

LONGEVITY 21

Decomposing Gender Differences in Cancer Mortality:

Incidence, Survival, and County-Level Variation in Taiwan

Actuarial Insights from Taiwan Cancer Registry & NHI Data (2000–2024)

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MORTALITY SHIFT

Acute -> Chronic

Life expectancy up; cancer #1 cause

DEMOGRAPHIC WAVE

1946-1960 Cohort

Turning 65+; crude rate doubled

5-YR SURVIVAL

49.3% M | 65.6% F

Massive chronic survivor pool

CLAIMS IMPACT

101.8B NHI Points

+482% surge; ALM hedging failure

Executive Agenda:

Part I: Macro Longevity & Mortality Transition

- **Focus:** From acute infectious death to chronic cancer survivorship; life table YLL.

Part II: Demographic Tidal Waves & Screening

- **Focus:** The 1946–1960 baby boom entering peak incidence; statutory screening shocks.

Part III: Stochastic Actuarial Diagnostics

- **Focus:** Poisson Lee-Carter formulation, overdispersion ($\phi=3\sim 4.15$), and SVD APC.

Part IV: Healthcare Financing Drag & Insurer Solvency

- **Focus:** 100-billion NHI points, breakdown of natural hedging, and co-financing.

TAKEAWAY: A structured actuarial journey from demographic causes to financial solvency impacts.

Part I: 21st Century Mortality Transition

Top 5 Leading Causes of Death in Taiwan (1935)

Rank	1	2	3	4	5
Leading Cause	Pneumonia	Gastroenteritis	Other Infectious & Parasitic	Respiratory Tuberculosis	Congenital Debility
% of Total Deaths	21.1%	12.2%	7.1%	6.8%	6.0%

Top 5 Leading Causes of Death in Taiwan (2010)

Rank	1	2	3	4	5
Leading Cause	Malignant Neoplasms (Cancer)	Cerebrovascular Disease (Stroke)	Heart Diseases	Pneumonia	Diabetes Mellitus
% of Total Deaths	28.4%	10.8%	7.0%	6.2%	5.7%

Source: 'Taiwan's Demographic & Social Transitions' and Ministry of Health and Welfare (MOHW).

Key Transition Drivers

- **1935 (Infectious Era):** Pneumonia (21.1%), Enteritis (12.2%), TB (6.8%) caused ~47% of deaths. Rapid mortality in youth.
- **2010 (Chronic Era):** Malignant Neoplasms (28.4%), Stroke (10.8%), Heart Disease (7.0%) dominate. Cancer #1 for 40+ years.
- **Actuarial Impact:** Postponed mortality shifts life from acute fatal events to multi-decade medical maintenance.

TAKEAWAY: Conquering acute infections created the modern chronic cancer survivorship paradigm.

Part I: Cause-Eliminated Life Tables & Years of Lost Life

Gains at Birth (Age 0)

- **Male Potential Gains:** Eliminating cancer adds +3.84 to +4.75 years to male life expectancy (77.4 -> 81.3 in 2024).
- **Female Potential Gains:** Eliminating cancer adds +2.95 to +3.55 years for females (84.3 -> 87.5 in 2024).
- **Sex Disparity:** Male life loss significantly exceeds female due to higher tumor aggressiveness.

Senior Residual Burden (Age 65)

- **Male Seniors (65+):** Eliminating cancer yields +2.68 additional years of remaining life (18.35 -> 21.03 years).
- **Female Seniors (65+):** Yields +2.18 additional years for 65-year-old females (22.41 -> 24.59 years).
- **Annuity Risk Ceiling:** Sets theoretical upper bound of pension duration under complete oncology cure.

Part II: The Post-War Demographic Wave (1946–1960)

Demographic Tidal Wave

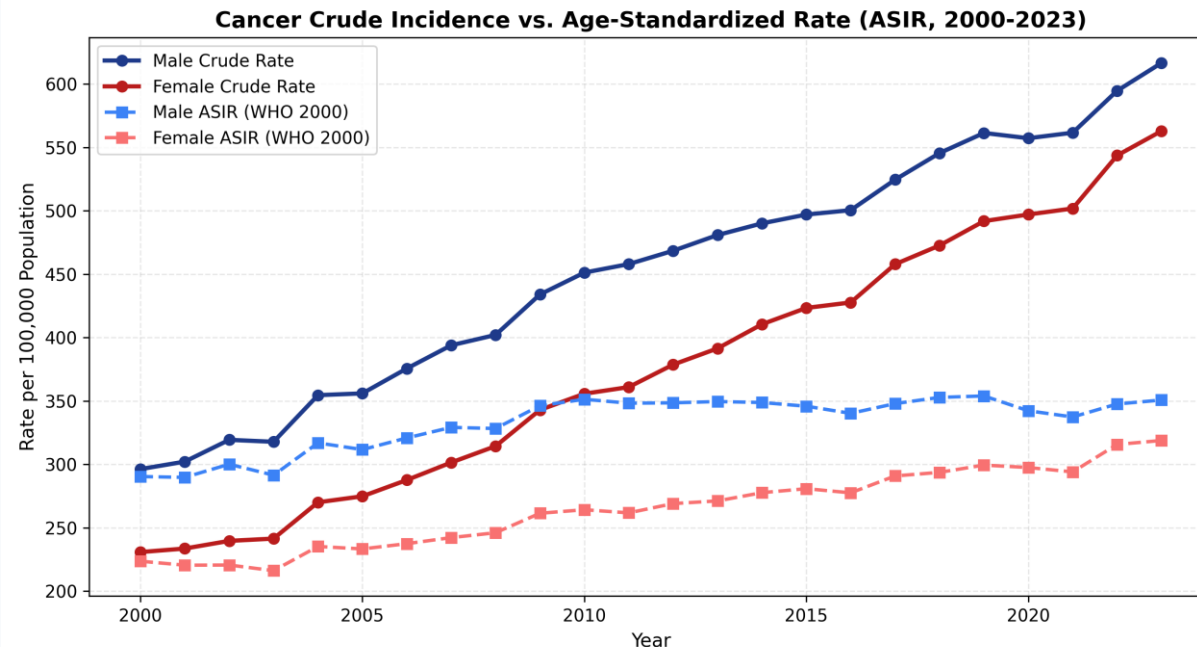
- **1946–1960 Bulge:** Taiwan's post-war high-fertility generation turned 65+ between 2010 and 2025.
- **Base Volume Inflow:** Massive cohort size entering peak cancer age brackets drove exponential crude case growth.
- **Super-Aged 2025:** Taiwan enters Super-Aged Society (>20% aged 65+), compounding clinical utilization.

Claims & Incidence Impact

- **Crude Rate Doubling:** Crude rate doubled (>560/100k) while age-standardized rates rose moderately.
- **Elderly Claims (>50%):** Seniors 65+ consume >51.7B points (50.8% of national cancer budget).
- **Core Conclusion:** Population aging is the primary volume engine of national oncology burden.

TAKEAWAY: The 1946–1960 demographic bulge entering ages 65+ is the true driver of crude cancer surge.

Part II: Crude vs. Age-Standardized Incidence Rate (ASIR)

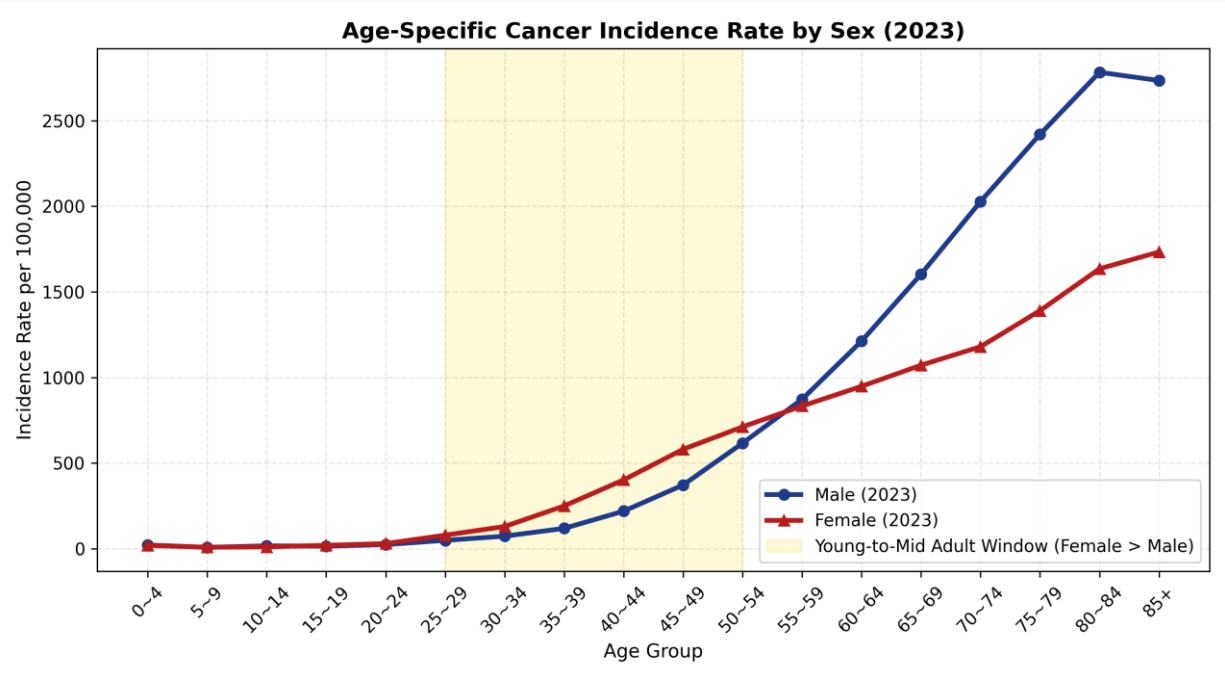


Epidemiological Deconstruction

- **Crude Rate Surge:** Male crude rate: 296 -> 617/100k (+108%); Female crude rate: 231 -> 563/100k (+143%).
- **Standardized Stability:** Male WHO 2000 ASIR rose only +20.8%; Female ASIR rose +42.6%.
- **Aging vs. Risk:** Confirms population aging accounts for >70% of total crude cancer expansion.

TAKEAWAY: Crude rates doubled while standardized rates grew moderately, proving aging drives volume.

Part II: Age-Specific Incidence & Sex Crossover

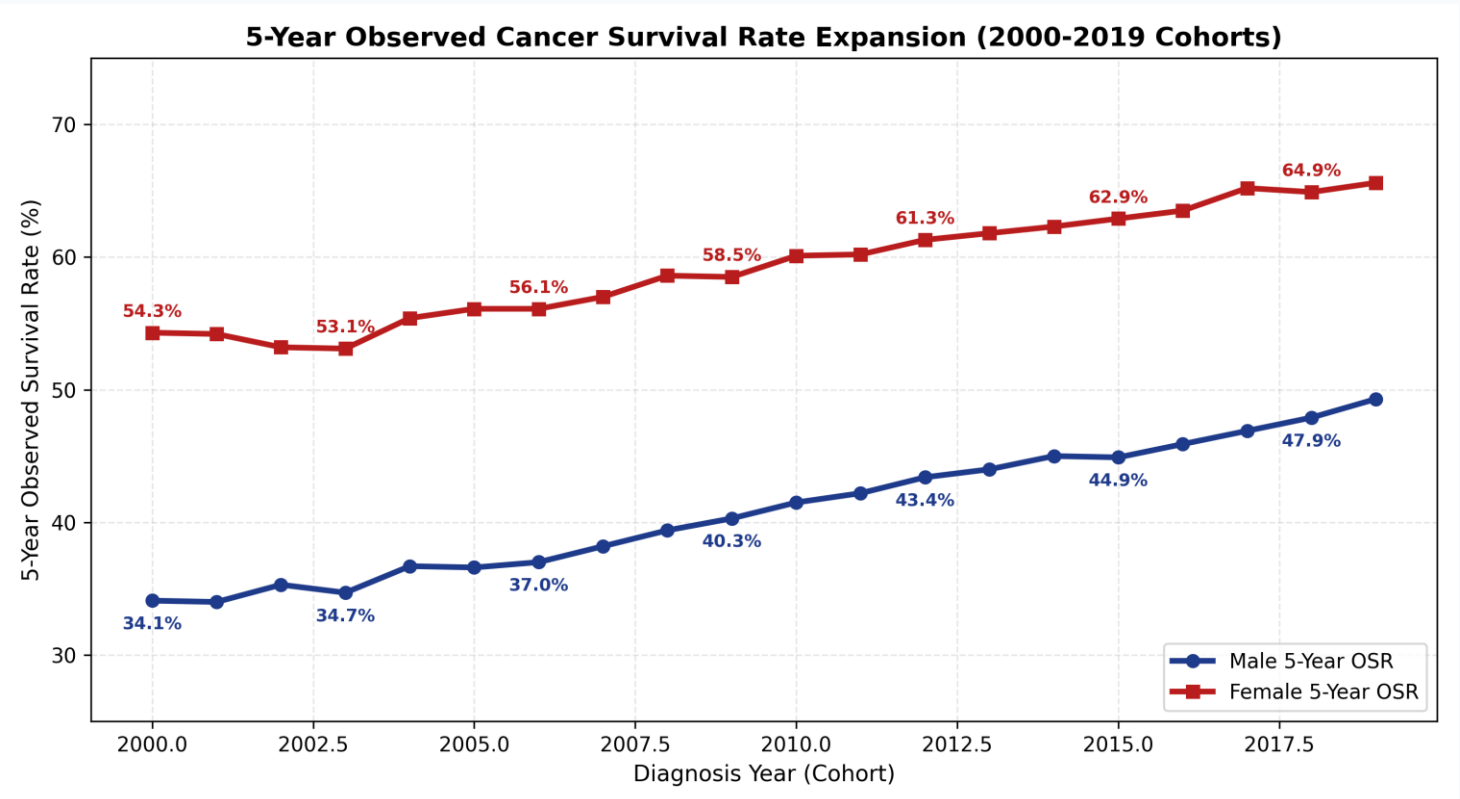


Sex Crossover Patterns

- **Ages 25–54 (Female > Male):** Female rate is up to 2.1x male (ages 35–39: 249.8 vs 118.7/100k).
- **Ages 55+ (Male Reversal):** Male incidence explodes exponentially, exceeding female after age 55.
- **Ages 80+ (Male Peak):** Male rate hits 2,781.9/100k vs 1,634.7 in females (1.7x higher).

TAKEAWAY: Working-age females face 2x incidence, but elderly males escalate to >2,780/100k.

Part II: 5-Year Observed Survival Gains (2000–2019)



Survivorship Breakthrough

- **Male 5-Year Gain:** Climbed from 34.1% (2000) to 49.3% (2019) (+15.2% jump).
- **Female 5-Year Record:** Expanded from 54.3% to 65.6% (+11.3%); 10-year survival sustained at 52.9%.
- **Standing Pool Impact:** Transforms fatal cancer into chronic survivorship, swelling active patients to 896,881.

TAKEAWAY: 5-year survival reached 49.3% (M) and 65.6% (F), expanding active patients to ~900k.

Part II: Public Health Policy Shocks & Screening Milestones

Statutory Policy Timeline

- **2004 Cancer Control Act:** Statutory screening mandate; pilot mammography & FOBT created +11% case surge.
- **2009 Tobacco Surtax:** Doubled surtax (NT\$10->20) to fund hospital screening.
- **2010 Free 4-Cancer Screening:** Institutionalized biennial colon, breast, oral, and cervix screens.
- **2022 LDCT Screening:** World-first national lung CT for high-risk smokers/family history.

Epidemiological Effects

- **Stage Migration:** Massive shift from Stage III/IV down to localized Stage 0/I.
- **Period Jumps:** Screening expansion generated artificial discrete incidence jumps.
- **Survivorship Drag:** Early detection prolonged measurable survival times significantly.

TAKEAWAY: Screening policies created discrete period jumps and accelerated stage migration.

Part III: Poisson Lee-Carter Formulation & Constraints

1. POISSON COUNT FORMULATION (COUNT DATA)

$$D_{x,t} \sim \text{Poisson}(\mu_{x,t}), \quad \mu_{x,t} = E_{x,t} \cdot \exp(a_x + b_x k_t)$$

2. LOG-LINEAR LINK & EXPOSURE OFFSET

$$\ln(\mu_{x,t}) = \ln(E_{x,t}) + a_x + b_x k_t$$

3. IDENTIFIABILITY CONSTRAINTS

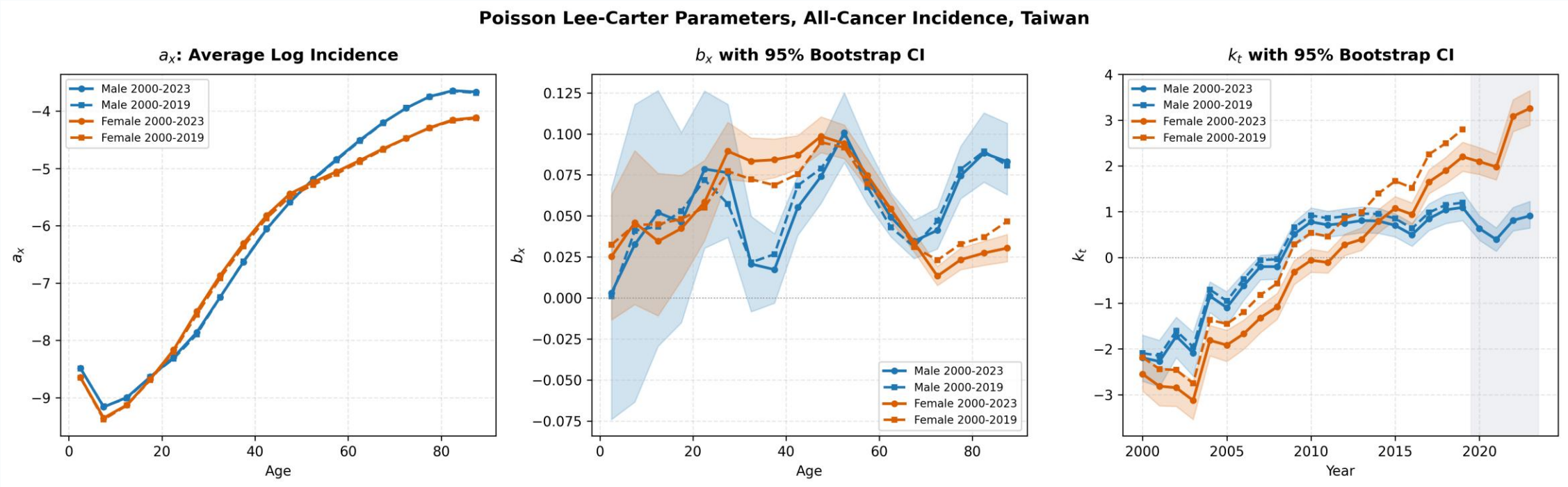
$$\sum_x b_x = 1, \quad \sum_t k_t = 0$$

Parameter Interpretation

- **a_x (Baseline Age Profile):** Static baseline risk across ages 0–85+; governed by biological aging.
- **k_t (Temporal Drift):** Macro time index. Drift = Mean(Delta k_t) measures annual trend speed.
- **b_x (Age Sensitivity):** Quantifies how intensely each age group reacts to macro trend shifts.

TAKEAWAY: Poisson Lee-Carter with exposure offsets provides non-divergent parameter estimation.

Part III: Poisson Lee-Carter Parameter Estimates (a_x , b_x , k_t)



TAKEAWAY: Female drift (0.2525) is ~2x male (0.1349); overdispersion $\phi=3\sim 4.15$ doubles CI widths.

Part III: Age-Period-Cohort (APC) Formulation & SVD Curvature

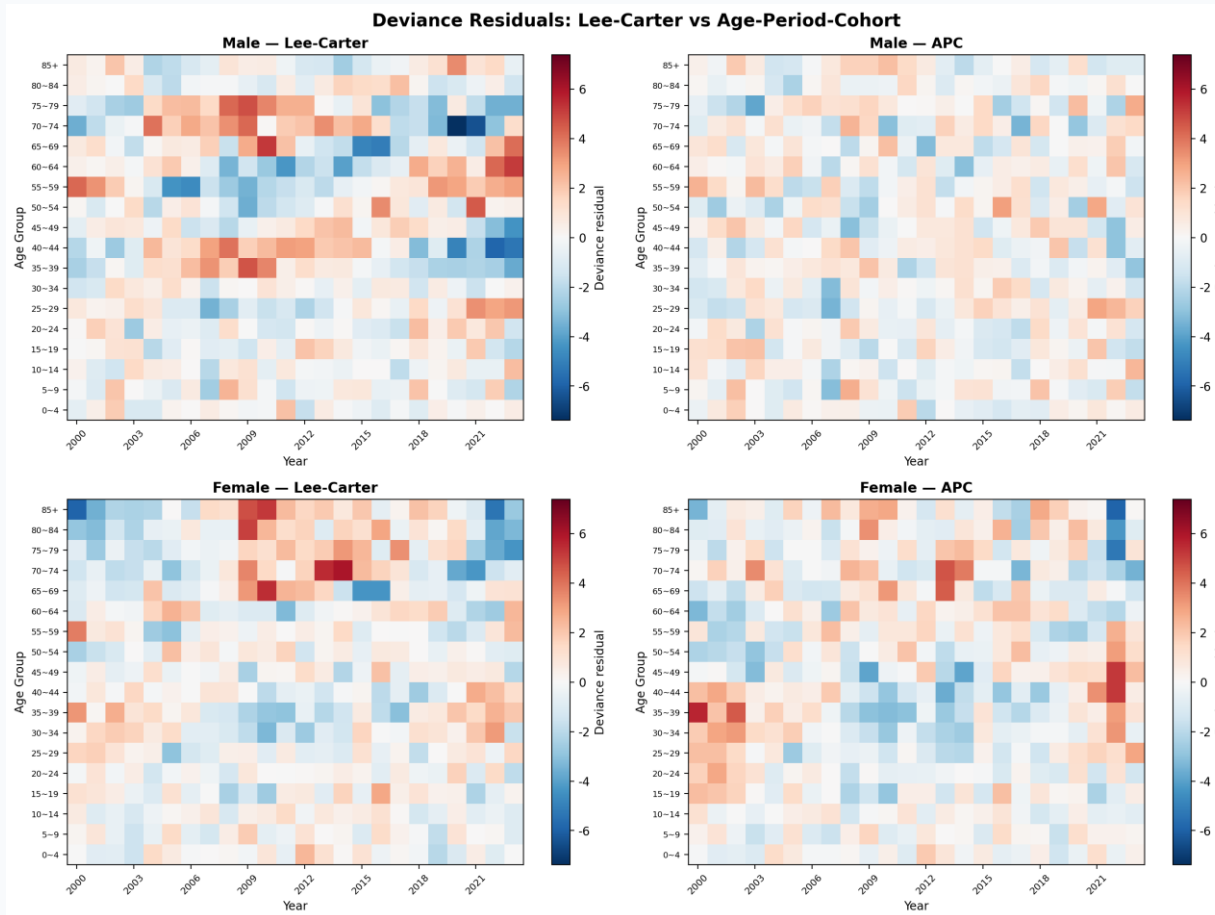
Identification Problem ($C = P - A$)

- **Linear Collinearity:** Cohort = Period - Age causes non-identifiability in standard GLM.
- **Log-Linear GLM:** $\ln(\mu_{xt}) = \ln(E_{xt}) + \alpha_x + \beta_t + \gamma_c$.
- **SVD Curvature Basis:** Project cohort dummies onto null space of linear trend: $P_{\text{perp}} = I - T(T^T T)^{-1} T^T$.
- **Full-Rank Design:** Isolates pure non-linear cohort curvature unambiguously.

Model Selection Criteria

- **Poisson Deviance (D):** $D = 2 * \sum [D * \ln(D / \mu) - (D - \mu)]$ measures residual error.
- **BIC Penalty:** $\text{BIC} = \text{Deviance} + p * \ln(N)$; penalizes parameter complexity $p * \ln(432)$.
- **Raftery Rule:** $\Delta \text{BIC} > 10$ indicates decisive evidence favoring cohort inclusion.

Part III: Gender Duality — Cohort Signatures vs. Period Forces

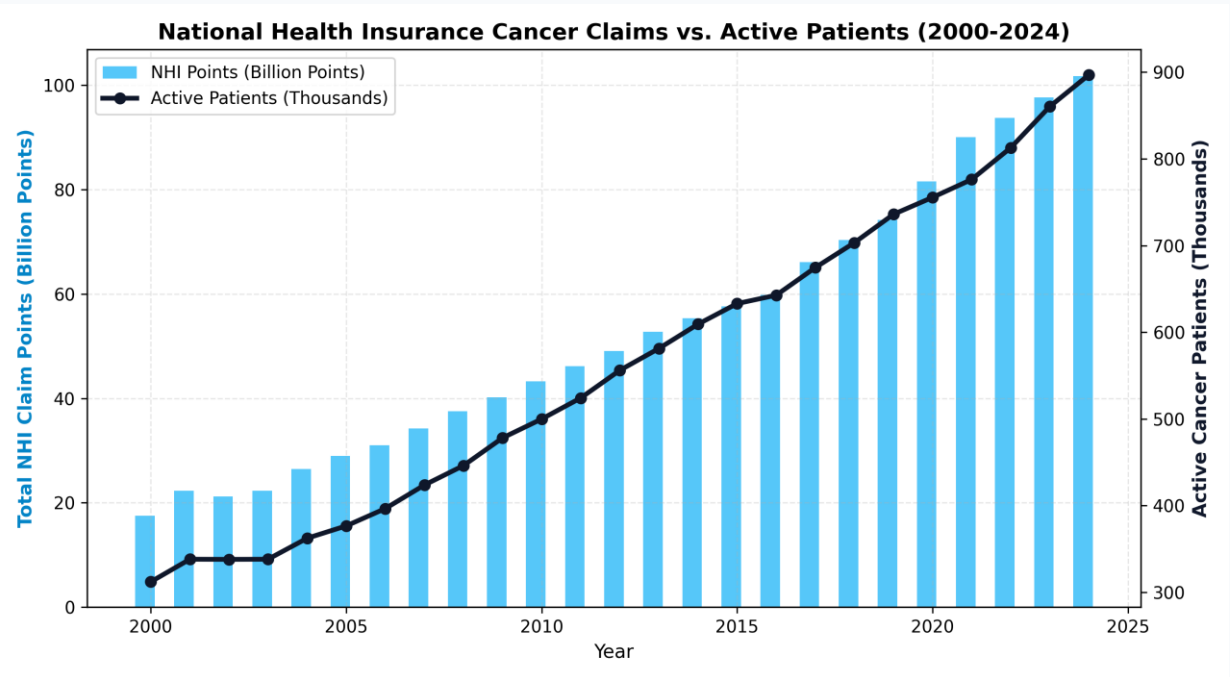


Model Comparison Insights

- **Male = Cohort Driven:** Lee-Carter shows diagonal stripes. APC slashes deviance (1555.6 $\rightarrow$ 691.5; Delta BIC = -852).
- **Female = Period Driven:** Lee-Carter BIC (1490.2) matches APC (1495.7). Governed by screening & lifestyle periods.
- **Policy Strategy:** Male requires cohort interception; Female requires continuous period screening.

TAKEAWAY: Male oncology is cohort-driven (Δ BIC = -852), while female risk is period-driven.

Part IV: National Health Insurance — 100-Billion Point Dilemma

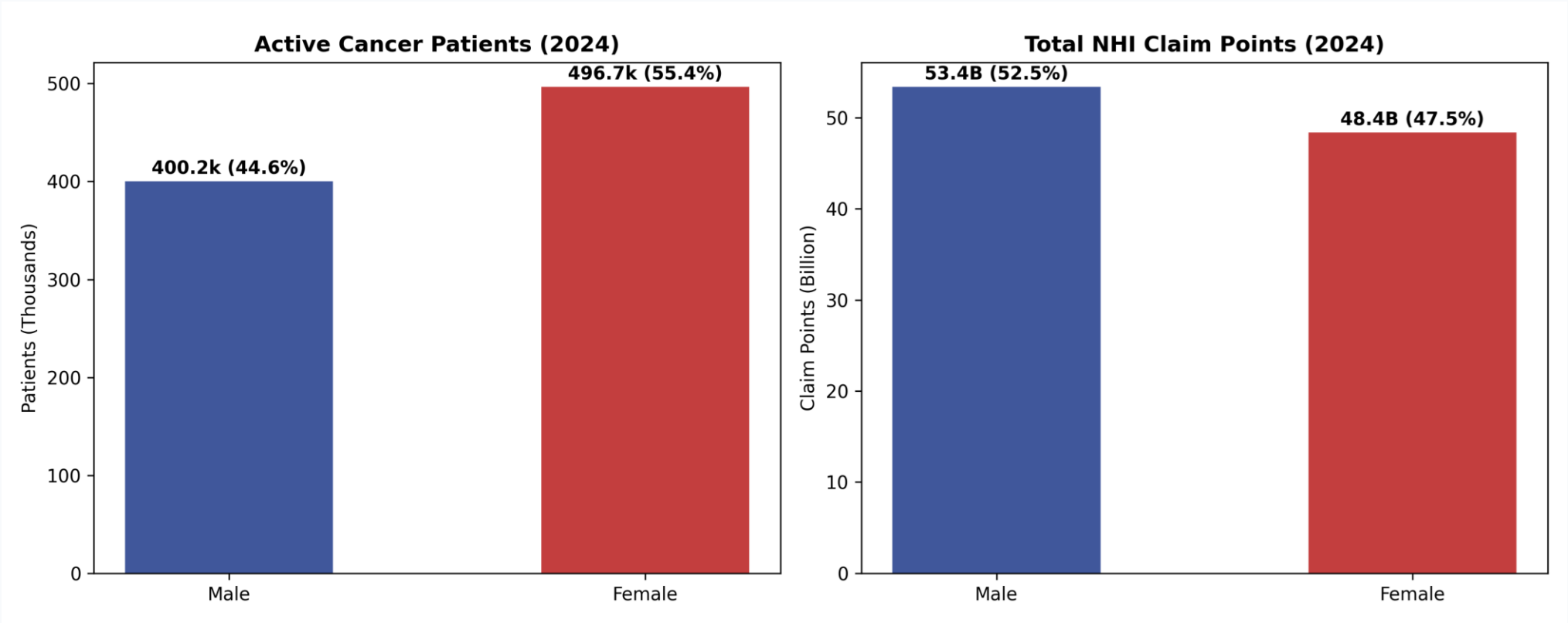


Financial Surge (2000–2024)

- **5.8x Claims Explosion:** NHI claims surged from 17.5B to 101.8B points (+482%, CAGR 7.61%).
- **Volume vs. Intensity:** Active patients grew +187% (312k -> 897k); cost/patient doubled (56k -> 113.5k).
- **Cost Drivers:** Targeted drugs, immunotherapies, and NGS drive expenditure growth.

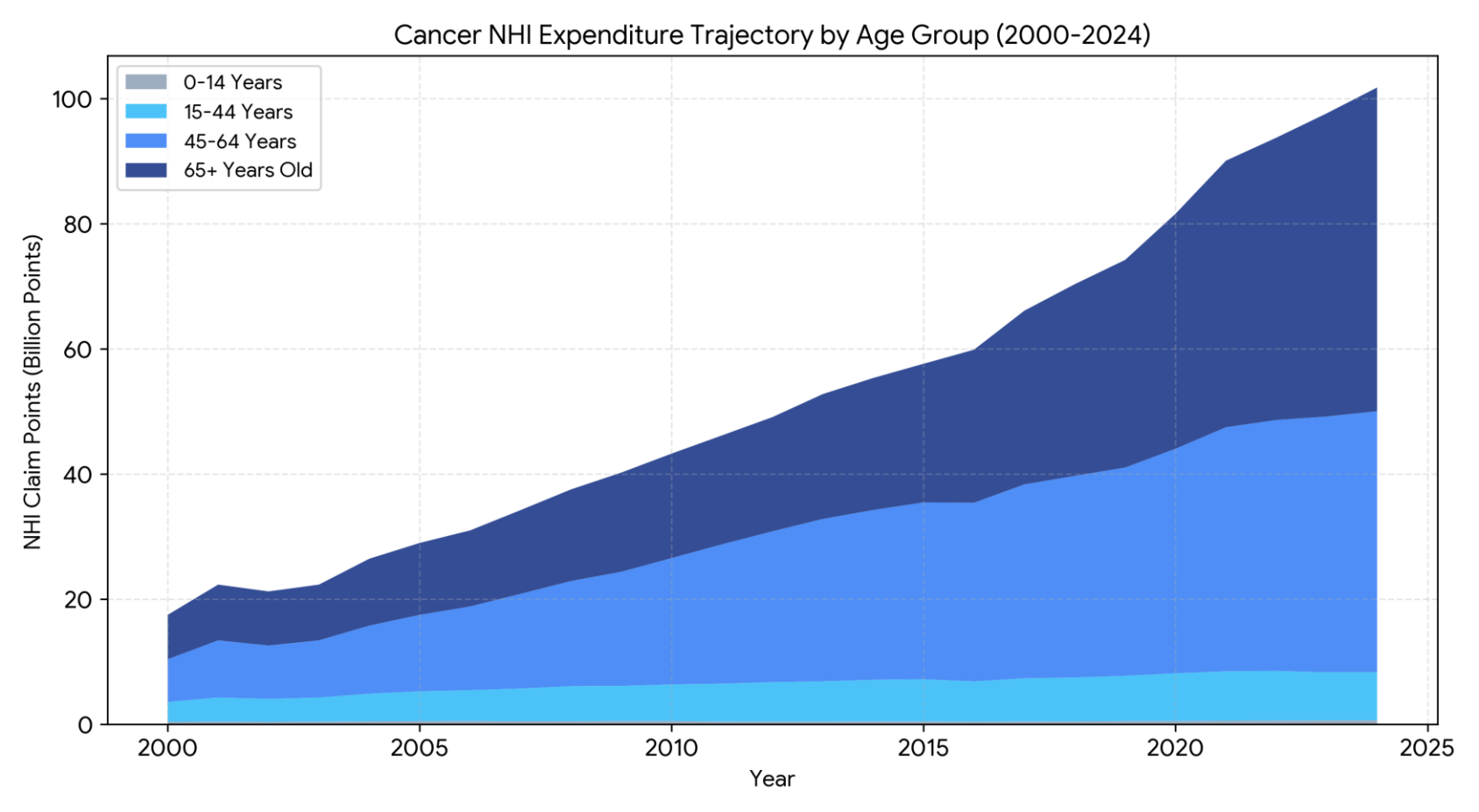
TAKEAWAY: Claims grew 5.8x to 101.8B points, driven by survivor volume (+187%) and cost intensity (+103%).

Part IV: Sex-Expenditure Paradox & Age Redistribution



TAKEAWAY: Females lead volume (55.4%), males lead cost (52.5%), and seniors 65+ consume >50.8% of claims.

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TAKEAWAY: Females lead volume (55.4%), males lead cost (52.5%), and seniors 65+ consume >50.8% of claims.

Part IV: Social Limits & Commercial Insurance Crisis

Social Insurance Limits (Sheep Wool)

- **Shrinking Base:** Ultra-low fertility contracts premium contributors; dependency ratio surges.
- **Global Budget Cap:** Point discounting creates hospital strain and drug listing delays.
- **Out-of-Pocket Drag:** Self-pay precision oncology creates severe household financial toxicity.

Commercial Insurance Crisis

- **Flawed Legacy Pricing:** Old policies assumed low screening rates and rapid post-diagnosis death.
- **Dual Claim Shock:** Screening drove lump-sum initial claims; survival drove multi-year reimbursement.
- **Hedging Breakdown:** Annuities (living longer) and health (extended claims) suffer dual losses.

Part IV: Public-Private Co-Financing & Governance Roadmap

Public Health Track

- **Male Cohort Track:** Target 1945–1965 birth cohorts with LDCT & colonoscopy to intercept acute stages.
- **Female Period Track:** Expand 30–50 screening; build community shared-care for 500k survivors.
- **Primary Care Shift:** Shift stable survivors to outpatient clinics to relieve medical centers.

Commercial Insurer Track

- **Staged Reimbursement:** Transition from upfront lump-sum payouts to chronic care installments.
- **Supplemental Riders:** Design private gap riders covering self-paid NGS and precision drugs.
- **Solvency Stress Testing:** Embed Quasi-Poisson overdispersion upper bounds into Solvency II/ICS.

TAKEAWAY: Public health must intercept male cohorts, while insurers transition to staged chronic coverage.

Summary: Longevity, Prevention & Financial Sustainability

1. Redefining Longevity Risk

Longevity risk is no longer merely extending life; it is managing prolonged chronic morbidity and escalating precision medical costs.

2. Reconciling Demographics & Mechanisms

1946–1960 baby boomers drive volume; male cohort imprints drive acuity; female period drift drives chronic survivor volume.

3. Public-Private Boundary Redesign

Accounting for overdispersion ($\phi=3\sim4.15$) and broken natural hedging is essential for social sustainability and private solvency.

Thank you for your attention!
Floor is open for Questions & Discussion (Q&A)

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