Group-Based Trajectory Modeling to Understand Trends in Under-Five Mortality

Background

Tragically, an estimated 4.9 million children died before reaching their fifth birthday in 2022 (UNICEF, 2024). Appropriate interventions could have prevented many of these deaths if they reached these children in a timely manner. In this analysis, group-based trajectory modeling was used to analyze under-five mortality data from 78 low- and middle-income countries for 2000–2019. The analysis allowed for the identification of distinct groupings of countries that followed similar trajectories in under-five mortality. Associations between health and non-health factors in under-five mortality among groups and within groups were also studied. The objective was to determine factors that could be particularly important to countries in their efforts to reduce under-five mortality. This policy brief highlights key points from a paper currently under peer review.

Methods

Group-based trajectory modeling was used to identify countries with similar trajectories in under-five mortality over time from 2000 to 2019. Stata's *Traj* program (Jones, 2020) was used to fit models to the under-five outcome data with difference polynomial types and numbers of groups. Model fit statistics, Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), parsimony, and interpretability were used to select the appropriate model of country groupings.

Potential predictors of under-five mortality were identified through a literature review. Then, bivariate analyses were run to understand the factors that predicted group membership. For this analysis, average scores for each covariate were created that examined the association with each covariate and group membership (Nagin, 2016). In order to look at within group differences, covariates were studied as time-varying and were examined for their association with the outcome, under-five mortality, in a bivariate analysis.

Results

Based on model fit statistics, a four-group model was selected as the best fit. Figure 1 includes a spaghetti plot of each individual country's trajectory and also the overall group trajectories in bold. A listing of countries in each group is presented in Table 1. Characteristics of each group are described in Table 2. Group 4, which is the high mortality group, has the steepest slope, indicating the largest decline in under-five mortality.

Figure 1. Trajectories of under-five mortality rates from 2000 to 2019 in individual countries by group membership, with group trajectories overlaid
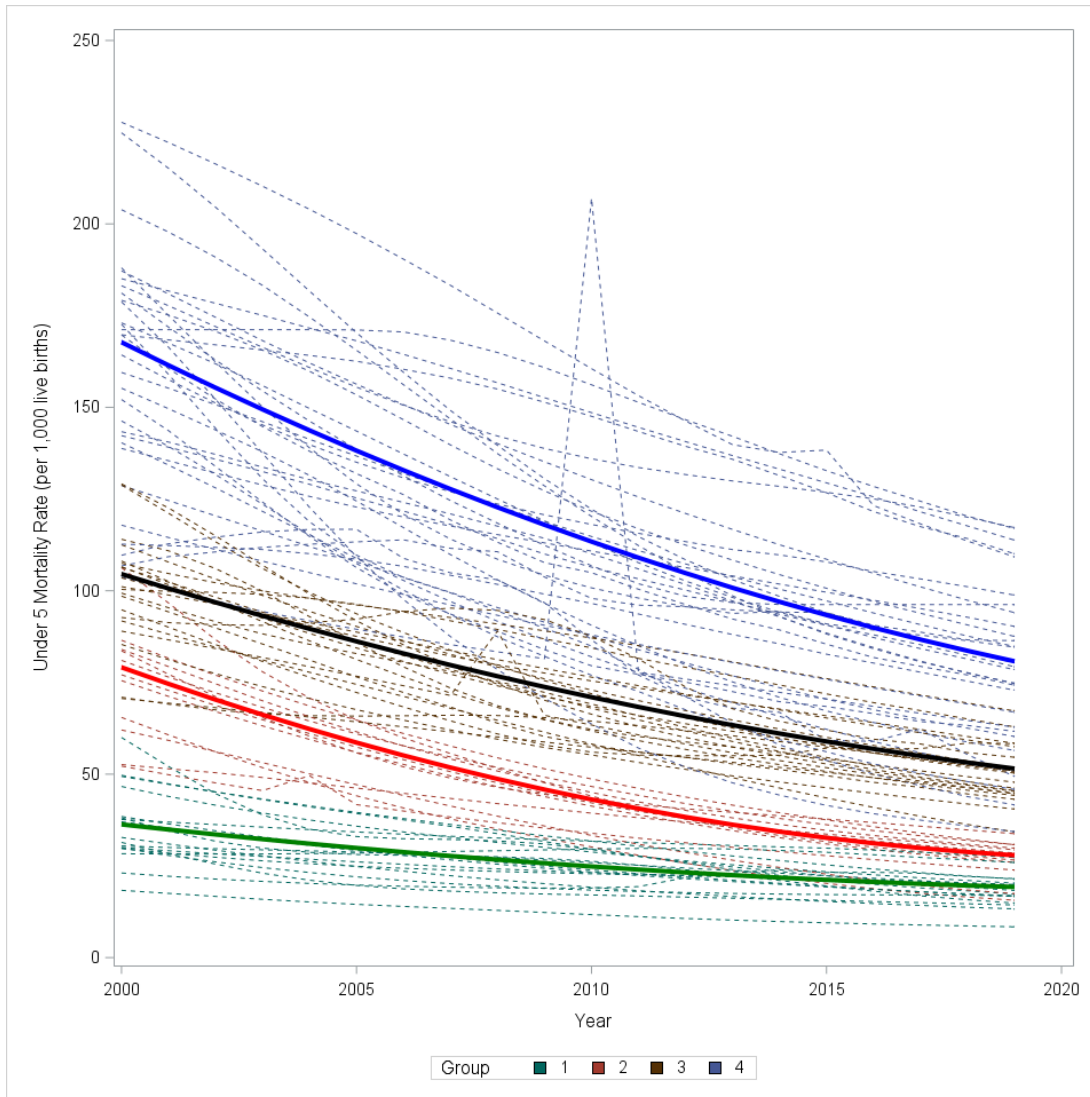

Table 1. Group membership for low- and lower-middle-income countries

Groups	Countries
1 (Low mortality)	Cabo Verde, Democratic People's Republic of Korea, Egypt, El Salvador, Honduras, Kyrgyzstan, Morocco, Nicaragua, Philippines, Republic of Moldova, Solomon Islands, State of Palestine, Syrian Arab Republic, Tunisia, Ukraine, Uzbekistan, Vanuatu, Vietnam
2 (Medium Mortality)	Bangladesh, Bhutan, Bolivia (Plurinational State of), Cambodia, Indonesia, Micronesia, Mongolia, Nepal, Sao Tome and Principe, Tajikistan, Uzbekistan
3 (Medium-high Mortality)	Comoros, Congo, Djibouti, Eritrea, Gambia, Ghana, India, Kenya, Kiribati, Lao People's Democratic Republic, Madagascar, Myanmar, Pakistan, Papua New Guinea, Senegal, Sudan, Timor-Leste, United Republic of Tanzania, Yemen, Zimbabwe
4 (High mortality)	Afghanistan, Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Democratic Republic of the Congo, Eswatini, Ethiopia, Guinea, Guinea-Bissau, Haiti, Lesotho, Liberia, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Sierra Leone, Somalia, South Sudan, Togo

Table 2. Key characteristics of groups of under-five mortality rate trajectories from 2000 to 2019

Characteristic	1 (Low mortality)	2 (Medium Mortality)	3 (Medium-high Mortality)	4 (High mortality)
Average under-five mortality 2000 (per 1,000 live births)	35.9	75.1	100.6	160.6
Average under-five mortality 2019 (per 1,000 live births)	18.4	26.6	49.9	78.5
Average Annual Rate of Decline	0.9	2.4	2.5	4.1
Regions, n(col%)				
East Asia and Pacific	5 (29)	4 (36)	5 (25)	0 (0)
Europe and Central Asia	3 (18)	2 (18)	0 (0)	0 (0)
Latin America and Caribbean	3 (18)	1 (9)	0 (0)	1 (3)
Middle East and North Africa	5 (29)	0 (0)	2 (10)	0 (0)
South Asia	0 (0)	3 (27)	2 (10)	1 (3)
Sub-Saharan Africa	1 (6)	1 (9)	11 (55)	28 (93)
Income groups, (col%)				
Low income	2 (12)	2 (18)	5 (25)	22 (73)
Lower-middle income	15 (88)	9 (82)	15 (75)	8 (27)

Results of the group membership analysis are presented in Table 3. The highest mortality group (4) served as the reference. All the covariates were significant for the comparison of membership in the lowest mortality group (1) to the highest mortality group (4). Five covariates were significant for all three group comparisons (i.e., Group 1 compared to Group 4, Group 2 compared to Group 4, and Group 3 compared to Group 4). These covariates were the fertility rate, percent of the population living with an improved water source, net secondary school enrollment of females, coverage of the third dose of the Diphtheria, Pertussis and Tetanus (DPT3) vaccine, and percent of Gross Domestic Product (GDP) on health expenditures. All these associations were in the expected direction. For example, greater DPT3 coverage was associated with a 16% increased odds of being in Group 1 compared to Group 4. Other factors were significant for some, but not all, of the comparisons, indicating the uniqueness of each group.

Table 3. Bivariate associations of risk factors and group membership

Risk Factor	Group Reference=Group 4 (high mortality)											
	1 (low mortality)				2 (medium mortality)				3 (medium-high mortality)			
	OR	LCL	UCL	p	OR	LCL	UCL	p	OR	LCL	UCL	p
Fertility/Demographics												
Fertility rate (births per woman)	0.03	0.01	0.13	***	0.05	0.01	0.20	***	0.22	0.09	2.55	**
Governance												
Political stability and absence of violence/terrorism	2.96	1.24	7.02	*	3.01	1.14	7.95	*	1.56	0.75	2.07	
Demographics												
Women with access to newspaper, television, and radio at least once per week (%)	1.31	1.12	1.53	***	1.08	1.05	1.43	***	1.08	0.95	1.16	
HIV prevalence (ages 15 to 49)	0.11	0.02	0.52	**	2.25	0.07	0.75	*	1.81	0.91	1.10	
Water, Sanitation, and Hygiene												
Population living in households with an improved water source (%)	1.09	1.02	1.17	**	1.04	1.02	1.20	*	1.04	1.00	1.06	*
Population living in households with an improved sanitation facility (%)	1.12	1.05	1.18	***	1.04	0.99	1.10		1.05	1.00	1.05	*
Nutrition												
Stunting (%)	0.82	0.73	0.91	***	0.92	0.84	1.01		1.00	0.93	1.07	
Wasting (%)	0.73	0.59	0.91	**	1.07	0.91	1.25		1.08	0.94	1.15	
Education												
Mean years of education for females age 20-24	2.57	1.53	4.32	***	1.57	0.99	2.48		1.41	1.03	1.37	*
Net female secondary school enrollment rate (%)	1.22	1.12	1.33	***	1.17	1.08	1.27	***	1.17	1.08	1.09	**
Health Delivery/Health Services												
At least four visits of antenatal care (%)	1.11	1.06	1.17	***	1.02	0.98	1.07		1.02	0.99	1.03	
Births delivered in a health facility (%)	1.10	1.05	1.15	***	1.04	1.00	1.08	*	1.00	0.98	1.03	
Care seeking for children under age 5 with fever (%)	1.06	0.99	1.15		1.02	0.95	1.09		1.00	0.96	1.05	
Post-natal health check for newborn within 2 days (%)	1.07	1.03	1.11	***	1.03	0.99	1.06		1.02	0.99	1.03	
Surviving infants who received first dose of DTP (%)	1.25	1.06	1.49	*	1.15	1.01	1.32	*	1.04	0.98	1.07	
Surviving infants who received third dose of DTP (%)	1.16	1.07	1.26	***	1.18	1.07	1.31	**	1.05	1.00	1.05	*
Health System												
Nurse and midwife density (per 1,000 population)	46.76	4.90	446.30	***	33.65	3.24	349.62	**	3.12	0.26	12.12	
Health Financing												
Out-of-pocket expenditures (% of current health expenditure)	0.99	0.96	1.02		0.99	0.96	1.03		1.00	0.97	1.03	
Domestic general government health expenditure (% of GDP)	2.94	1.44	6.00	**	1.88	0.88	4.00	*	1.46	0.73	1.99	*

Notes. OR=odds ratio; SE=standard error; LCL=lower confidence limit of 95% confidence interval; UCL=upper confidence limit of 95% confidence interval; DTP=Diphtheria, Tetanus, Pertussis. The basis for comparison is trajectory group 4 (the highest mortality group). For political stability and absence of violence and terrorism: range=-2.5 to 2.5 (higher indicates more stable and less violence and terrorism). * p<0.05; **p<0.01; ***p<0.001

Results of the within group analysis are presented in Table 4. Within all four groups, five factors were significantly associated with under-five mortality. Higher fertility and increased out-of-pocket (OOP) expenditures were significantly associated with increased mortality. Increases in childbirth in a health facility, political stability, and percent of GDP on health expenditures were all negatively associated with under-five mortality. Once again, several factors were significant for only some of the groups, indicating the importance of looking at distinct groups of countries.

Table 4: Group-based trajectory bivariate models: coefficients (standard error) (n=78^): modeling within groups

	Group Model			
	1 (Low Mortality)	**2 (Medium Mortality)**	**3 (Medium-High Mortality)**	**4 (High Mortality)**
Number of countries	17	11	20	30
Group Prevalence	21%	17%	24%	38%
Bivariate Models: Variables (sample size)	*Coefficients (Standard Error)*			
Fertility rate (n=77)	3.50 (0.31)***	10.95 (0.38)***	9.35 (0.44)***	14.88 (0.93)***
DTP 3 vaccine (n=77)	-0.01 (0.03)	-0.41 (0.03)***	-0.40 (0.04)***	-0.83 (0.05)***
Political stability (n=77)	- 2.33 (0.47)***	-6.93 (0.45)***	-5.72 (0.44)***	-11.22 (1.20)***
Stunting (n=74)	0.49 (0.10)***	0.76 (0.05)***	0.38 (0.13)**	0.43 (0.33)
Wasting (n=74)	0.32 (0.26)	0.68 (0.12)***	-0.27 (0.32)	2.60 (0.50)***
ANC 4 visit (n=75)	-0.15 (0.07)*	-0.27 (0.05)***	-0.03 (0.06)	-0.01 (0.13)
Births in health facilities (n=77)	-0.36 (0.04)***	-0.24 (0.01)***	-0.38 (0.06)***	-0.90 (0.11)***
Nurse and midwives density (n=76)	-0.52 (0.26)*	-1.36 (0.12)***	-1.92 (0.78)*	-4.57 (3.72)
OOP expenditures (n=75)	0.06 (0.03)*	0.24 (0.02)***	0.34 (0.02)***	0.70 (0.05)***
% GDP on health expenditures (n=75)	-3.14 (0.28)***	-4.01 (0.53)***	-2.08 (0.26)***	-5.42 (1.15)***

*p<0.05,**p<.01,***p<0.001

^Some observations (countries) dropped in bivariate models due to missing covariate data

Conclusion

In this analysis, four distinct groups of countries were identified based on their under-five mortality trajectory. All groups achieved reductions in under-five mortality from 2000–2019, with the highest mortality group (4) having the greatest decline. Two separate analyses were also conducted to understand differences between groups and within countries. There were several factors, both health and non-health, that were significant for all comparisons or groups. Notably, fertility and percent of GDP on healthcare were important for all comparisons and all groups. Other factors were significant for some of the comparisons or groups, indicating the importance of doing this analysis by group. Policy makers, program implementors, and donors could use findings from group-based trajectory modeling to identify interventions that have the most potential to improve an outcome in specific countries.

References

Jones, B.L. (2020). Traj: group-based modeling of longitudinal data. https://www.andrew.cmu.edu/user/bjones/. Accessed June 17, 2020.

Nagin, D.S., Jones, B.L., Ria, V., Passos, L., & Tremblay, R.E. (2016). Group-based multi-trajectory modeling. *Stat Methods Med Res*. 0(0):1. doi:10.1177/096228021667308

UNICEF. (2024). Levels and Trends in Child Mortality. Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation.

Citation

For more information

D4I supports countries to realize the power of data as actionable evidence that can improve programs, policies, and—ultimately—health outcomes. We strengthen the technical and organizational capacity of local partners to collect, analyze, and use data to support sustainable development. For more information, visit https://www.data4impactproject.org/

www.data4Impactproject.org