Institute and Faculty of Actuaries

IFoA Life Conference

Workshop B1: A Lifetime of Risk

Speakers

Ashley Campbell

Director, Crystallise Ltd

Ashley is an Actuary with over 13 years' experience working in the insurance and pensions industry. He is a consultant in the areas of longevity, mortality and infectious disease risk modelling and has worked with some of the largest insurers, reinsurers, and pensions consultants in the market. His area of expertise is devising innovative multi-disciplinary solutions to clients' risk modelling problems.

Dr William Letton

Senior Consultant, Crystallise Ltd

Will leads the Research & Development team at Crystallise, where he focuses on building models and tools to support data-driven decision-making in healthcare. After his doctoral studies in Stem Cell and Developmental Biology, he has a deep interest in complex systems and how to use statistical modelling to help clients uncover insights from messy, uncertain data.

Contributors

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Managing Director, Crystallise

Nicky Draper
Director, Crystallise

A Lifetime of Risk

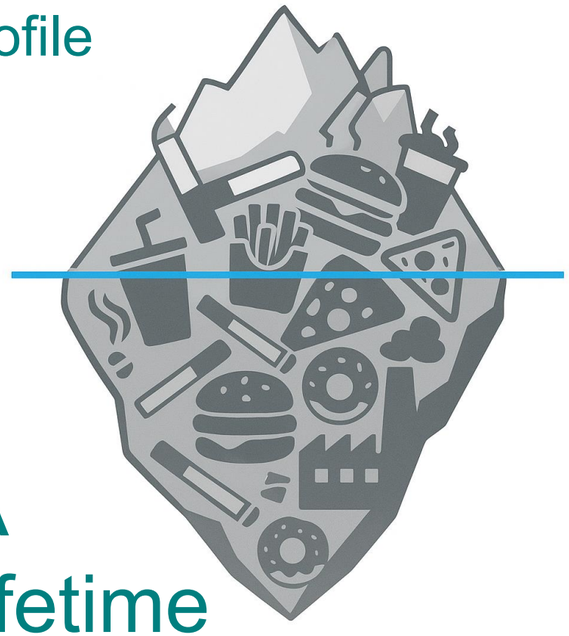
Introduction

Introduction

- Variable choice is constrained.
  - Access to data
  - Magnitude of effect
  - Strength of evidence
  - Interaction with other variables

- Health risks depend not only on **whether** we are exposed to a risk factor, but also **when**, **how much** and **for how long**
  - **For individuals**
    - A smoker's risk is shaped by how many cigarettes and when they were smoked
    - An overweight individual's risk reflects both degree and duration of excess weight
  - **At a population level**:
    - Current prevalence (e.g. % of smokers) is not sufficient
    - Risk depends on lifetime exposure history across cohorts
    - Age, period, and cohort effects shape future mortality trends

Current risk profile



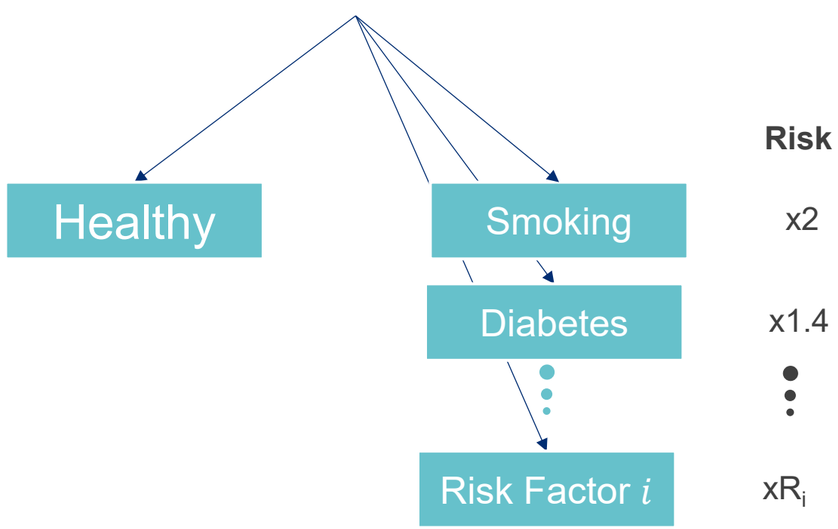
A lifetime of risk

Introduction

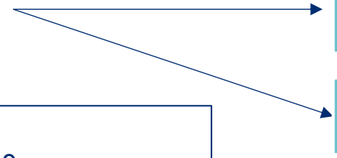
Traditional Evidence-based Approach

Evidence-Gathering

UK Cohort Study
Average age=73



Underwriting



- Age: 55
- Smoker, 20yrs
- Type II diabetes, 15 years

Pricing uplift = x2.8

Capital & Reserving

What if…

- ❑ Smoking trend continues? Total ban on sales?
- ❑ Cure for diabetes?
- ❑ GLP-1 impact on obesity?

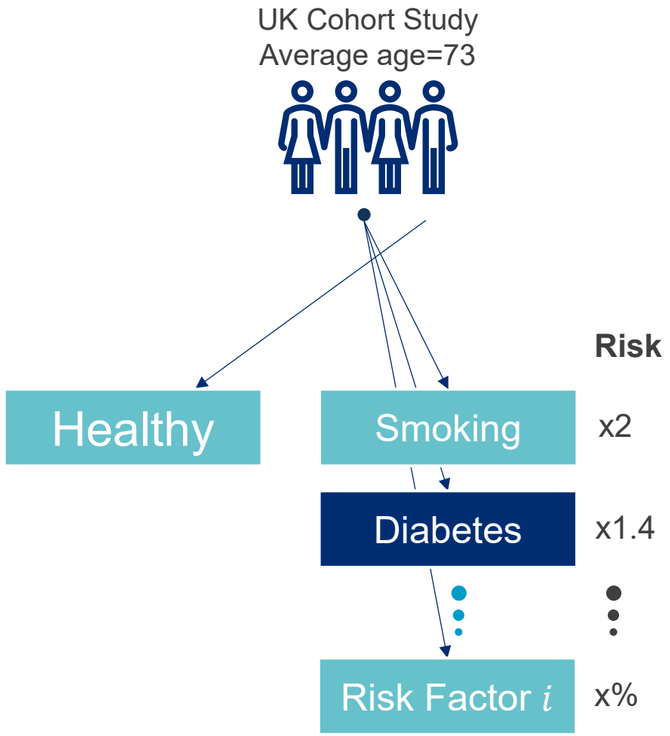
Use Case

Underwriter wants to capture diabetes risk

Underwriter wants to capture diabetes risk

Evidence-based Approach

Evidence-Gathering



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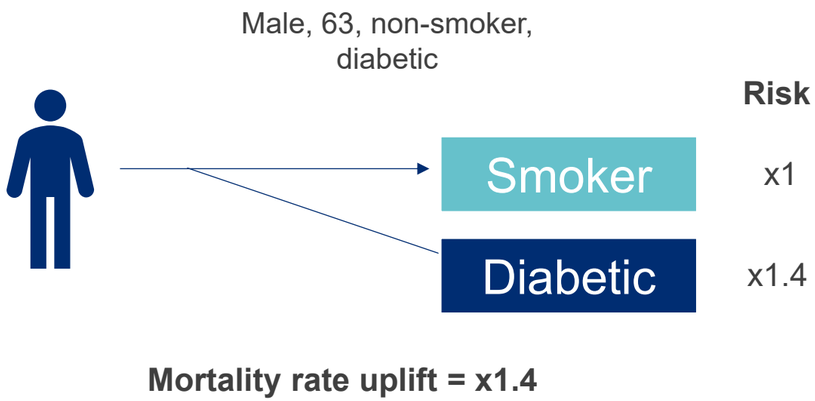
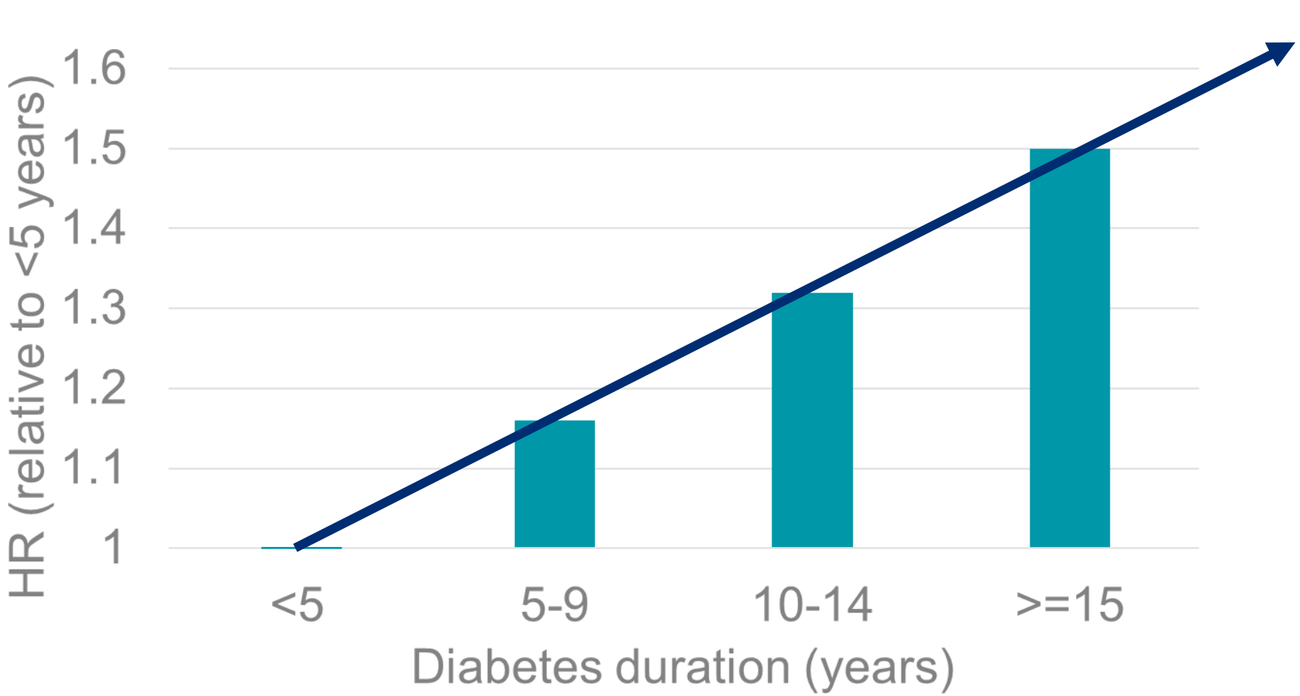


Mortality rate uplift = x1.4

Underwriter wants to capture diabetes risk

Considering the impact of duration of Hazard Ratio



Approximately linear growth in risk

Cea Soriano, L., Johansson, S., Stefansson, B. *et al.* Cardiovascular events and all-cause mortality in a cohort of 57,946 patients with type 2 diabetes: associations with renal function and cardiovascular risk factors. *Cardiovasc Diabetol* **14**, 38 (2015). https://doi.org/10.1186/s12933-015-0204-5

Adjusted for sex, **age at start date**, duration of diabetes, BMI, smoking status, number of medications, HbA1c level, presence of hypertension hyperlidemia, and history of MI, IS/TIA, IHD. and eGFR category

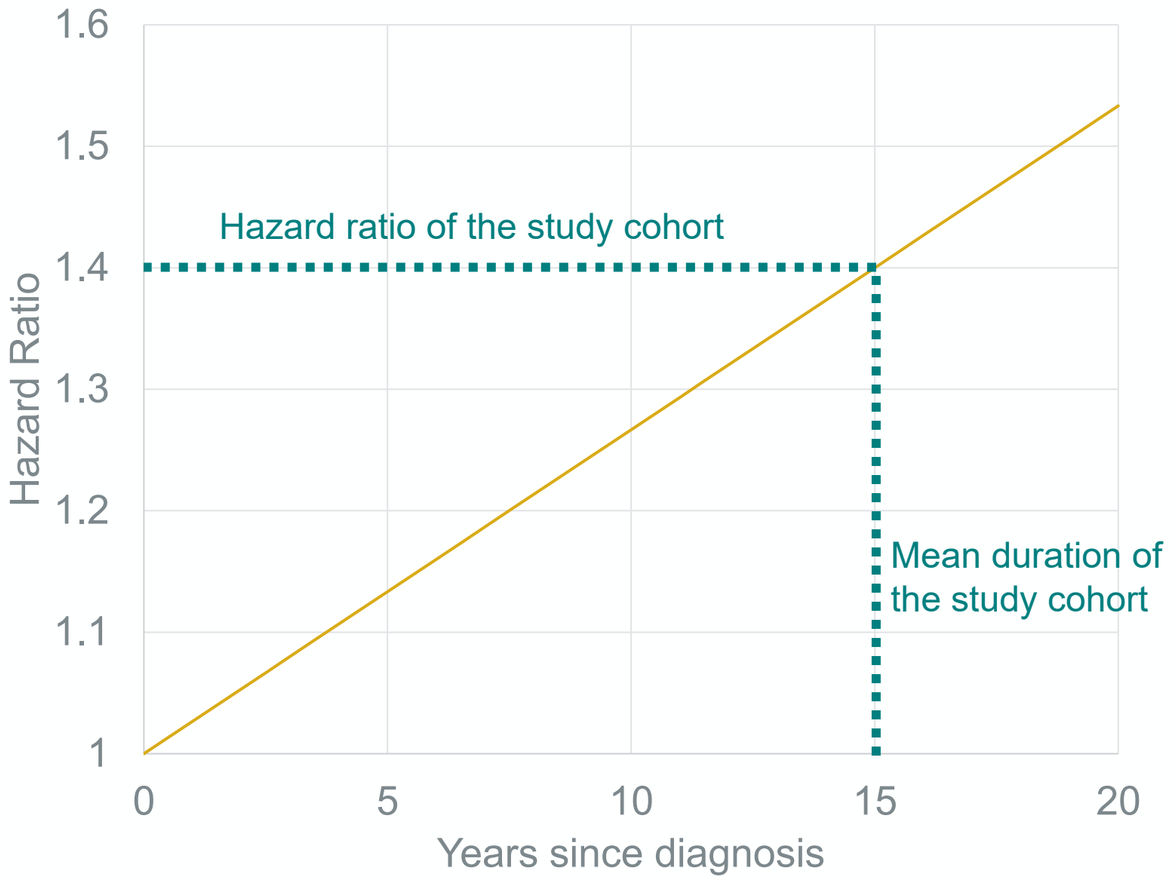
Underwriter wants to capture diabetes risk

Considering Duration

Approximately linear growth in risk

+

UK Cohort Study
Risk = 40%
Average duration = 15 years



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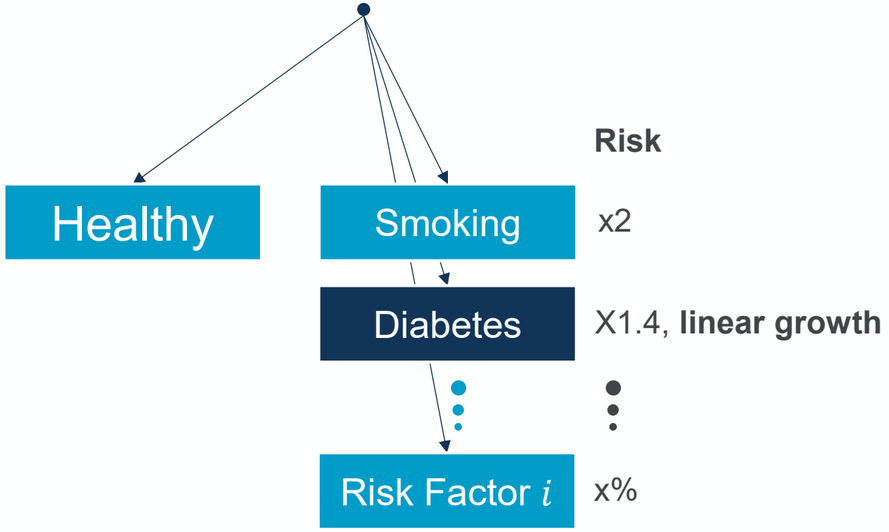
Considering Duration

Evidence-Gathering

UK Cohort Study
Average age=73

Average diabetes duration 15 years



Risk

x2

X1.4, **linear growth**

x%

Underwriting

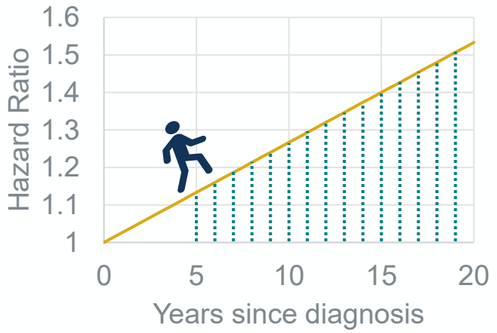
Male, 63, non-smoker,
diabetes **duration 5 years**

Risk, t=0

Smoker x1

Diabetes x1.13

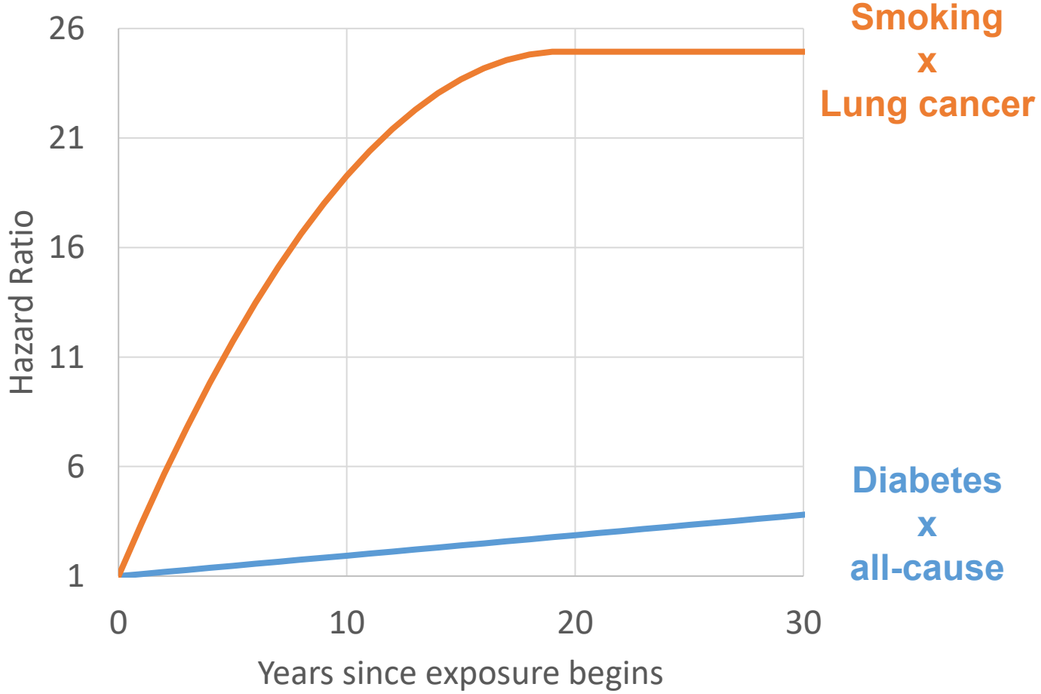
Mortality rate uplift = 13% in year 1
16% in year 2
19% in year 3
21% in year 4
24% in year 5
26% in year 6
etc.



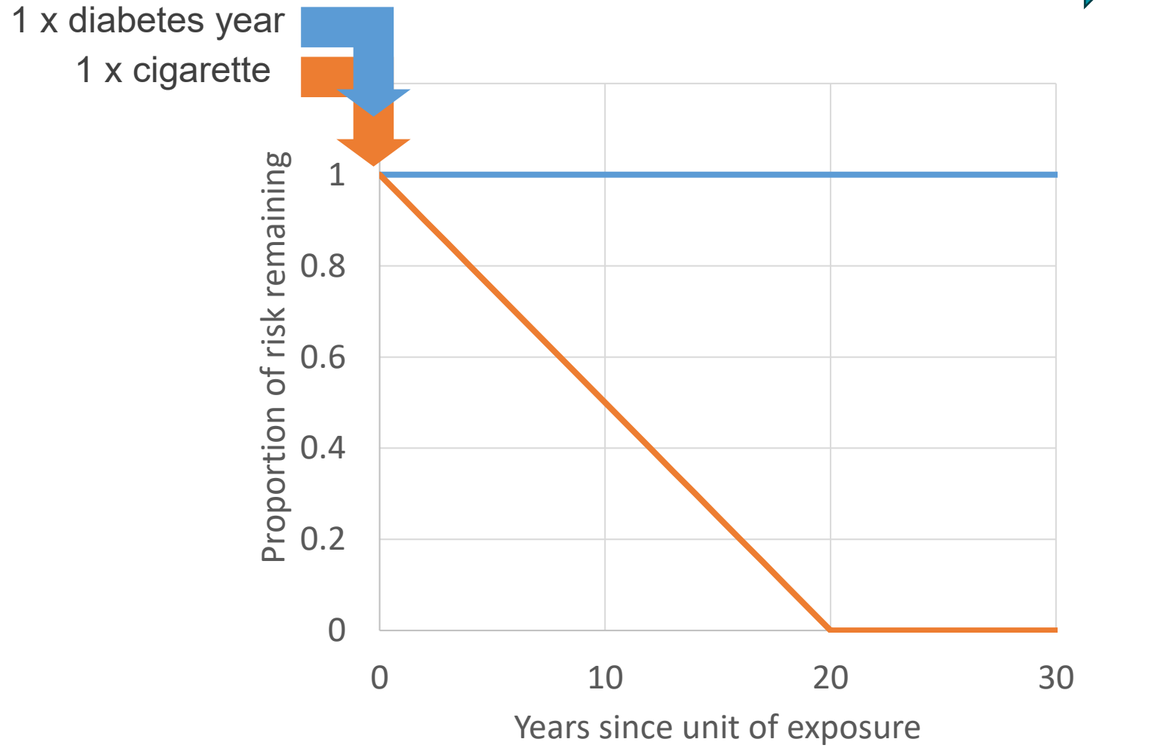
Alternative Risk Profiles?

From risk factor to mortality risk

Growth of risk with constant exposure



Remaining risk from a single unit of exposure



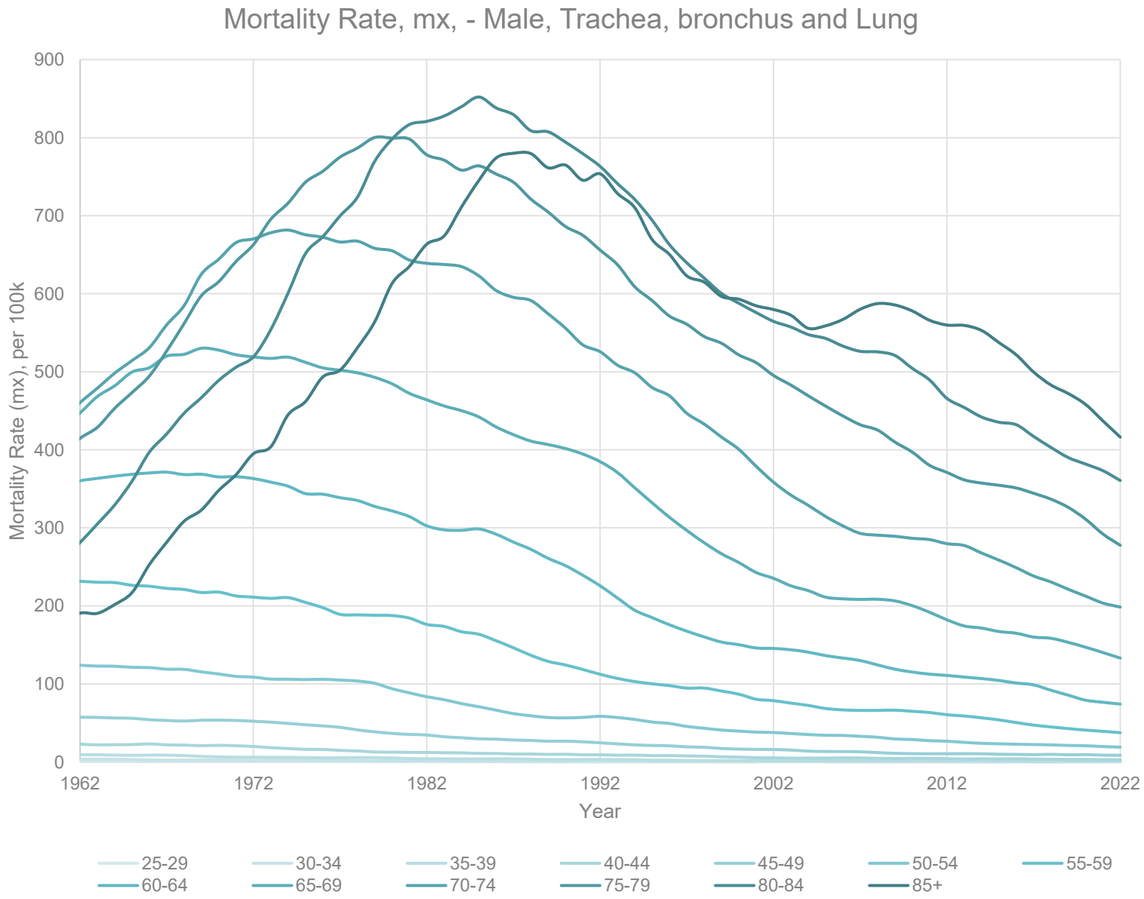
Illustrative only

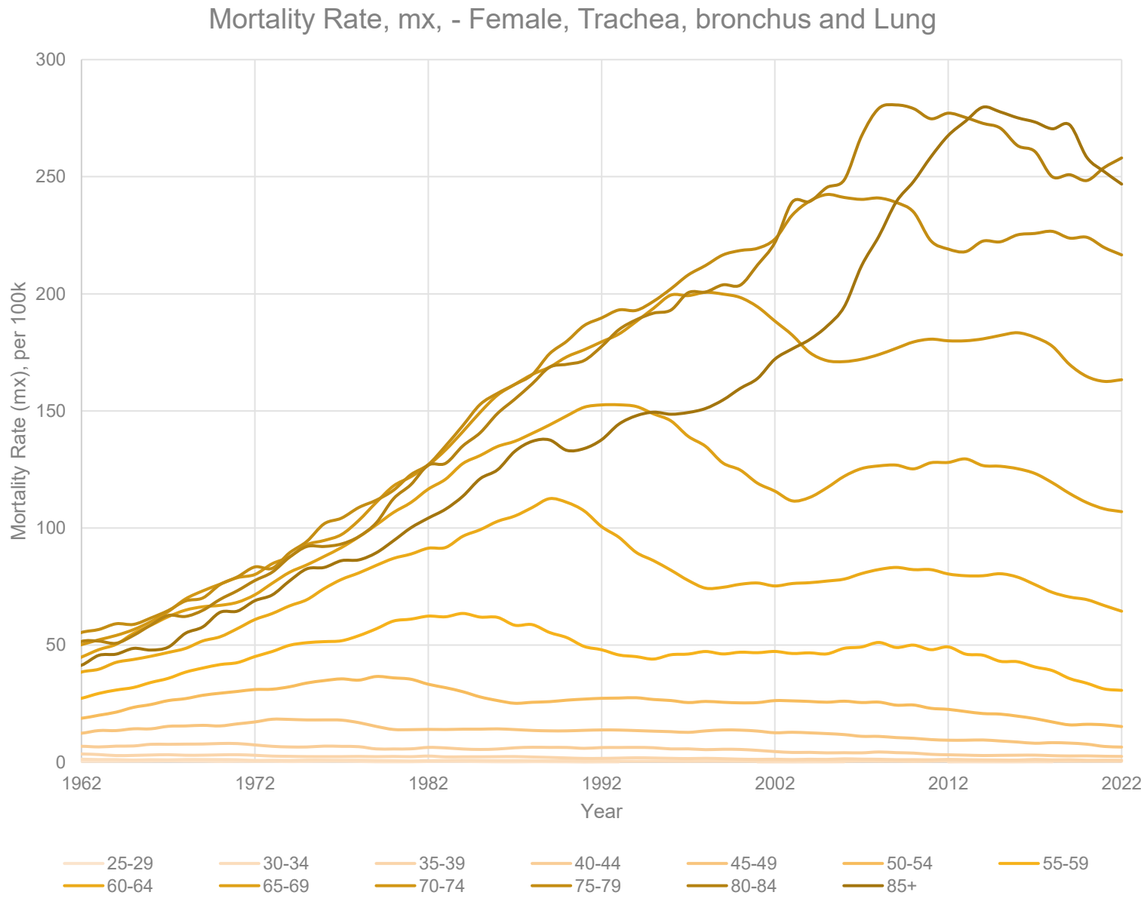
Complex Use Case

Risk Actuary modelling smoking trends

Risk Actuary modelling smoking trends

Lung Cancer Mortality trends





Source: the Office For National Statistics

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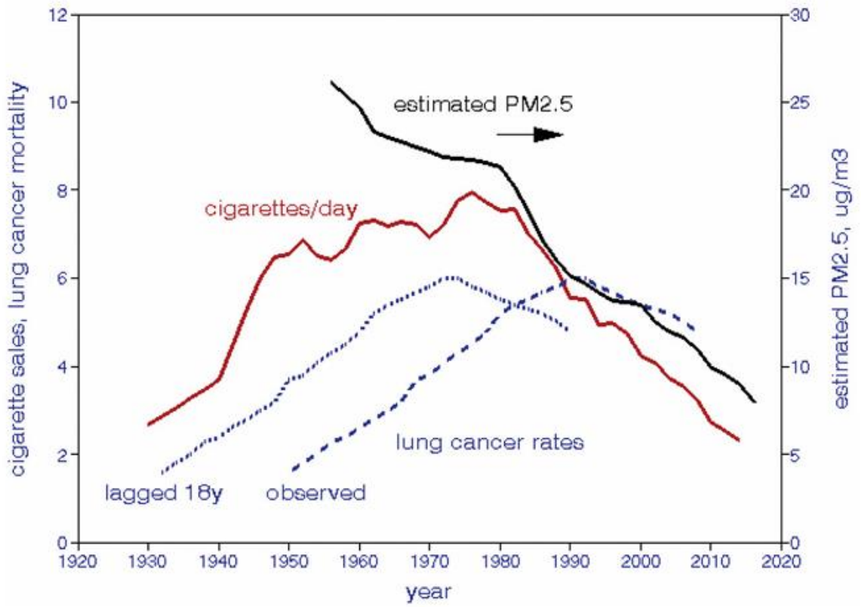
Traditional Methods

1. Consumption-Based Approach[1]



Latency, y	Period	LCM vs. cig sales
None	1956–2016	**−0.41**
none	1980–2016	
none	1990–2016	
10	1956–2016	**0.88**
18	1956–2016	**0.91**
30	1956–2016	**0.91**

Bold values = $p < 0.05$.

Key Strengths:

- ✓ Captures life history indirectly
- ✓ Fits historic aggregate mortality trends well

Key Weaknesses:

- × Ecological Approach – prior not stratified by age/sex
- × Insensitive to near-term policy change

LCM=Lung Cancer Mortality (age standardised)

1. Lipfert, F. W., & Wyzga, R. E. (2019). Longitudinal relationships between lung cancer mortality rates, smoking, and ambient air quality: a comprehensive review and analysis. Critical reviews in toxicology, 49(9), 790–818. https://doi.org/10.1080/10408444.2019.1700210;

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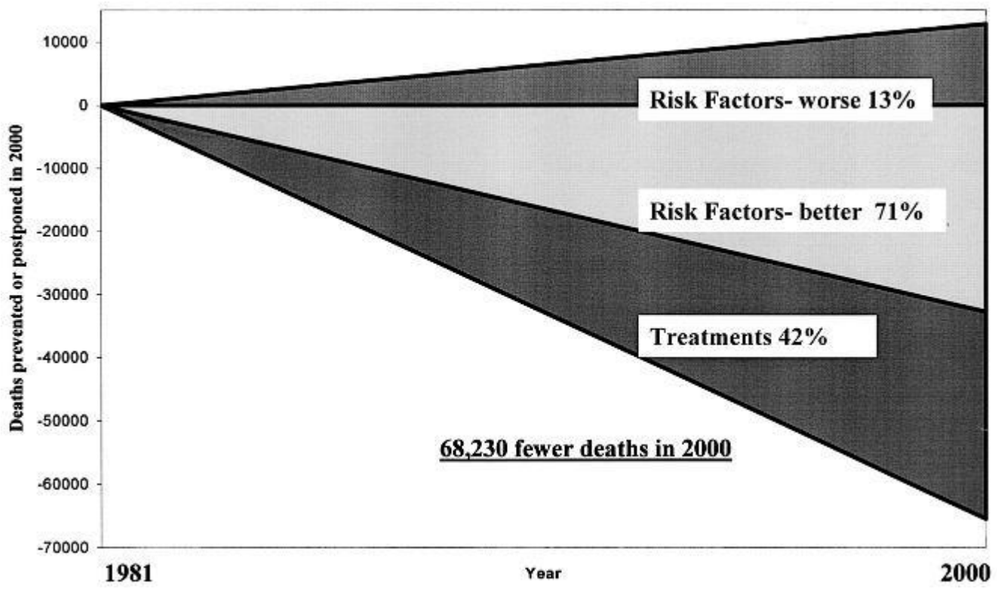
Traditional Methods

2. Prevalence-Based Approach[2]

Explaining the Decline in Coronary Heart Disease Mortality in England and Wales Between 1981 and 2000

Belgin Unal, MD, MPH, Julia Alison Critchley, DPhil, and Simon Capewell, MD | AUTHOR INFO & AFFILIATIONS

Circulation • Volume 109, Number 9 • https://doi.org/10.1161/01.CIR.0000118498.35499.B2



$$PAR\% = 100 \times \frac{p \times (RR - 1)}{p \times (RR - 1) + 1}$$

Key Strengths:

- ✓ Stratified by age/sex
- ✓ Hazards-based approach

Key Weaknesses:

- × Ignores life history
- × Generally, a poor fit to observed mortality
- × Oversensitive to near-term policy change

PAR%=Population Attributable Risk
p=prevalence
RR= Relative Risk

2. Unal, B., Critchley, J. A., & Capewell, S. (2004). Explaining the decline in coronary heart disease mortality in England and Wales between 1981 and 2000. Circulation, 109(9), 1101–1107. https://doi.org/10.1161/01.CIR.0000118498.35499.B2

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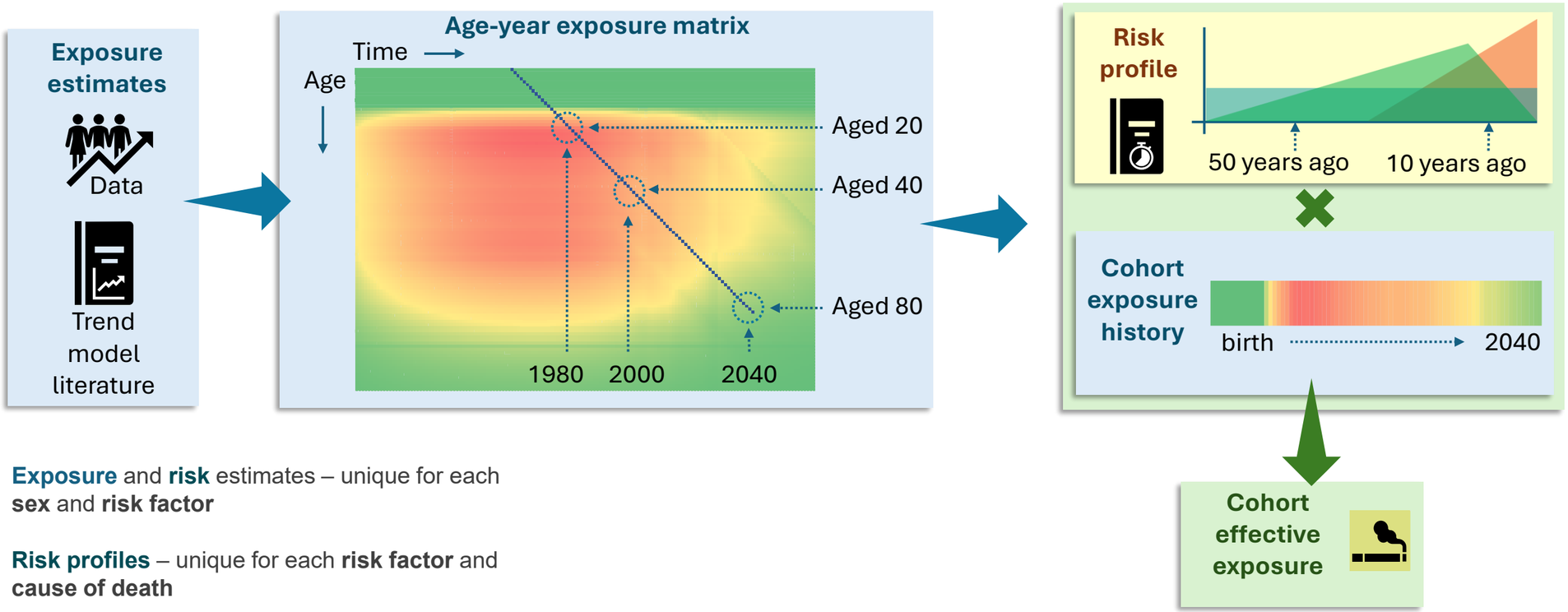
Lifecourse Modelling Framework



- **Exposure** and **risk** estimates – unique for each **sex** and **risk factor**
- **Risk profiles** – unique for each **risk factor** and **cause of death**

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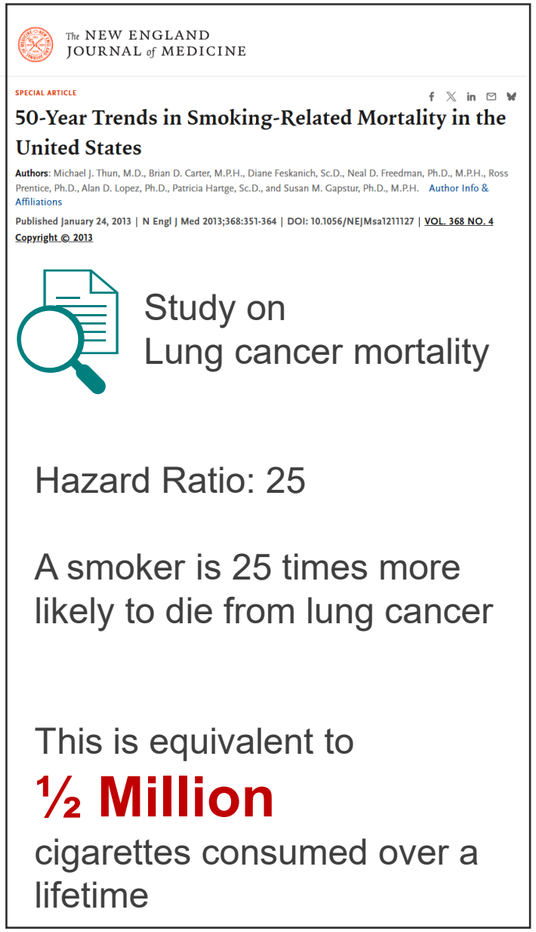
Lifecourse Modelling Framework



The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

50-Year Trends in Smoking-Related Mortality in the United States

Authors: Michael J. Thun, M.D., Brian D. Carter, M.P.H., Diane Feskanich, Sc.D., Neal D. Freedman, Ph.D., M.P.H., Ross Prentice, Ph.D., Alan D. Lopez, Ph.D., Patricia Hartge, Sc.D., and Susan M. Gapstur, Ph.D., M.P.H. Author Info & Affiliations

Published January 24, 2013 | N Engl J Med 2013;368:351-364 | DOI: 10.1056/NEJMsa1211127 | VOL. 368 NO. 4

Study on
Lung cancer mortality

Hazard Ratio: 25

A smoker is 25 times more likely to die from lung cancer

This is equivalent to

½ Million

cigarettes consumed over a lifetime

Cohort Mortality Risk = $\frac{\text{Cohort effective exposure}}{\text{Study effective exposure}} \times \text{Study Mortality Risk}$

Source: Hazard Ratio: Thun, M. J., Carter, B. D., Feskanich, D., Freedman, N. D., Prentice, R., Lopez, A. D., Hartge, P., & Gapstur, S. M. (2013). 50-year trends in smoking-related mortality in the United States. The New England journal of medicine, 368(4), 351–364. https://doi.org/10.1056/NEJMsa1211127

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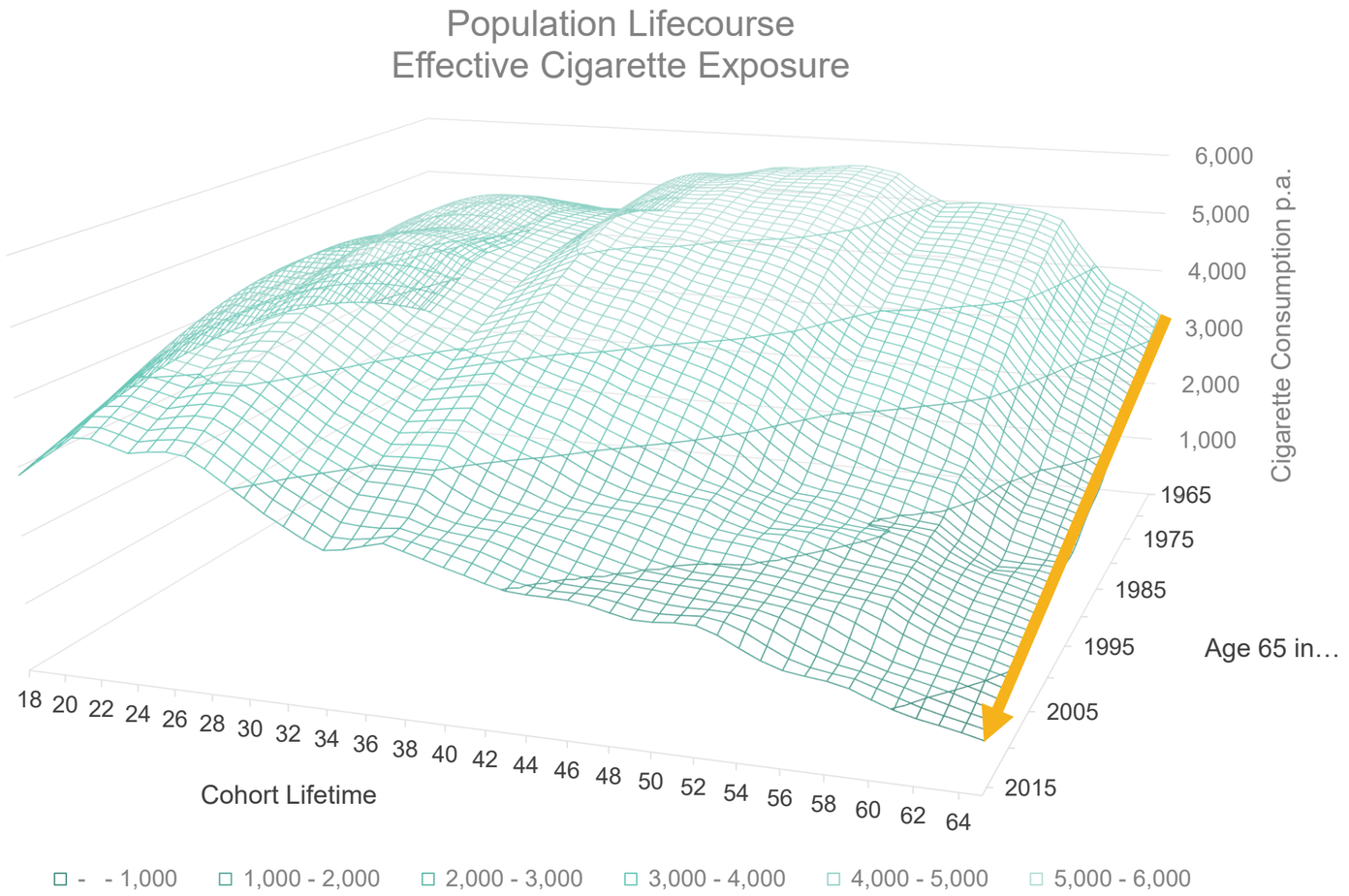
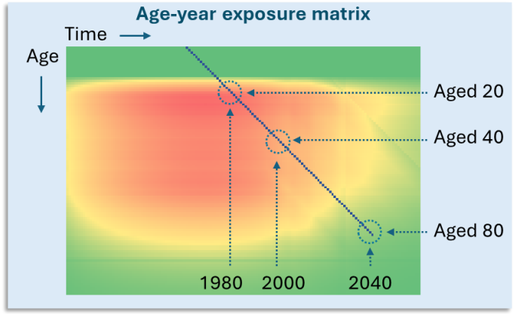
Population Cigarette Exposure History (Male)





Sources:
prevalence data: Opazo Breton, M. orcid.org/0000-0002-1226-7541, Gillespie, D. orcid.org/0000-00033450-5747, Pryce, R. orcid.org/0000-0002-4853-0719 et al. (5 more authors) (2022) Understanding long-term trends in smoking in England, 1972-2019 : an age-period-cohort approach. Addiction, 117 (5). pp. 1392-1403. ISSN 0965-2140 https://doi.org/10.1111/add.15696
Cig consumption data: Office for National Statistics – Opinions and Lifestyle Survey 1975-2023; Cigarette sales data British Archives 1900 and 1985

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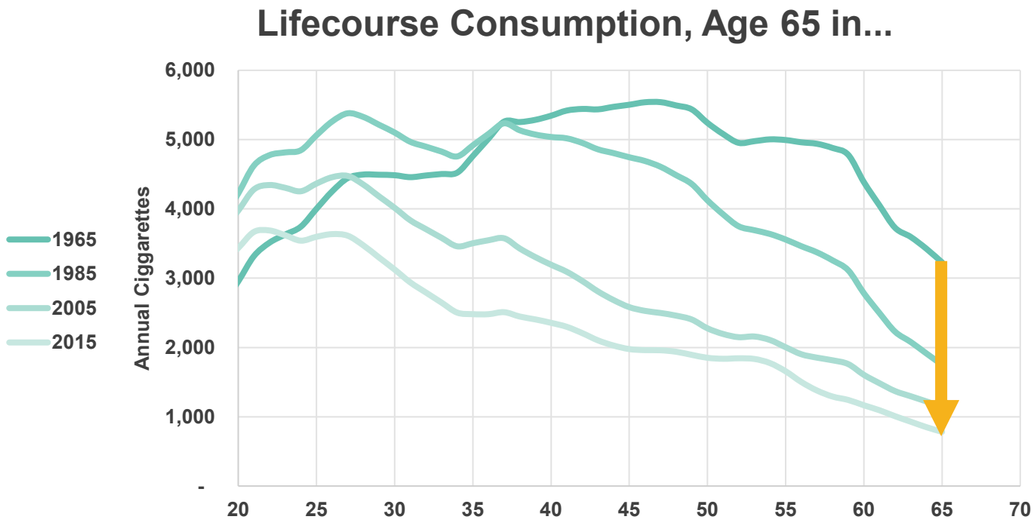
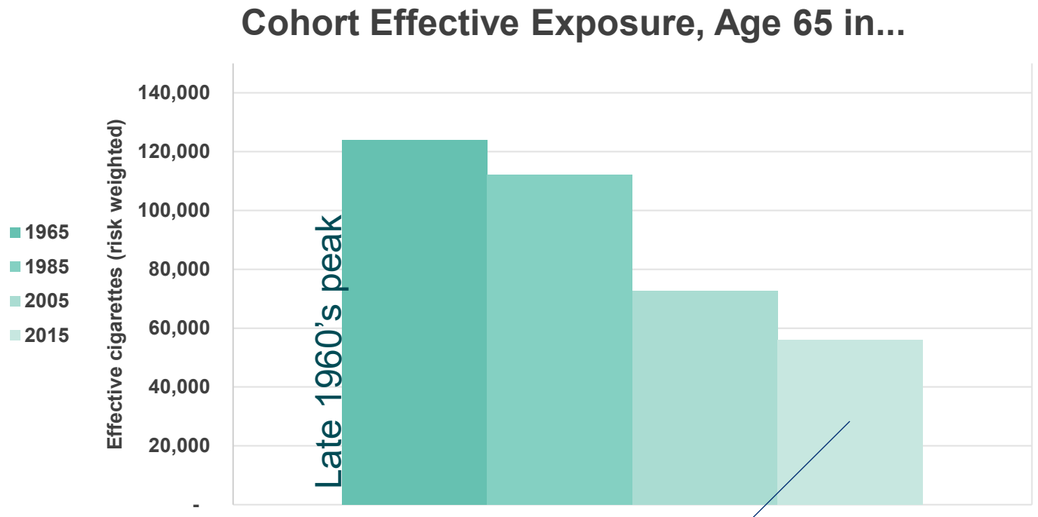
Population Exposure History (Males)





There remains a large amount of exposure within the population which will reduce over time with incoming cohorts

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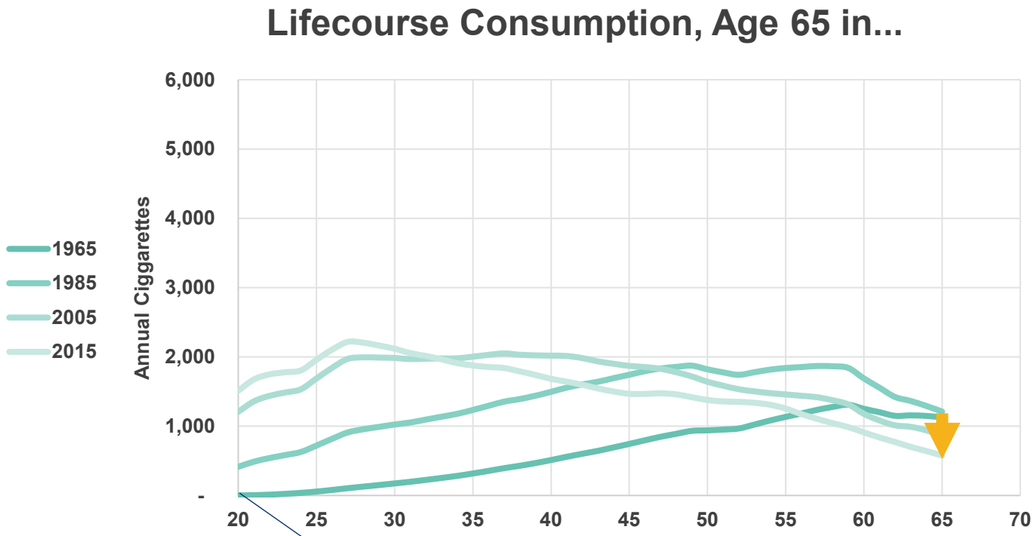
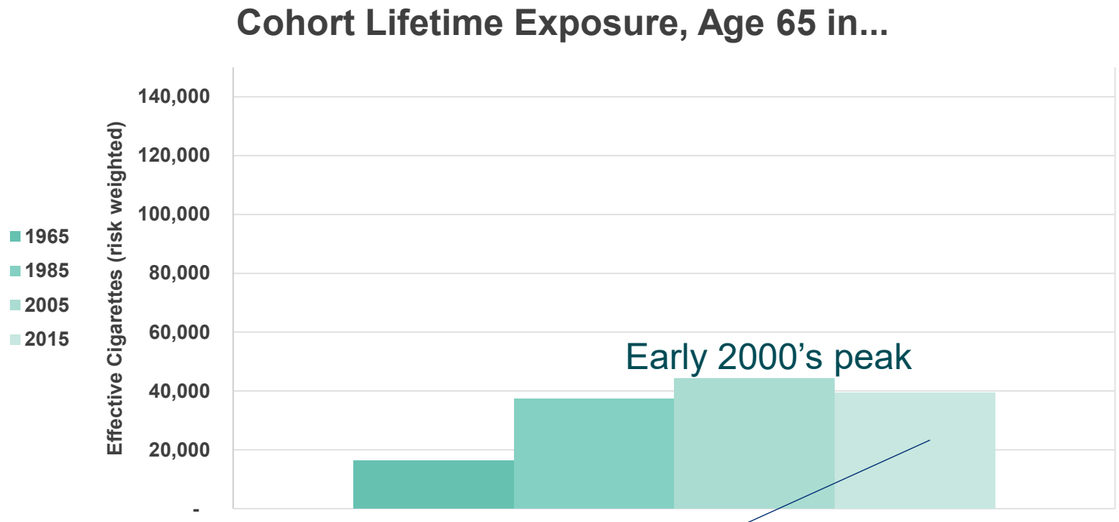
Population Exposure History (Females)

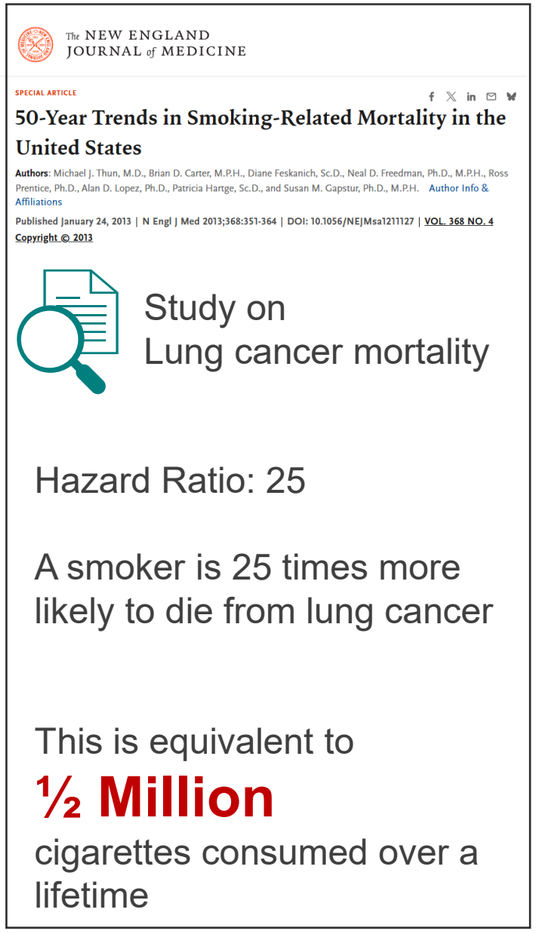




Women began smoking a lot later, and smoke at a lower intensity to men.
However, men are converging on women

Risk Actuary modelling smoking trends

Results



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Hazard Ratio: 25

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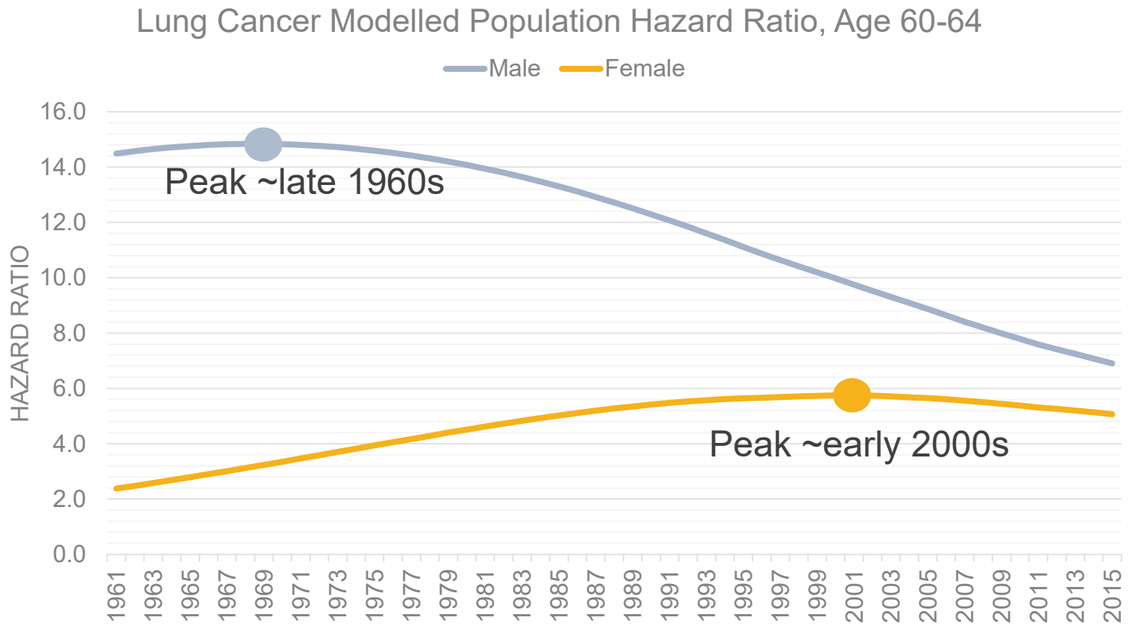

Source: Hazard Ratio: Thun, M. J., Carter, B. D., Feskanich, D., Freedman, N. D., Prentice, R., Lopez, A. D., Hartge, P., & Gapstur, S. M. (2013). 50-year trends in smoking-related mortality in the United States. The New England journal of medicine, 368(4), 351–364. https://doi.org/10.1056/NEJMsa1211127

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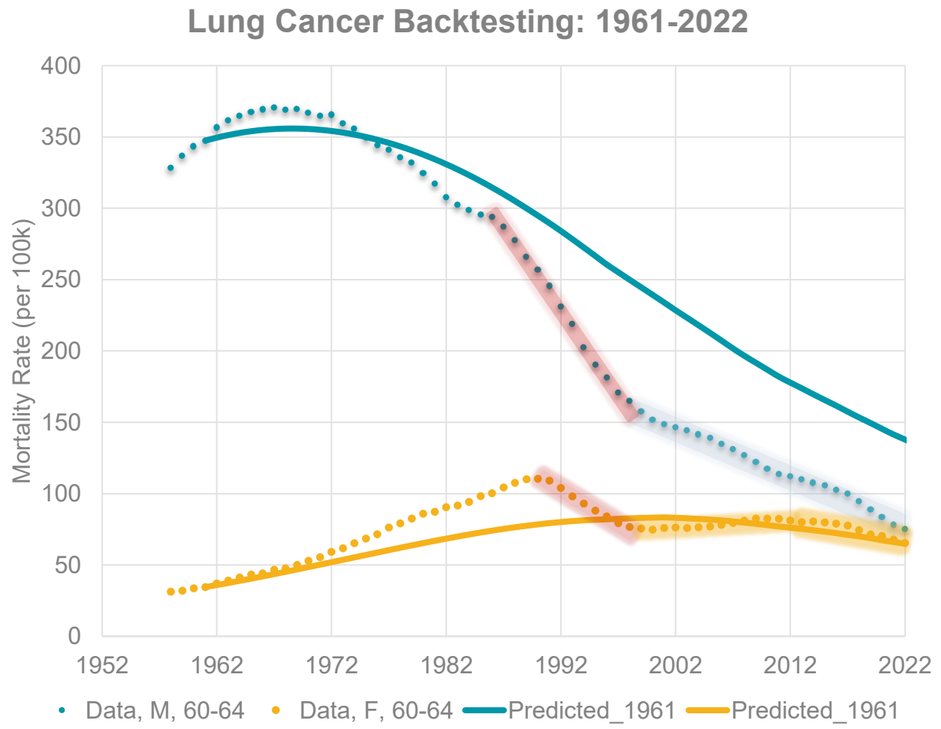
Back-testing, Male/Female, Age 60-64



We expect differences due to unmodelled risks:

- **Historic smog/industrial exposure (PM2.5)**
- **Medical Technologies** - Improvements in survival rates

Key Strengths:

✓Stratified by age/sex

✓Captures life history indirectly

✓Fits historic aggregate mortality trends well

✓Better reflects true sensitivity to policy change

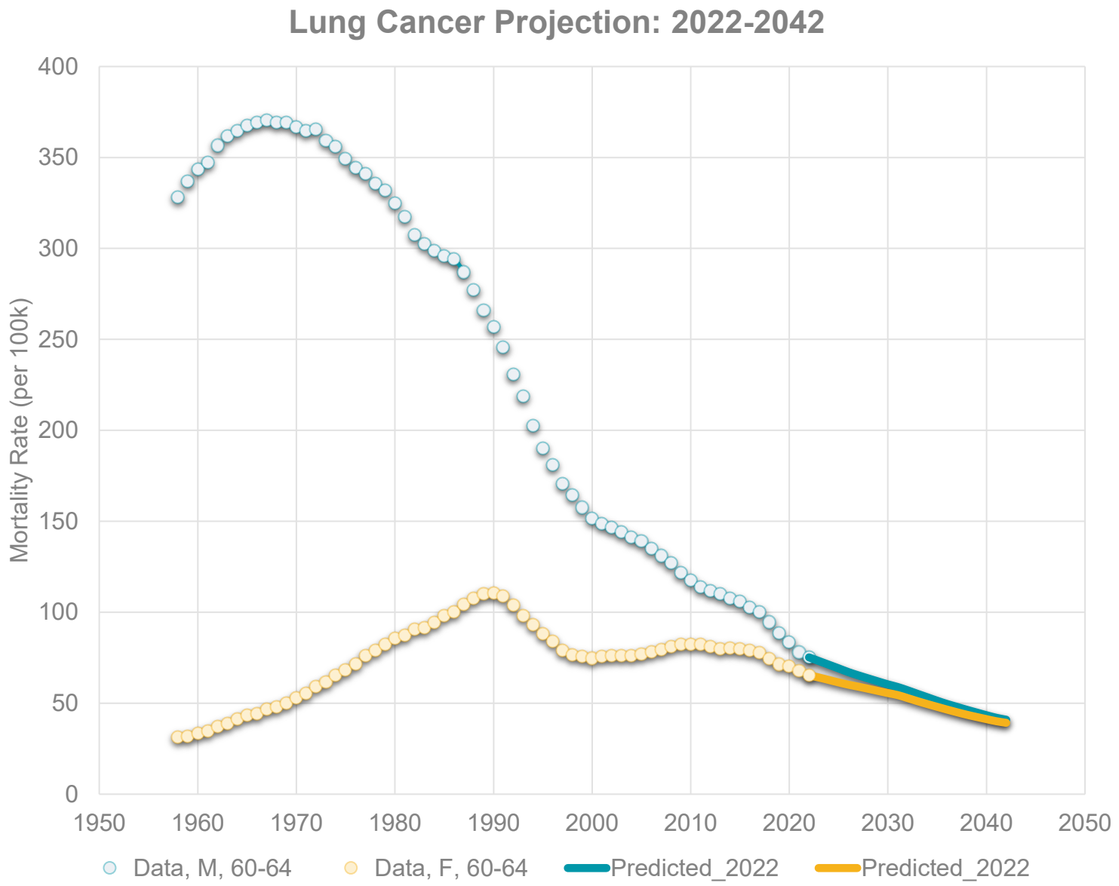
Key Weaknesses:

× Data requirements

× Complexity

Risk Actuary modelling smoking trends

Projection, Male/Female, Age 60-64



20-year statistical projection of:

- **Smoking Prevalence:** Age-Period-Cohort trend
- **Cigarette Consumption:** Age-Period trend

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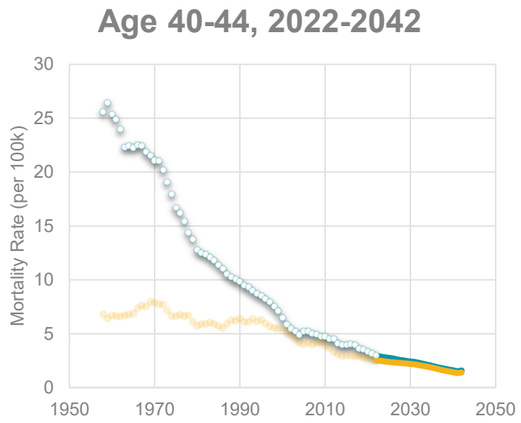
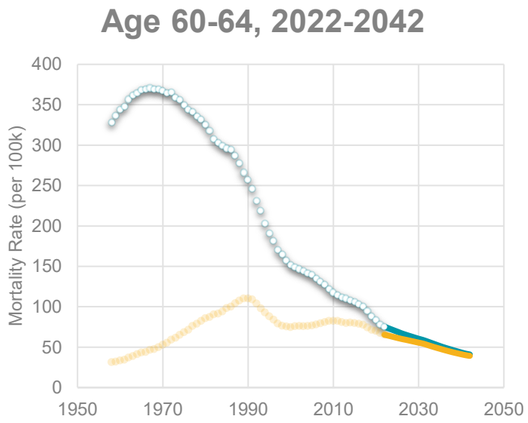
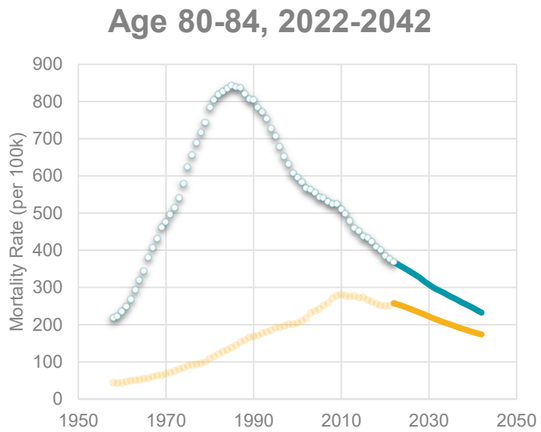
Projection, Male/Female



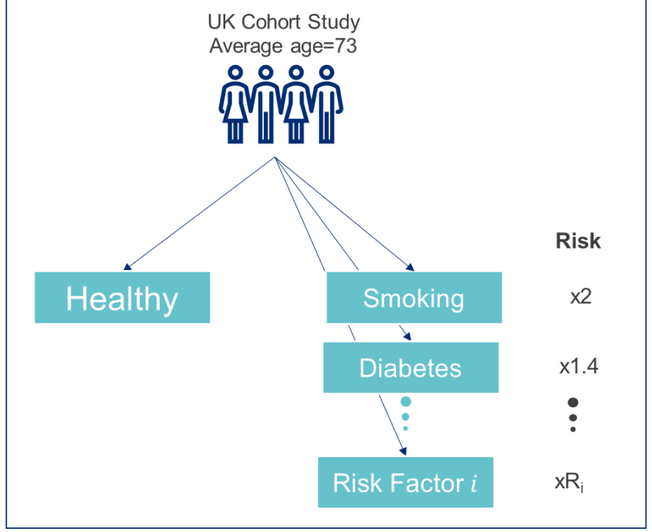




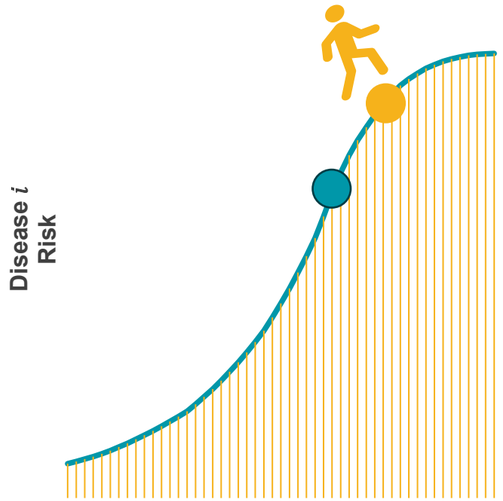
A Lifetime of Risk

Embedding the Lifecourse Approach

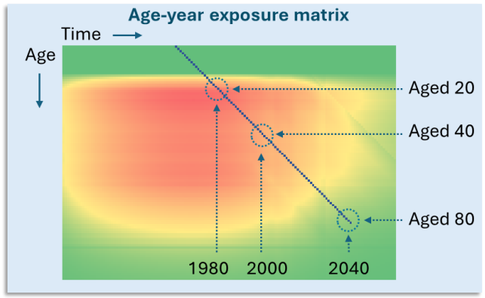
Evidence-Gathering



Lifecourse Framework



Lifecourse



Underwriting

Risk, t=0

Smoker x1.50

Diabetes x1.13

- Age: 55
- Smoker, 20yrs
- Type II diabetes, 15 years

Pricing uplift = ~~2.8~~ 1.70

Capital & Reserving

What if…

- ❑ Smoking trend continues? Total ban on sales?
- ❑ Cure for diabetes?
- ❑ GLP-1 impact on obesity?

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A Lifetime of Risk

Key takeaways

- A lifecourse approach allows us look beneath the surface of current risk
- Evidence-based, reflecting underling disease mechanisms
- Integrates past, present and future risk factor exposure within scenarios
- Can be applied as appropriate on a per risk factor basis
- Applicable beyond mortality – e.g. morbidity.

Q&A