New perspectives in MATHEMATICAL AND STATISTICAL METHODS FOR ACTUARIAL SCIENCES AND FINANCE
June 27 & 28, 2025

Recent Transformations in Global Life Expectancy: A Trajectory Perspective

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Abstract

This paper analyzes recent structural changes in global life expectancy trajectories using breakpoint detection methods and linear deterministic trend models. Three primary metrics are computed: the post-break trend slope (β_2), the change in slopes ($\Delta\beta$), and the recency of the last detected breakdate (Δt_{2024}). The study further compares these metrics across different economy-type and income-level country groups, highlighting significant actuarial and economic implications.

Introduction

Global life expectancy at birth ($e_{0,t}$) has generally increased. However:

* Countries exhibit diverse trajectories over time;
* These paths are often nonlinear, with plateaus or accelerations.

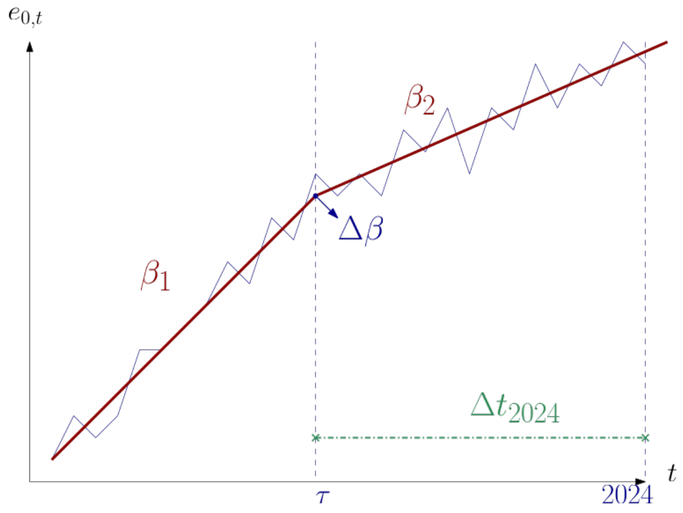
We detect and quantify structural breaks using the Bai and Perron (2003) model, then we take the last breakdate $\bar{\tau}$.

Objectives:

* Detect structural changes in $e_{0,t}$ time series for 242 countries;
* Compute three descriptive metrics post-break;
* Compare across income and economy groupings.

Metrics:

* Post-break slope: β_2
* Slope change: $\Delta\beta = \beta_2 - \beta_1$
* Time since last break: $\Delta t_{2024} = 2024 - \bar{\tau}$



Methodology

Step 1: Structural Break Detection

$$e_{0,t} = \beta_j t + u_t \quad \text{for } t \in (\tau_{j-1}, \tau_j]$$

* $e_{0,t}$: life expectancy at time t;
* β_j: slope of the trend in segment j;
* u_t: error term;
* τ_j: breakpoints dividing regimes.

Residual minimization:

$$SSR = \sum_{j=1}^{m+1} \sum_{t=\tau_{j-1}+1}^{\tau_j} (e_{0,t} - \beta_j t)^2$$

Step 2: Metrics

$$\Delta\beta = \beta_2 - \beta_1, \quad \Delta t_{2024} = 2024 - \bar{\tau}$$

Step 3: Comparative Analysis

* Regress metric on group dummies:

$$y_{f,i} = \alpha + \sum \delta_g \mathbb{1}(G_{f,i} = g) + \varepsilon$$

* Welch's t-test and Bonferroni correction:

$$p_{\text{adj}} = \min(p \cdot K, 1)$$

Summary Statistics

Distribution by Income Level

	Developed	Developing	Emerging	Least Developed	Total
High income	51	27	2	1	81
Low income	0	2	2	38	42
Lower middle income	0	38	9	13	60
Upper middle income	5	37	15	2	59
Total	56	104	28	54	242

Statistical Results

Mean **Comparison**

Income Group	β_2	$\Delta\beta$	Δt_{2024}
High Income	0.075***	-0.227***	16.948***
	(0.011)	(0.023)	(0.964)
Upper Middle Income	0.126***	-0.257***	20.164***
	(0.021)	(0.034)	(1.265)
Lower Middle Income	0.227***	-0.176***	21.071***
	(0.029)	(0.043)	(1.306)
Low Income	0.413***	**0.114**	20.243***
	(0.058)	**(0.074)**	(1.809)

Economy–Group Means

Economy Group	β_2	$\Delta\beta$	Δt_{2024}
Developed	0.067***	-0.157***	15.000***
	(0.010)	(0.018)	(0.583)
Emerging	0.140***	-0.307***	21.290***
	(0.028)	(0.051)	(2.100)
Developing	0.152***	-0.236***	20.229***
	(0.020)	(0.028)	(0.995)
Least Developed	0.385***	**0.042**	21.163***
	(0.047)	**(0.066)**	(1.606)

Regression Comparison

Income-Level Dummies

	Δt_{2024}	β_2	$\Delta\beta$
High income	16.95***	0.090***	-0.204***
	(1.09)	(0.024)	(0.035)
Upper middle income	3.22·	0.049	-0.031
	(1.65)	(0.036)	(0.052)
Lower middle income	4.12*	0.137***	0.032
	(1.69)	(0.036)	(0.054)
Low income	3.30·	0.323***	0.301***
	(1.92)	(0.041)	(0.061)

Economy-Type Dummies

	Δt_{2024}	β_2	$\Delta\beta$
Developed	15.00***	0.083**	-0.132**
	(1.27)	(0.028)	(0.042)
Developing	5.23**	0.073*	-0.094·
	(1.60)	(0.035)	(0.052)
Emerging	6.29**	0.076	-0.145*
	(2.12)	(0.047)	(0.069)
Least Developed	6.16**	0.303***	0.163**
	(1.85)	(0.041)	(0.060)

Pairwise Mean Comparisons

Pairwise (Income)

β_2

	Low	Lower Mid	Upper Mid	High
Low	—	0.006**	0.000***	0.000***
Lower Mid	0.006**	—	0.020*	0.000***
Upper Mid	0.000***	0.020*	—	0.038*
High	0.000***	0.000***	0.038*	—

$\Delta\beta$

	Low	Lower Mid	Upper Mid	High
Low	—	0.003**	0.000***	0.000***
Lower Mid	0.003**	—	0.267	0.522
Upper Mid	0.000***	0.267	—	0.467
High	0.000***	0.522	0.467	—

Δt_{2024}

	Low	Lower Mid	Upper Mid	High
Low	—	0.712	0.971	0.114
Lower Mid	0.712	—	0.619	0.013*
Upper Mid	0.971	0.619	—	0.045*
High	0.114	0.013*	0.045*	—

Pairwise (Economy)

β_2

	Least Dev	Developing	Developed	Emerging
Least Dev	—	0.000***	0.000***	0.000***
Developing	0.000***	—	0.001**	0.918
Developed	0.000***	0.001**	—	0.012*
Emerging	0.000***	0.918	0.012*	—

$\Delta\beta$

	Least Dev	Developing	Developed	Emerging
Least Dev	—	0.001**	0.018*	0.000***
Developing	0.001**	—	0.007**	0.402
Developed	0.018*	0.007**	—	0.013*
Emerging	0.000***	0.402	0.013*	—

Δt_{2024}

	Least Dev	Developing	Developed	Emerging
Least Dev	—	0.622	0.001**	0.962
Developing	0.622	—	0.000***	0.650
Developed	0.001**	0.000***	—	0.007**
Emerging	0.962	0.650	0.007**	—

Visual Comparisons

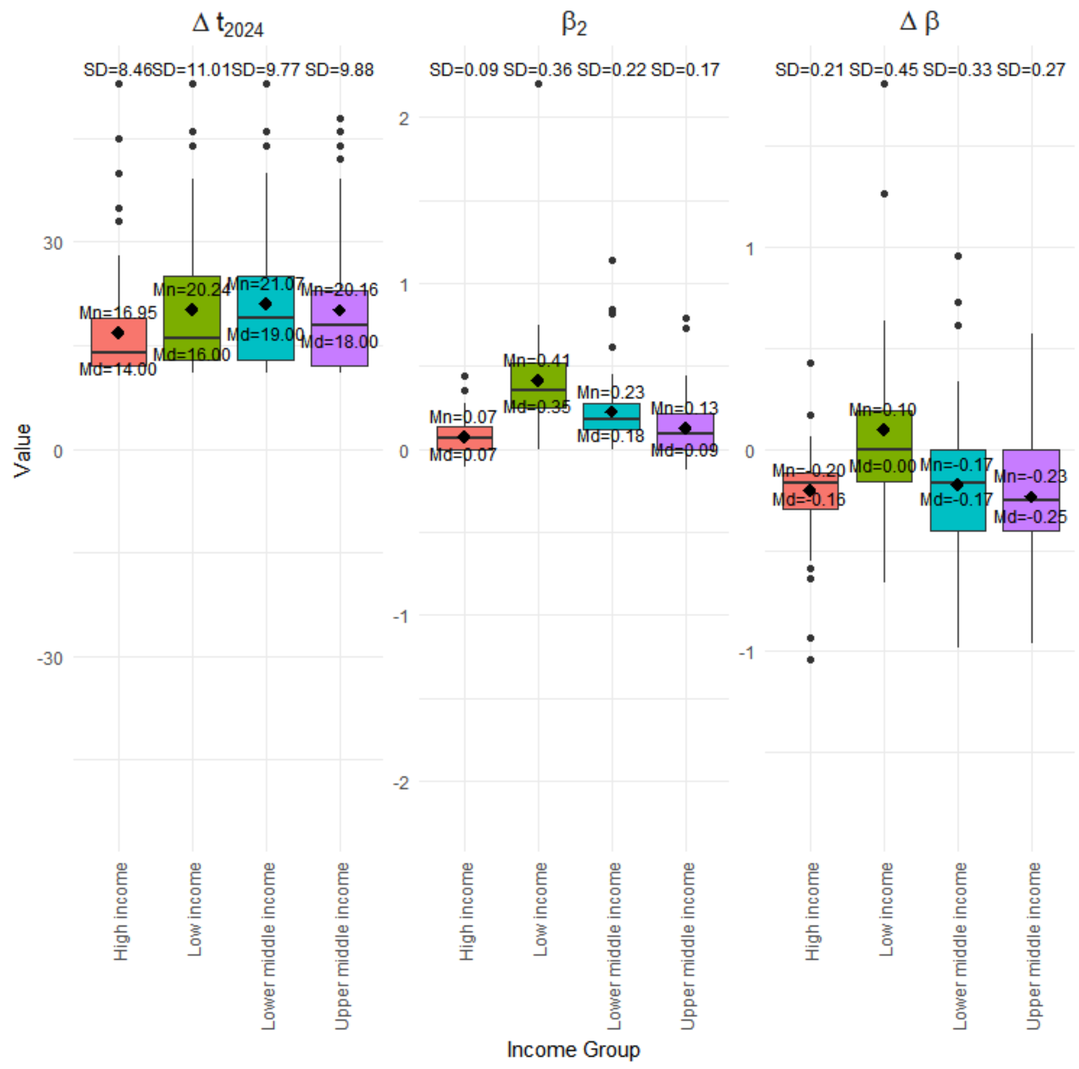


Figure: Income-based comparison boxplots

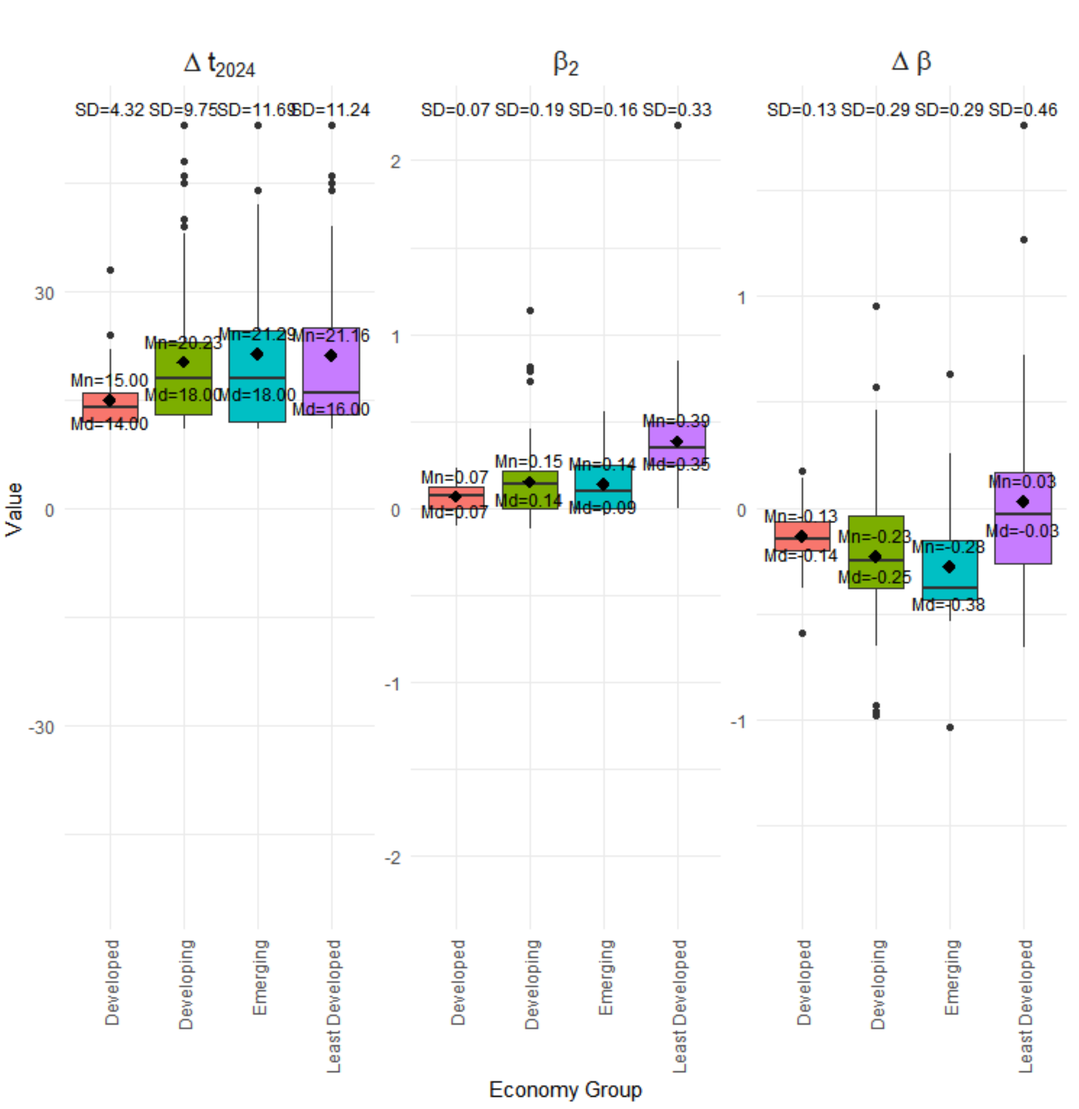


Figure: Economy-based comparison boxplots

Conclusions & Further Research

* The β_2 gradient increases as income decreases, indicating faster post-break gains in low-income countries.
* Greater dispersion in $\Delta\beta$ among less developed economies signals structural heterogeneity.
* Developed countries show shorter Δt_{2024}, suggesting earlier trend stabilization.
* Low-income groups exhibit high volatility, with wide interquartile ranges and standard deviations.
* This variability reflects divergent national dynamics, complicating actuarial projections.
* Accelerating longevity may lead to under-reserving in insurance and pension systems.
* Actuarial models must account for country-specific demographics and break patterns.
* Global risk pooling enhances diversification; subsidies may support equity.
* Break-aware forecasting improves reliability; trend monitoring enables timely model revisions.
* Future work could apply broken-stick models to test individual country breakpoints.
* Comparative analysis by geographical region may reveal further structural differences.