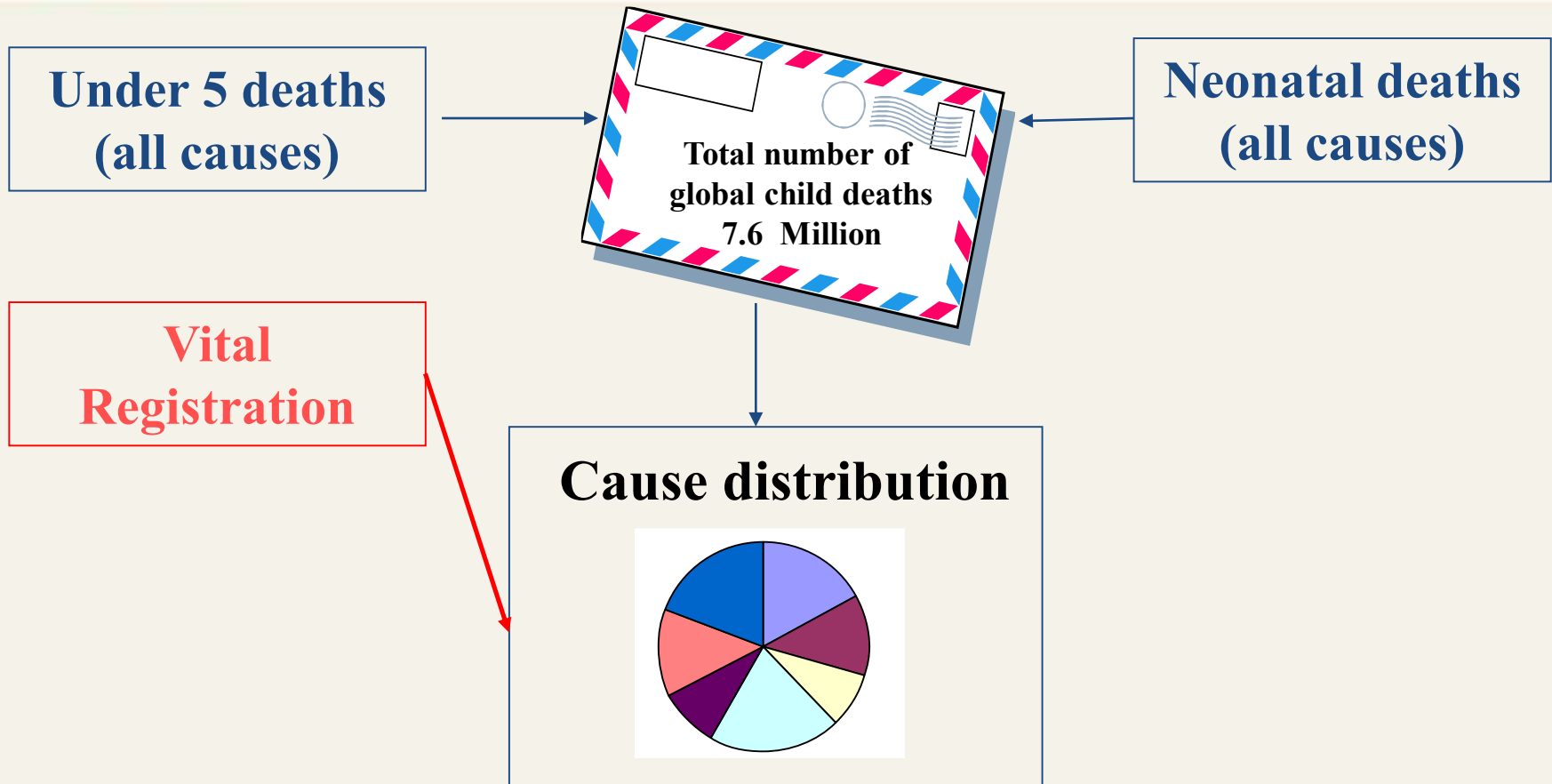
Child Mortality Rate: IGME 2011 Release



2008 and 2010 Envelopes by IGME and IHME



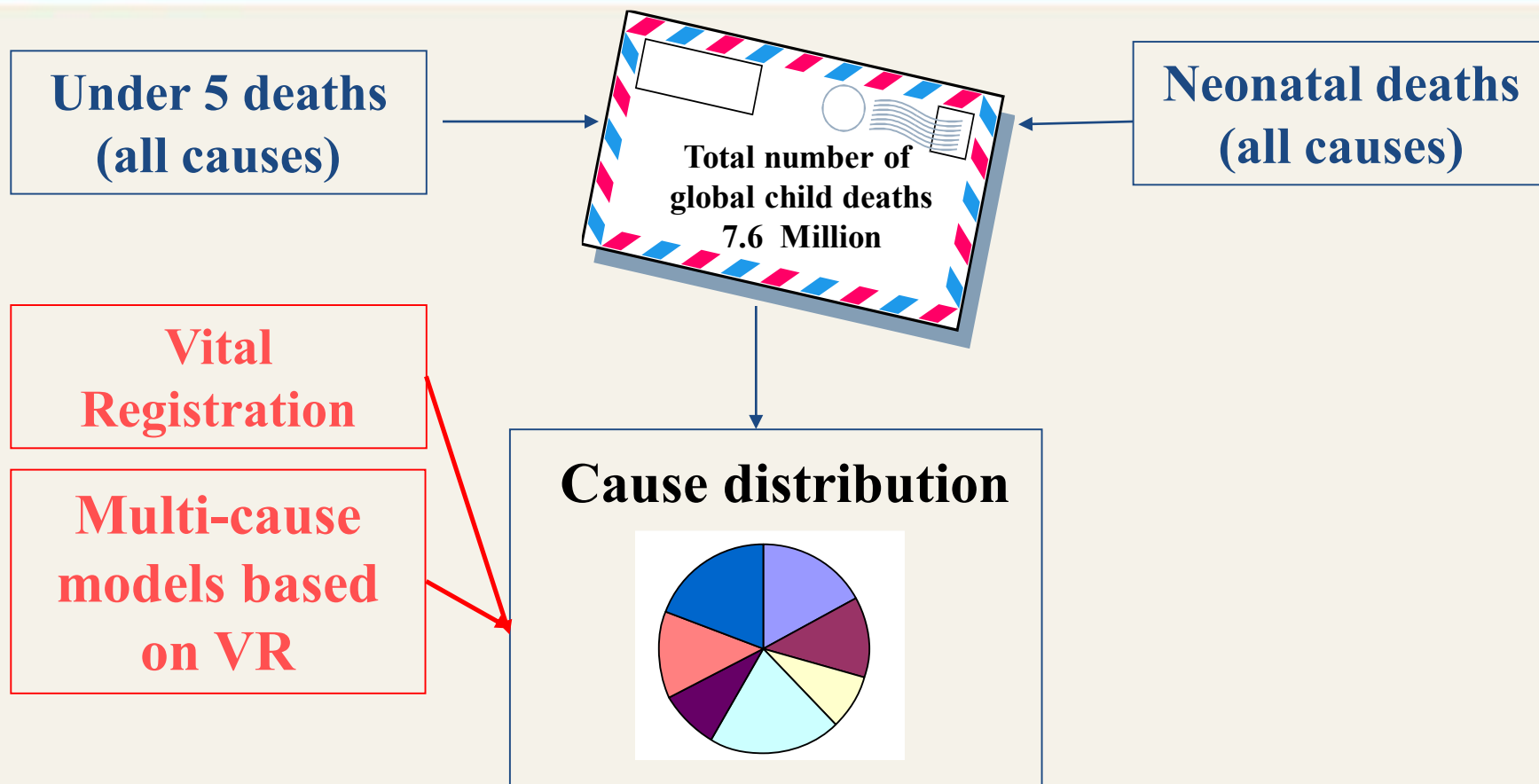
Mortality “Envelope (total number of deaths)” and Causes of Child Death



Use of Vital Registration (VR) Data from WHO Mortality Database

- **Vital registration**, adjusted for incomplete coverage if needed
- **Inclusion criteria** for adequate death registration
 - 80% with adequate quality for neonates and children aged 1-59 months
- Data closest to **year of estimation** used (mean of closest 3-5 years used for very small countries)
- Causes Categorized by **International Classification of Diseases**, 10th Revision (ICD-10)

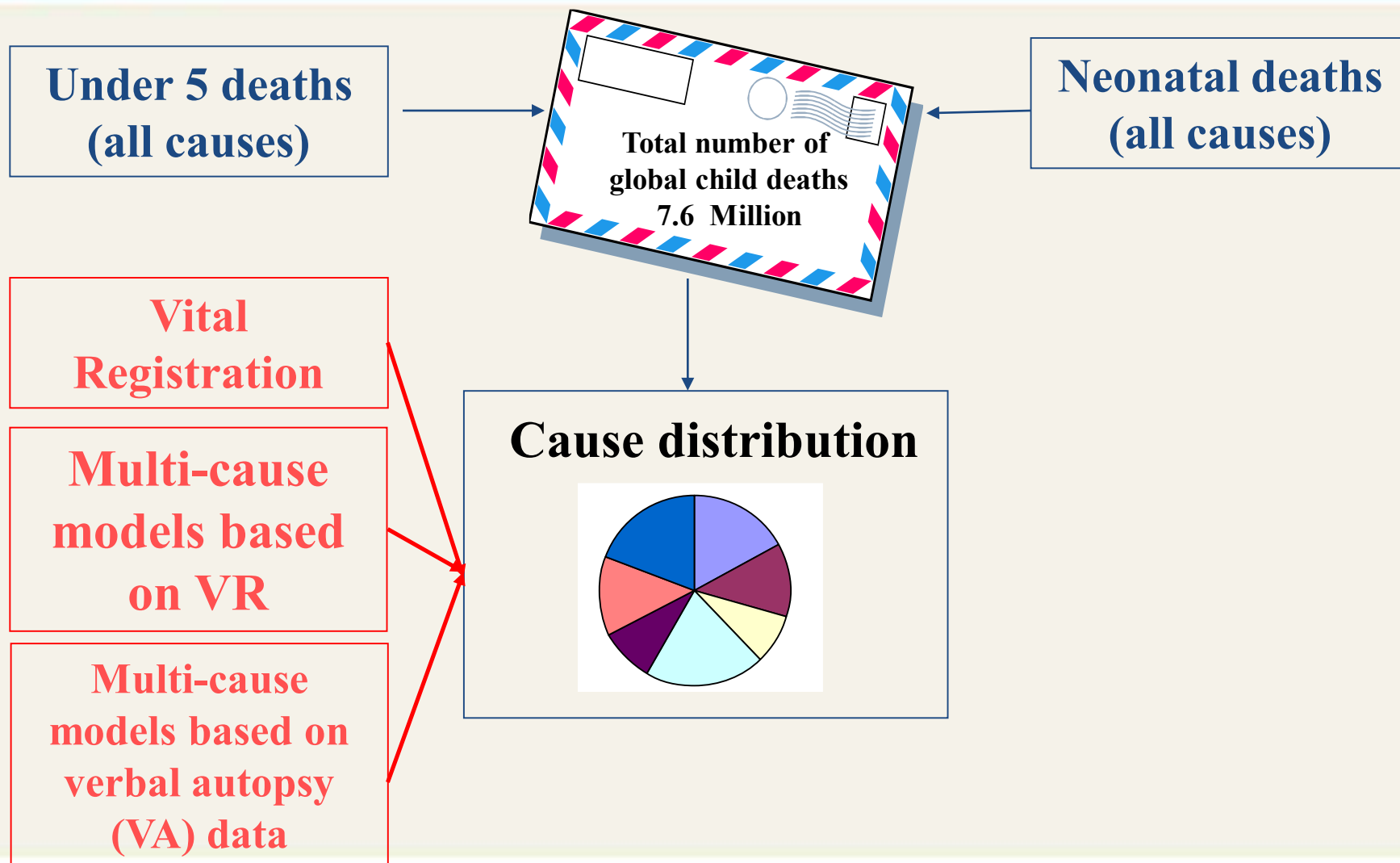
Mortality “Envelope” and Causes of Child Death



VR data based multi-cause model (VRMCM) for Neonatal and Post-neonatal Causes if No Usable VR and $U5MR \leq 35$

- Step one: covariate selection
 - Log ratio of each cause to a “base” cause, calculated using meta-regression and step-wise ordinary-least-squares regression with **explanatory variables**
- Step two: Explanatory variables identified in step one fitted simultaneously in a **multinomial logistic regression model** to estimate the proportionate cause of deaths

Mortality “Envelope” and Causes of Child Death



VA Data based multi-cause model (VAMCM) for Neonatal Causes if No Usable VR Data and U5MR>35

- Two step approach taken as with VRMCM to develop a multi-cause model using **VA data**
- **Explanatory variables** e.g. female literacy, TT coverage, percent of skilled attendance, etc.
- **Proportionate causes of death derived** and adjusted country-by-country to fit the estimated number of neonatal deaths by year

VAMCM for Causes in Children 1-59 Months if No Usable VR Data and U5MR>35

CHERG

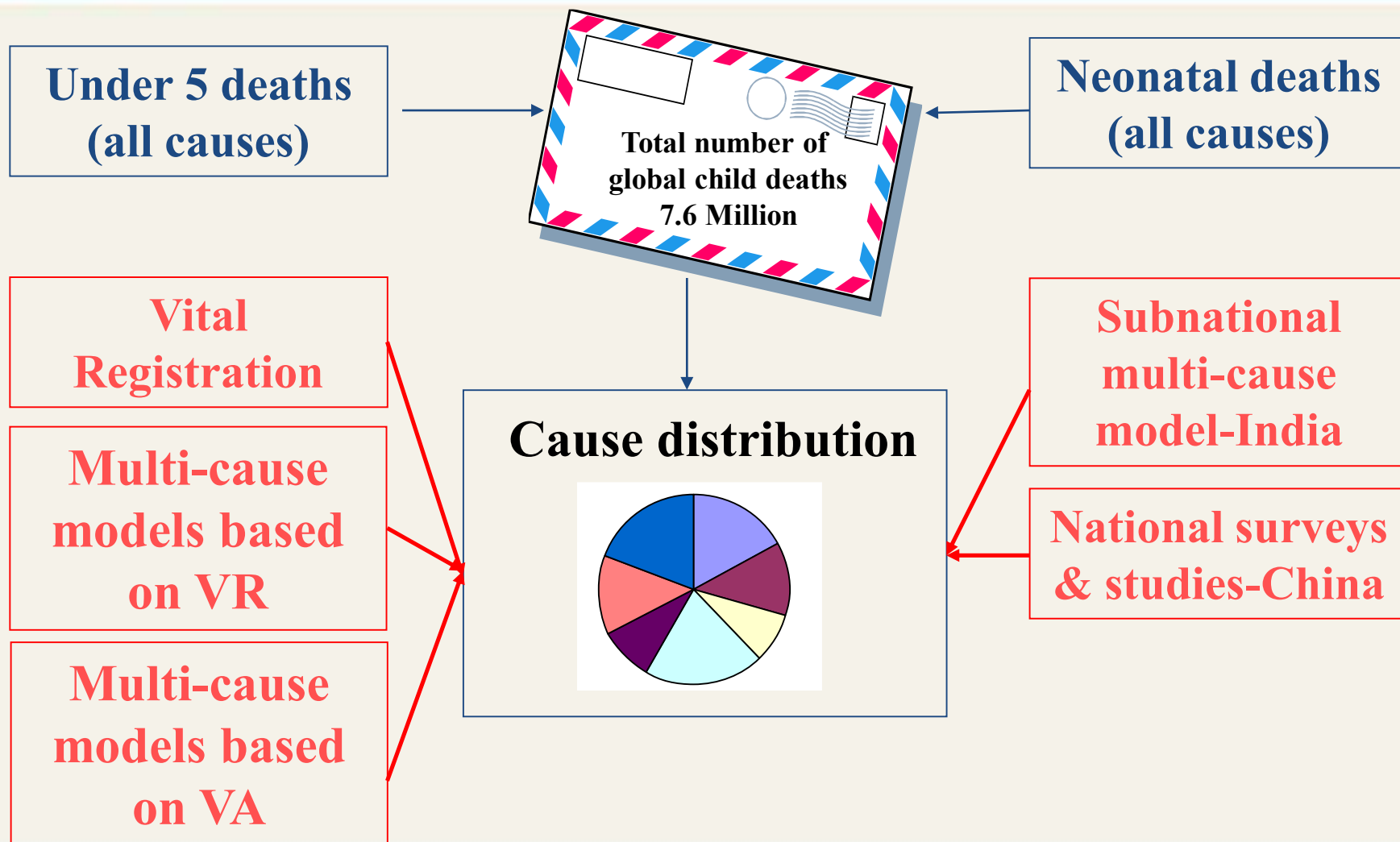
- 113 data points from community-based mortality studies and
 - ≥ 2 COD were report
 - done after 1979 with 12 (or multiple of 12) month duration
 - ≥ 25 under-five deaths, with each death represented once
 - <25% of deaths due to unknown causes
 - Also included a few data points from countries with U5MR > 20 per 1,000 live births
- 8 cause categories: pneumonia, diarrhea, malaria, injury, meningitis/encephalitis, congenital abnormalities, causes arising during the perinatal period, and other causes

VAMCM for Causes in Children 1-59 Months if No Usable VR Data and U5MR>35, cont'd

CHERG

- **Multinomial logistic regression framework** applied to study-level data to derive the multi-cause model
- Apply country-level covariates to derive country estimates
- **Post-hoc adjustment for:**
 - effects of recently scaled up interventions: use and effectiveness of
 - Hib vaccine for pneumonia and meningitis
 - insecticide-treated bednets for malaria

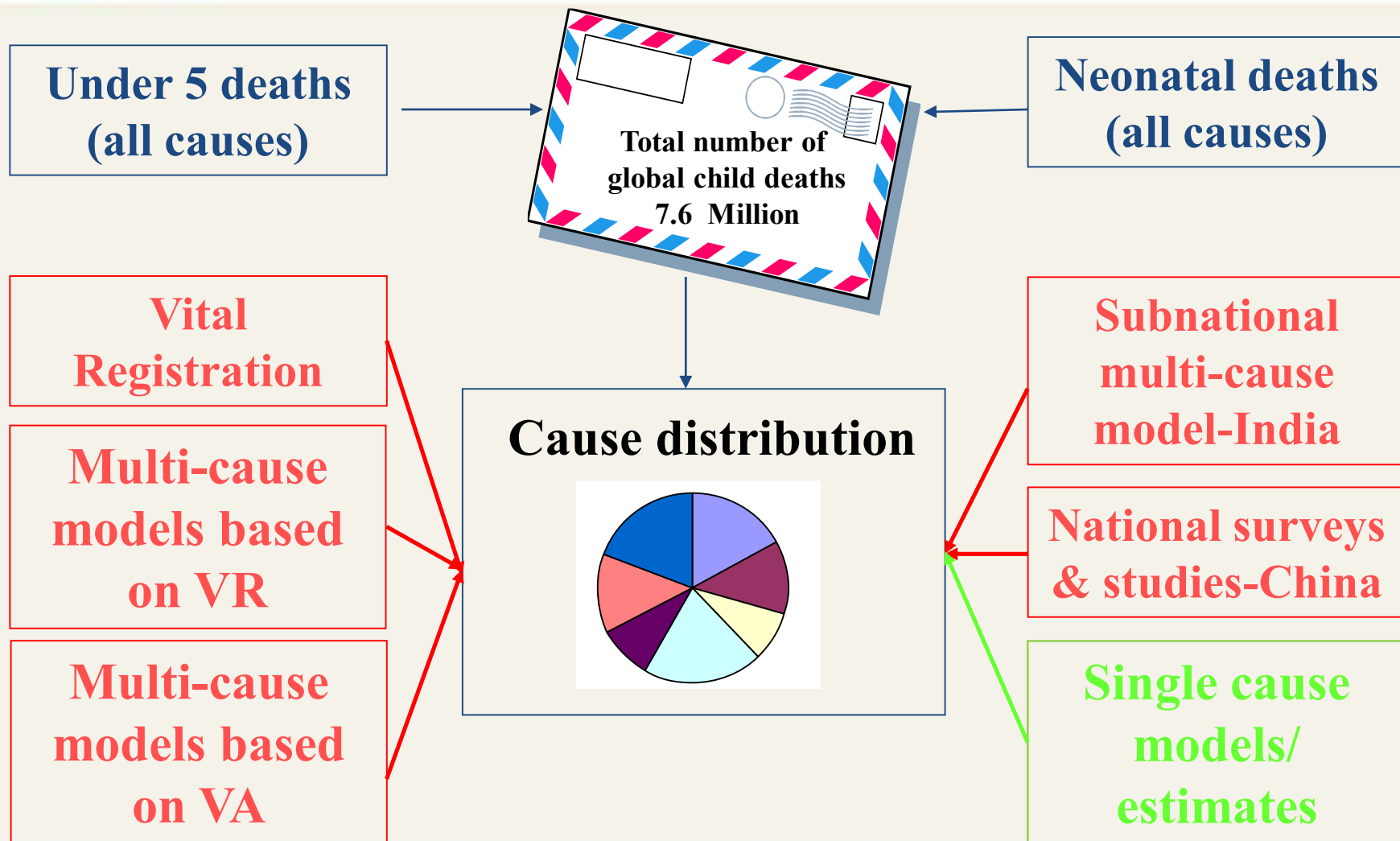
Mortality “Envelope” and Causes of Child Death



India and China

- India: state-level multi-cause model
 - 45 study data points include Million Death Study state-level data and all India sub-national VA studies
 - Study covariates collected from studies, subnational and national database, e.g. NFHS/DLHS
- China: single cause model based on VA studies
 - 206 VA studies abstracted from Chinese language literature databases
 - Model covariates include U5MR and squared U5MR
- Predict at the state/province level and aggregate to obtain national-level estimates

Mortality “Envelope” and Causes of Child Death



Malaria

- In high-burden African countries
 - Estimated using VAMCM
 - Malaria equation covariates include: CHERG malaria index (based on MARA malaria endemicity and Guerra's population at risk), % births by skilled attendant
 - ITN use was considered in the post-hoc adjustment
- In low-burden African countries and outside Africa
 - Natural history model developed by WHO malaria programme

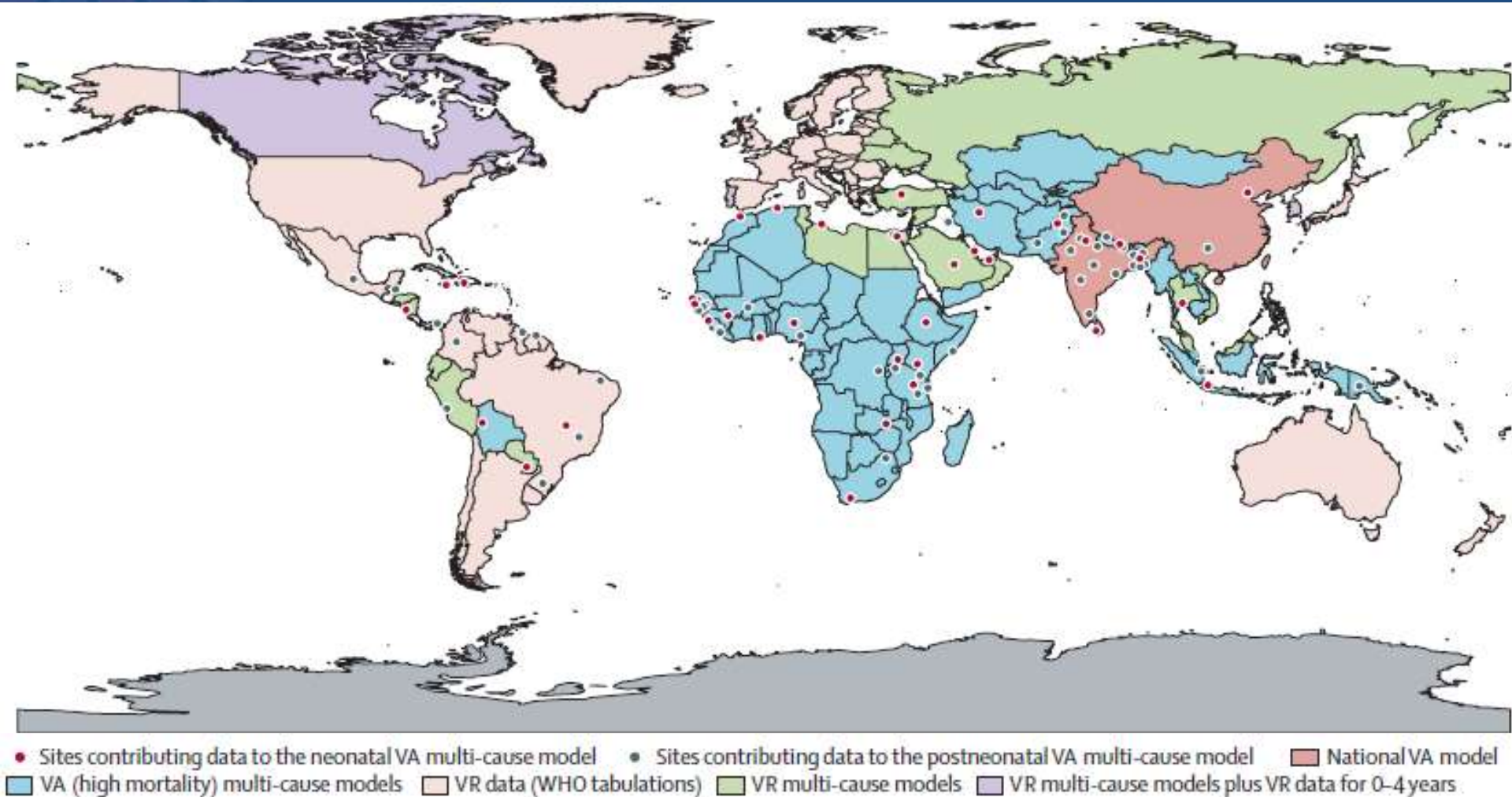
Deaths due to Measles, Tetanus and AIDS

- **Measles:** state space models from WHO's department of Immunization, Vaccines and Biologicals
 - estimate country-and-year specific cases using surveillance data
 - stratify cases by age, applied age-specific case-fatality ratios, and aggregated age-specific deaths
 - took into account herd immunity
 - split endemic and outbreak deaths.
- **Tetanus:** IVB/CHERG-developed statistical model based on WHO estimates of female literacy, percent of births protected by TT, percent delivered by SBA
- **AIDS:** UNAIDS

Estimation of Uncertainty

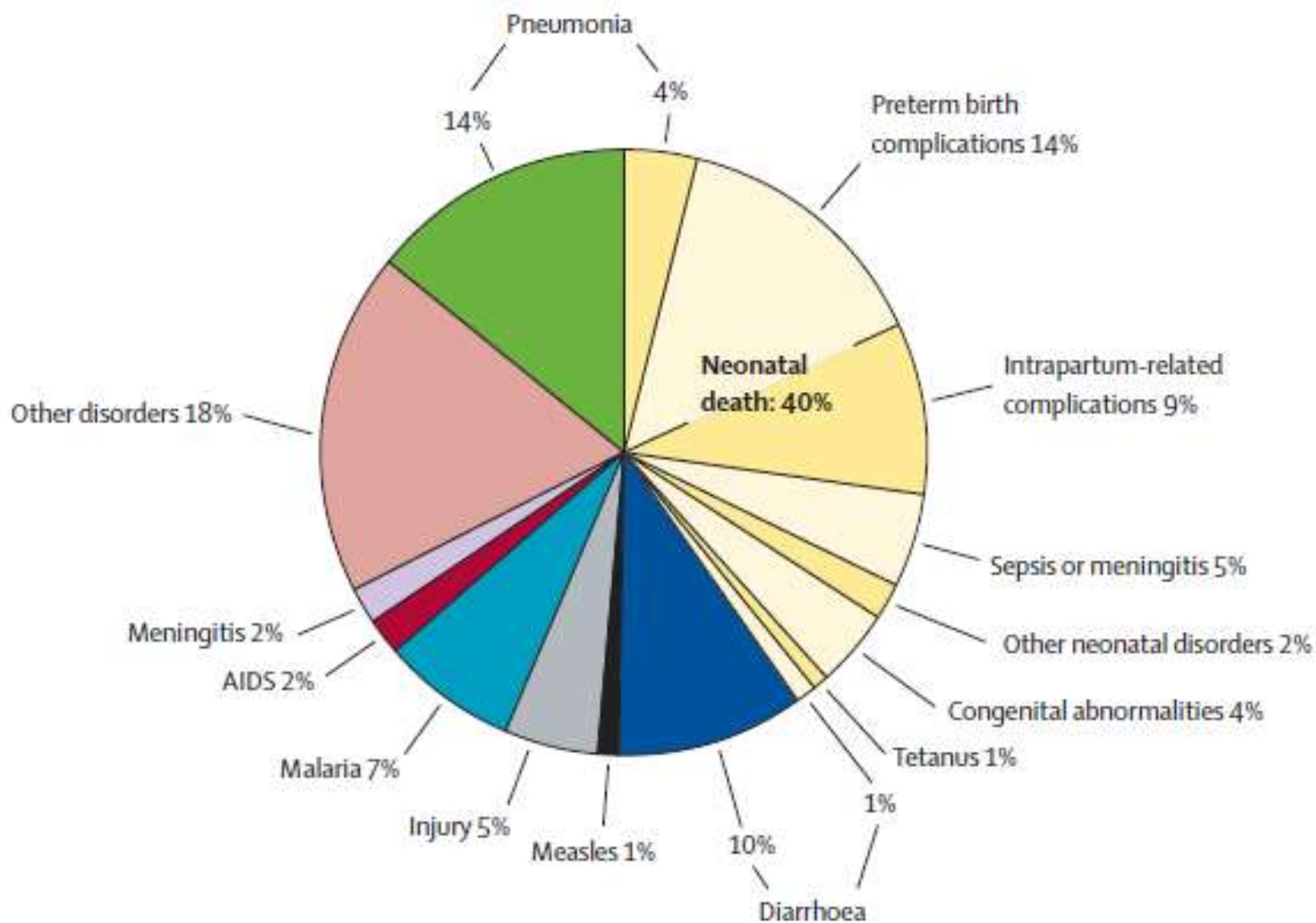
- Bootstrapping analysis: with 1/10 of study data reserved each time and the remaining to build the model and predict for out-of-sample error.
- This was repeated 2000 times to get the average of the relative predictive error
- **Uncertainty ranges (URs) = 2.5 - 97.5 centiles**
- Neonatal and children aged 1-59 months estimated separately
- Combines the uncertainties from the VRMCM, VAMCM and those estimated by the WHO technical programmes by adding up the corresponding lower and upper bounds

Methods Used to Estimate Causes of Death

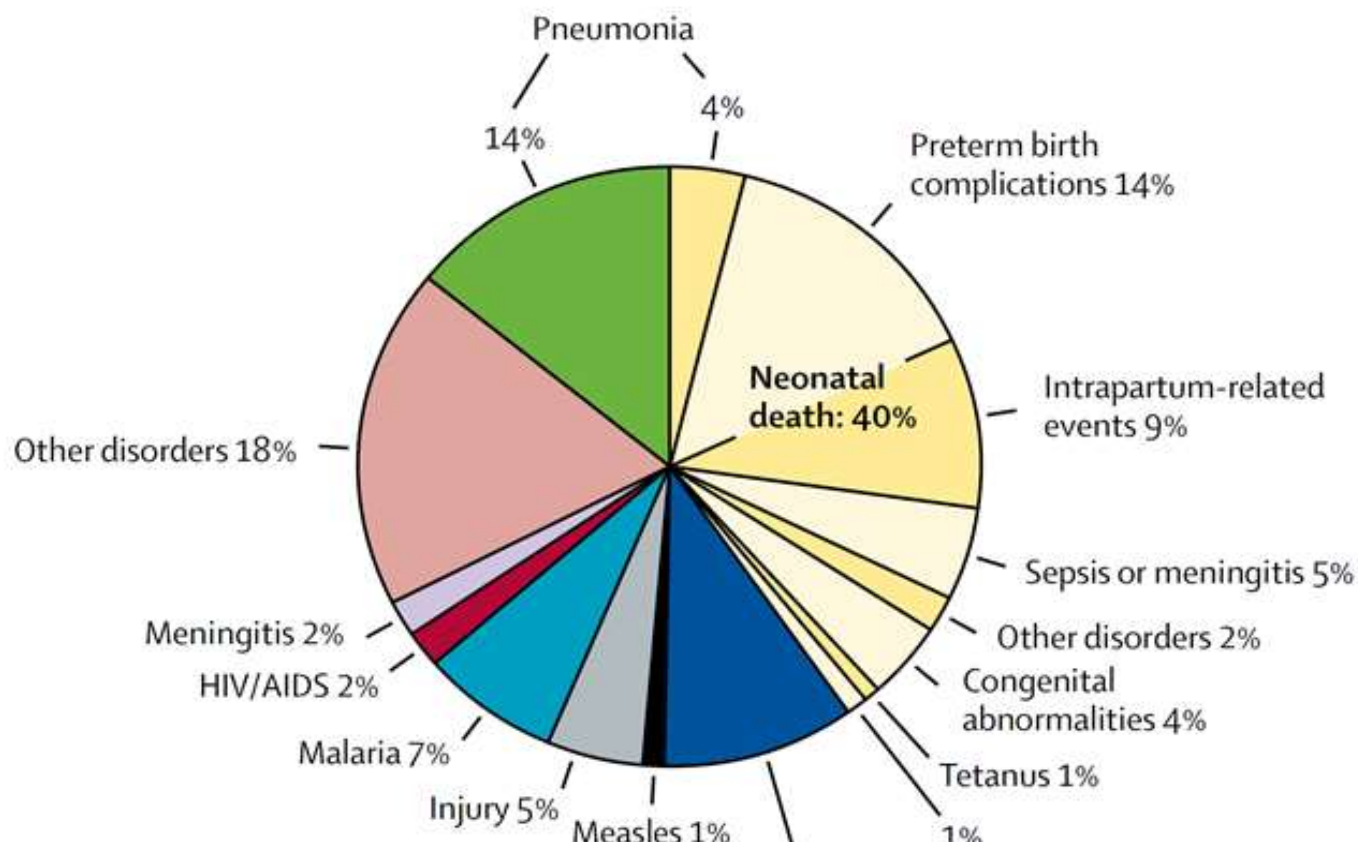


Child Causes of Death Estimates for 2010

Global Causes of Child Deaths, 2010



Global Causes of Under-Five Deaths in 2010



Through synergy with infectious diseases undernutrition causes 35% of child deaths

Summary of Global Estimates in 2010

7.6 million deaths in children < 5 years

64% (4.9 million) of deaths were from infectious diseases

Pneumonia	18%	1.40 million
Diarrhea	10%	0.80 million
Malaria	7%	0.56 million

40% (3.1 million) of deaths occurred in neonates

PTB Complications	14%	1.08 million
Intrapartum-related complications	9%	0.72 million
Sepsis or meningitis	5%	0.39 million
Pneumonia	4%	0.33 million

2010 Estimates of Causes of Child Deaths

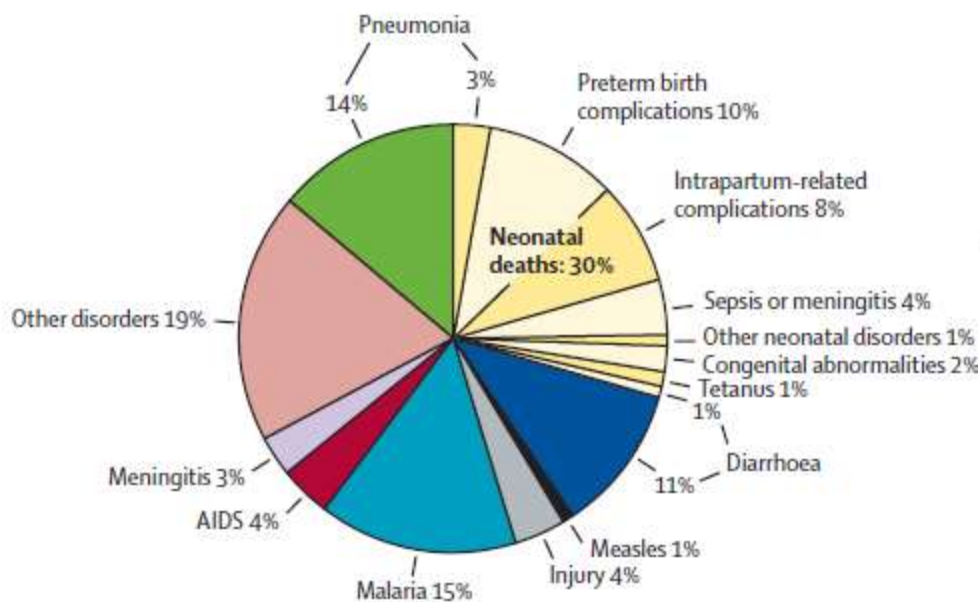
- All children under 5 years – for 193 countries
 - most important single COD:
 - pneumonia
 - preterm birth complications
 - other important causes: diarrhea, birth asphyxia and malaria
 - measles responsible for 1% of deaths (successful vaccination programs)

Regional Distribution of Deaths and their Causes – Africa and southeast Asia

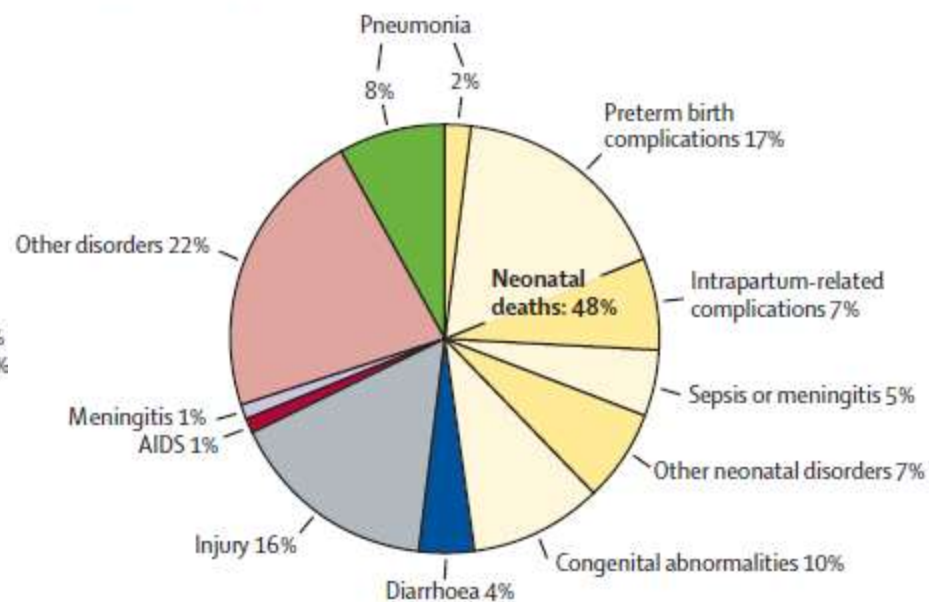
- Number of deaths varied widely across WHO regions - largest number of deaths in:
 - African region (3.5 million)
 - Southeast Asian region (2.1 million)
- Differing patterns of neonatal causes of death:
 - lower proportion of **neonatal deaths** in African region (30%, 1.1 million) than in Southeast Asian region (52%, 1.1 million),
 - 73% of deaths in children < 5 years due to infectious causes in Africa, including 96% of global child malaria deaths and 90% of global child AIDS deaths.
 - Pneumonia and preterm births important in SE Asia

Regional Causes of Deaths, 2010: Africa and Americas

Africa (N=3.552 million)

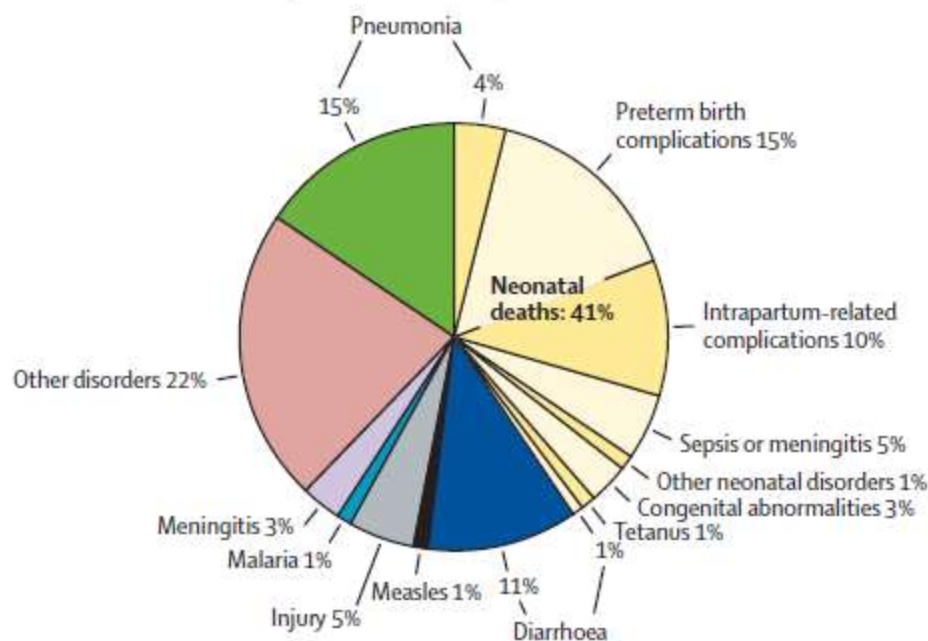


Americas (N=0.284 million)

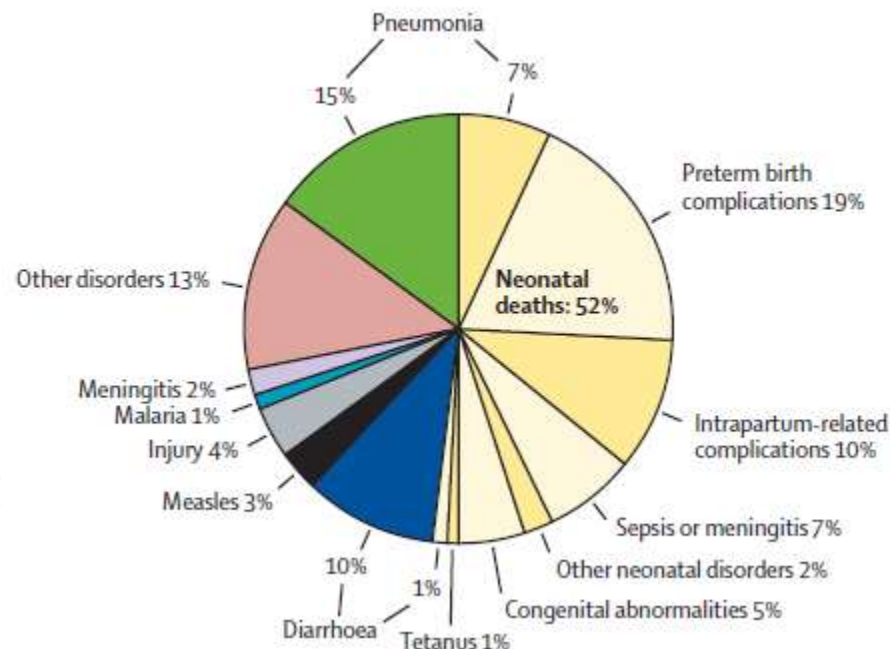


Regional Causes of Deaths, 2010: Eastern Mediterranean and SE Asia

Eastern Mediterranean (N=1.062 million)



Southeast Asia (N=2.096 million)



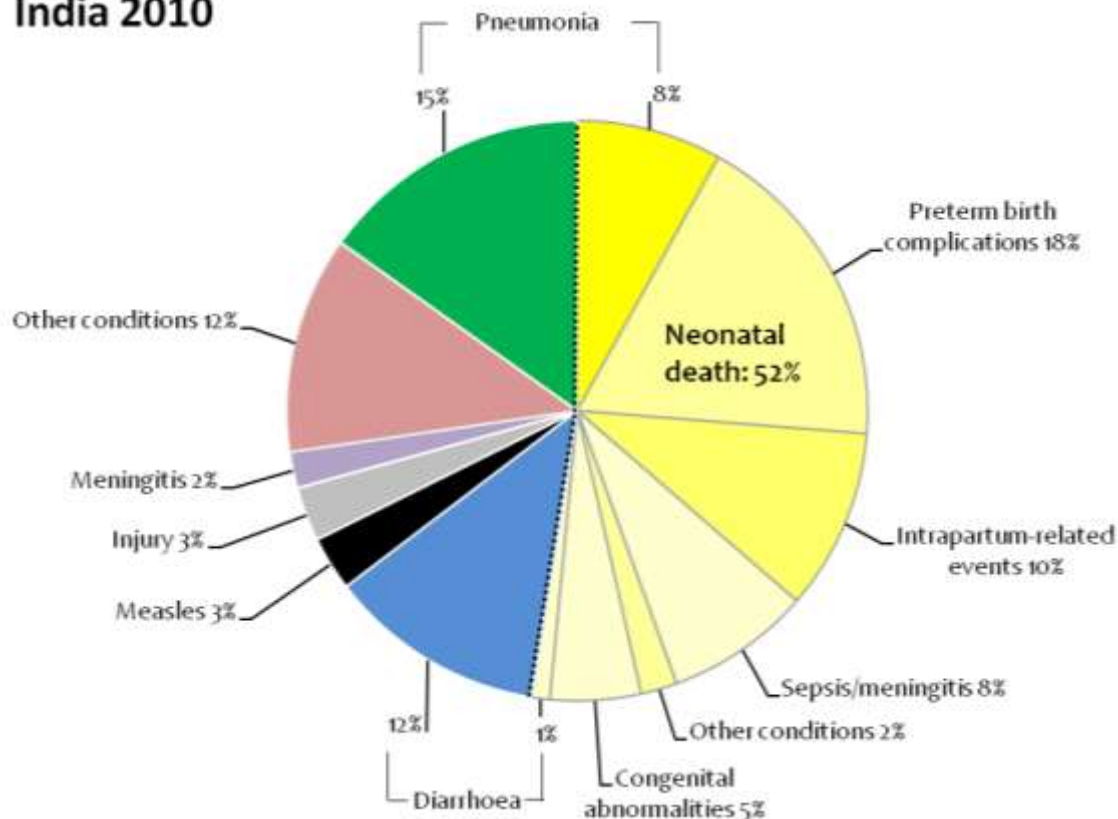
India, Nigeria, Pakistan, China and Democratic Republic of Congo

- **49% (3.8 million) of all under-five deaths in 2010**
- High proportions of global totals for neonatal COD

Cause	Percent	Estimated #
Birth Asphyxia	52%	0.37 million
Sepsis	54%	0.24 million
Preterm Birth Complications	51%	0.54 million
Congenital Abnormalities	47%	0.13 million

India

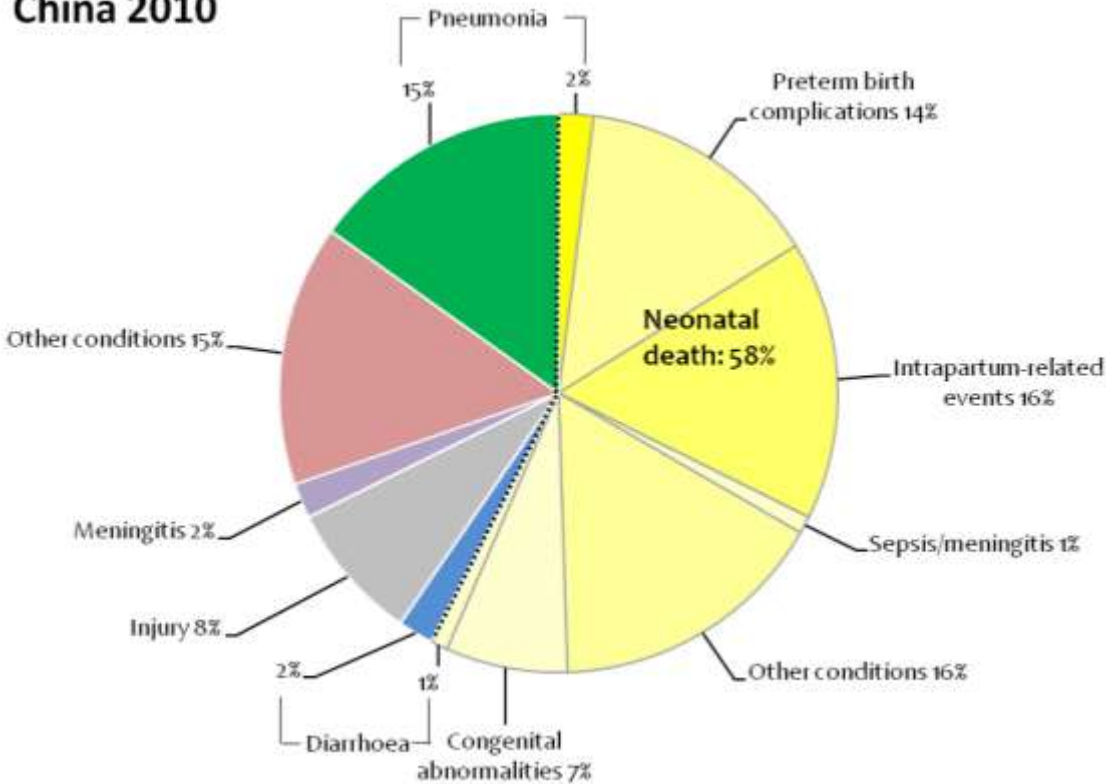
India 2010



- 1.7m (23% of world total) U5 children died in 2010
- 51% deaths occurred in first month
- Major causes:
 - pneumonia
 - prematurity
 - diarrhea

China

China 2010



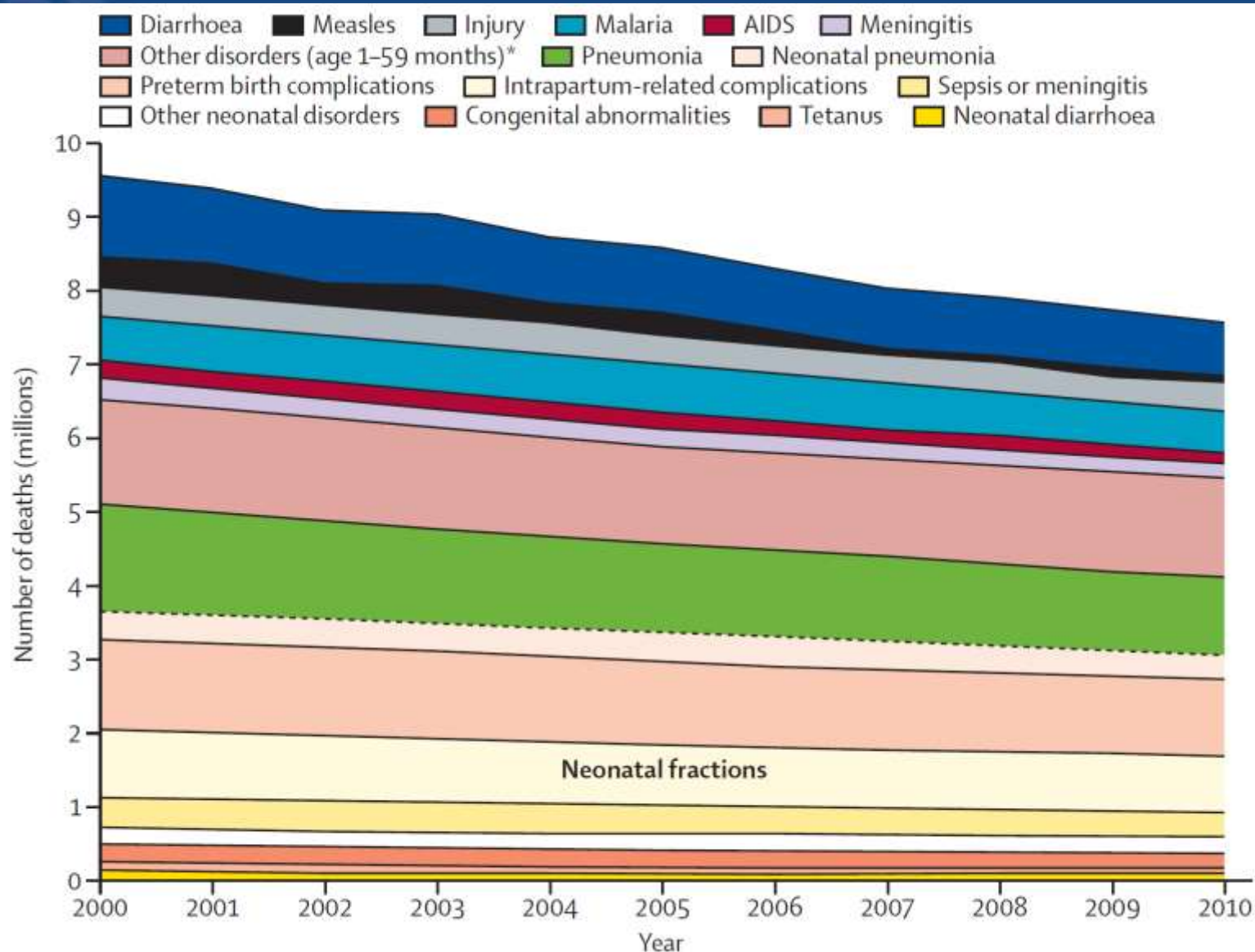
- 0.31m total U5 deaths
- 58% of neonatal deaths
- Major causes
 - Pneumonia
 - Birth asphyxia
 - Prematurity

Children Under 5 Years Old

- Collectively, **infectious diseases (almost 2/3 of deaths)** are most important COD.
- Most important single causes are pneumonia and preterm birth complications.
- Numbers of deaths varied widely across WHO regions (most deaths in Africa and southeast Asia).
- Despite continuing increase in population of children under 5, mortality rate is declining (7.6 million in 2010 vs. 9.6 million in 2000).

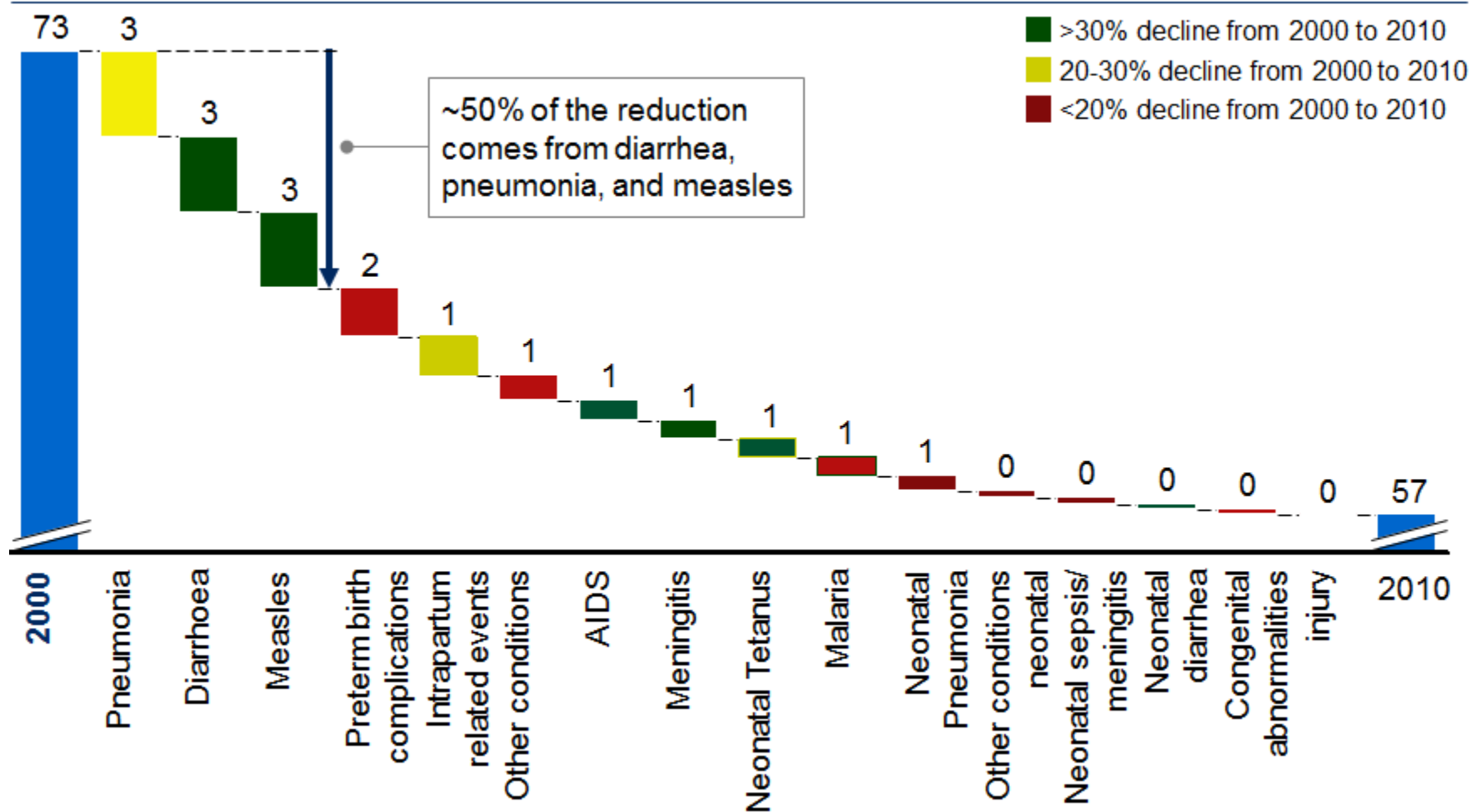
Estimates for 2000-2010

Global trends in burden of childhood deaths in 2000–10

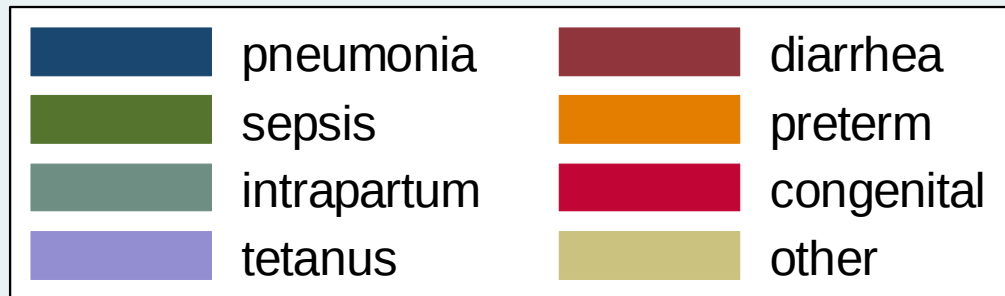
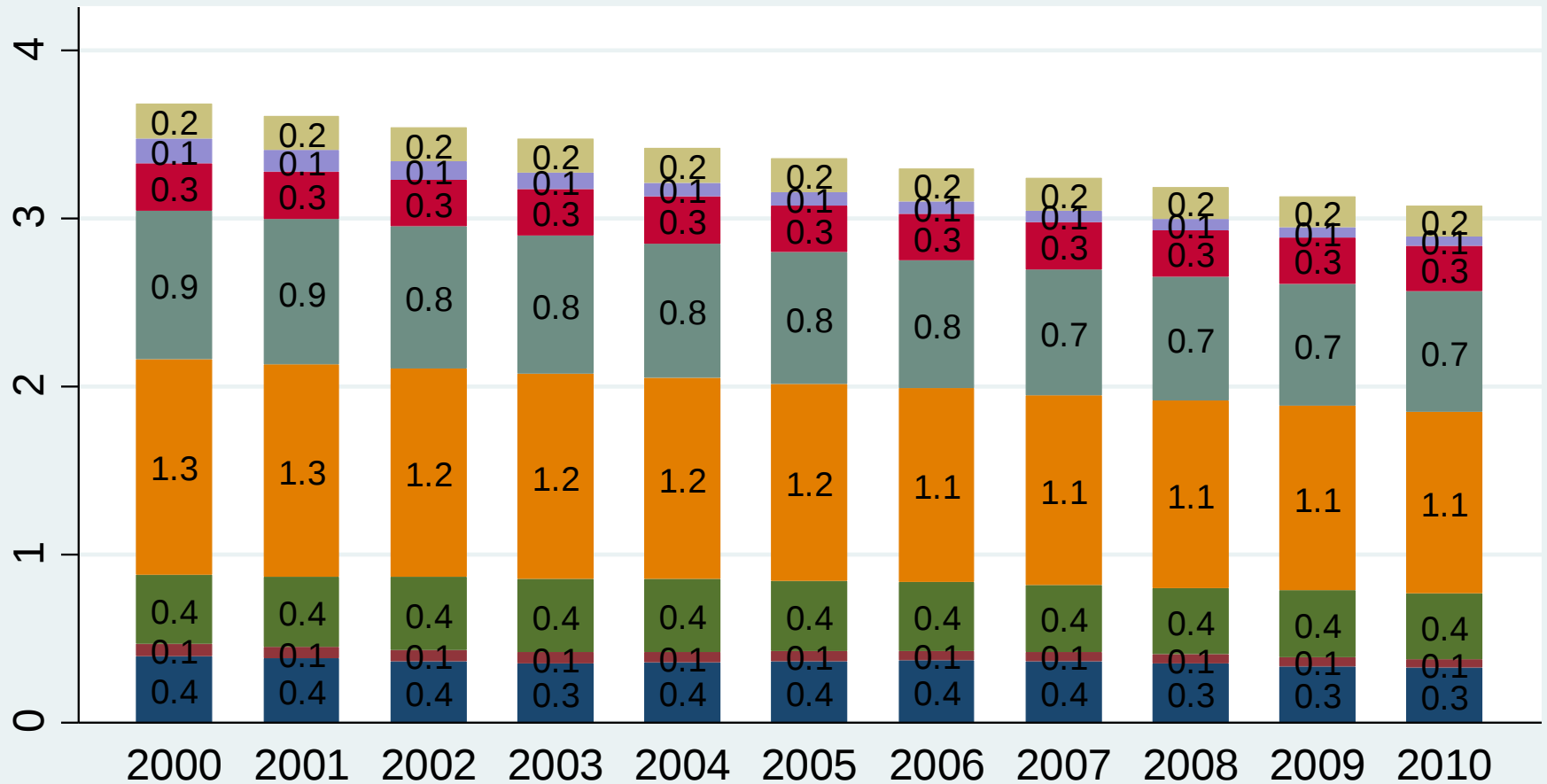


Reduction In Global U5MR By Disease, 2000 to 2010

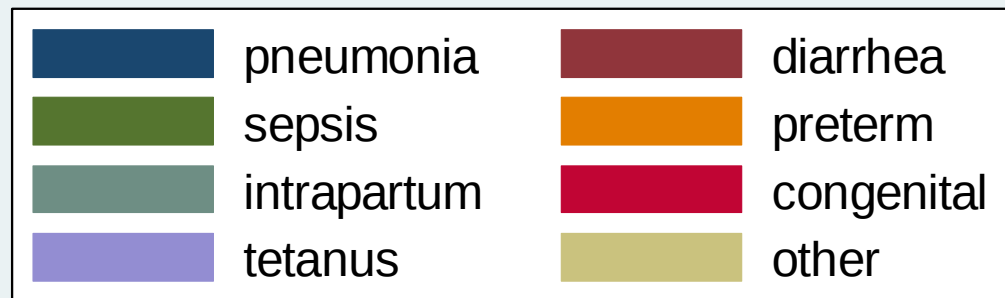
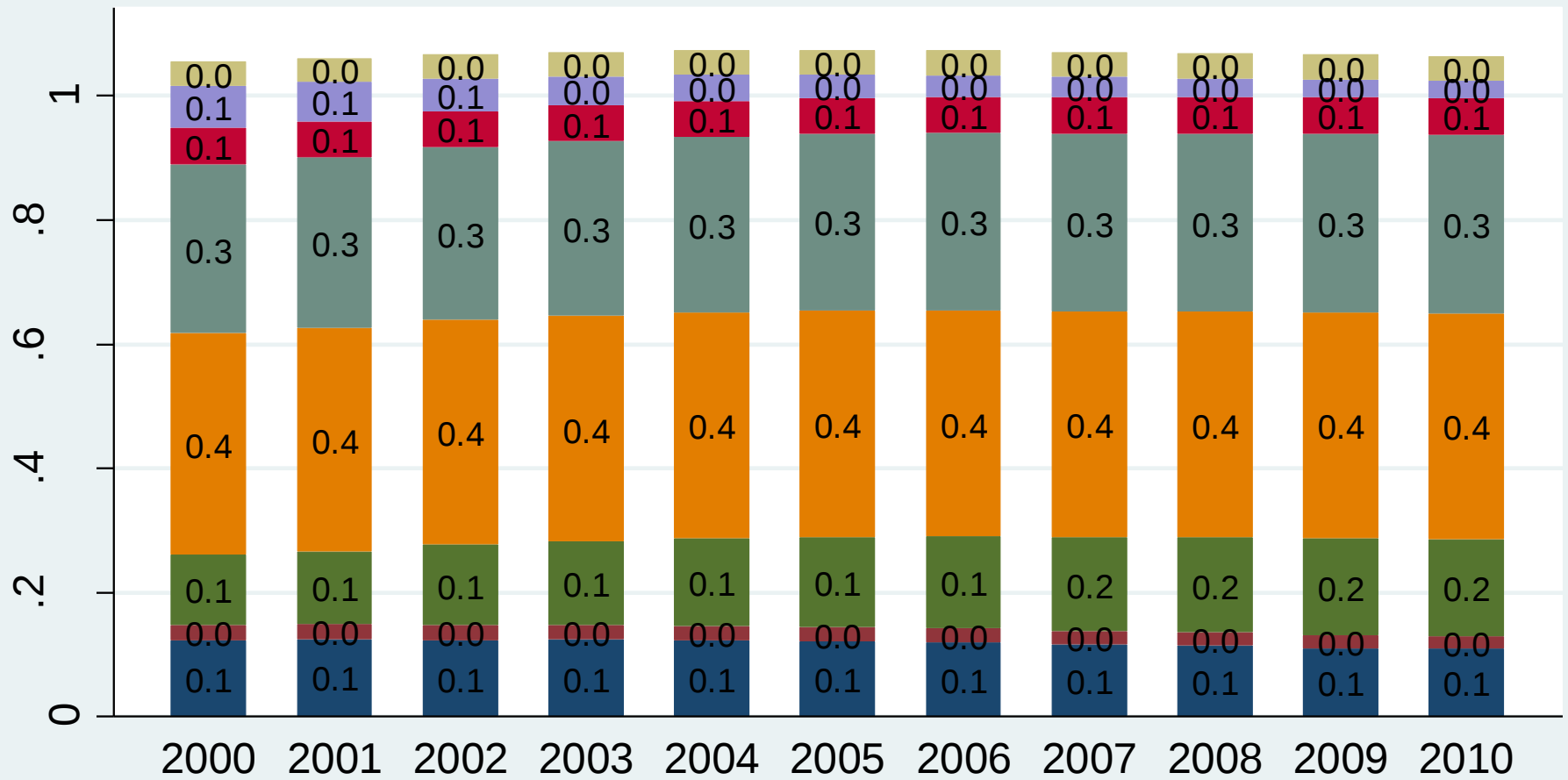
Deaths per 1,000 births



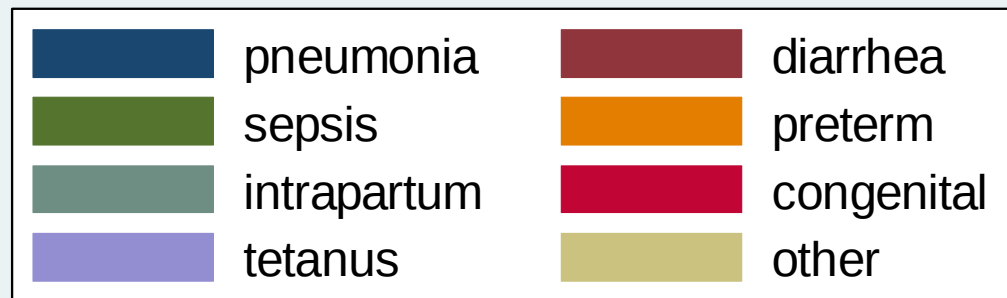
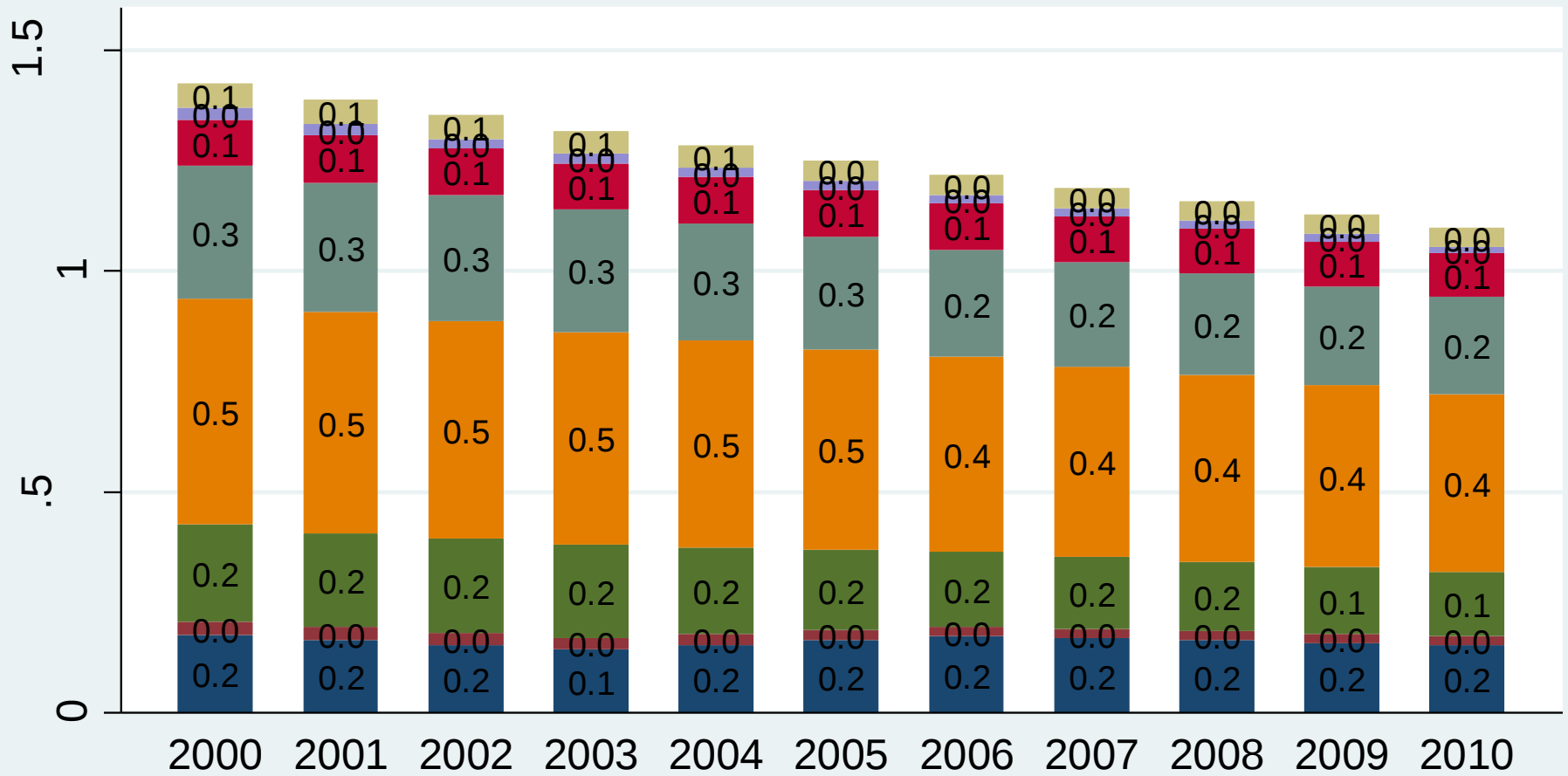
World, 0-1m



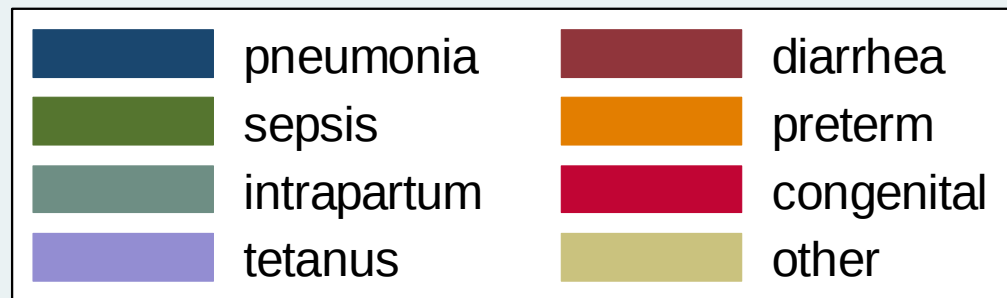
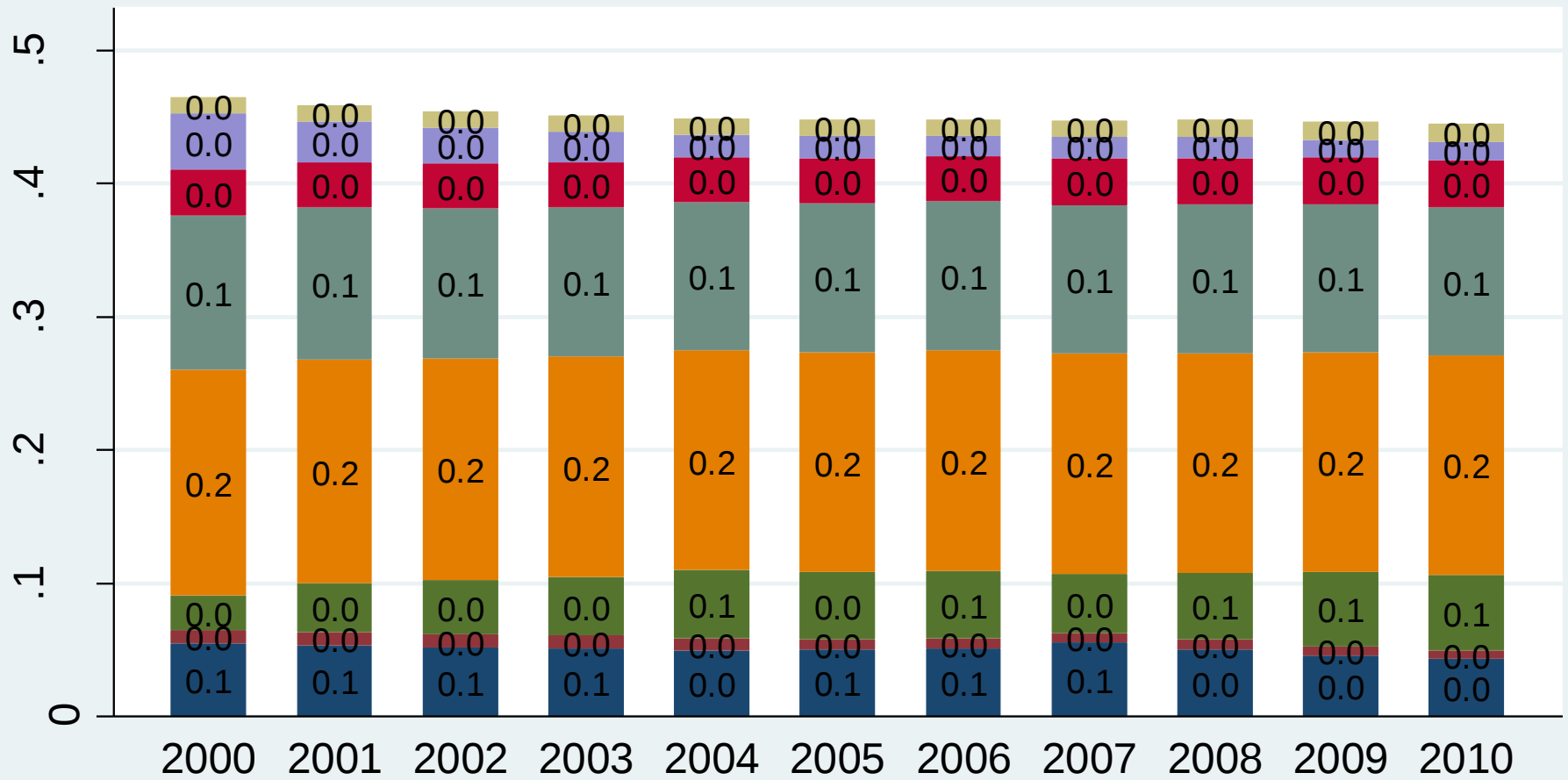
AFRO, 0-1m



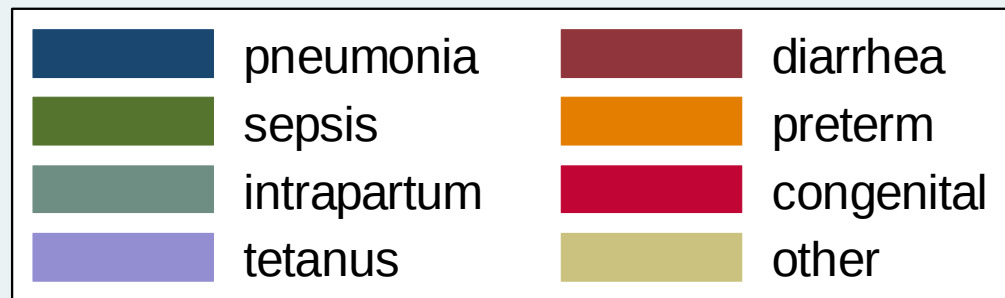
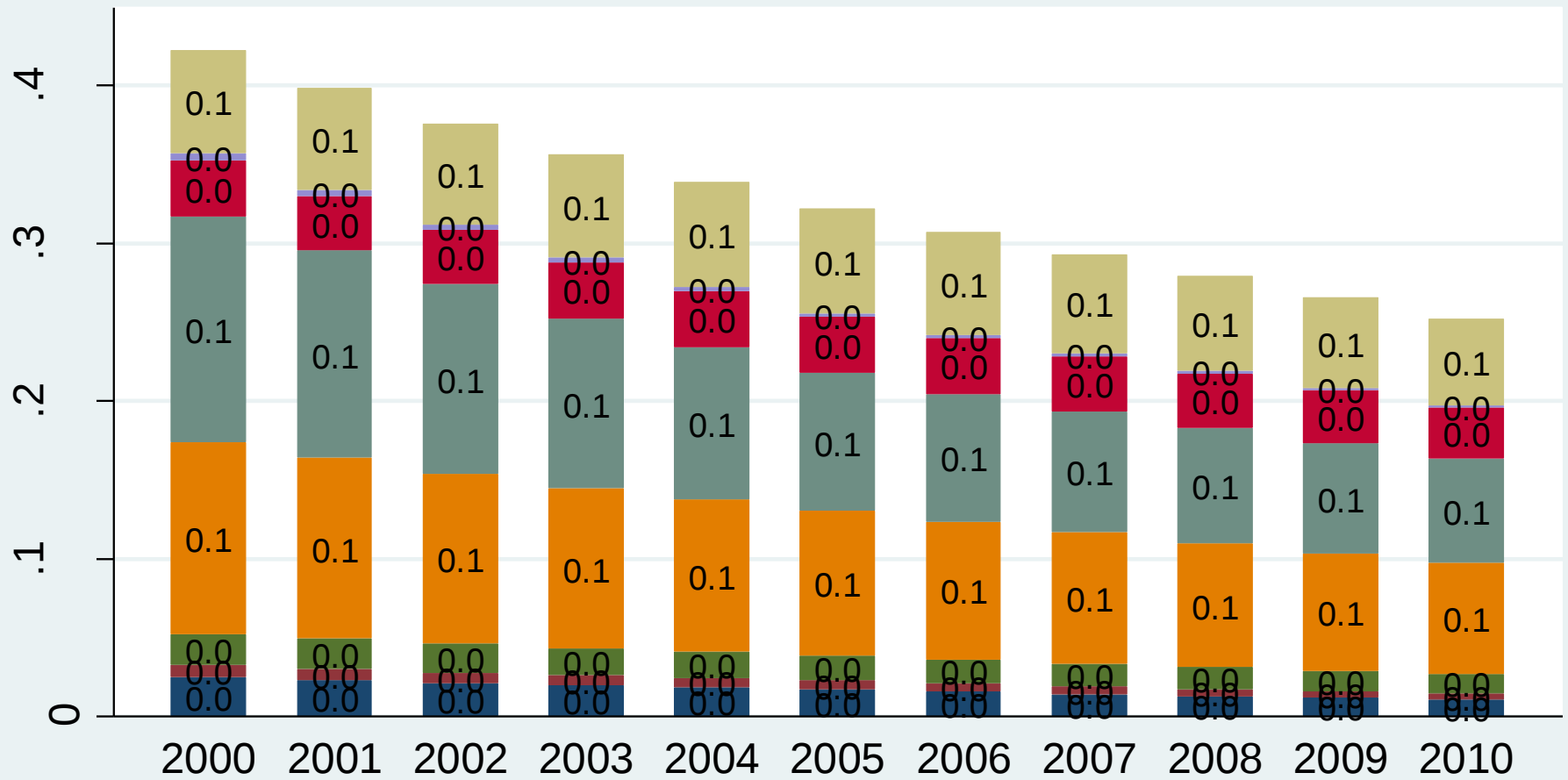
SEARO, 0-1m



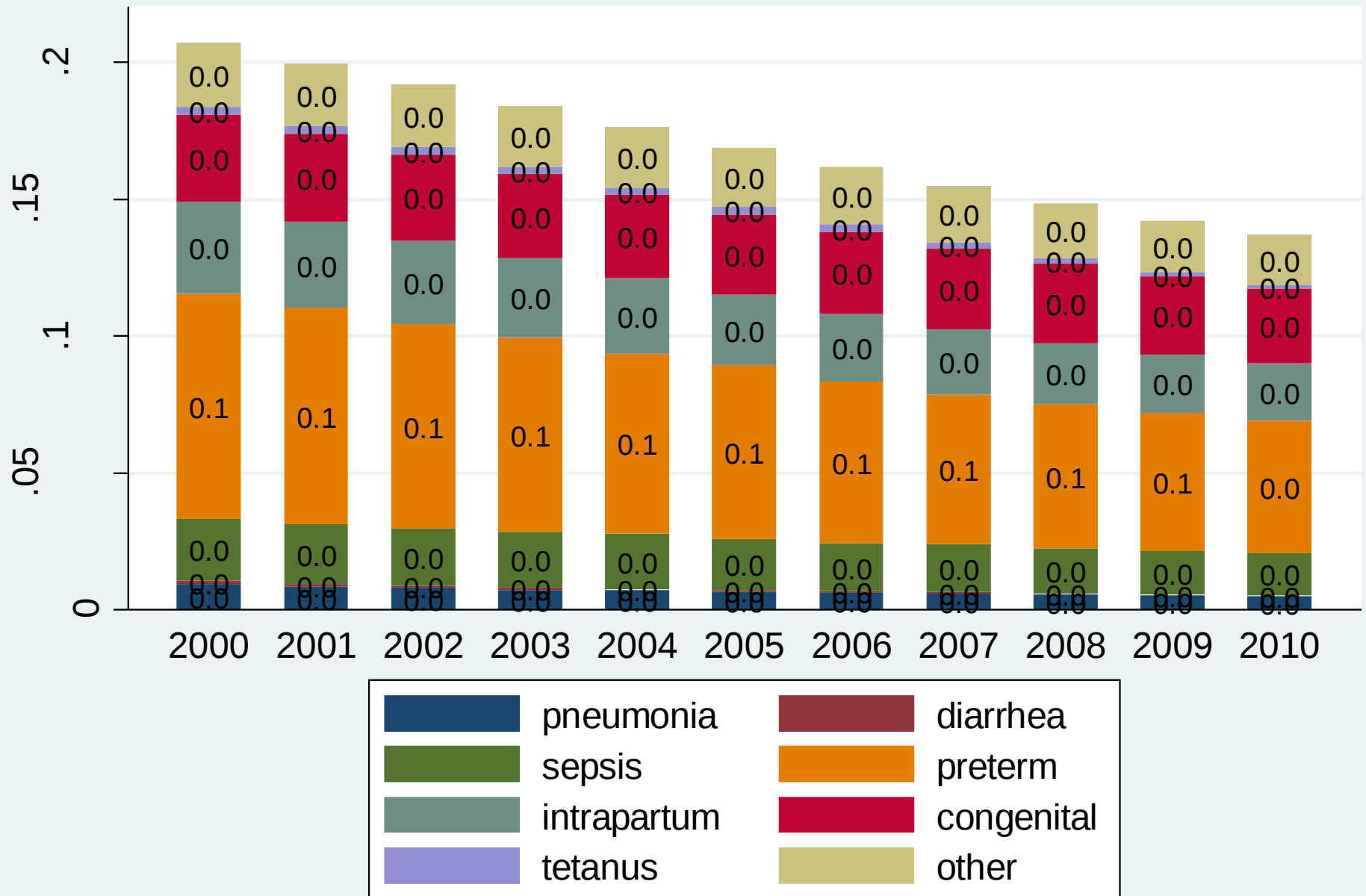
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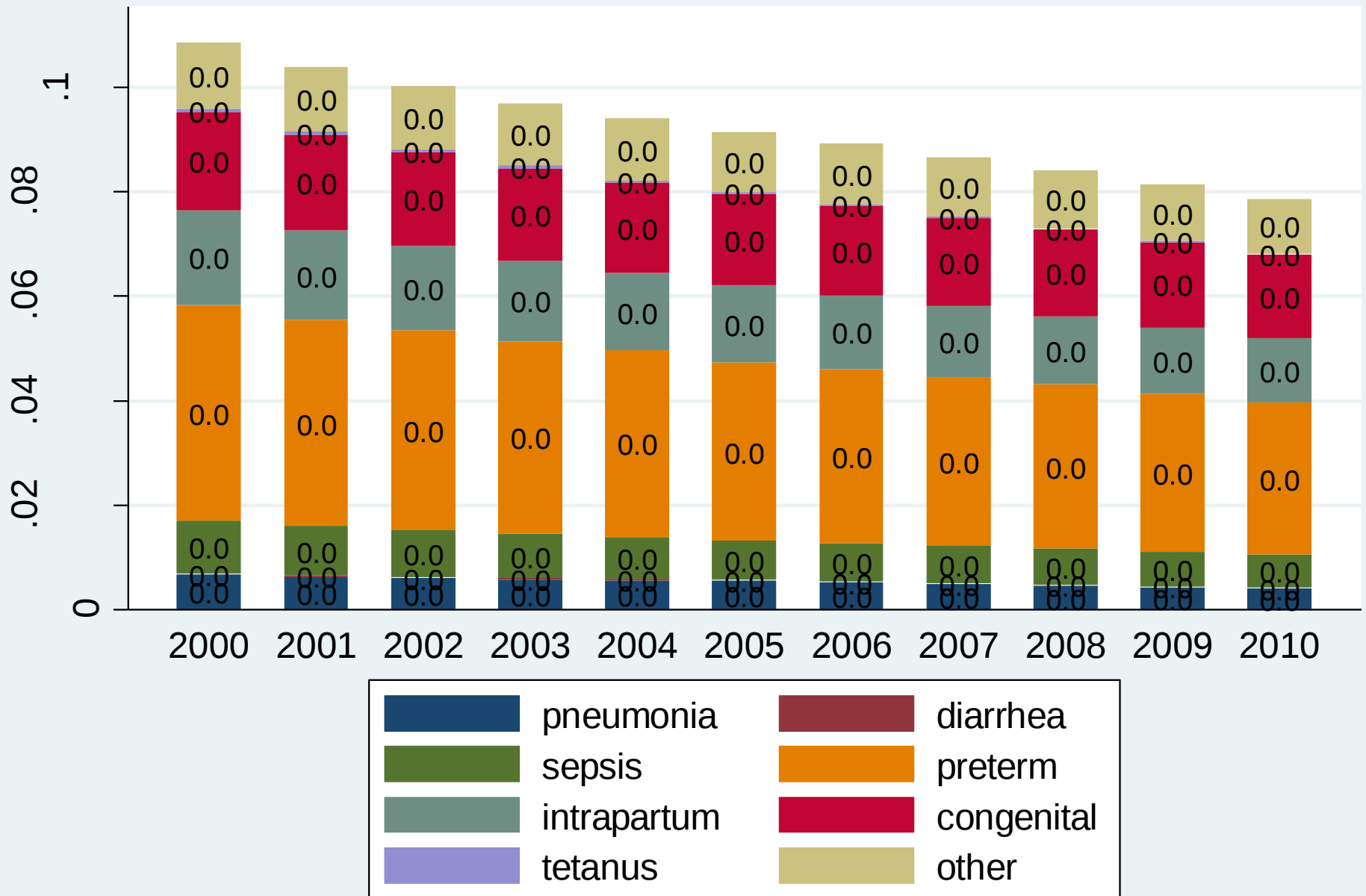
WPRO, 0-1m



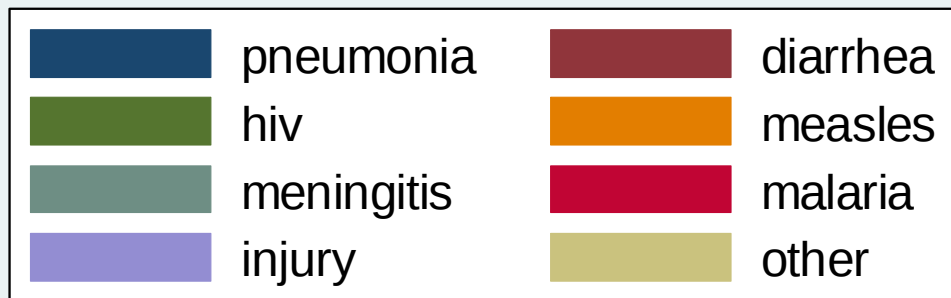
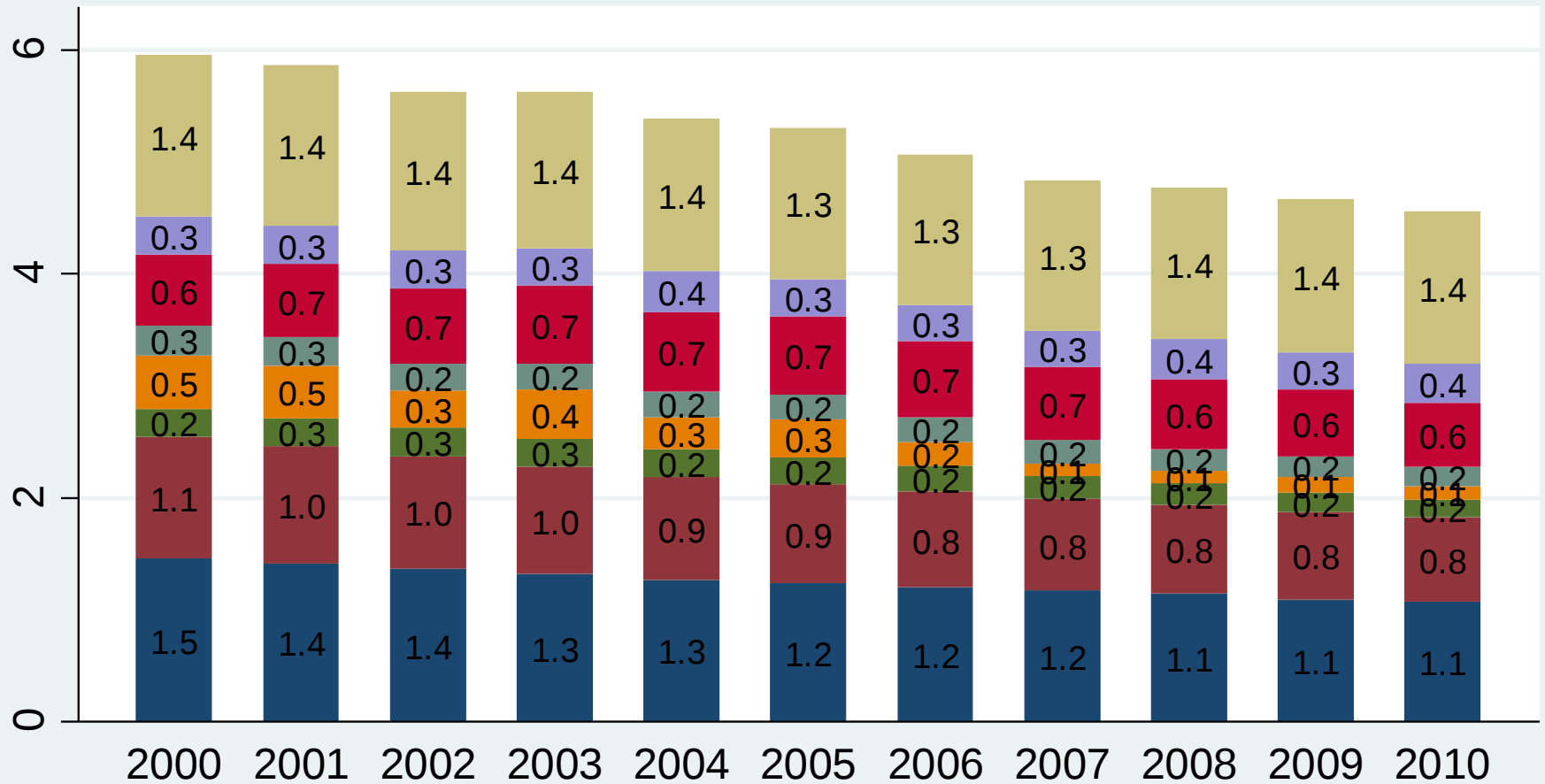
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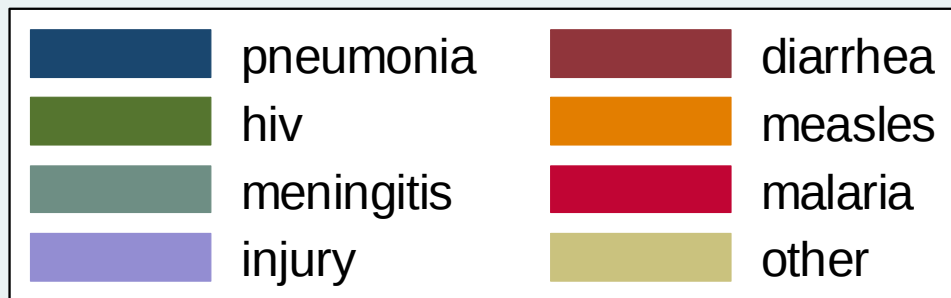
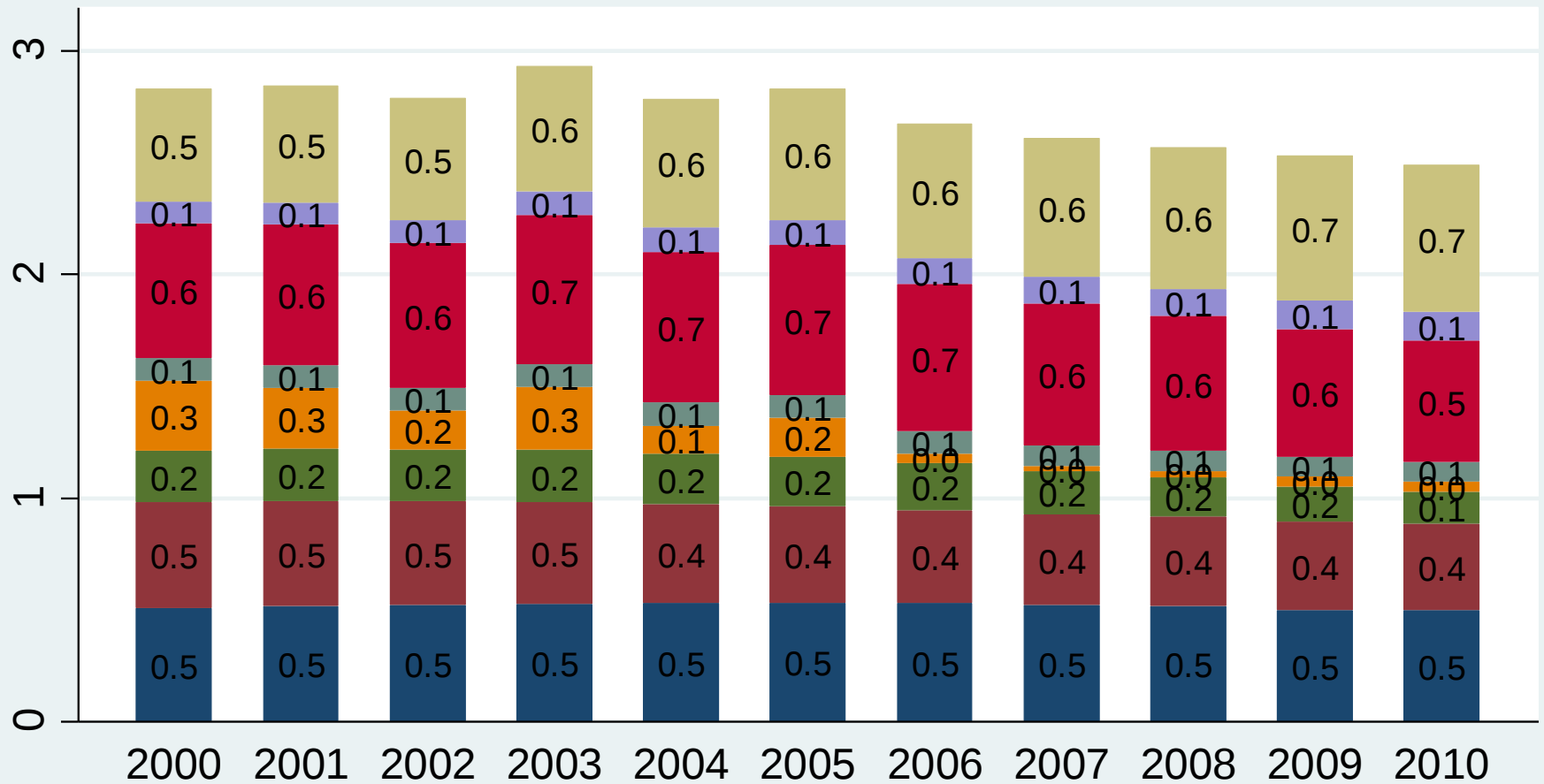
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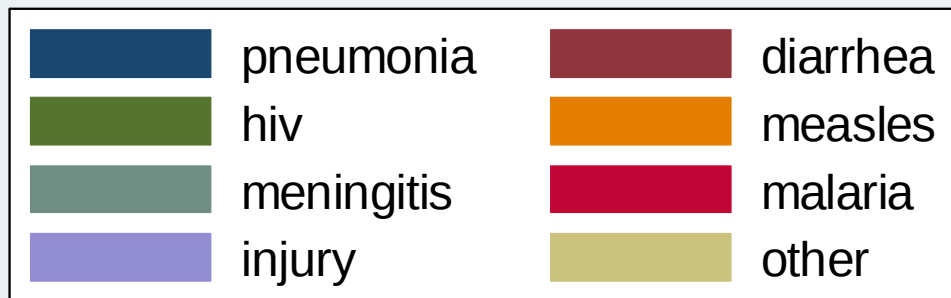
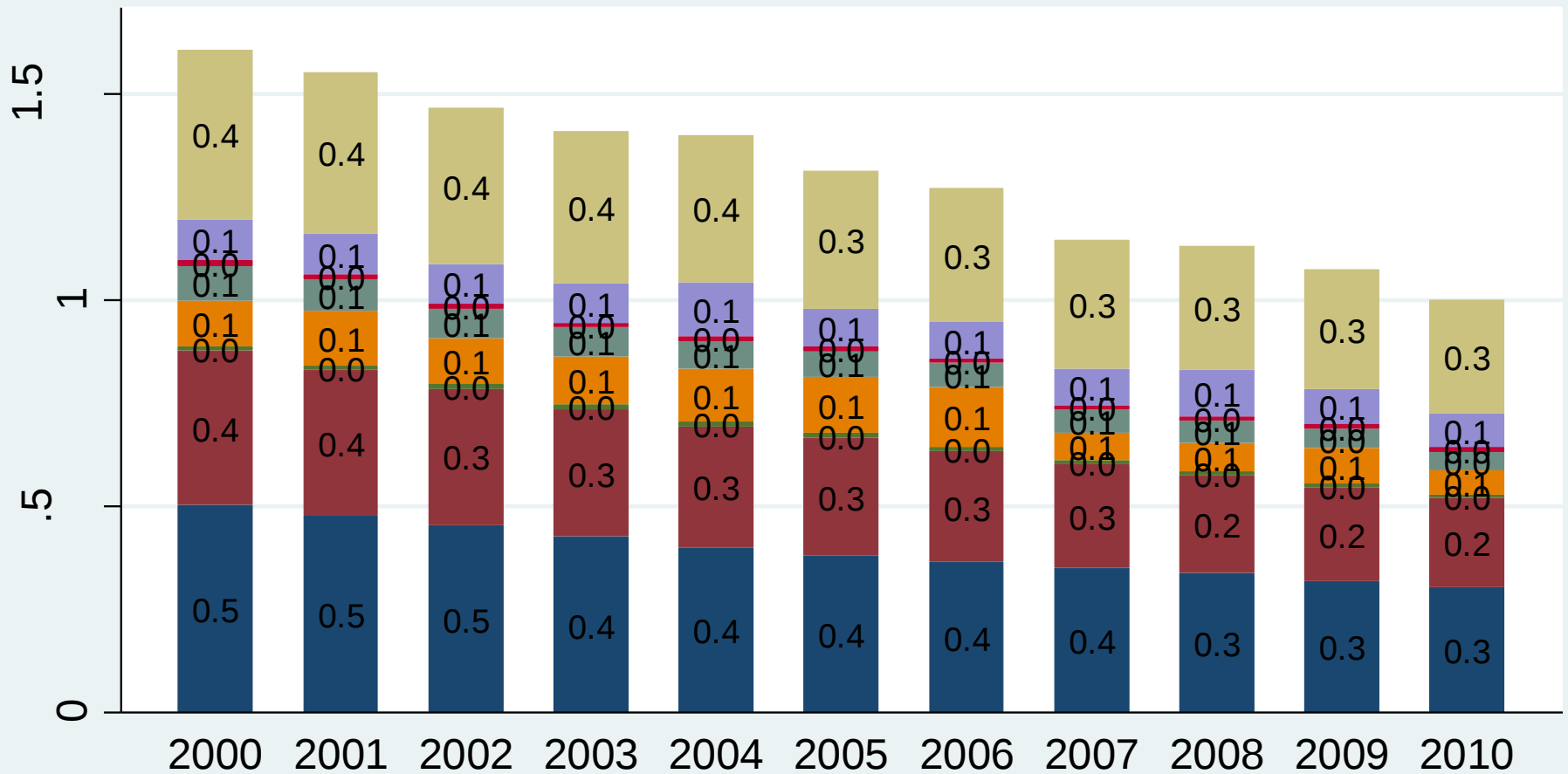
World, 1-59m



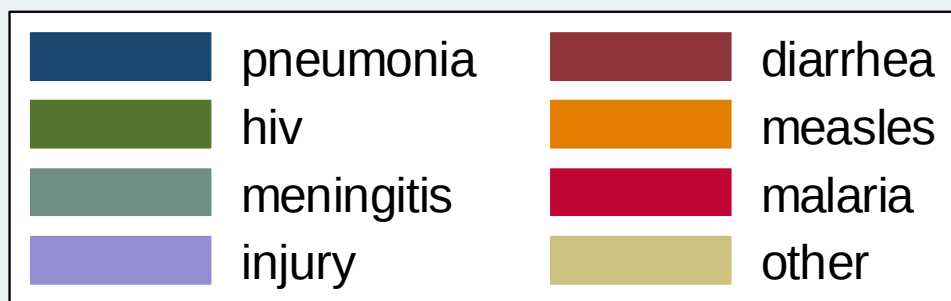
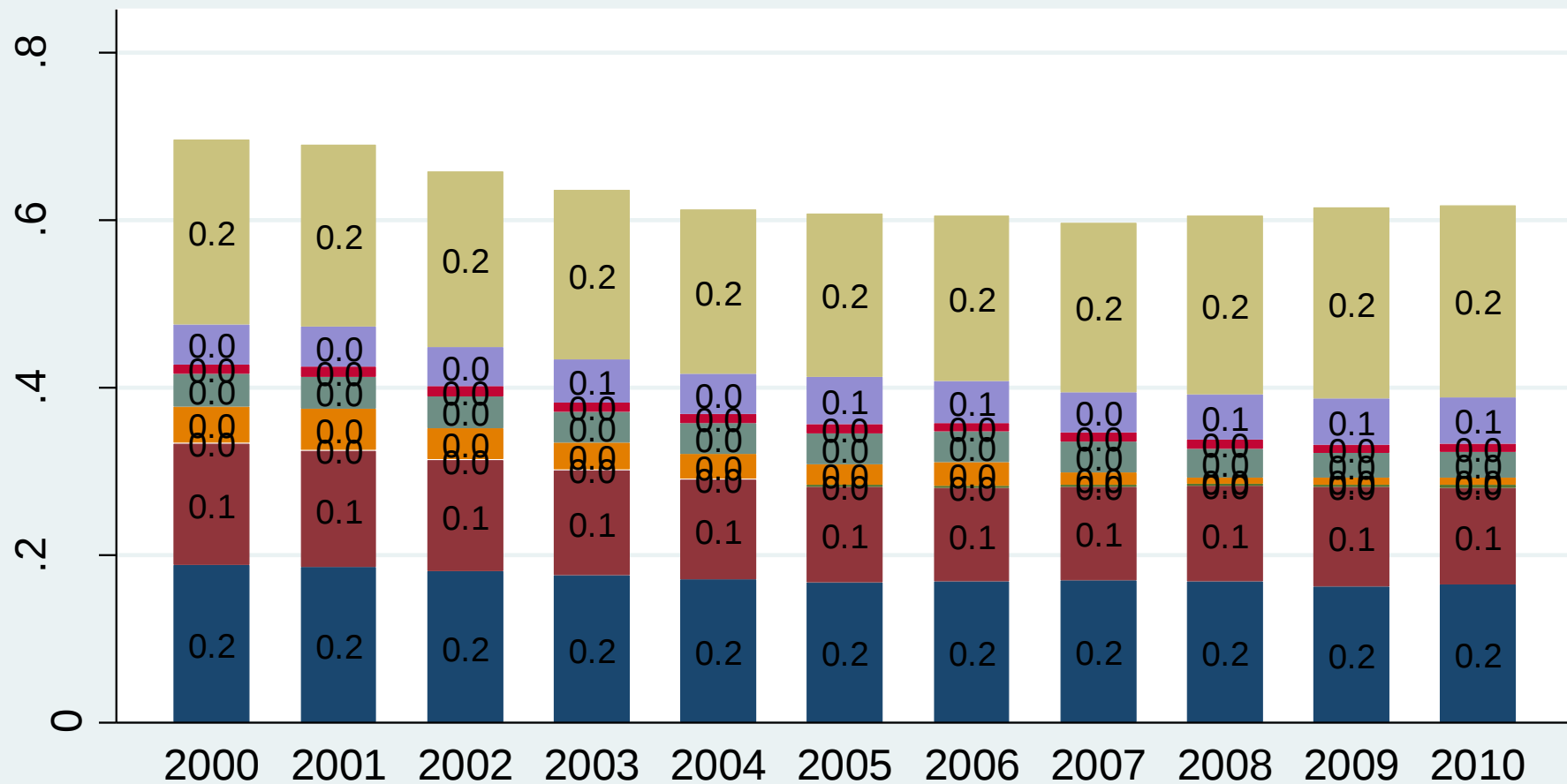
AFRO, 1-59m



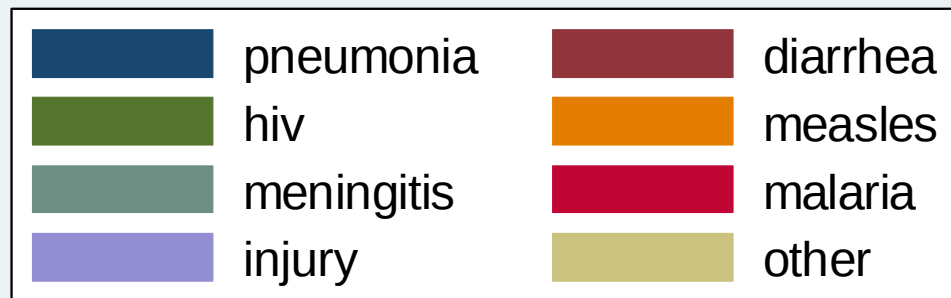
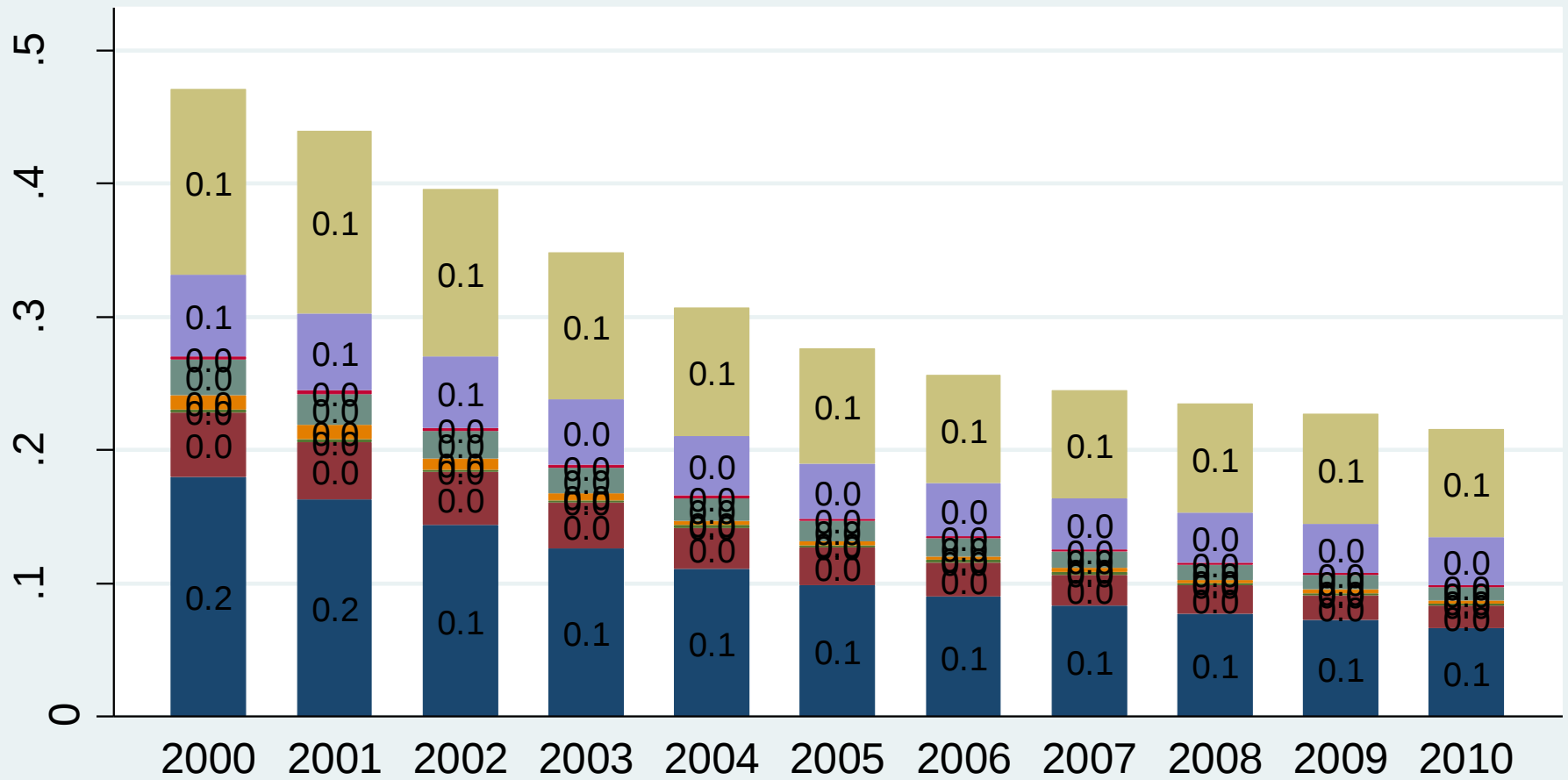
SEARO, 1-59m



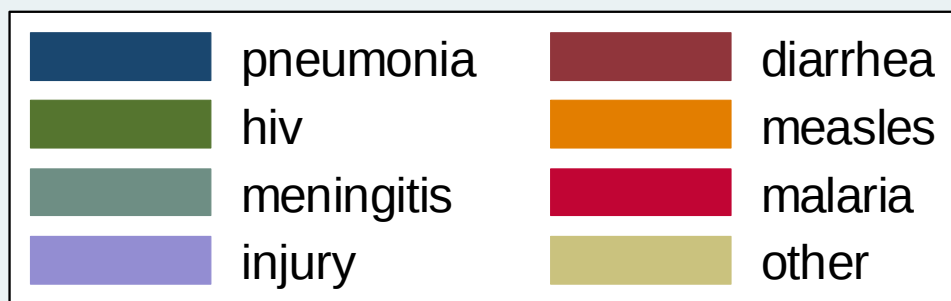
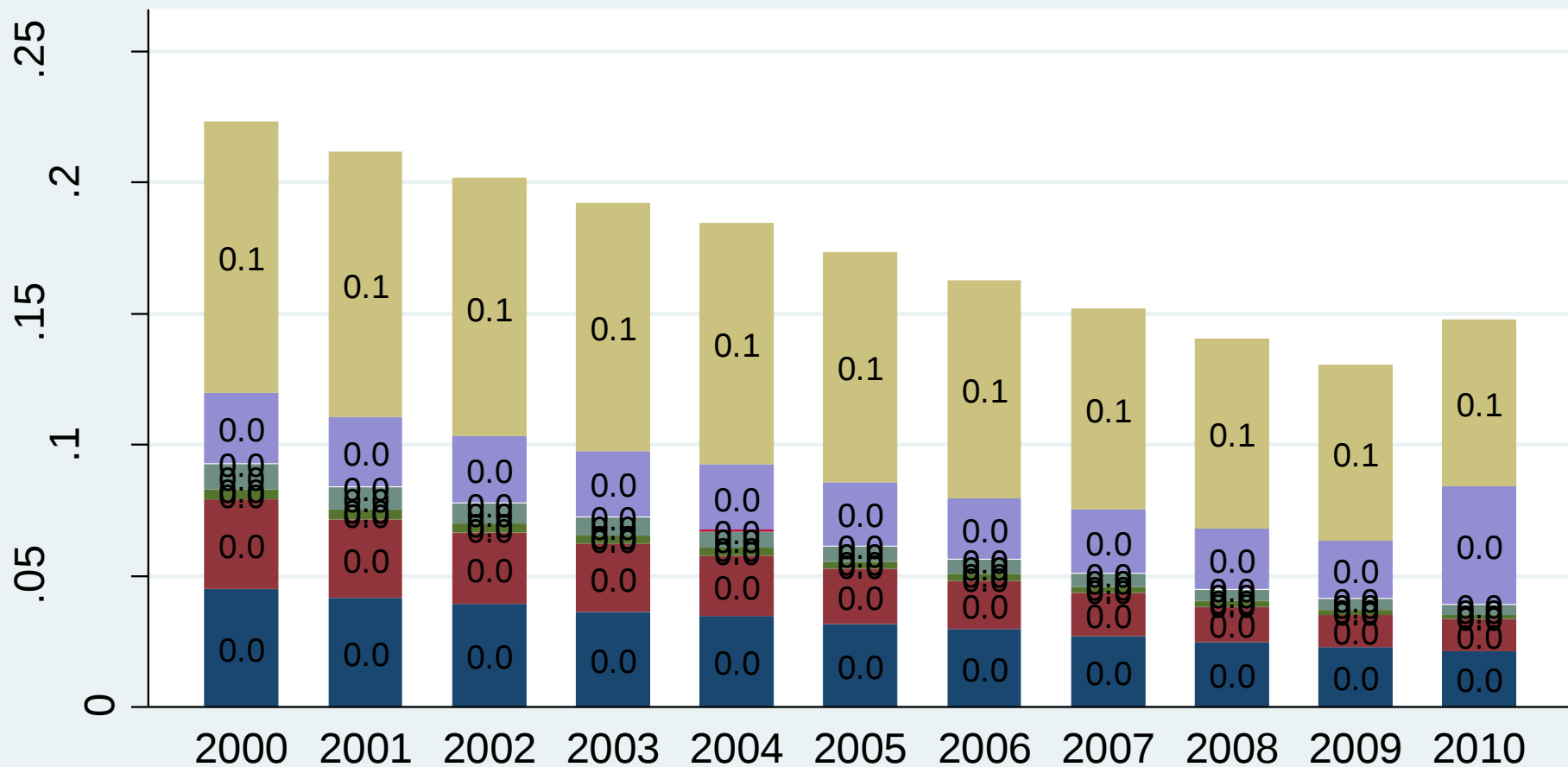
EMRO, 1-59m



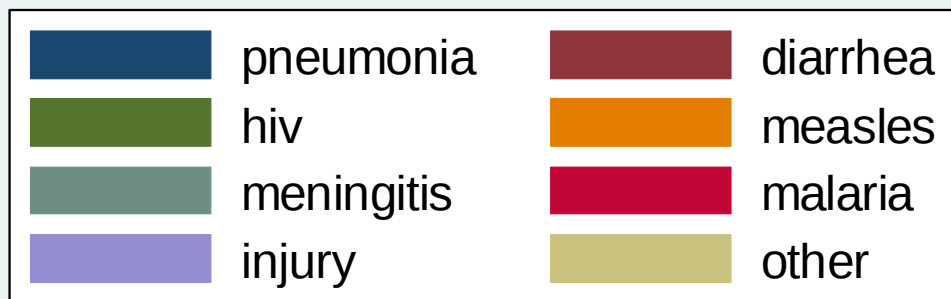
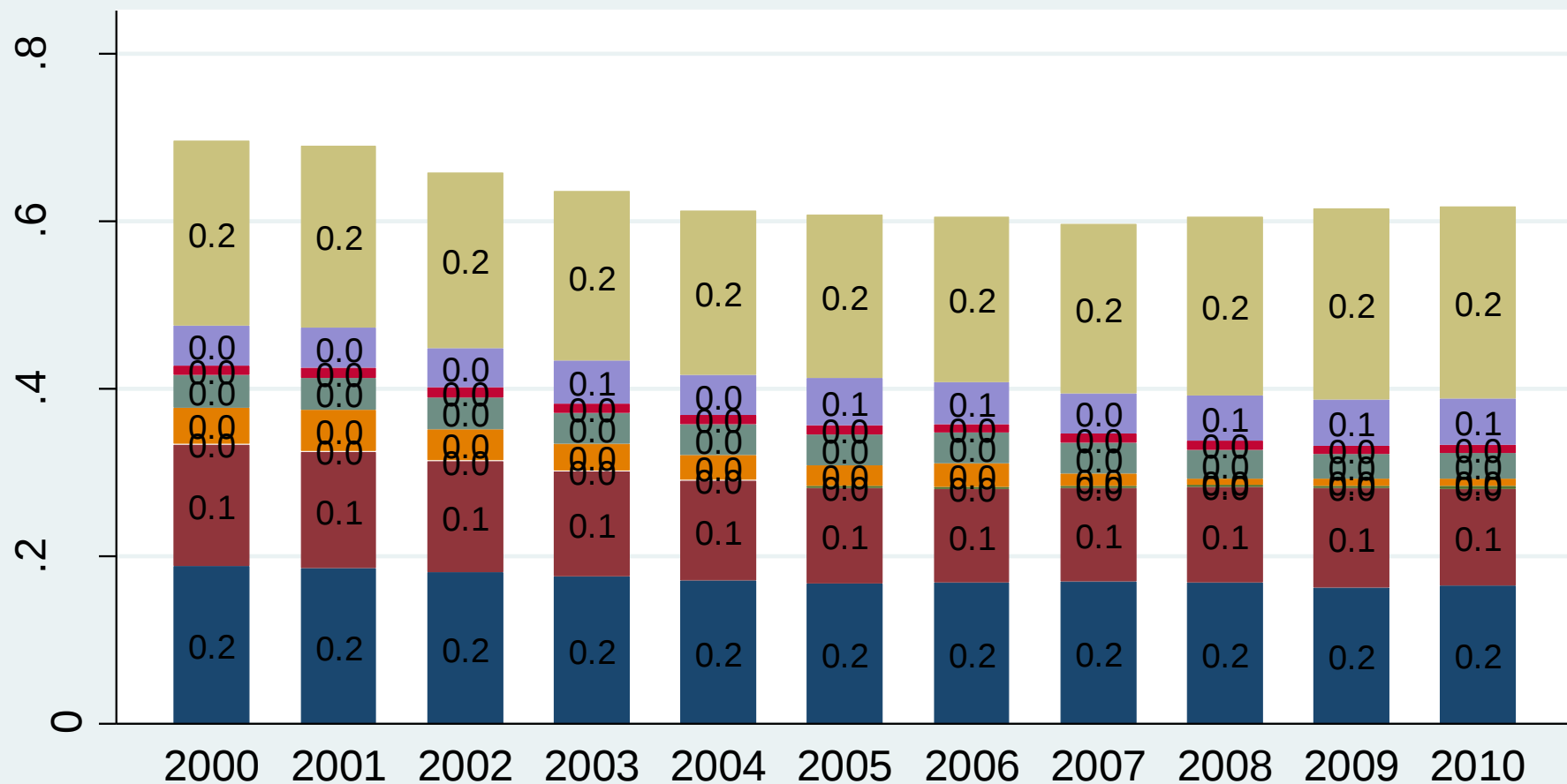
WPRO, 1-59m



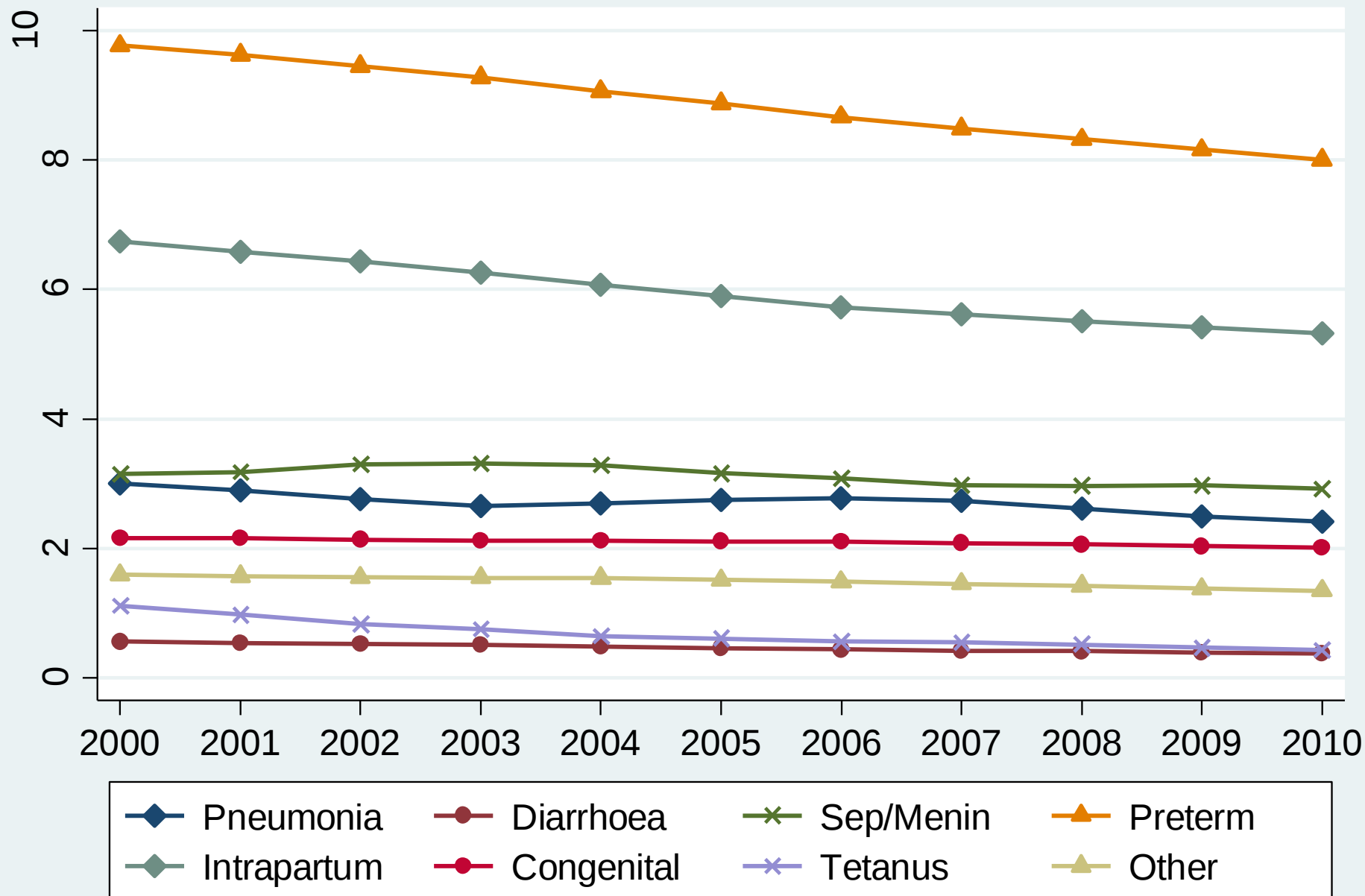
AMRO, 1-59m



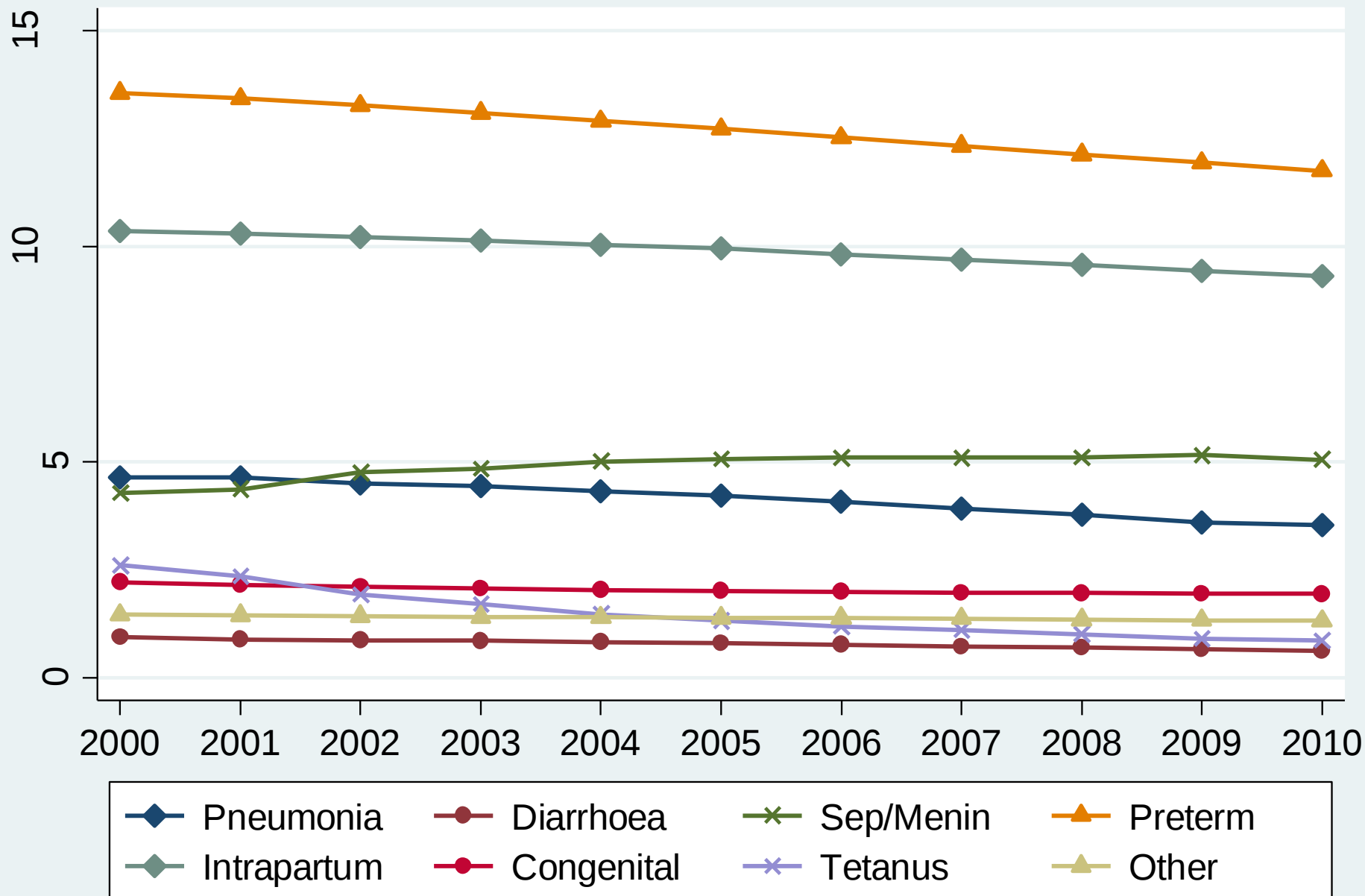
EMRO, 1-59m



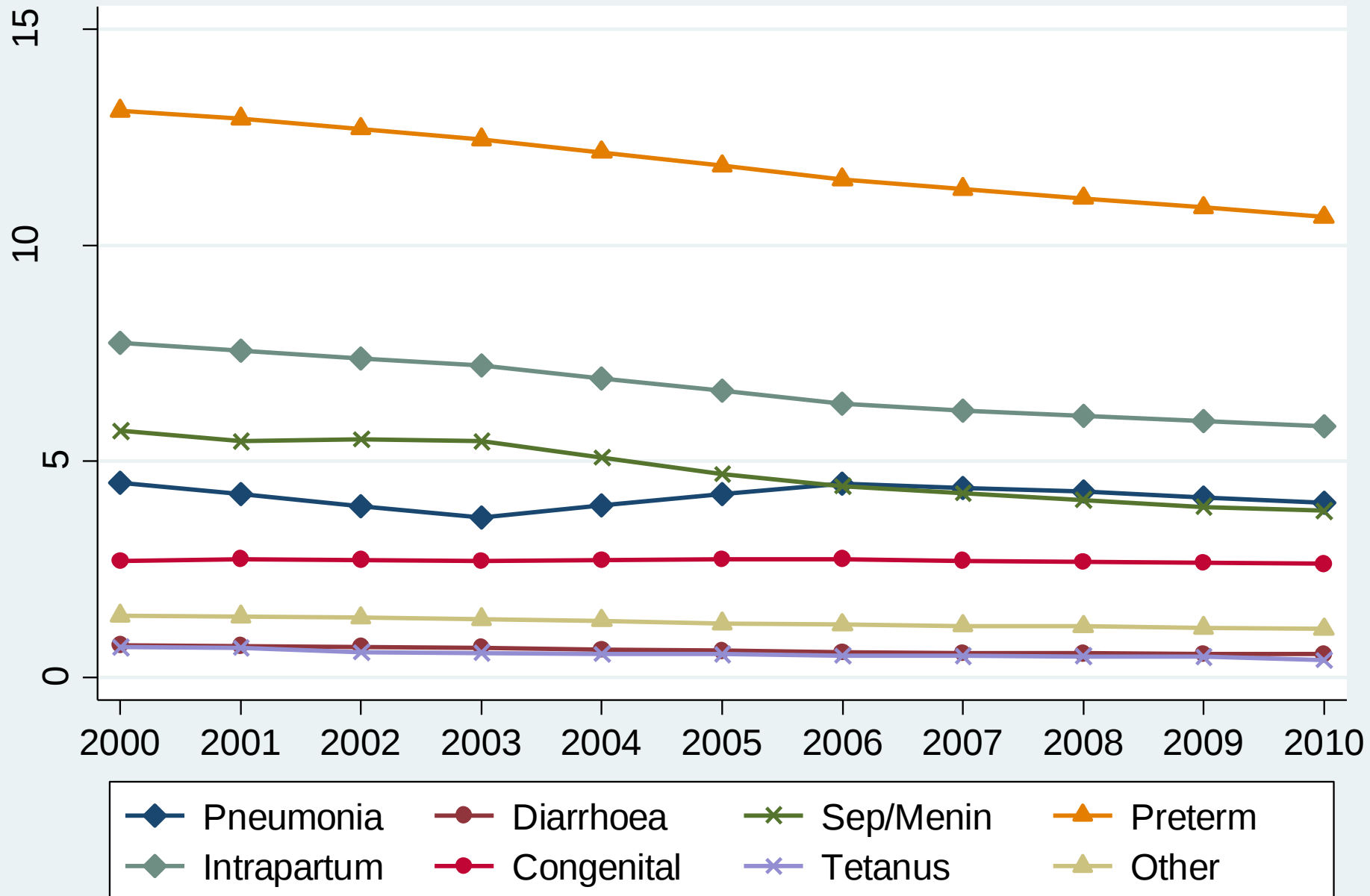
World, 0-1m



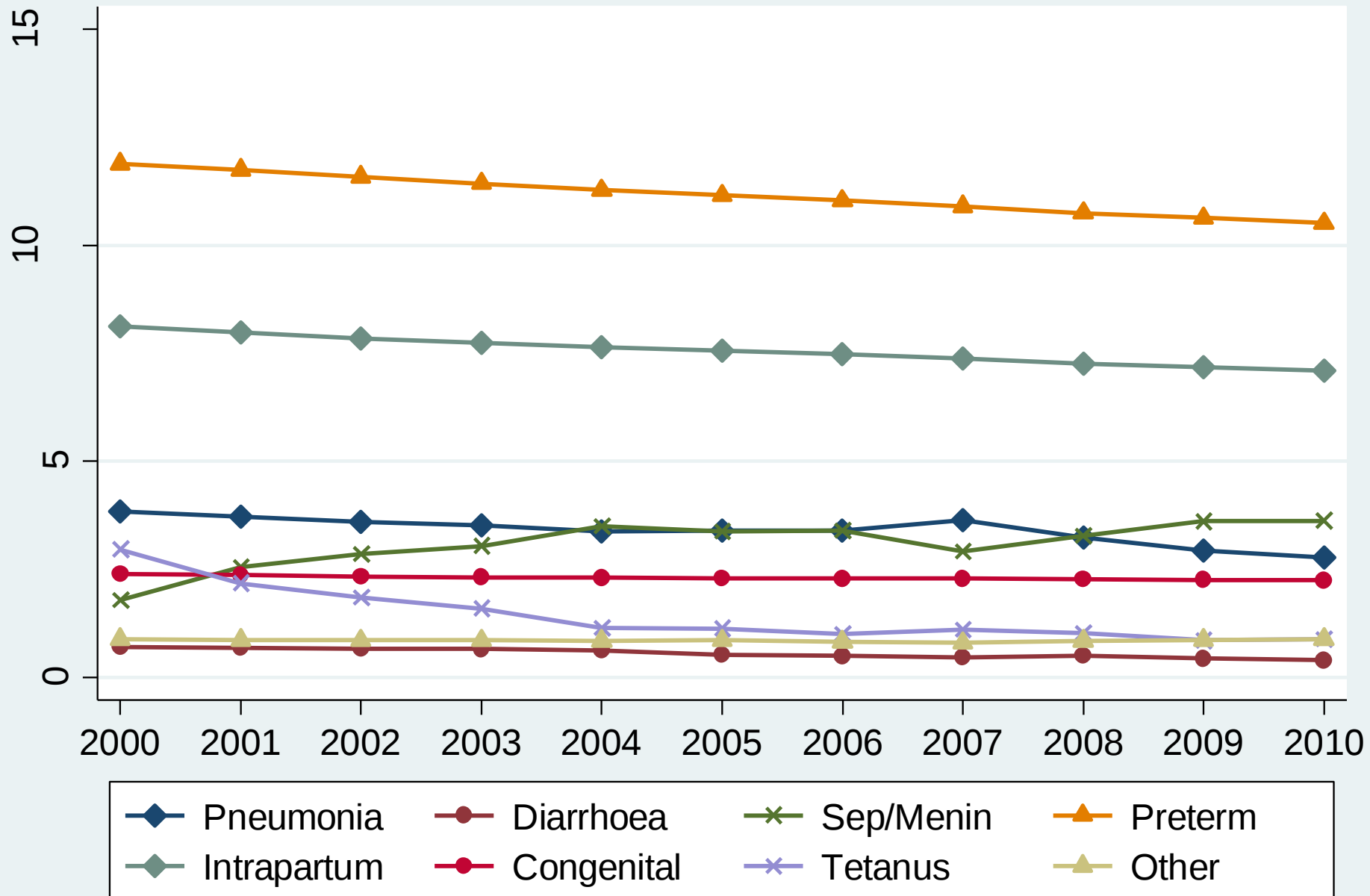
AFRO, 0-1m



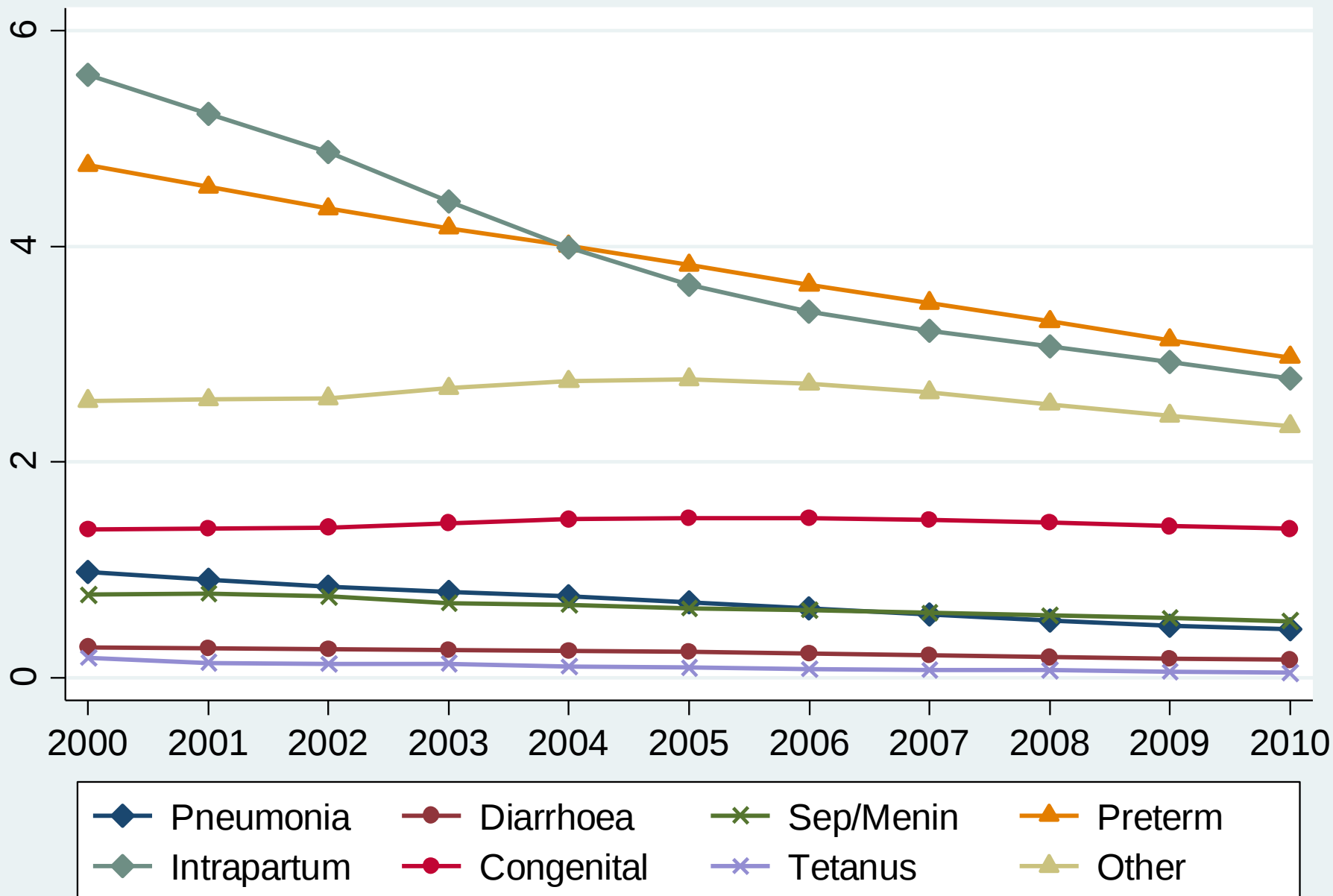
SEARO, 0-1m



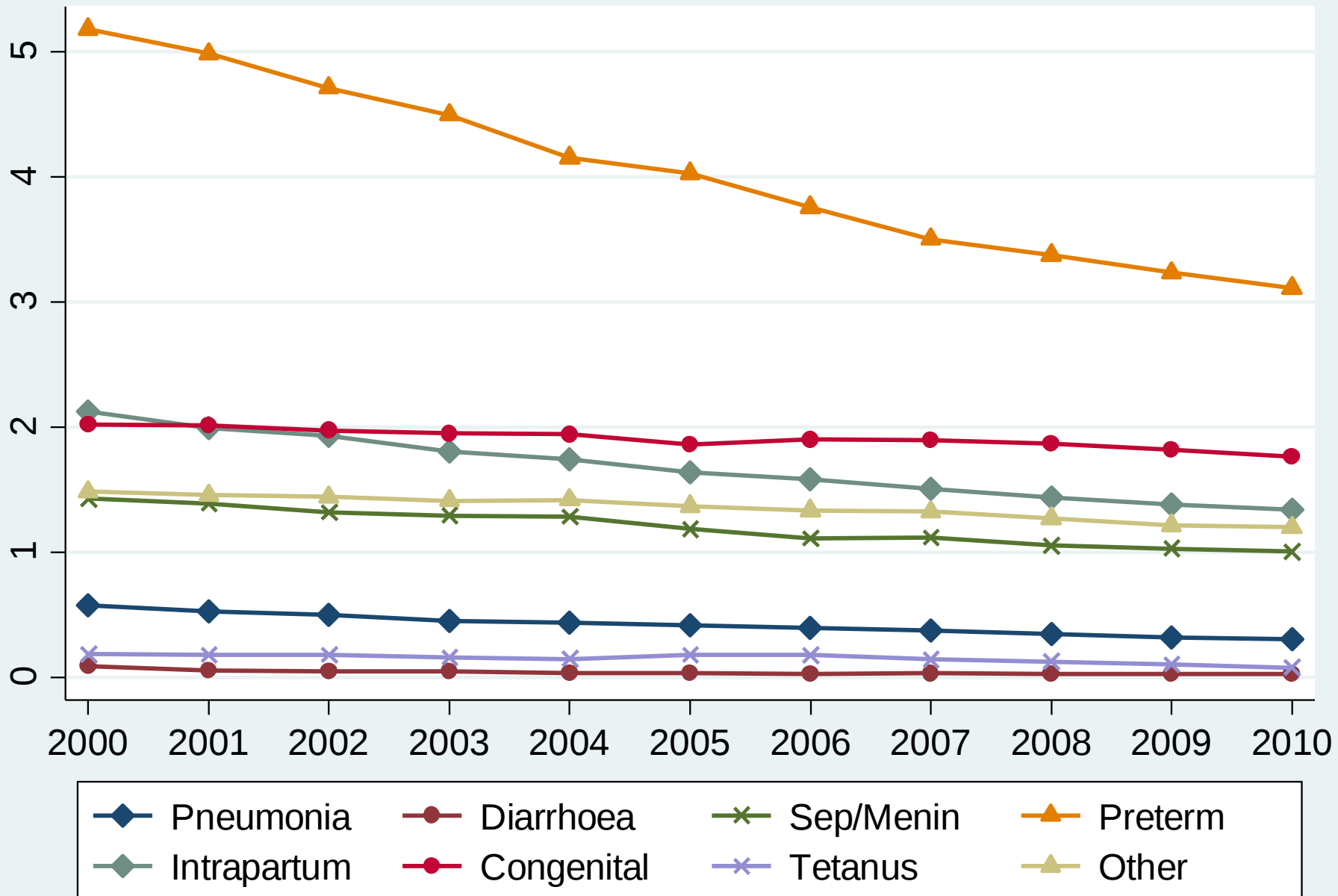
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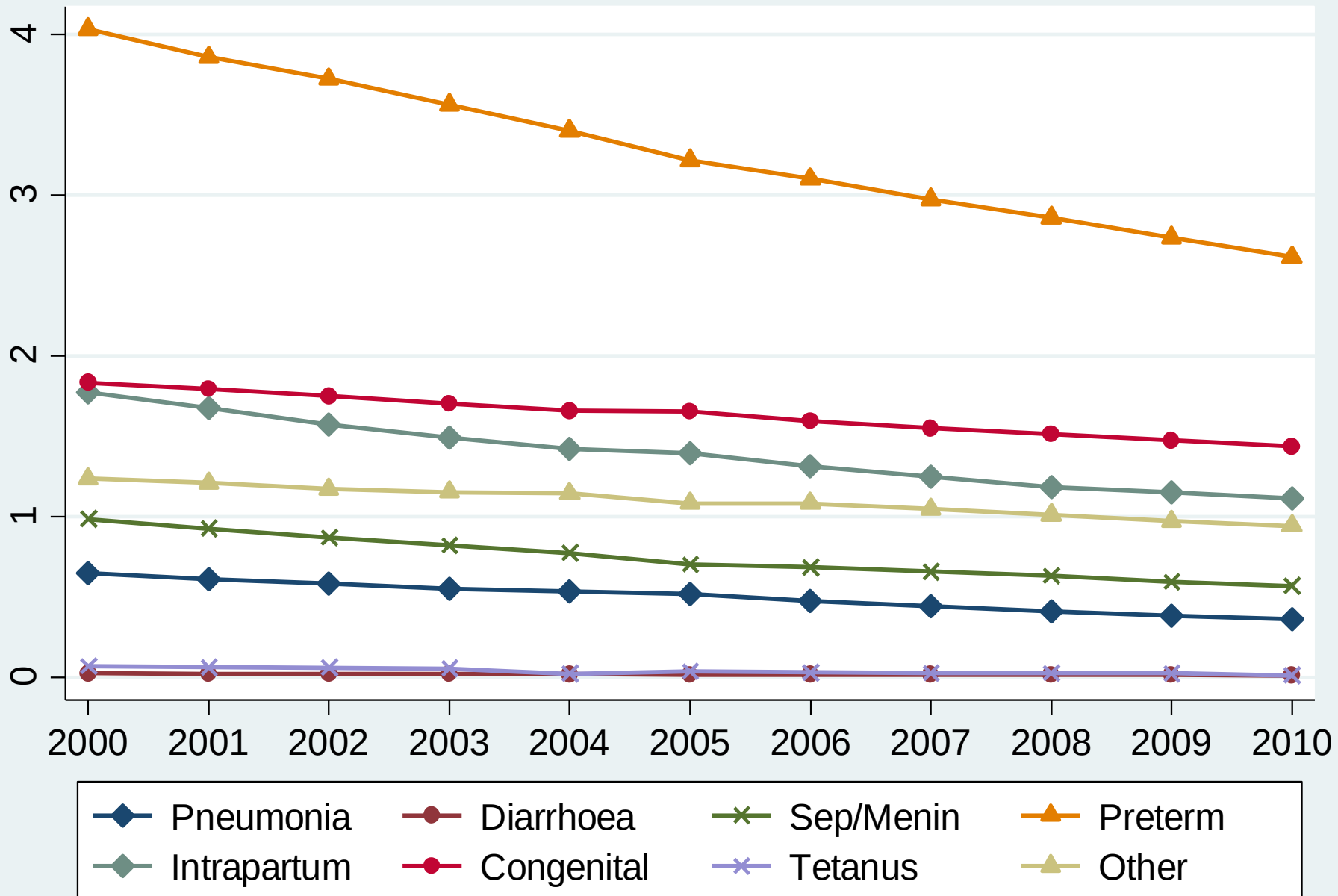
WPRO, 0-1m



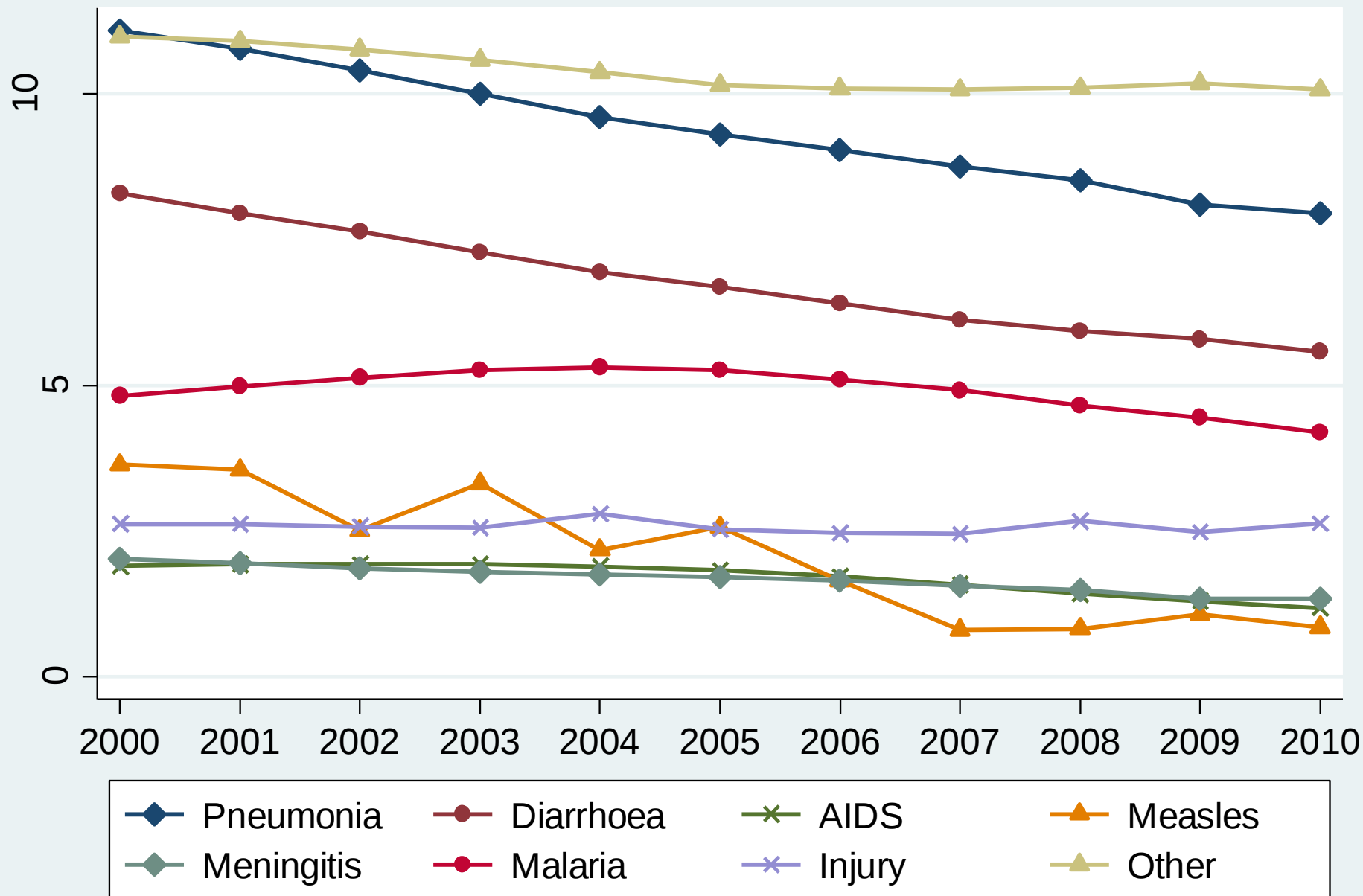
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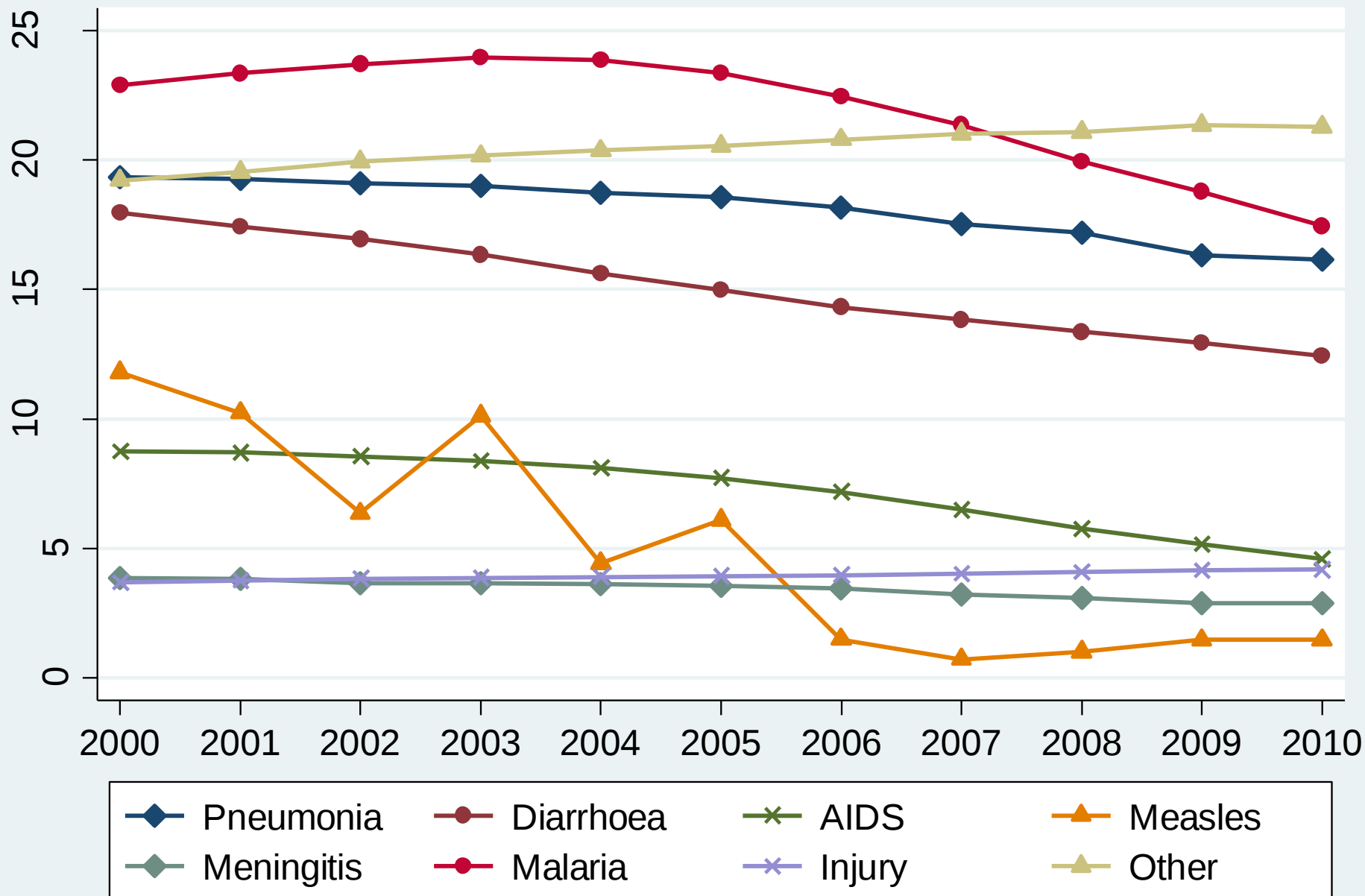
EURO, 0-1m



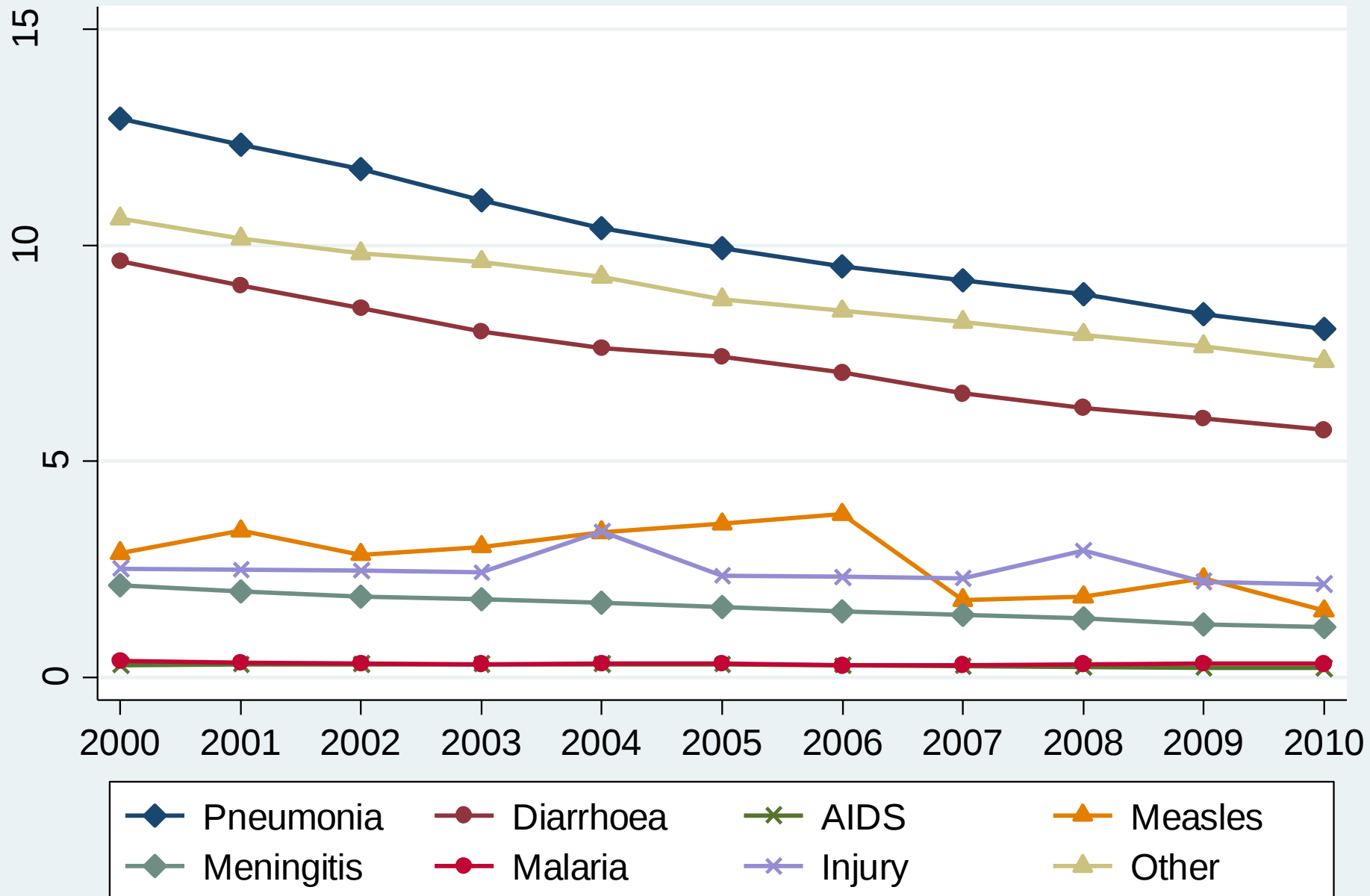
World, 1-59m



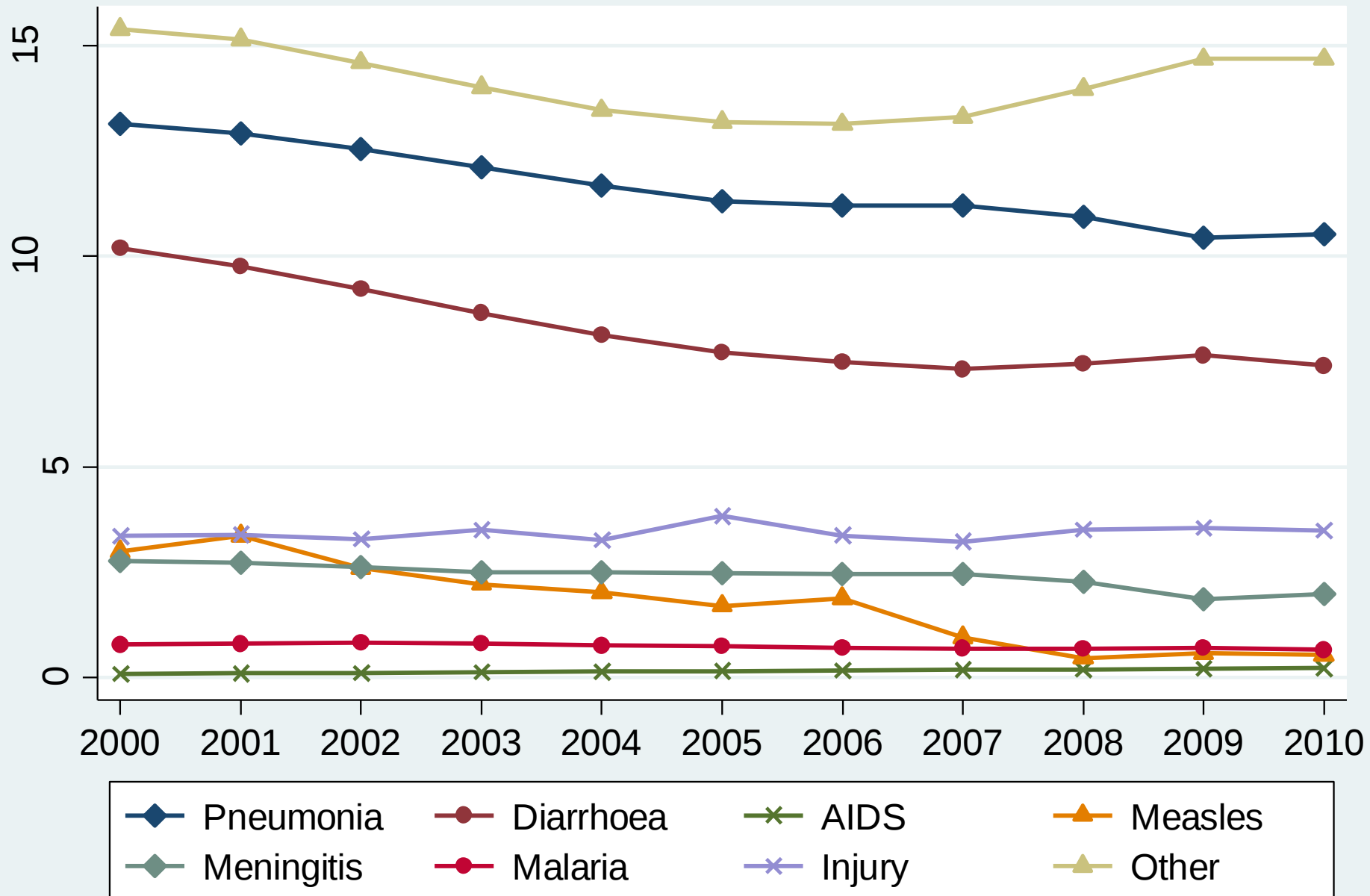
AFRO, 1-59m



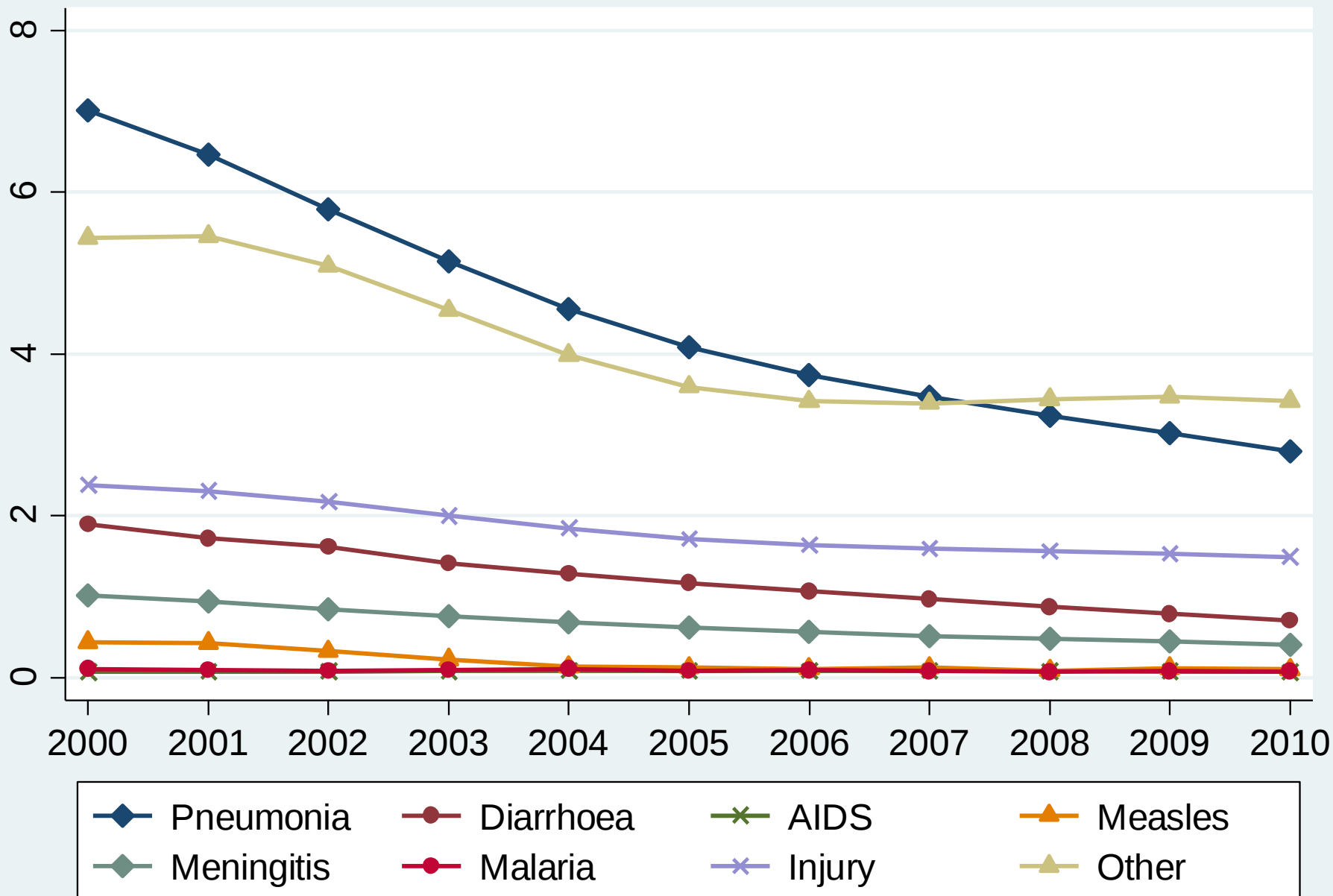
SEARO, 1-59m



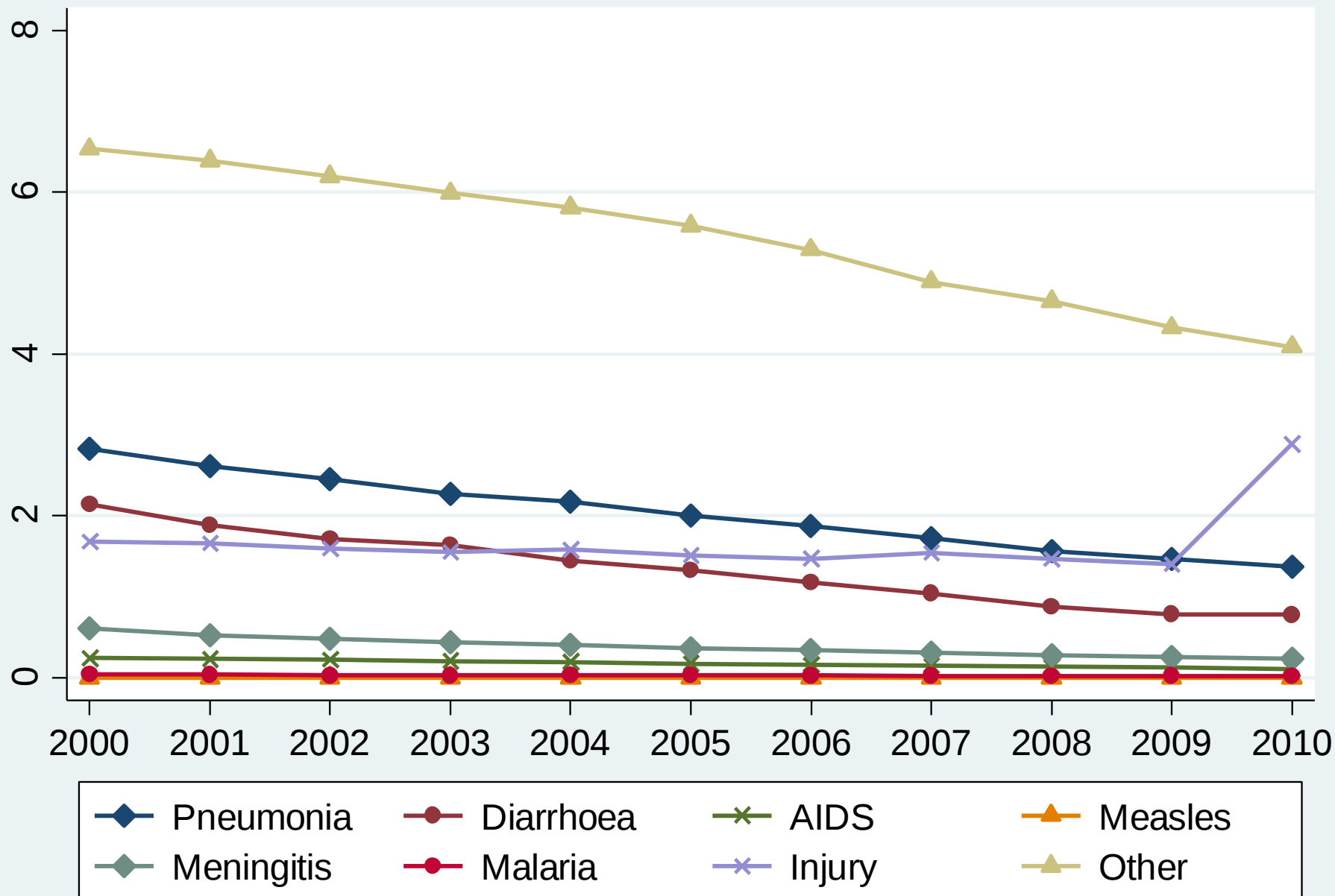
EMRO, 1-59m



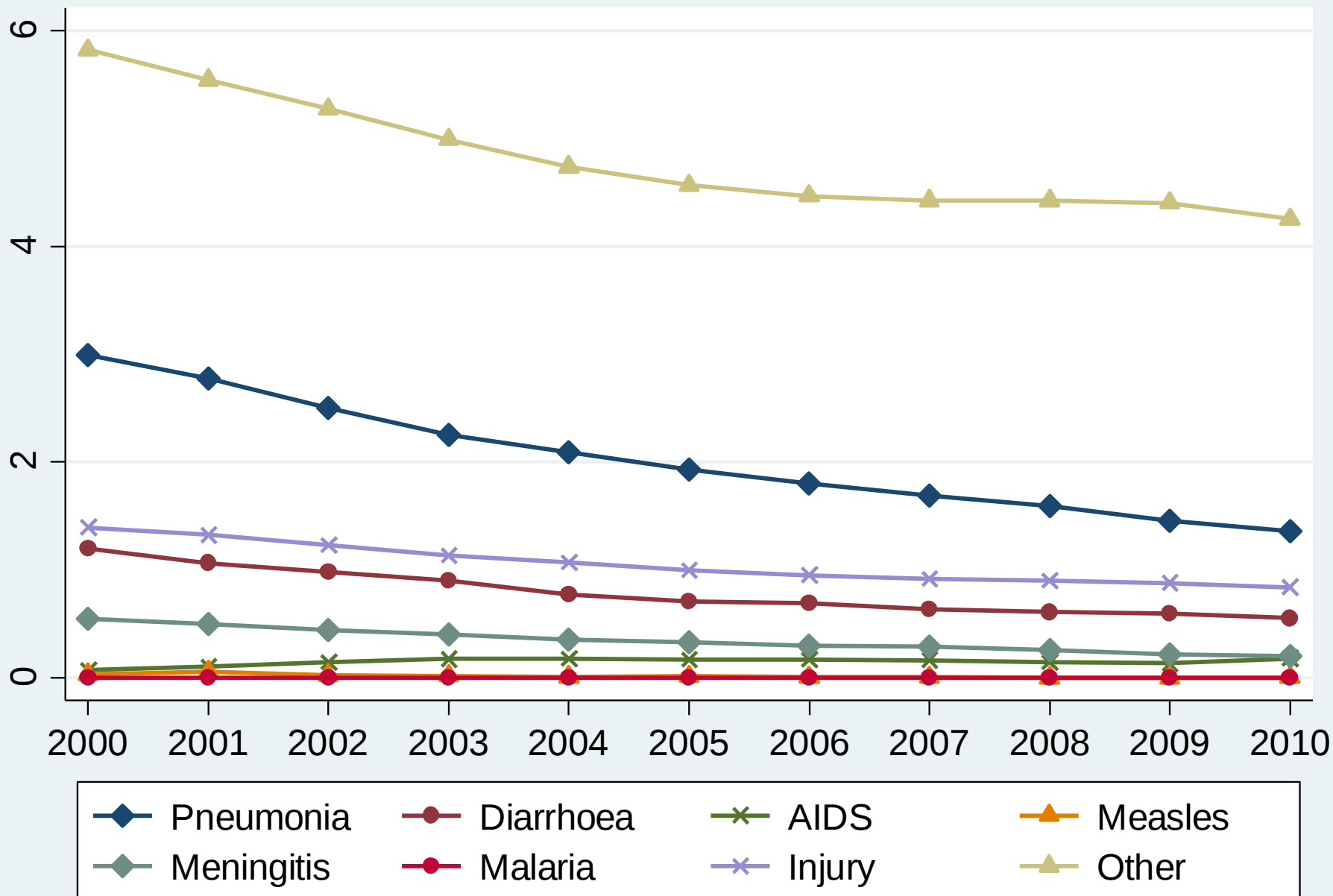
WPRO, 1-59m



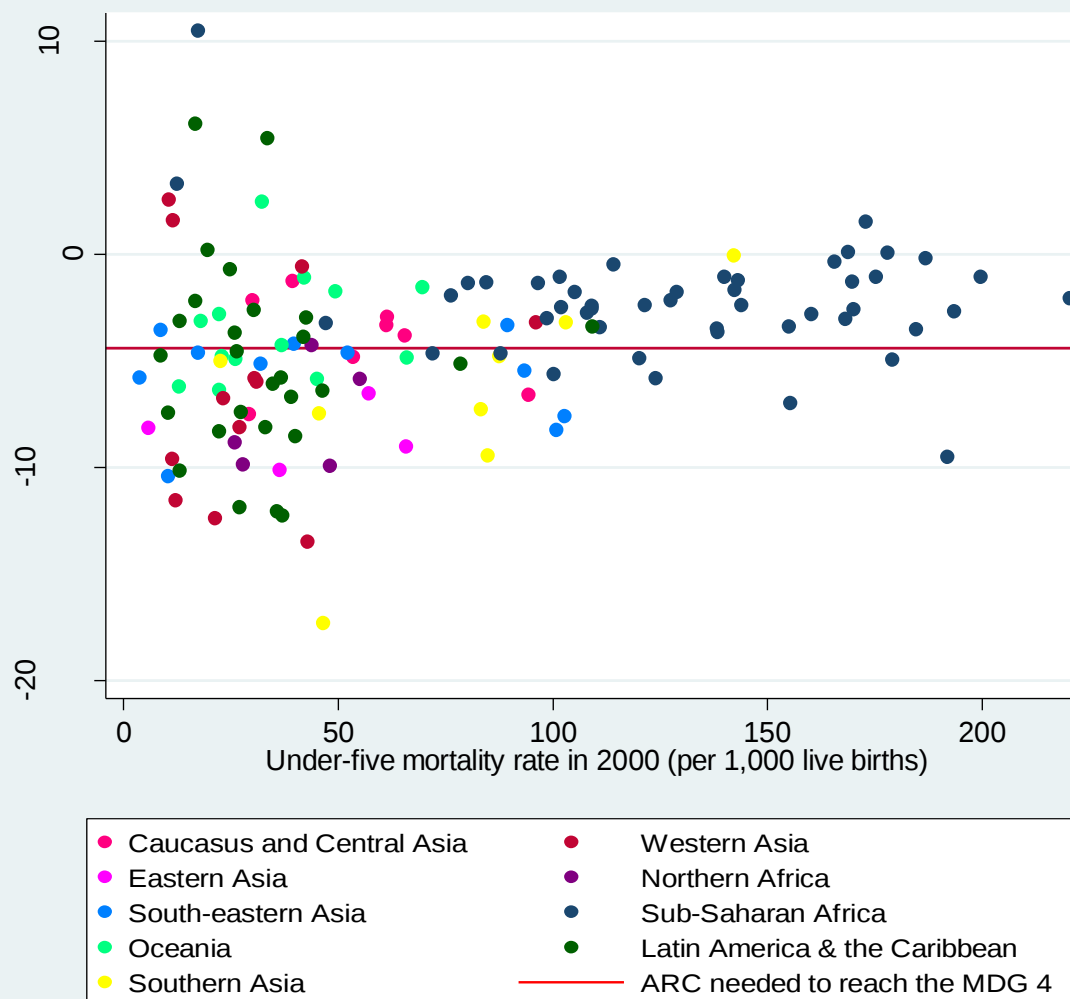
AMRO, 1-59m



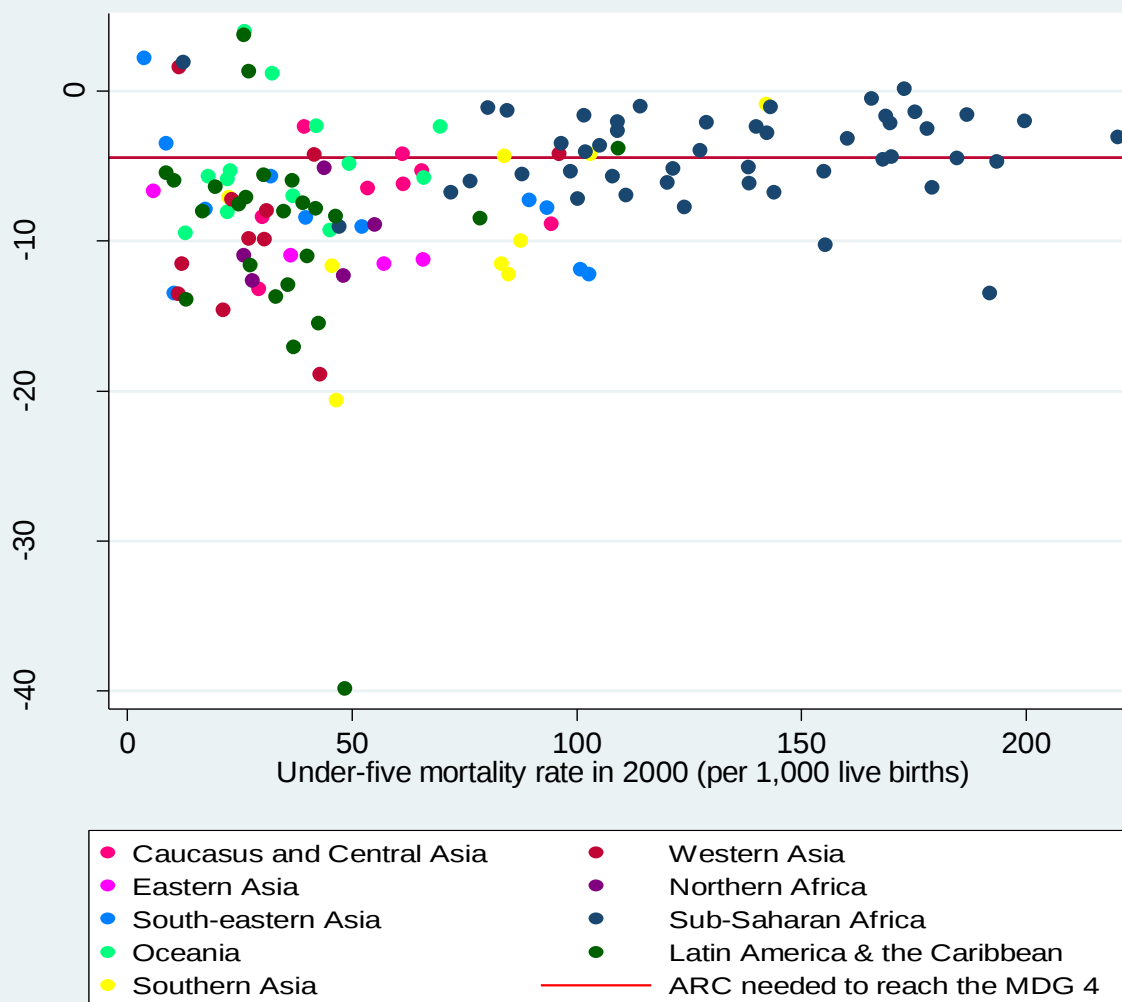
EURO, 1-59m



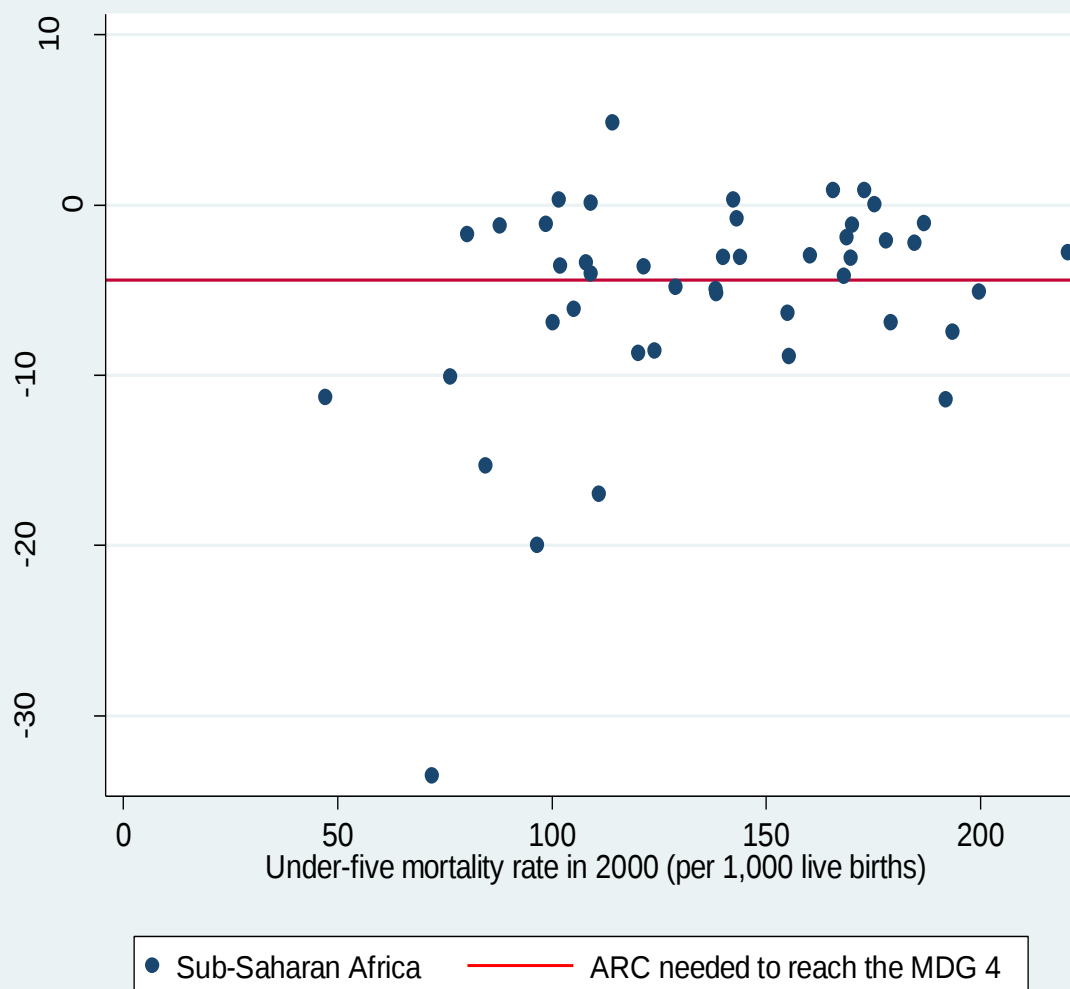
Annual Rate of Change in Pneumonia Deaths Among Children < 5 Years



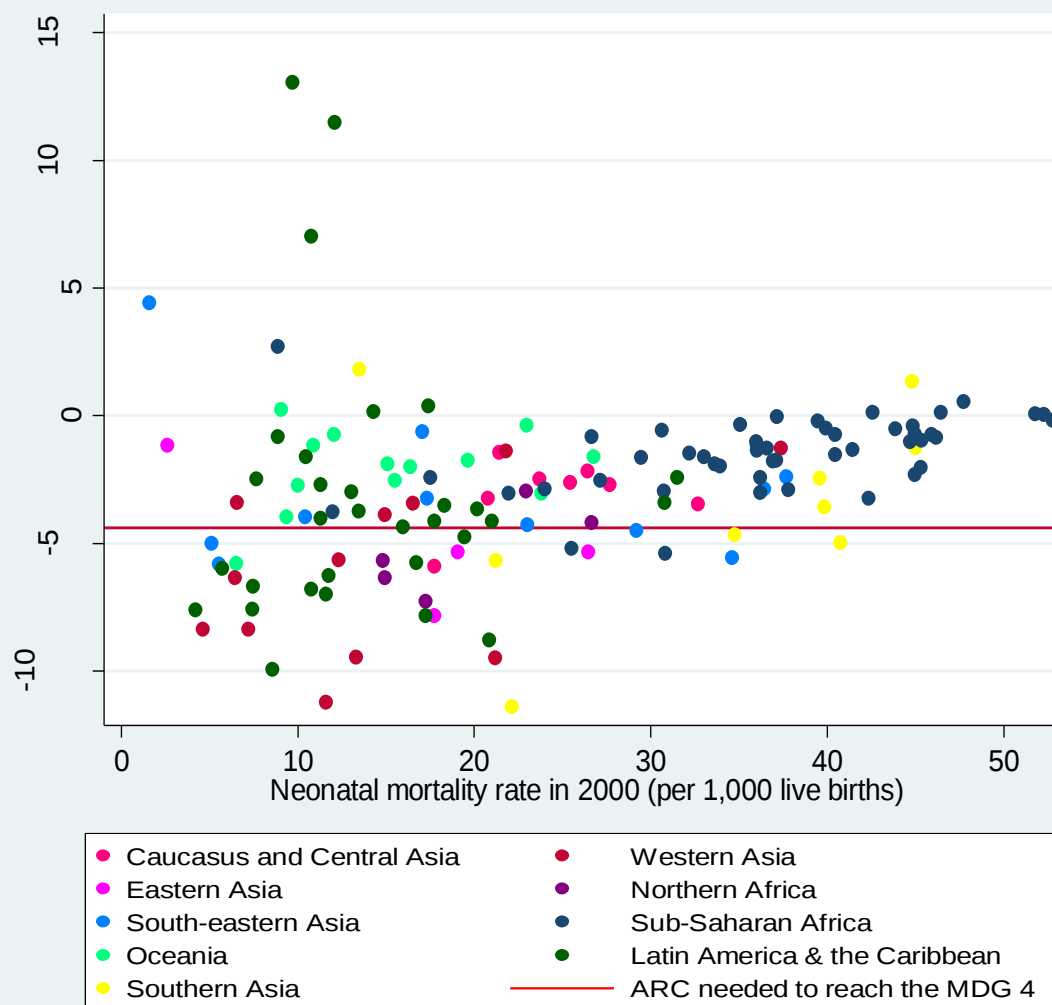
Annual Rate of Change in Diarrhea Deaths Among Children < 5 Years



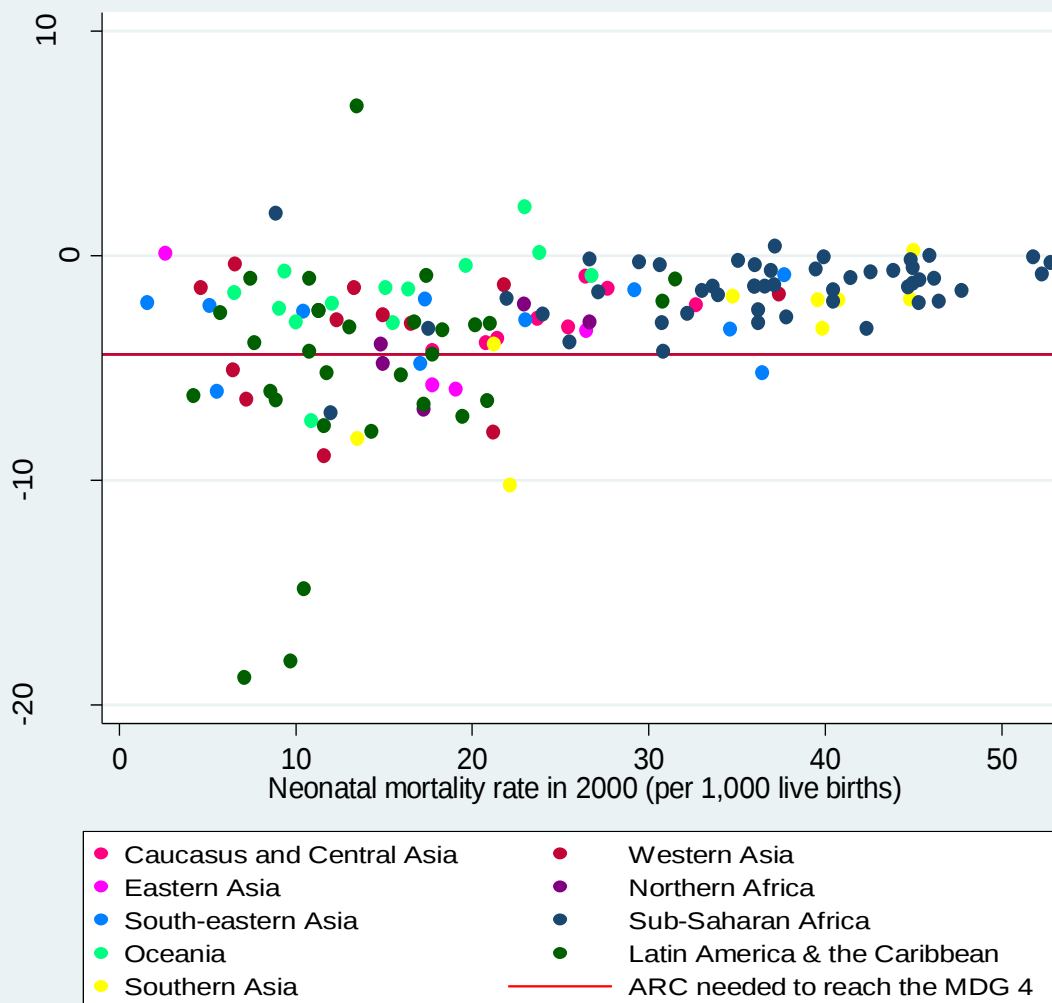
Annual Rate of Change in Malaria Deaths Among Children < 5 Years in Sub-Saharan Africa



Annual Rates of Change in Deaths Due to Intrapartum-Related Complications Among Neonates



Annual Rates of Change in Deaths Due to Preterm Birth Complications Among Neonates



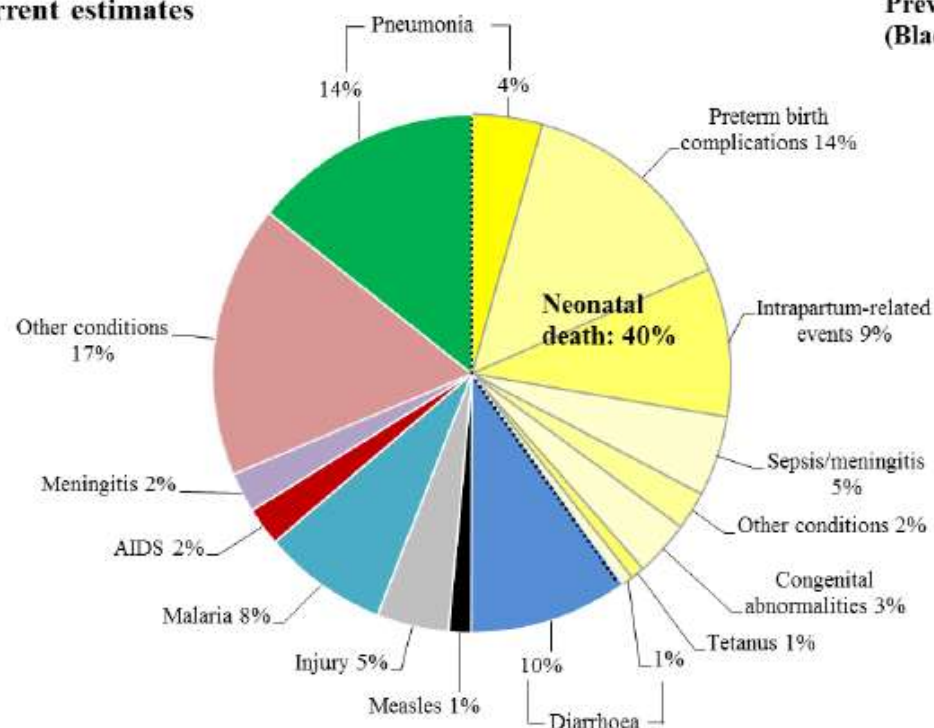
Comparison between this round (R2011) and last round (R2010)

Method Changes Between R2010 and R2011

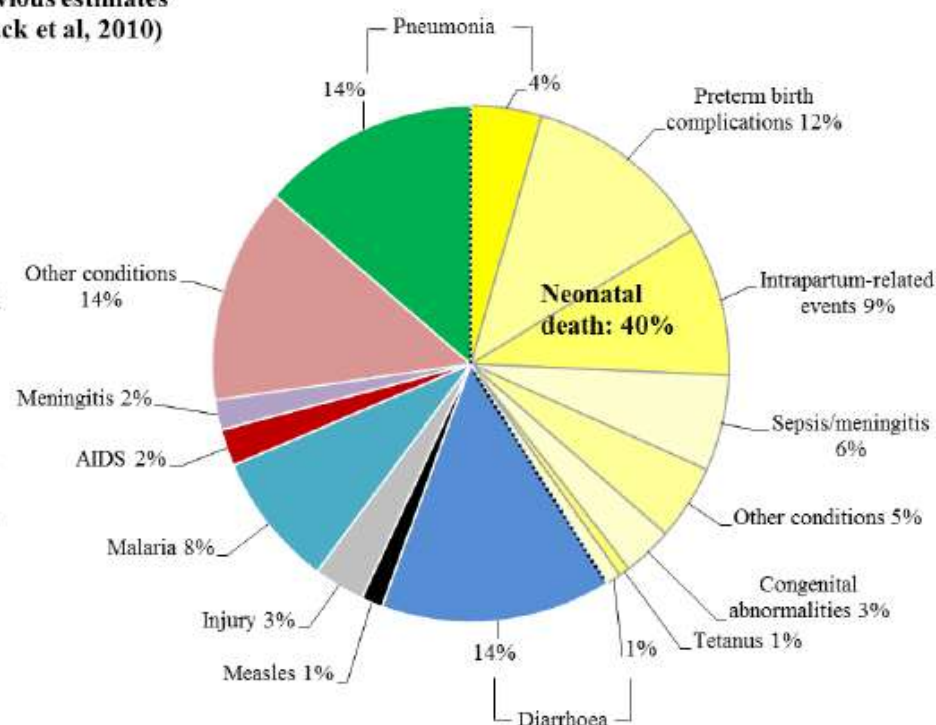
- Improved consistency between methods used to estimate deaths occurred in the two age groups
- Additional systematic review done to include more contemporary VA studies in the VAMCMs.
- Improved cause categories adopted
- Malaria deaths in high transmission countries estimated using the post-neonatal VAMCM vs. exclusive use of a single-cause model
- Measles deaths occurring from outbreaks estimated separate from those caused by endemic transmission
- Million Death Study and a number of Indian VA studies used in a subnational multi-cause model for India
- Improved uncertainty estimation using bootstrapping methods; out-of-sample prediction performed applying cross-validation to conduct model selection

Global Causes of Deaths, 2008

Current estimates



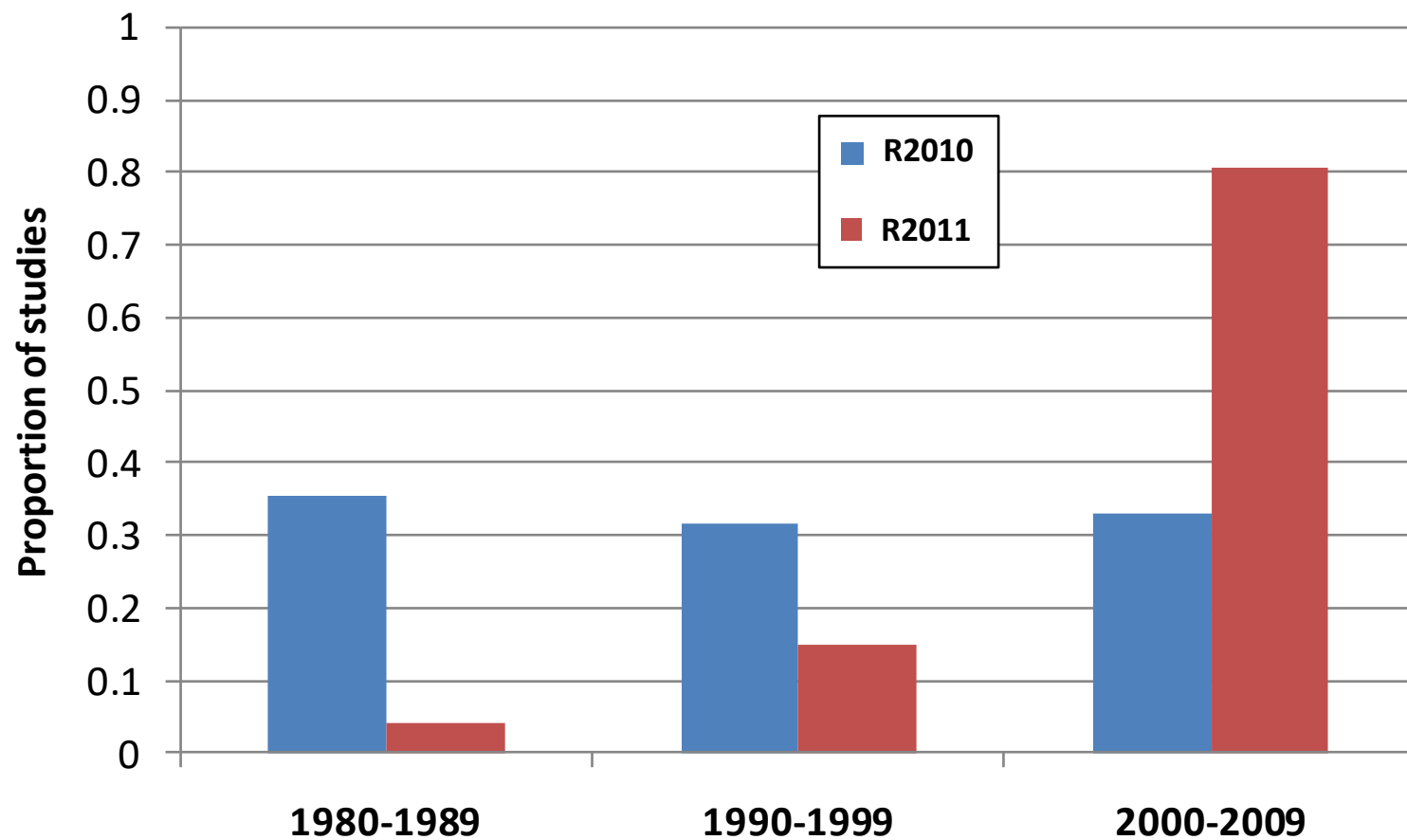
Previous estimates
(Black et al, 2010)



Changes in Estimates Between R2010 and R2011

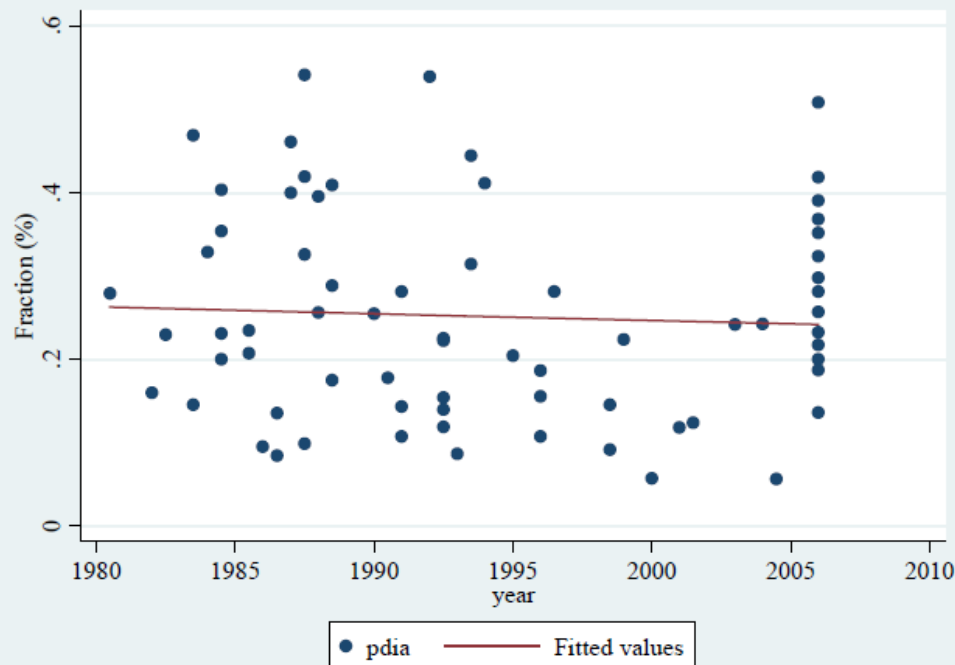
- Most noticeable change is a smaller diarrhea fraction.
- It is a result of newly included VA studies, which were conducted more recently and reported fewer diarrhea deaths (shown in the next two slides).
- Otherwise, results are largely comparable between the two rounds for year 2008.

Distribution of Studies by Mid-study Year

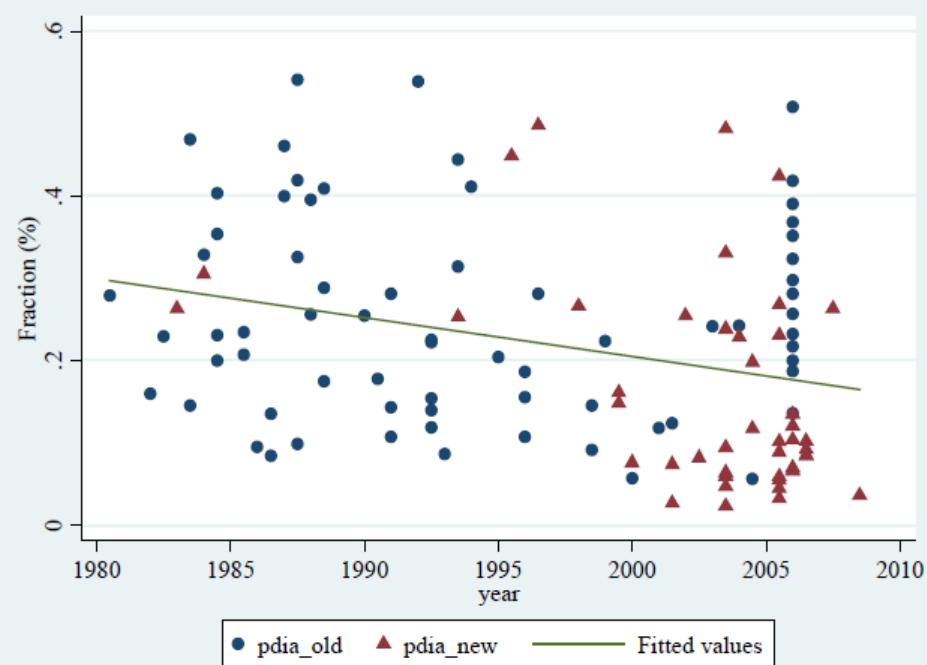


Distribution of Diarrhea Fractions by Year, studies included in the last vs. this round

Studies included in the last round



Studies included in this round



Discussion

- Leading causes of deaths are pneumonia and preterm birth complications.
- Regional variation is striking.
- Only a few causes made enough progress to achieve the MDG 4.
- Nearly all countries face challenge to reduce child deaths from preventable conditions, irrespective of number/cause.

Limitations

- Scarcity of COD data in highest U5MR countries
 - Medically certified vital registration only available for 2.7% of 7.6 million under-5 deaths
 - Evidence gap most acute for sub-Saharan Africa
 - Where mortality rates and need for data are the highest, resources and data are the lowest
- Estimates derived from statistical modeling include substantial uncertainty, but are useful for planning national health and nutrition efforts.

Limitations, cont'd

- Few studies of mortality surveillance in settings where there has been scale-up of child survival interventions.
 - Performed post-hoc adjustment to account for ITN
- Representativeness/lack of availability of study-level covariate data
 - Attempted to obtain via author requests but only 9 replied with changes among 42 newly included studies
- Ability to estimate deaths due to outbreaks is limited (meningitis, measles)

Implications

- Country-specific estimates of major COD should help focus national programs & donor assistance.
- Achievement of MDG 4 is only possible if high numbers of deaths are addressed by maternal, newborn, and child health interventions.
- Additional data are essential for improving future estimates.

Conclusion

- Child mortality has declined by 35% globally from 1990 to 2010 and by more than 50% in many world regions
- High rates of child mortality persist, especially in Southern Asia and sub-Saharan Africa, regions that now have 82% of child deaths
- Two-thirds of child deaths are due to preventable or treatable infectious diseases, especially pneumonia, diarrhea, sepsis/meningitis and malaria
- Deaths in the first month of life now constitute 40% of all child deaths, with complications of premature births and intrapartum-related events as the major causes
- Comparing 2000 with 2010 the number of child deaths decreased by 2 million to 7.6 million with 50% of the decline due to reductions in diarrhea, pneumonia and measles
- The annual rate of change in child deaths has not been sufficient to achieve the MDG4 but for all major causes of death some countries have exceeded this 4.4% rate and achieved rates of 5-10% or even higher

Additional Details Available in Liu et al, 2012

Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000



Li Liu, Hope L Johnson, Simon Cousens, Jamie Perin, Susana Scott, Joy E Lawn, Igor Rudan, Harry Campbell, Richard Cibulskis, Mengying Li, Colin Mathers, Robert E Black, for the Child Health Epidemiology Reference Group of WHO and UNICEF

Summary

Background Information about the distribution of causes of and time trends for child mortality should be periodically updated. We report the latest estimates of causes of child mortality in 2010 with time trends since 2000.

Methods Updated total numbers of deaths in children aged 0–27 days and 1–59 months were applied to the corresponding country-specific distribution of deaths by cause. We did the following to derive the number of deaths in children aged 1–59 months: we used vital registration data for countries with an adequate vital registration system; we applied a multinomial logistic regression model to vital registration data for low-mortality countries without adequate vital registration; we used a similar multinomial logistic regression with verbal autopsy data for high-mortality countries; for India and China, we developed national models. We aggregated country results to generate regional and global estimates.

Findings Of 7·6 million deaths in children younger than 5 years in 2010, 64·0% (4·879 million) were attributable to infectious causes and 40·3% (3·072 million) occurred in neonates. Preterm birth complications (14·1%; 1·078 million, uncertainty range [UR] 0·916–1·325), intrapartum-related complications (9·4%; 0·717 million, 0·610–0·876), and sepsis or meningitis (5·2%; 0·393 million, 0·252–0·552) were the leading causes of neonatal death. In older children, pneumonia (14·1%; 1·071 million, 0·977–1·176), diarrhoea (9·9%; 0·751 million, 0·538–1·031), and malaria (7·4%; 0·564 million, 0·432–0·709) claimed the most lives. Despite tremendous efforts to identify relevant data, the causes of only 2·7% (0·205 million) of deaths in children younger than 5 years were medically certified in 2010. Between 2000 and 2010, the global burden of deaths in children younger than 5 years decreased by 2 million, of which pneumonia, measles, and diarrhoea contributed the most to the overall reduction (0·451 million [0·339–0·547], 0·363 million [0·283–0·419], and 0·359 million [0·215–0·476], respectively). However, only tetanus, measles, AIDS, and malaria (in Africa) decreased at an annual rate sufficient to attain the Millennium Development Goal 4.

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References for Estimates

Levels and trends
in child mortality

UN Interagency Group
for Child Mortality
Estimation

Causes of child
deaths and trends
in cause-specific
mortality

Child Health
Epidemiology Reference
Group of WHO and
UNICEF
(Liu L et al Lancet 2012)

