ARC CENTRE OF EXCELLENCE IN POPULATION AGEING RESEARCH

Multimorbidity and functional disability
Implications for life annuities and long–term care insurance

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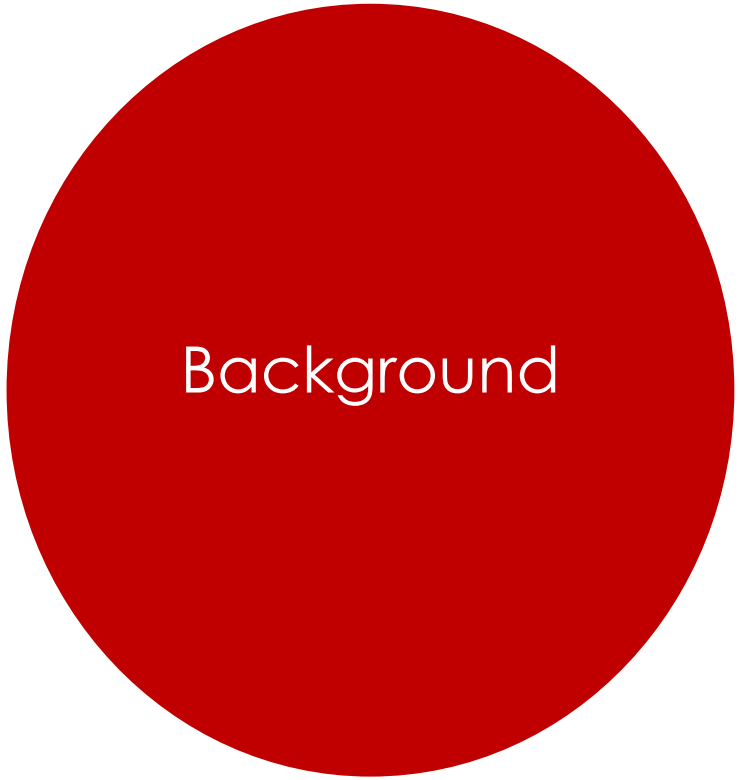
Outline

1. **Motivation**
2. Data
3. Methodology
4. Results
5. Conclusion

Motivation



- Demand for long–term care is expected to increase globally in the next few years as more than 50% of individuals aged 65 and above are expected to need long–term care
- Multimorbidity is commonly described as the presence of more than one chronic condition at a particular time
- It is an under researched area in the actuarial literature given the prevalence of multiple diseases amongst older individuals
- The backdrop of an ever increasing ageing population worldwide and significant costs of chronic conditions on disease burdens globally has garnered more attention towards multimorbidity

Literature Review

Ageing Population

Definitions

Presence of 2 or more diseases with or without impairment (Marengoni et al. 2012)

Indexation approach (Charlson et al. 1987, Greenfield et al. 1983, Imamura et al. 1997)

Pool of diseases, Fortin et al. 2012 recommend considering 12 or more diseases to reduce variability in prevalence estimates

Prevalence

Kingston et al. (2018) estimate that more than half of the older population will have multimorbidity from 2015-2035

Risk factors

Being older, female and having a lower socio-economic status are associated with multimorbidity (Van den Akker et al. 1998, 2000)

Literature gap

Three state models of health and functional disability do not distinguish between multimorbid and healthy individuals (Fong, Shao and Sherris, 2015; Li, Shao and Sherris, 2017; Hanewald et al, 2019; Fu, Sherris and Xu, 2021, Wang et al, 2022)

Sherris and Wei (2021) propose a five state health status and disability model but do not consider multimorbidity

Multi–state models are used to calculate mortality rates, incidence and prevalence rates of multimorbidity for both men and women (Kingston et al. 2018; Chan et al. 2019). However, they do not consider functional disability or recovery from multimorbidity

We are unaware of a link in the literature between multimorbidity and the pricing of long term care products

Research questions

How to incorporate multimorbidity in actuarial pricing?

- What is the impact of multimorbidity on transition rates in a three state model of health status and functional disability that controls for age and gender?
- To what extent does a five state model of multimorbidity and functional disability capture differences in mortality and functional disability risks?
- What are the pricing and life expectancy implications of using the two different methods of capturing the effect of multimorbidity on transition rates in multiple state health models?

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How do we incorporate multimorbidity in actuarial pricing?

Definition

- Multimorbidity is the presence of one or more of the following conditions high blood pressure, diabetes, cancer, lung disease, heart problems, stroke, psychiatric problems and arthritis

Data

- University of Michigan Health and Retirement Study
- Biennial nationally representative longitudinal study following Americans aged 50+
- Exclude individuals who provide inappropriate responses and those who fail to respond in any wave

Activities of daily living

Functional disability is triggered when an individual has some difficulty in 2 or more activities of daily living

Note. Reprinted from "User Experience Design of Stroke Patient Communications Using Mobile Finger (MOFI) Communication Board With User Center Design Approach", by Priana et al. , 2018, *International Journal of Interactive Mobile Technologies*,12 (2), p 4.

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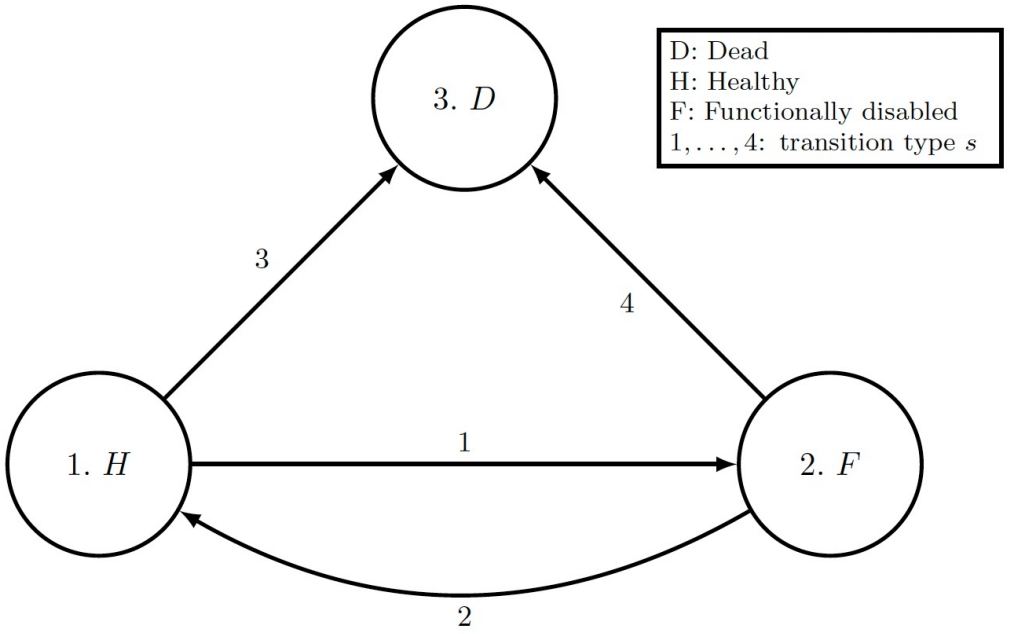
Health and functional disability model



Following the proportional hazard specification in Li, Shao, and Sherris (2017); Sherris and Wei (2021), we model the transition intensity of type $s = 1, \ldots, S$ for an individual k for $k = 1, \ldots, K$ at time t years with

$$\lambda_{k,s}(t) = \exp(\beta_s + \gamma_s' w_k(t) + \alpha_s \psi(t)) H_{k,s}(t),$$

where β_s is the time invariant baseline log–intensity for transition type s, $w_k(t)$ is a vector of the observed predictors for each individual k, $\psi(t)$ is frailty which is a stochastic latent process, γ_s is a vector measuring the sensitivity of $\lambda_{k,s}(t)$ with respect to $w_k(t)$, α_s is a scalar measuring the sensitivity of $\lambda_{k,s}(t)$ with respect to $\psi(t)$ and $H_{k,s}(t) = 1$.

$$\ln \lambda_{k,s}(t) = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k + \gamma_s^{multimorbidity} M_k$$

$$\ln \lambda_{k,s}(t) = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k + \gamma_s^{multimorbidity} M_k + \phi_s^{time} t$$

$$\ln \lambda_{k,s}(t) = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k + \gamma_s^{multimorbidity} M_k + \phi_s^{time} t + \alpha_s \psi_t$$

Five state model of multimorbidity and functional disability

Static model

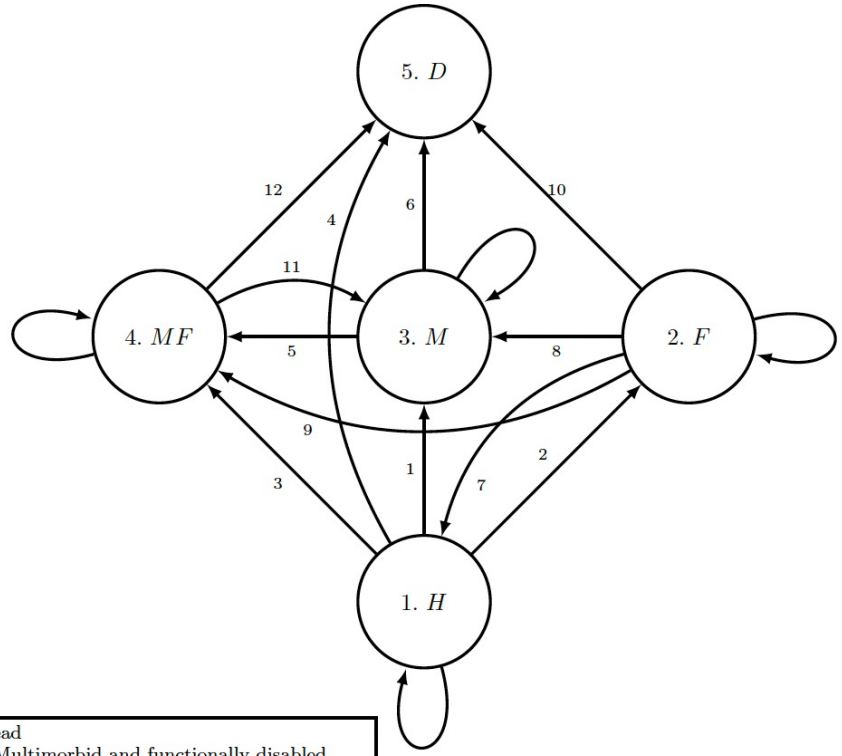
$$\ln \lambda_{k,s} = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k$$

Model with systematic trend

$$\ln \lambda_{k,s} = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k + \phi_s^{time} t$$

Frailty model with systematic trend and uncertainty

$$\ln \lambda_{k,s} = \beta_s + \gamma_s^{age} x_k(t) + \gamma_s^{female} F_k + \phi_s^{time} t + \alpha_s \psi_i$$



D: Dead
MF: Multimorbid and functionally disabled
M: Multimorbid and not functionally disabled
F: Functionally disabled and not multimorbid
H: Not multimorbid and not functionally disabled
$1, \ldots, 12$: transition type s

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Three state model of health and functional disability

Disability rates increase with age but recovery rates decrease with age

Females are more likely to become disabled than males

Multimorbidity increases disability and mortality rates while it also decreases the chance of recovery

Future lifetime statistics

Females have longer life expectancy and spend more time disabled

Individuals who are not multimorbid live longer and healthier lives

Individuals who are multimorbid become functionally disabled earlier than others

HLE/TLE is higher than both the multimorbid and the overall group

Five state model of multimorbidity and functional disability

Mortality rates increase with age

(H→D, M→D, F→D and MF→D)

Disability rates increase with age

(H→F, H→MF and M→MF)

Multimorbidity rates from the healthy state increase with age

(H→M, H→MF)

Multimorbidity from the functionally disabled state decreases with age

(F→MF)

Recovery rates from functional disability decrease with age

(F→H, F→M and MF→M)

Five state model of multimorbidity and functional disability

Females have lower mortality rates and more likely to become disabled than males

Females are more likely to become multimorbid and functionally disabled than males

(H→MF and M→MF)

Females are less likely to become multimorbid than males

(H→M, H→MF)

Summary of key findings

Conclusions reached on life expectancy and pricing are very sensitive to the selected multimorbidity model

Three state functional disability model correctly shows that there are distinct life expectancy and healthy life expectancy patterns between morbid and non–morbid groups

Five state model of multimorbidity and functional disability improves this model by showing that providers can expect to makes significant losses on life annuities, long term care and lifecare annuities due to mispricing of mortality and functional disability risks

Strong evidence that gains in life expectancy are being lost to increasing multimorbidity which supports the theory of morbidity expansion

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References I

Charlson, Mary E., Peter Pompei, Kathy L. Ales, and C. Ronald MacKenzie. 1987. "A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation." *Journal of Chronic Diseases* 40 (5): 373–83. https://doi.org/10.1016/0021-9681(87)90171-8.

Fong, Joelle H, Adam W Shao, and Michael Sherris. 2015. "Multistate Actuarial Models of Functional Disability." *North American Actuarial Journal* 19 (1): 41–59. https://doi.org/10.1080/10920277.2014.978025.

Fu, Yu, Michael Sherris, and Mengyi Xu. 2021. "Functional disability with systematic trends and uncertainty: a comparison between China and the US." *Annals of Actuarial Science*, 1–30. https://doi.org/10.1017/S1748499521000233.

References II

Greenfield, Sheldon, Giovanni Apolone, Barbara J. McNeil, and Paul D. Cleary. 1993. "The importance of co-existent disease in the occurrence of postoperative complications and one-year recovery in patients undergoing total hip replacement. Comorbidity and outcomes after hip replacement." *Medical Care* 31 (2): 141–54. https://doi.org/10.1097/00005650-199302000-00005.

Hanewald, Katja, Adam W Shao, and Han Li. 2019. "Modelling multi-state health transitions in China: A generalised linear model with time trends." *Annals of Actuarial Science* 13 (1): 145–65. https://doi.org/10.1017/S1748499518000167.

Imamura, Kyoko, Morag McKinnon, Robert Middleton, and Nick Black. 1997. "Reliability of a comorbidity measure: The index of co-existent disease (ICED)." *Journal of Clinical Epidemiology* 50 (9): 1011–16. https://doi.org/10.1016/S0895-4356(97)00128-5.

References III

Li, Zixi, Adam W Shao, and Michael Sherris. 2017. "The Impact of Systematic Trend and Uncertainty on Mortality and Disability in a Multistate Latent Factor Model for Transition Rates." *North American Actuarial Journal* 21 (4): 594–610. https://doi.org/10.1080/10920277.2017.1330157.

Shao, Adam W, Michael Sherris, and Joelle H Fong. 2017. "Product pricing and solvency capital requirements for long-term care insurance." *Scandinavian Actuarial Journal* 2017 (2): 175–208. https://doi.org/10.1080/03461238.2015.1095793.

Sherris, Michael, and Pengyu Wei. 2020. "A Multi-state Model of Functional Disability and Health Status in the Presence of Systematic Trend and Uncertainty." *North American Actuarial Journal*, February, 1–23. https://doi.org/10.1080/10920277.2019.1708755.

References IV

Van Den Akker, Marjan, Frank Buntinx, Job F. M. Metsemakers, and J. André Knottnerus. 2000. "Marginal impact of psychosocial factors on multimorbidity: results of an explorative nested case-control study." *Social Science & Medicine* 50 (11): 1679–93. https://doi.org/10.1016/S0277-9536(99)00408-6.

Van den Akker, Marjan, Frank Buntix, Job F. M. Metsemakers, Sjef Roos, and J. André Knottnerus. 1998. "Multimorbidity in General Practice: Prevalence, Incidence, and Determinants of Co-Occurring Chronic and Recurrent Diseases." *Journal of Clinical Epidemiology* 51 (5): 367–75. https://doi.org/10.1016/S0895-4356(97)00306-5.

Wang, Qiqi, Katja Hanewald, and Xiaojun Wang. 2022. "Multistate health transition modeling using neural networks." *Journal of Risk and Insurance* 89 (2): 475–504. https://doi.org/10.1111/JORI.12364.