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Using English National Dataset to estimate Models of Functional Disability

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Agenda

- Background on functional disability in older age
- Dynamics of functional disability
- The dataset
- The multistate model, and GLM framework for graduation

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Functional disability

Definition and National Statistics

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Functional disability - definition

- Functional disability is measured by self-reported difficulties in the activities of daily living (ADLs) at older age.
- ADLs include activities such as:
  - dressing (including putting on shoes and socks),
  - eating (such as cutting up your food),
  - using the toilet (including getting up and down),
  - bathing and showering,
  - getting in and out of bed, and
  - walking across a room

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Functional disability – why?

- Functional disability is a significant health indicator, for two reasons:
  - their high prevalence and
  - their adverse consequences.
- It is a fundamental predictor of mortality at older age.
- It is also a strong predictor of utilisation of institutional long-term care and other health services (Anderson et al. (1998) and others)

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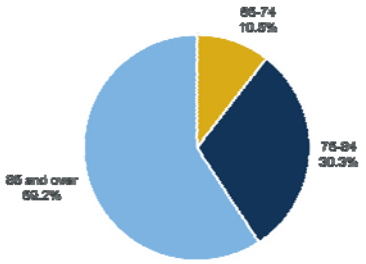
Functional disability in the UK

- **Half** of the English people aged **65 and over** have a **disability** and/or activity limiting health problem.
- 352 thousand persons **living in care home** with/without nursing in 2011
- 80% of the care home residents aged **65 and older**

Proportions of the resident care home population aged 65 and over by age in England and Wales, 2011



Source: Office of National Statistics (2014)

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Dynamics of functional disability

Literature perspective

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Causes and patterns

- Factors that cause functional disability can be
  - physical,
  - mental,
  - emotional, or
  - memory problems
- Patterns of functional disability are highly variable, it can be
  - prolonged or permanent disability,
  - a single discrete short episode of disability, or
  - recurrent episodes of disability (Hardy et al. (2005); Anderson et al. (1998)).

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Literature on disability dynamics

- the Established Populations for Epidemiological Studies of the Elderly (de Leon et al. (1999, 1997); Gill et al. (1997)),
- the Longitudinal Study on Ageing (Rudberg et al. (1996); Anderson et al. (1998); Dunlop et al. (1997)), and
- the National Long-Term Care Survey (Manton and Gu (2001)).
- the English Longitudinal Study for Ageing (Anderson and Elsheemy (2015))
- Moreover, the dynamics of recovery are seen when subjects were followed up more frequently; e.g. monthly interviews (Hardy et al. (2005)).

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Long-term care (LTC) insurance

- LTC insurance is a financial product that provides cover to the costs associated with needing, i.e. the payments start in later life when a carer is needed or the policyholder is admitted to care home.
- Benefit pay-outs from long-term-care (LTC) insurance covers are typically triggered when the insured becomes functionally disabled or chronically ill and requires support in various facets of living over prolonged periods.
- Surprisingly few studies have attempted to characterize the full set of morbidity and mortality transition probabilities across different functional states.

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The Dataset

English Longitudinal Study of Ageing

English Longitudinal study of Ageing

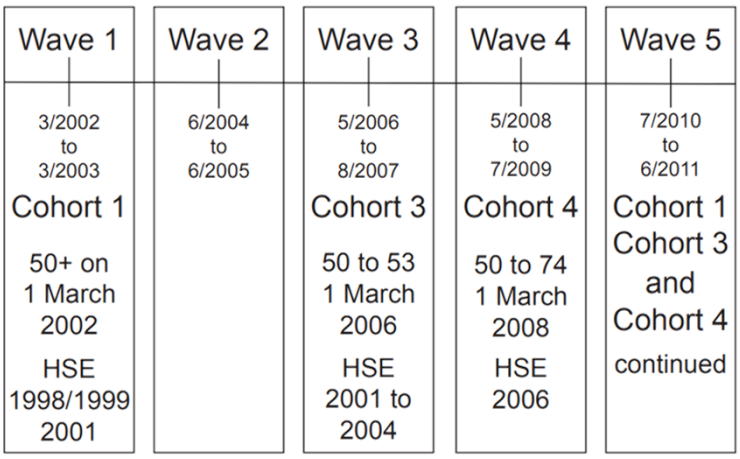
- ELSA is a longitudinal survey dataset for the study of:
  - health,
  - economic position, and
  - quality of life among the elderly.
- It was modelled after the Health and Retirement Study (HRS), a similar longitudinal survey dataset for the United States.

ELSA interviews

- ELSA is a large scale longitudinal panel study of people aged **50 and over** and their partners, living in private households in England.
- Respondents have been interviewed **biennially**.
- At each wave all interviews comprised of:
  - a personal face-to-face CAPI (main questionnaire),
  - a self-completion questionnaire, and
  - Waves 2, 4 and 6 also included a separate nurse visit.

ELSA sampling

- The technical details of this study and the results of primary analyses have been published elsewhere (Scholes et al. (2009); Steptoe et al. (2012)) and are also available at the web site of the Institute of Fiscal Studies http://www.ifs.org.uk/elsa/



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Disabilities reported in ELSA

Motor skills

- Skills dependent on using lower limbs, hips and waist
  - walking, sitting, getting up, climbing stairs, and stooping
- skills dependent on using upper limbs
  - reaching, pulling/ pushing, carrying/ lifting, and picking a coin.

ADLs

- Respondents were shown cards that listed 6 ADLs:
  - dressing (including putting on shoes and socks),
  - eating (such as cutting up your food),
  - using the toilet (including getting up and down),
  - bathing and showering,
  - getting in and out of bed, and
  - walking across a room.

Instrumental ADLs

- Respondents were shown cards that listed 7 IADLs:
  - Using a map
  - Preparing a hot meal
  - Shopping for groceries
  - Making a phone call
  - Taking medication
  - Work around the house or the garden, and
  - Managing money such as paying bills.

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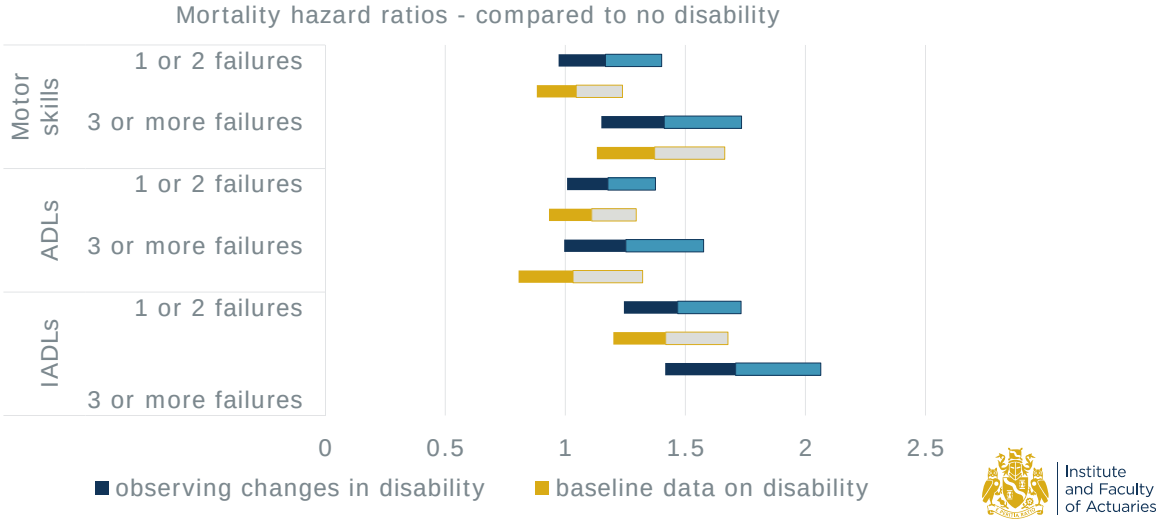
Mortality predictions



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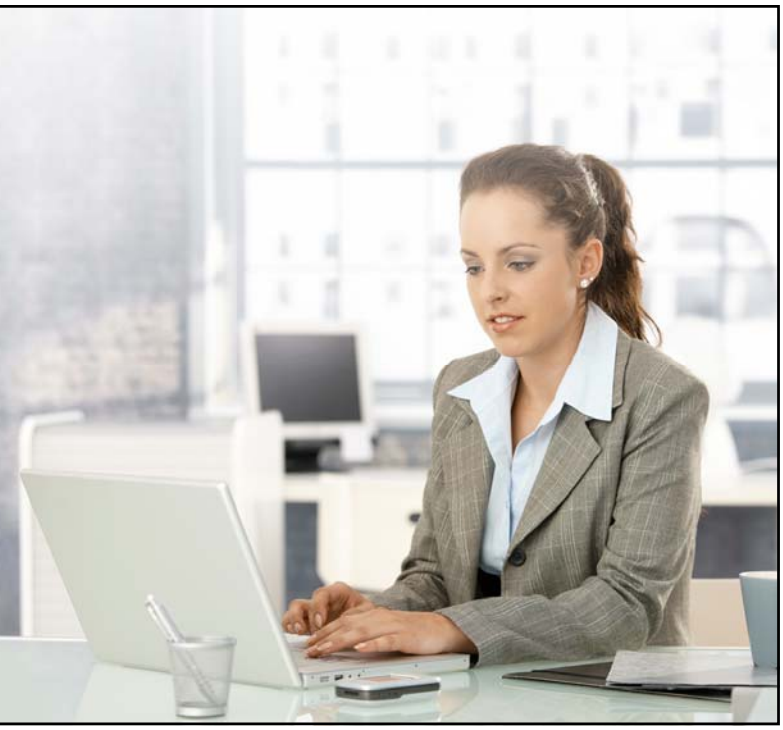
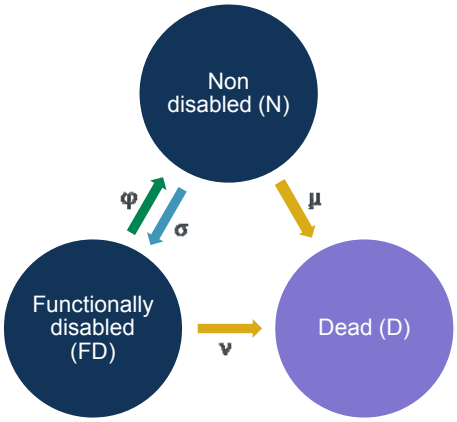
The modelling

Multistate Actuarial model



The model

- The goal is to estimate **age-specific** disability transition probabilities among a sample of English older adults aged 50 to 90 at baseline in 2002
- A time-continuous inhomogeneous Markov chain was adopted
- Generalized linear models (GLM) were adopted for graduating both mortality and disability transition intensities
- The effects of different benefit trigger configurations on the sensitivity of the disability incidence rates



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Markov process for transition probabilities

- The transition probability P_{ij} from state i to state j after t years from policy issue is defined by
  - $P_{ij}(t, t+\Delta t) = Pr\{S(t+\Delta t) = j | S(t) = i\} \quad , t \geq 0, \Delta t \geq 0, i, j \in \{N, FD, D\}$
- The instantaneous transition intensities are aged dependent and are assumed to be defined on compact intervals, and are defined by
  - $I_{ij} = \lim_{\Delta t \to 0^+} \frac{P_{ij}(t,t+\Delta t)}{\Delta t} , t \geq 0, i \neq j$
- Transition intensities were estimated from the data, the transition probabilities were derived using Kolmogorov differential equations (Haberman and Pitacco 1999)

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Definitions of functional states

- The numbers of reported difficulties in ADLs were used to define the state FD.
- Two definitions were specified according to the minimum level of functional disability that triggers LTC insurance benefit pay-outs:
  - two or more ADLs
  - three or more ADLs
- Moving between the states of non-disabled and disability were captured by the change in number of ADLs between six ELSA interview waves, between 2002 to 2012.
- Follow up on death data were available for the years 2002 to 2012

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Estimating transition intensities

- Let each of the four transition intensities ($\mu, \nu, \sigma, or\ \varphi$) be a function of the age of onset x
- An invertible link function $g(.)$ is chosen to define the linear regressor η_x as a function of a transition intensity I_x
  - $\eta_x = g(I_x) \quad , I \in \{\mu, \nu, \sigma, \varphi\}$
- Age is used as the only covariate affecting disability/mortality transitions. Therefore, the regressor η_x is defined as a polynomial of age x
  - $\eta_x = \sum_{s=0}^{k} \beta_s x^s$, where the size of the polynomial k is chosen to minimise the model change in deviance.

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Estimating transition intensities - continued

- Define i_x and e_x as the number of transitions at age x and corresponding central exposure to risk in years, respectively.
- i_x are assumed to be constant between complete years of age, and thus
  - $i_x \sim i.i.d.\ Poisson(e_x I_x) \forall x$
  - $E(i_x | e_x, I_x) = e_x I_x$
  - $Var(i_x | e_x, I_x) = e_x I_x \ , I \in \{\mu, \nu, \sigma, \varphi\}$
- The GLMs are fitted to the data using maximum likelihood methods to obtain the estimates of the regression coefficients (β_s)
- Transitions from state N to FD (and vice versa) are assumed to occur, on average, halfway between two known interview dates.

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Raw transitions counts and exposure years

	l_x = Number of transitions				e_x = exposure years	
Age band	σ: N → FD	φ: FD→N	μ: N→D	ν: FD→D	in state N	in state FD
50-54	88	72	14	6	7,798.6	443.9
55-59	216	180	66	23	16,032.6	1,138.0
60-64	228	218	96	38	15,093.0	1,175.6
65-69	217	200	130	55	12,781.1	1,133.3
70-74	294	217	211	66	11,212.4	1,326.4
75-79	286	200	328	90	8,618.0	1,287.5
80-84	282	169	338	146	5,703.0	1,211.4
85-89	196	103	334	140	2,967.8	910.6
90 and over	94	43	252	162	1,038.8	605.1
Total	**1,901**	**1,402**	**1,769**	**726**	**81,236.3**	**9,211.7**

Data from 10 years follow-up period between 2002 and 2012, of ELSA respondents for household residents aged 50 and over

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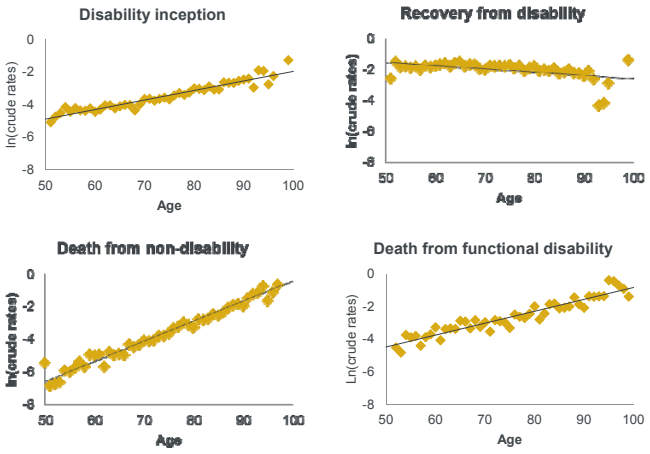
Testing linearity of the regressor η_x



- Generally linear patterns support the use of the proposed log transformation based on Poisson GLMs
- Recovery from disability is slowing down at older ages
- Mortality from functional disability is higher than mortality from non-disability in younger ages, but this difference lessens at older ages.

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Poisson GLM: Goodness of fit of the models

k	AIC	BIC	D	Dc	p-value
σ:N→FD	disability incidence				
1	6.27	-126.84	65.82		
2	**6.10**	**-133.33**	**55.39**	**-10.43**	**0.001**
3	6.11	-130.87	53.93	-1.47	0.201
φ:FD→N	recovery				
1	5.98	-121.04	71.62		
2	**5.47**	**-144.71**	**44.01**	**-27.60**	**0.003×10^{-4}**
3	5.49	-141.78	43.01	-1.00	0.482
μ:N→D	death from non-disability				
1	6.43	-115.65	77.01		
2	**6.35**	**-117.64**	**71.08**	**-5.93**	**0.016**
3	6.36	-115.32	69.48	-1.61	0.232
v:FD→D	death from disability				
1	5.53	-119.18	73.48		
2	**5.46**	**-120.52**	**68.20**	**-5.27**	**0.018**
3	5.45	-119.11	65.68	-2.52	0.096

- k denotes the number age related parameters.
- the use of quadratic polynomial of age is statistically significant for all four transition intensities.

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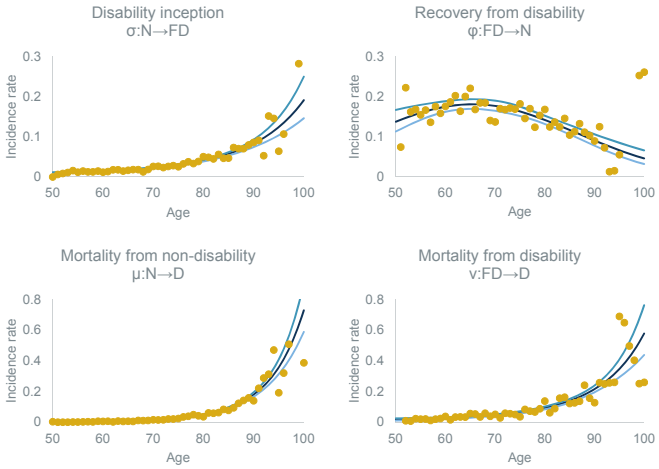
Graduated (smoothed) transition rates



- Not surprisingly, the risk of developing LTC disability increases for each additional year of age
- The recovery pattern from LTC disability is quite unusual. The rate of recovery actually increases between ages 50 and 70 before gradually declining

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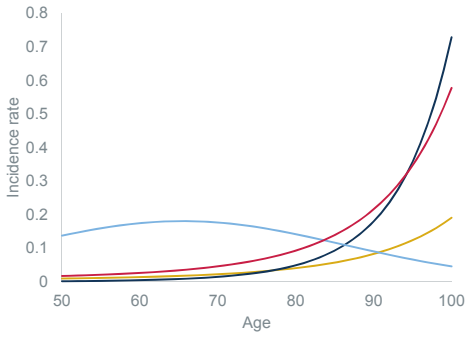
Competing risks (mortality vis-à-vis disability)

- Mortality hazard for the disabled is higher than for the non-disabled at all ages except the oldest age.
- Disability inception risk is higher than mortality (non-disabled) at all ages leading up to 76. This changes and the force of mortality exceeds disability thereafter.



	Parameters estimates (p-value)			
	σ:N→FD	φ:FD→N	μ:N→D	ν:FD→D
β_0	-4.47 (0.001)	-6.81 (0.001)	-9.69 (0.001)	-4.09 (0.021)
β_1	-0.03 (0.236)	0.16 (0.001)	0.04 (0.168)	-0.03 (0.421)
$\beta_2 \times 10^{-4}$	6.16 (0.001)	-11.87 (0.001)	5.13 (0.014)	6.92 (0.016)

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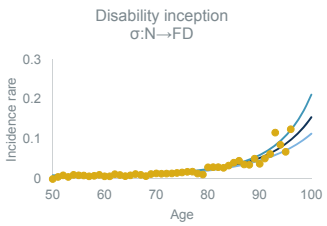
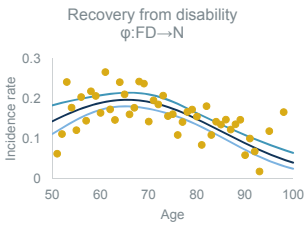
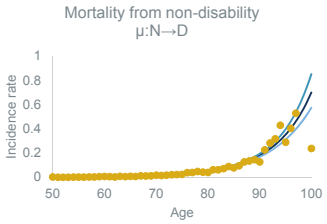
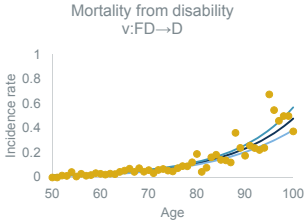
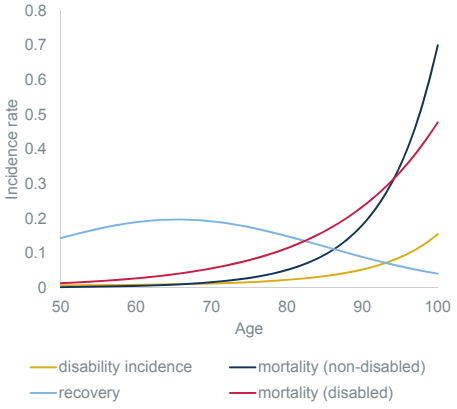
Alternative disability trigger (3 ADLs)











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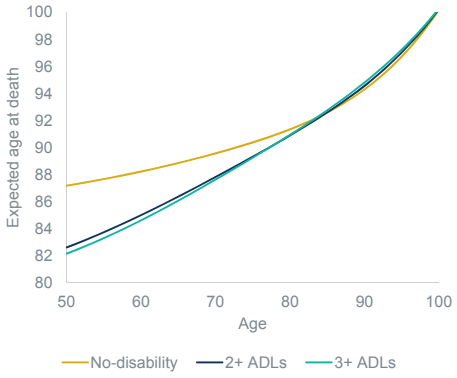
Expected age at death

- Different trigger configurations have an evident impact on disability and recovery transition probabilities but little impact on mortality probabilities.
- One might assume that insurers using more stringent criterion are able to set prices competitively. It is important to highlight that ELSA respondents are mainly household residents. Subjects who moved to care homes were excluded from the sample.



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Summary and conclusion

- The force of disability exceeds the competing mortality hazard for all ages when using 2+ ADLs as disability trigger. The opposite holds true for more stringent disability trigger (3+ ADLs).
- Recovery in disability is not news, and should be taken in consideration when designing LTC products. For example, the use of preventive or adaptive interventions to prolong periods of recovery.
- Death rates are higher among the disabled than for the nondisabled.
- It was not possible to model the duration dependence using the available data. Transitions for persons with recurrent disability can lead to overestimation of the disability inception rate.

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Future research

- Investigate the inclusion of cognitive impairment as disability trigger
- Use data on disability and mortality for people living in care homes – perhaps using the Cognitive Functioning for Ageing Study (CFAS).
- Examine gender differentials, and other factors that affect the hazard rates of disability and mortality in older age. For example:
  - Socio-economic factors
  - Chronic conditions that lead to disability, e.g. dementia

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Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

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