Modeling and forecasting premature cardiovascular mortality: The role of obesity and education

Han Li and Tim Adair

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

This research is sponsored by the Society of Actuaries through the project titled "*U.S. Cardiovascular Disease Mortality – Phase 1*".

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

Summary of the project:

This project aims to model and forecast premature cardiovascular mortality, defined as deaths due to cardiovascular diseases at ages 35–74.

A key contribution of this research is to investigate the role of obesity and education in determining age-gender-specific premature cardiovascular mortality. We estimate the conditional probability of cardiovascular deaths given overweight/obesity status and education attainment level.

US data on mortality, health, and socioeconomic variables are considered over the period 2003–2019, and we collect both individual-level and macro-level information.

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

Definitions:

Overweight- and obesity-related CVD deaths: Deaths with cardiovascular disease being reported as an **associated cause of death**, along with one or more of obesity, diabetes, chronic kidney disease, lipidemias or hypertensive heart disease.

Obesity is defined as a BMI greater than or equal to 30 kg/m2.

Education level: 1 (Low education level), 2 (Medium education level), or 3 (High education level).

code	meaning	level
1	Less than 9th grade	low
2	9-11th grade (Includes 12th grade with no diploma)	low
3	High school graduate/GED or equivalent	medium
4	Some college or AA degree	medium
5	College graduate or above	high

Method:

Based on Bayes' theorem, for a certain age and gender, the conditional probability of cardiovascular death given overweight/obesity status and education attainment level is calculated as follows

$$\Pr(CVD|O,E) = \frac{\Pr(O,E|CVD)\Pr(CVD)}{\Pr(O,E)} = \frac{\overset{A}{\boxed{\Pr(O,E|CVD)}}\overset{B}{\boxed{\Pr(CVD)}}}{\underset{C}{\boxed{\Pr(O|E)}}\underset{D}{\boxed{\Pr(E)}}}$$

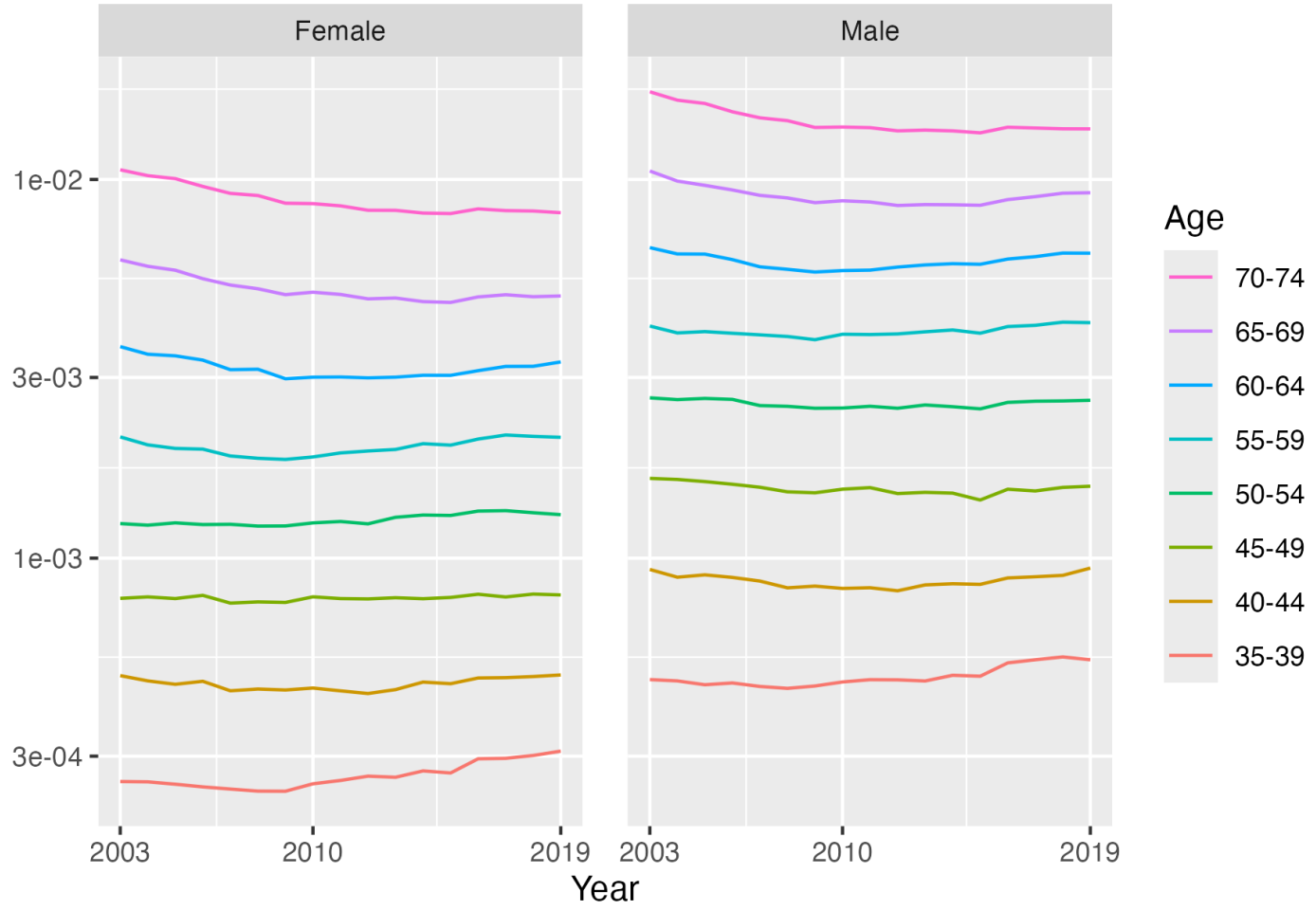
A: The proportion of cardiovascular disease (CVD) deaths within a specific obesity and education category.

B: The mortality rate due to CVD.

C: The proportion of overweight/obesity status within a specific education attainment category.

D: The proportion of individuals within a specific education category in the total population.

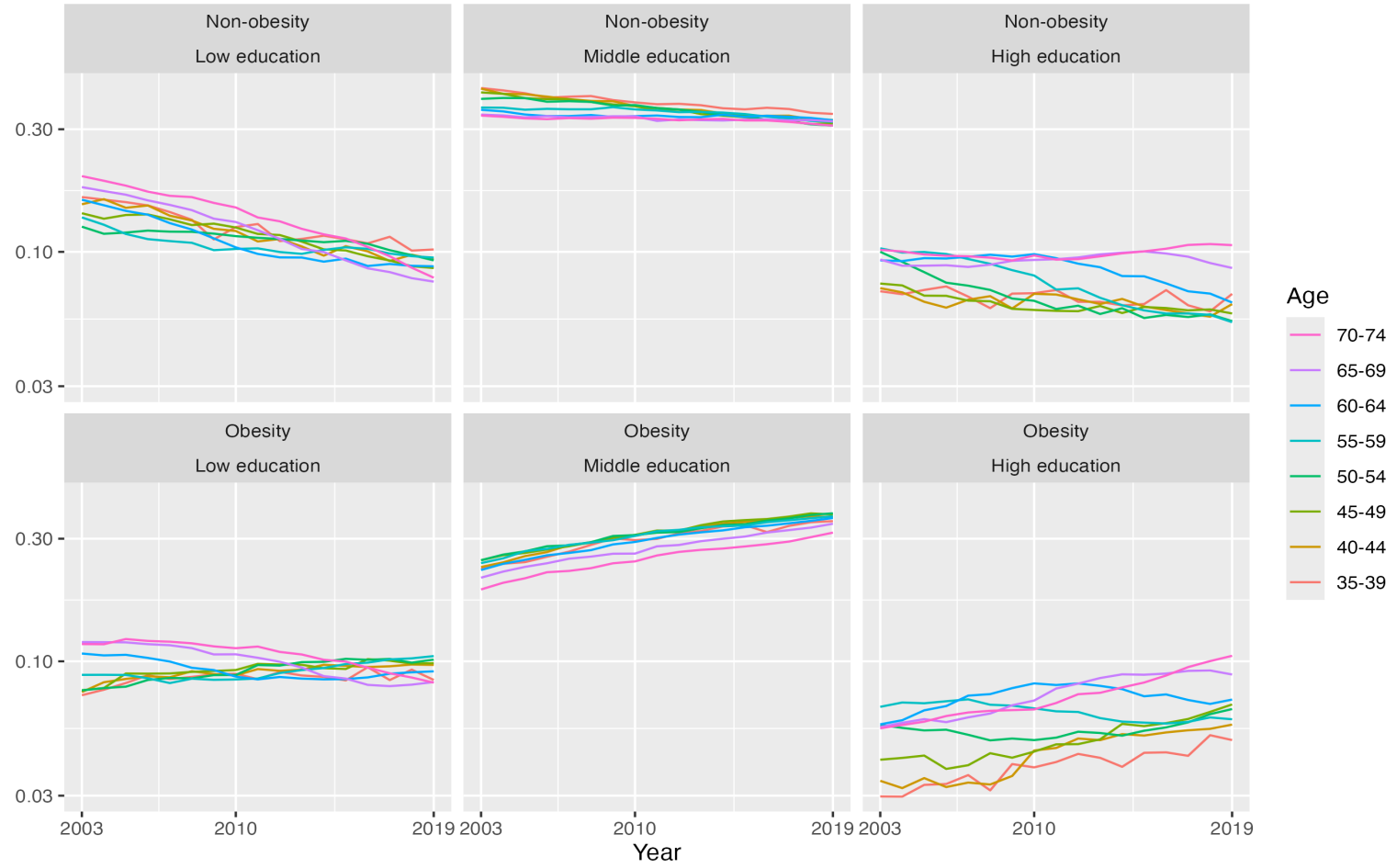
$\Pr(CVD)$: The mortality rate due to CVD



SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

$\Pr(O,E \mid CVD)$: The proportion of cardiovascular disease (CVD) deaths within a specific obesity and education category



SOCIETY OF ACTUARIES

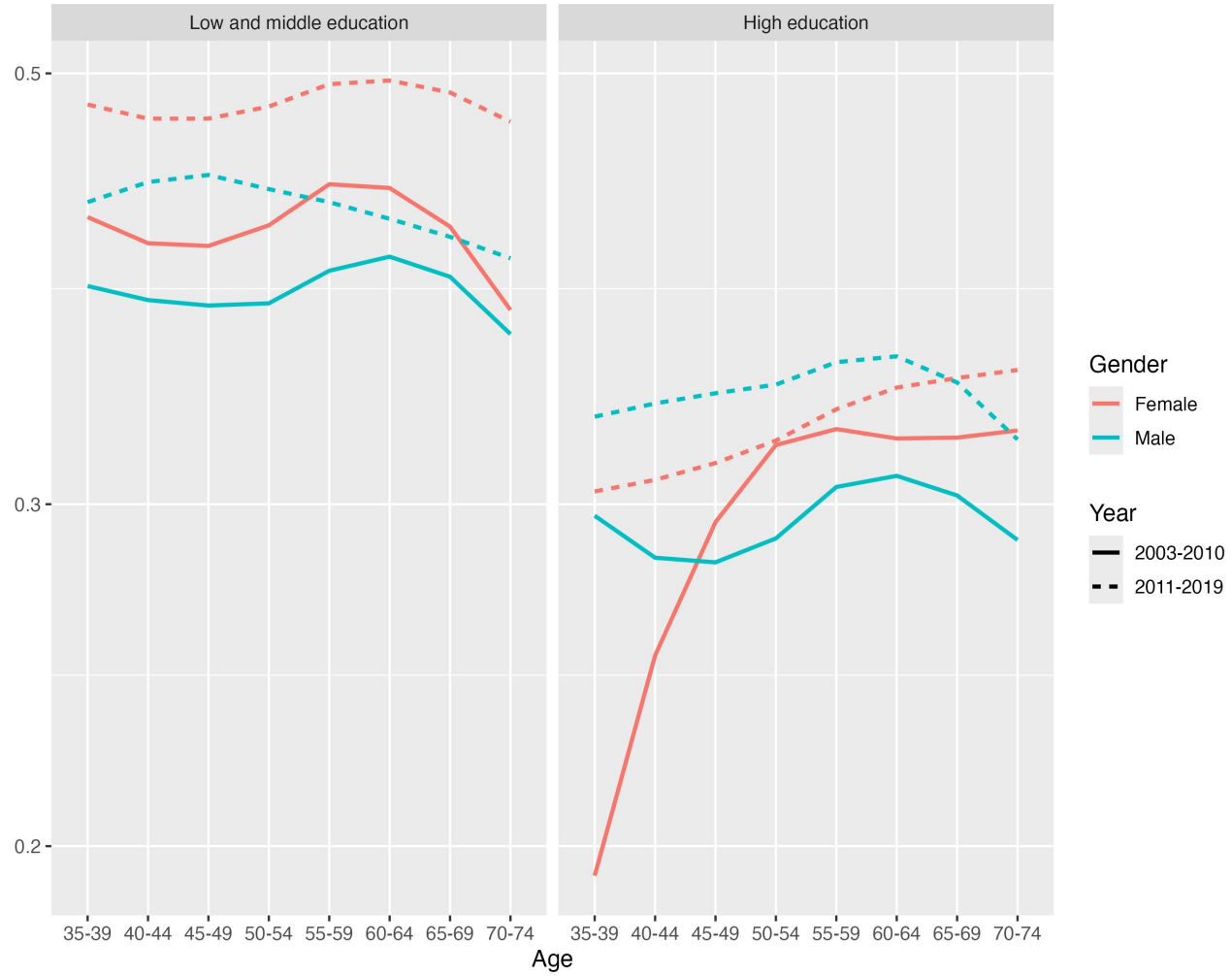
THE UNIVERSITY OF MELBOURNE

$\Pr(E)$: The proportion of individuals within a specific education category in the total population.

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

$\Pr(O \mid E)$: The proportion of overweight/obesity status within education attainment categories.



SOCIETY OF ACTUARIES

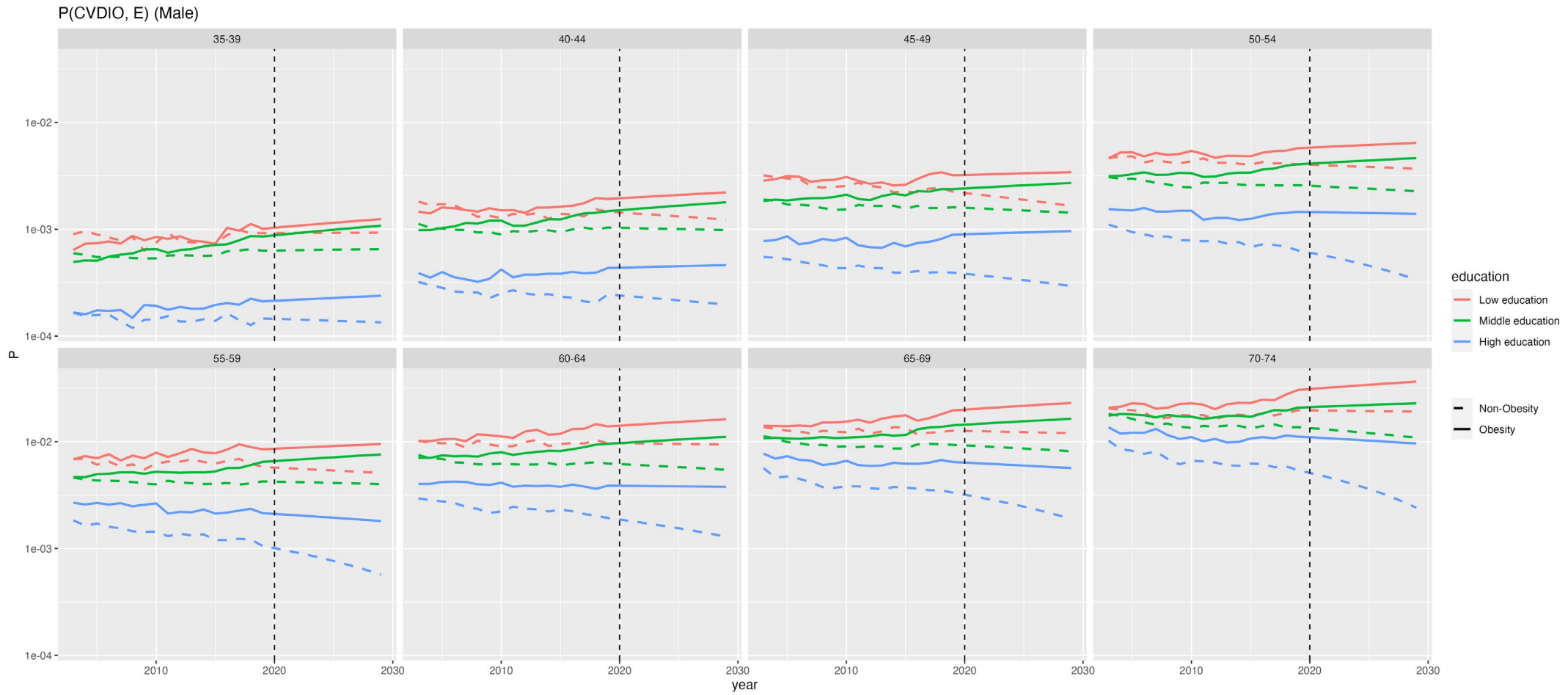
THE UNIVERSITY OF MELBOURNE

$\Pr(CVD \mid O, E)$: Conditional probability of cardiovascular deaths given overweight/obesity status and education attainment level

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

$\Pr(CVD \mid O, E)$: Predictions



SOCIETY OF ACTUARIES

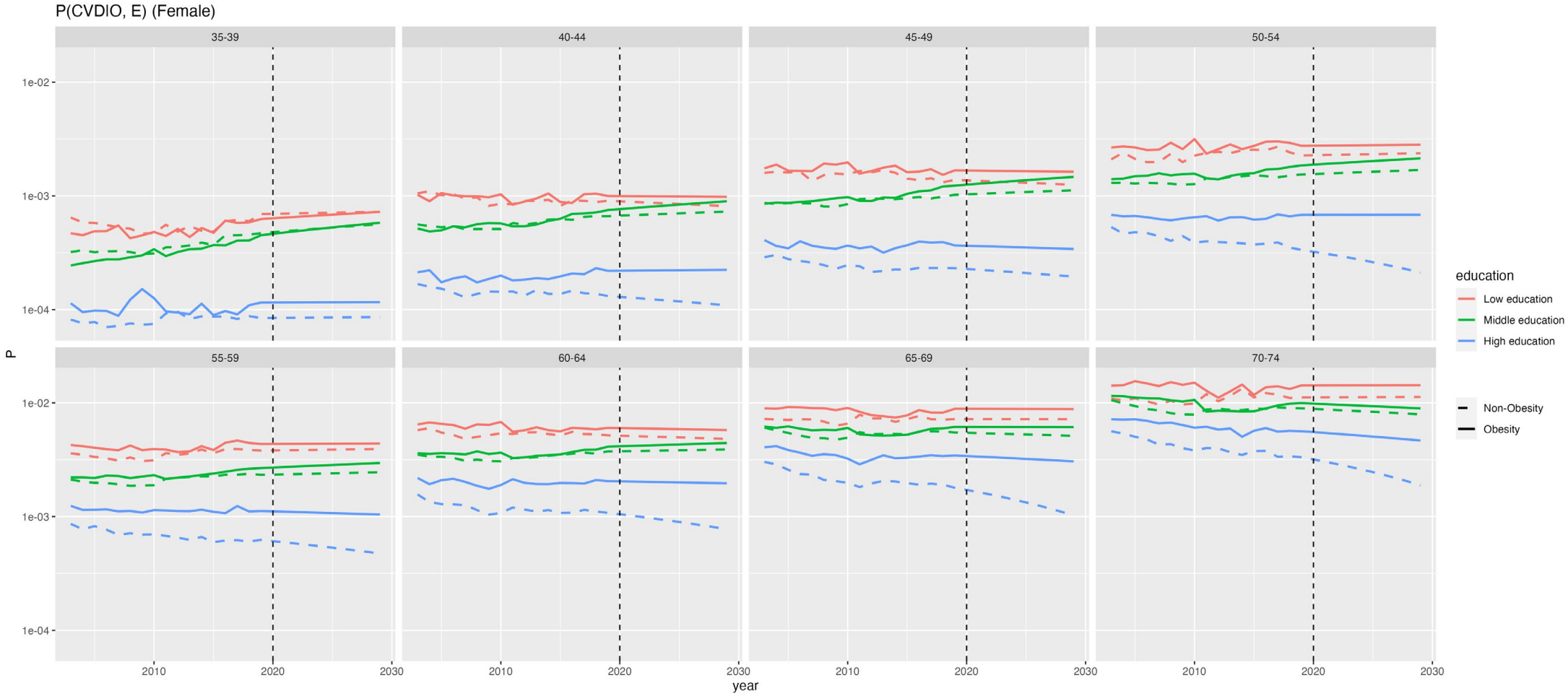
THE UNIVERSITY OF MELBOURNE

$\Pr(CVD \mid O, E)$: Conditional probability of cardiovascular deaths given overweight/obesity status and education attainment level

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

$\Pr(CVD \mid O, E)$: Predictions



SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

Main findings:

- CVD mortality is **increasing/stabilizing,** with worse trends in **younger age groups**.
- The prevalence of obesity is **increasing** across all age groups and education levels.
- The proportion of **highly educated** individuals is **increasing** over time.
- The proportion of CVD deaths that are **obesity-related** is **increasing** over all education levels.
- There is a **tendency of divergence** in CVD mortality **for obese vs non-obese** populations across all education levels.
- The **obese** population is experiencing, and is projected to experience, an **increase** or **stabilisation** in CVD mortality, with worse outcomes for **males**.
- The **non-obese highly educated population** is experiencing, and is projected to experience, a **decrease** in CVD mortality.
- Higher rates of CVD mortality due to **obesity status** more than offset lower rates due to **higher education**.

Actuarial implications:

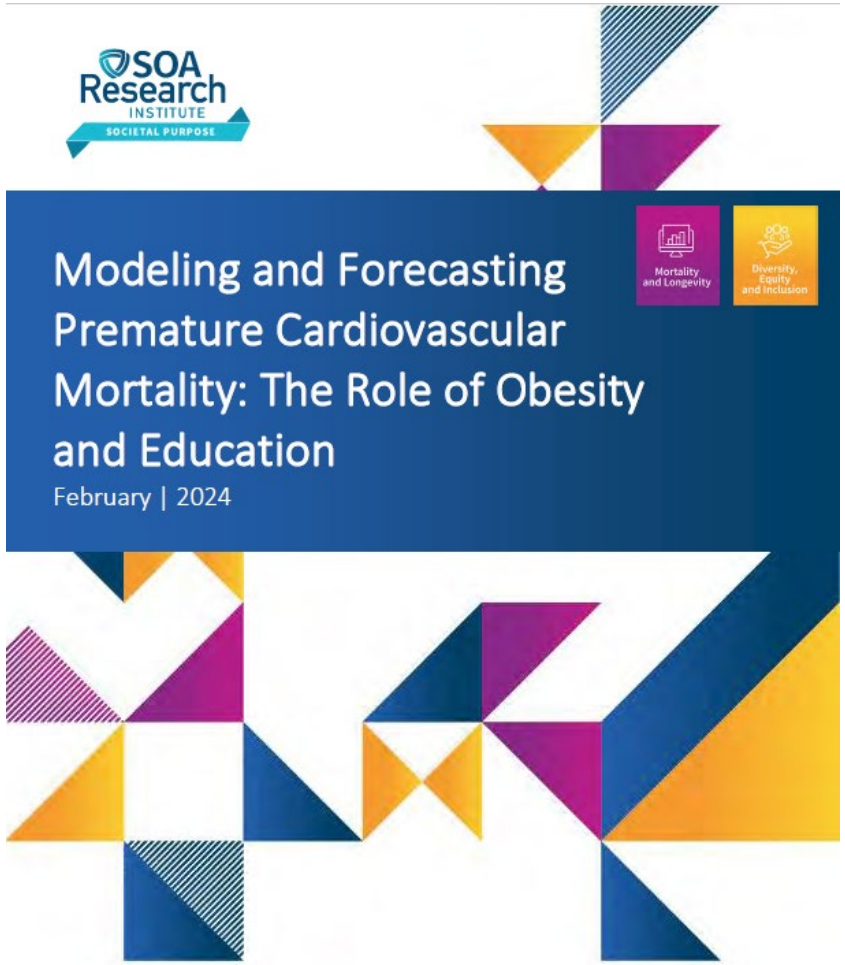
- Understanding the trends and patterns in premature CVD mortality can aid insurers in **refining their risk assessment and management strategies**.
- Insurers may be able to **tailor their underwriting processes**. The insights from our research can also enhance risk assessment for the insurance company and improve portfolio monitoring.
- Insurance companies may **play a role in supporting healthy choices**, not only by offering insurance coverage, but also by **incentivizing policyholders to adopt healthier lifestyles**.
- Pension actuaries and actuaries specializing in U.S. individual life and annuities may find it valuable to note that **improvements in CVD mortality** for individuals in **white-collar jobs** and **preferred underwriting classes** are likely to be **higher than** those observed in the **general population**.

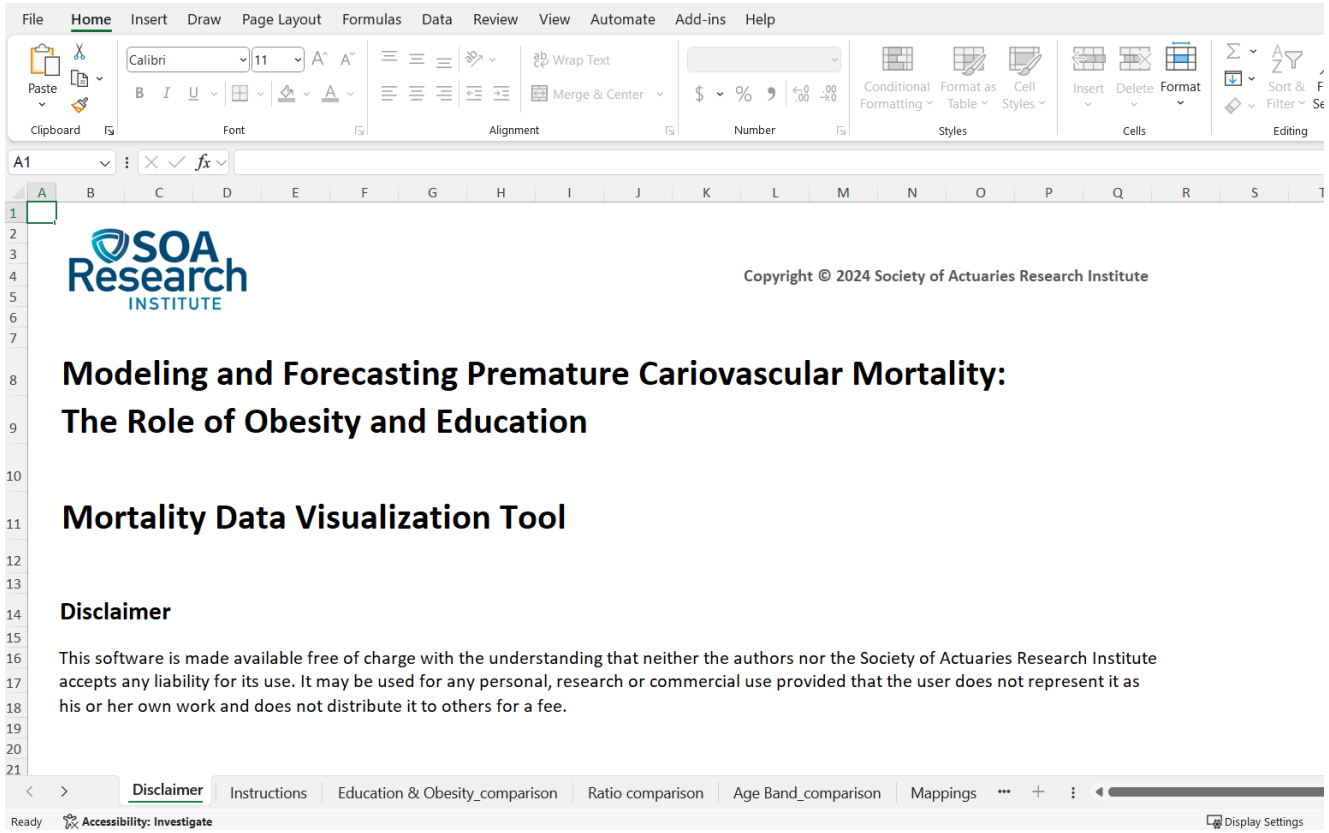
SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

Full report and Excel visualization tool:

https://www.soa.org/resources/research-reports/2024/modeling-premature-cardiovascular-mortality/





SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

Q&A:

Any questions/comments/suggestions?

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE

References:

1. Adair, T. (2023). Premature cardiovascular disease mortality with overweight and obesity as a risk factor: Estimating excess mortality in the United States during the COVID-19 pandemic. International Journal of Obesity. Forthcoming.

2. Adair, T. and Lopez, A. D. (2020). The role of overweight and obesity in adverse cardiovascular disease mortality trends: An analysis of multiple cause of death data from Australia and the USA. BMC Medicine, 18(1), 1–11.

3. Lopez, A. D. and Adair, T. (2019). Is the long-term decline in cardiovascular-disease mortality in high income countries over? Evidence from national vital statistics. International Journal of Epidemiology, 48(6), 1815–1823.

4. Ogden CL, Fakhouri TH, Carroll MD, et al. Prevalence of Obesity Among Adults, by Household Income and Education — United States, 2011–2014. MMWR Morb Mortal Wkly Rep 2017;66:1369–1373.

SOCIETY OF ACTUARIES

THE UNIVERSITY OF MELBOURNE