

Schulich Business School, Toronto

# Pricing longevity risk

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2. About longevity risk
3. Risk factors for pricing
4. Location, location, location. . .
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# 1 Pension plans

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## Definition

PRT = Pension Risk Transfer, the transfer of risk from a pension plan to an insurer

Some example contracts:

- A bulk annuity for a pension plan ('buy-in' or 'buy-out').
- A longevity swap.

(Index-based hedges appear a lot in the academic literature, but they are of little business relevance.)

*British Airways (BA) [...] agreed a £4.4bn buy-in with Legal & General — the largest pensioner bulk annuity transaction ever seen in the UK.*

IPE.com, September 2018

## Why do this?

- The announcement refers to the *smaller* of the two company pension plans.
- The bigger plan had a deficit of £3.7bn in 2017.
- IAG's market cap. was just £10.1bn on 18th Oct. 2019...

Source: NAPS Annual Report and Financial Statements, 31 March 2018.

*British Airways did not pay a dividend during its 2010 accounting year but contributed £364m to its pension scheme.*

Lane, Clark and Peacock (2011)

Pension schemes can be a *major* management distraction!

## 2 About longevity risk

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### Definition

Longevity risk is the risk that pensioners live longer than expected.

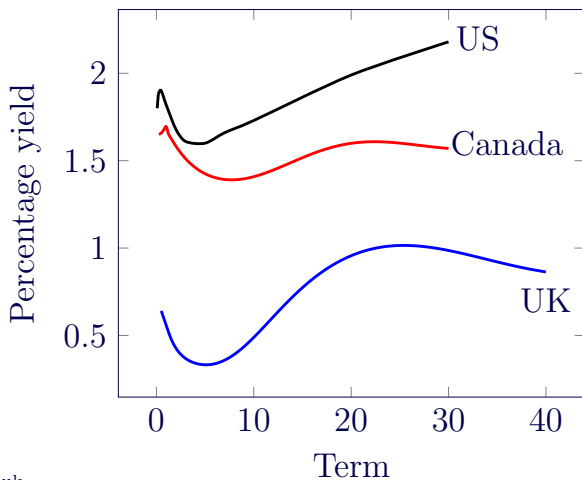
*“Whereas a catastrophe can occur in an instant, longevity risk takes decades to unfold”*

The Economist [2012]

Price in haste, repent at leisure...

## 2 Longevity risk

Nominal spot yield curves for government debt, 25th September 2019. Sources: US Treasury, Bank of Canada and Bank of England.



### Definition

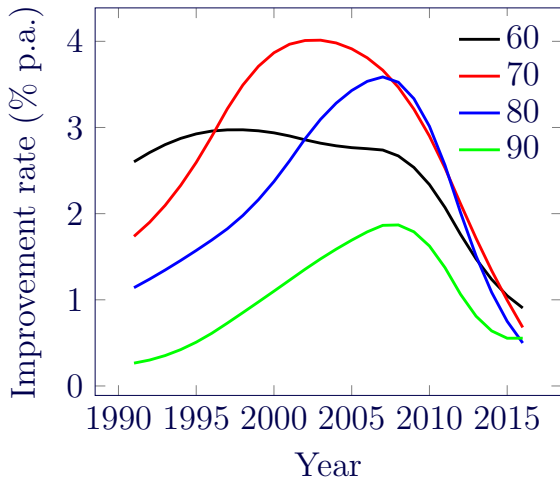
$\mu_{x,y}$  = mortality hazard at age  $x$  in year  $y$ .

### Definition

Mortality improvement rate =  $1 - \frac{\mu_{x,y}}{\mu_{x,y-1}}$ .

## 2 Longevity risk

Mortality-improvement rates for UK males aged 60–90, 1991-2016.  
Source: Own calculations using HMD data.



Two key points:

1. Low interest rates mean that mortality rates are central to PRT profitability.
2. Low mortality-improvement rates mean assessing current mortality rates is critical.

### Definition

Underwriting is the process of assessing insurance risk.

### Definition

Basis risk stems from using data not directly related to the portfolio concerned.

Avoid basis risk by using only the portfolio's own experience data.

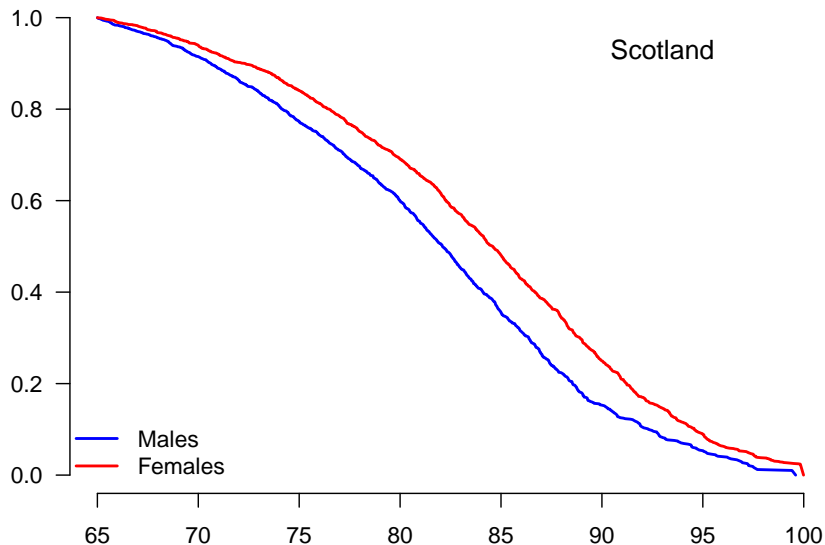
# 3 Risk factors for pricing

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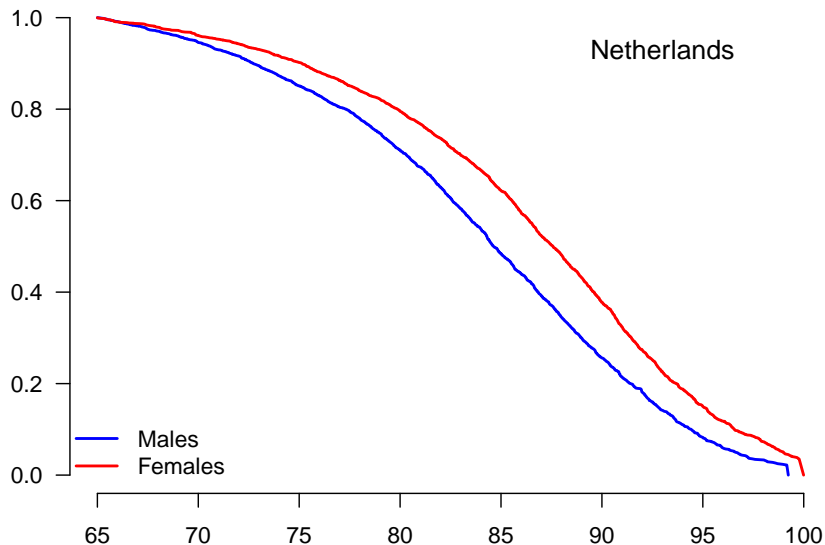
- Age and gender always available.
- Kaplan-Meier survival function a good test of data quality...



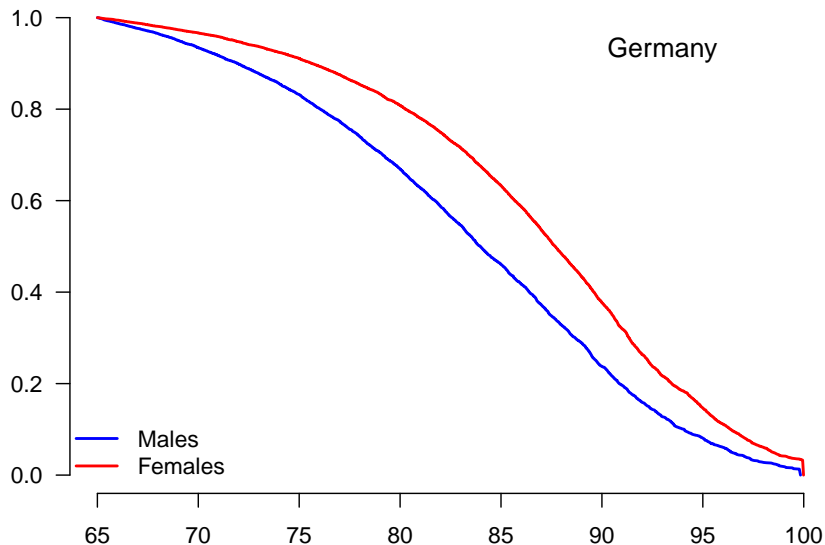
# 3 Scottish public-sector pension LONGEVITAS



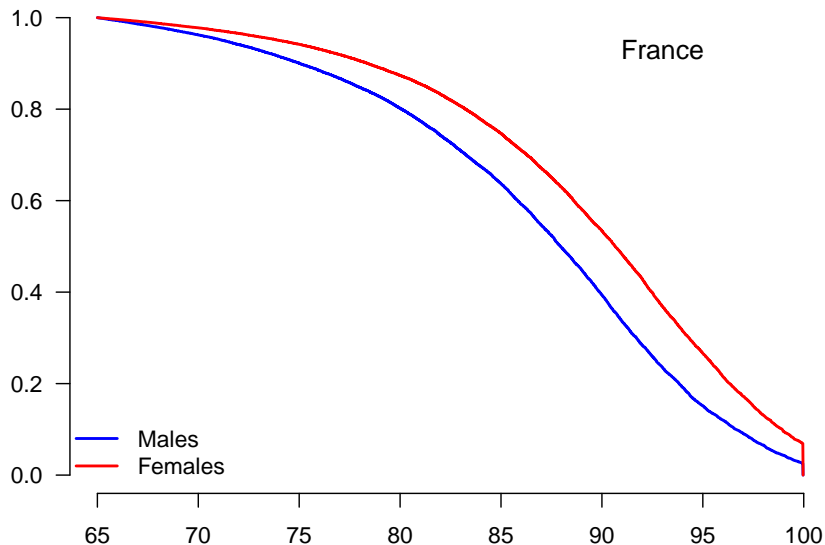
# 3 Dutch private-sector pension



# 3 German public-sector pension LONGEVITAS

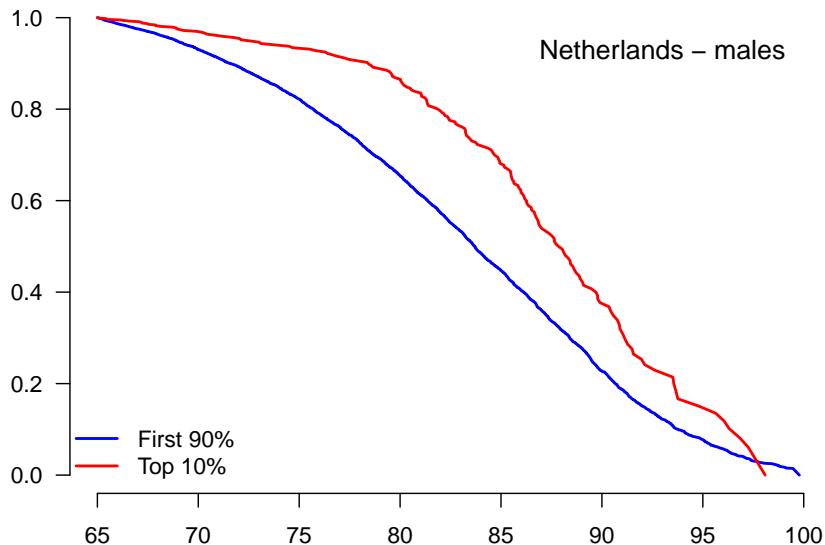


# 3 French top-up pension plan

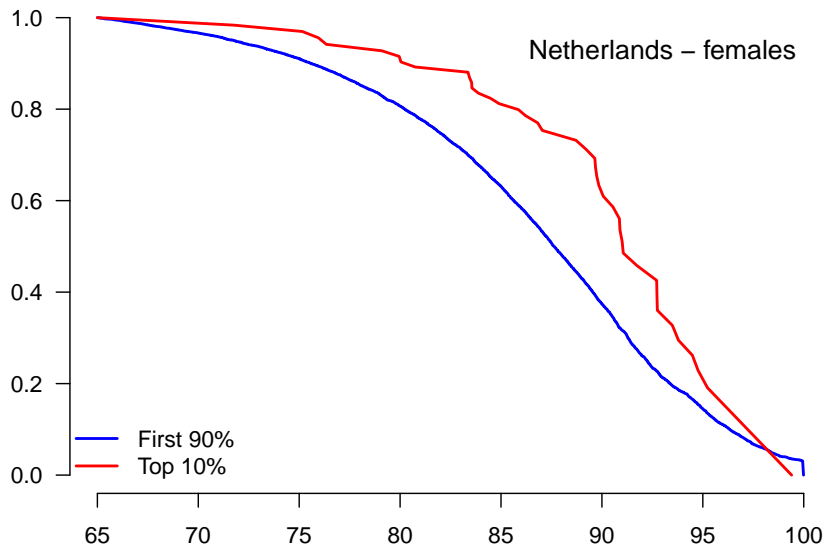


- Pension size also always available.
- Impact not always simple...

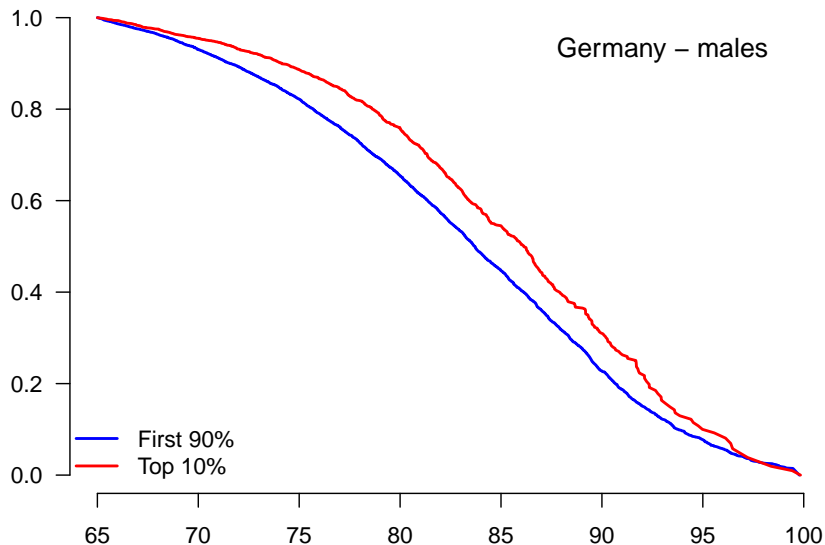
# 3 Dutch private-sector pension



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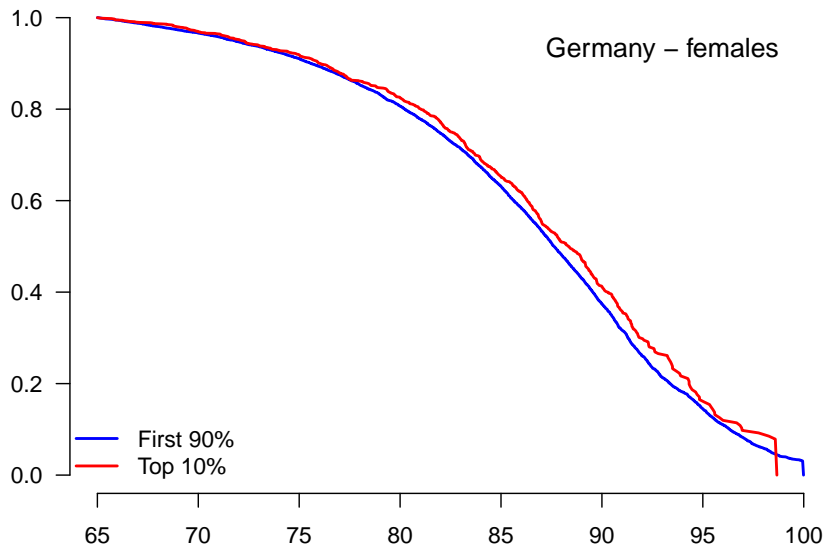


# 3 German public-sector pension LONGEVITAS





# 3 German public-sector pension LONGEVITAS



- Differentials vary from plan to plan.
- Need to understand portfolio's own experience data.
- Using data from other portfolios adds basis risk.

- Many powerful risk factors not recorded, e.g. smoker status.
- Have to use what is available...

Richards and Jones [2004] used:

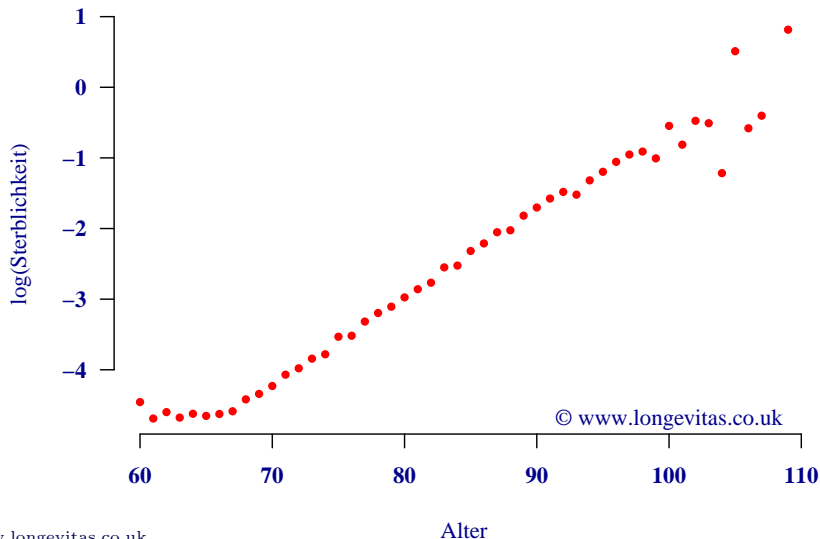
- Region (North v. South).
- Duration since retirement.
- Postcode.

Richards et al. [2013] used:

- Region (*Bundesland*).
- Ill-health v. normal retirement.
- First life v. widow(er).
- Private v. public sector.
- Whether member of largest scheme.

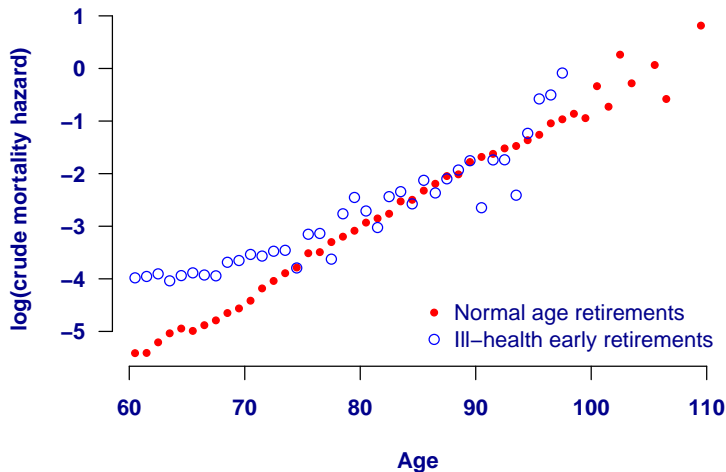
# 3 Importance of differentials

log(mortality) by age. Source: Richards et al. [2013, Figure 1].



### 3 Importance of differentials

log(mortality) by age and health status. Source: Richards et al. [2013, Figure 4].



Richards [2019] used:

- First life v. widow(er).
- Early v. normal retirement.
- Duration since retirement.
- Season.

(Single local-authority employer with high geographical concentration, so region unworkable)



Some risk factors are illegal to use for *individual* insurance contracts:

- Gender,
- Ethnicity,
- Religion.

... but gender is legal to use for B2B transactions.

# 4 Location, location, location. . LONGEVITAS

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- Consider two hypothetical Edinburgh pensioners.
- Same age, gender and pension size.
- One lives at postcode EH11 3NP.
- Other lives at postcode EH4 1PJ.
- Do they have the same mortality characteristics?

Source: ESPC, March 2019.



Source: Google Street View, May 2019.

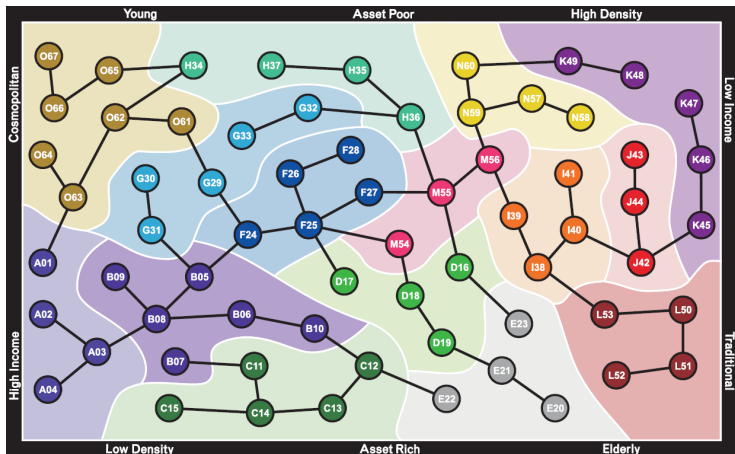


- Housing says a lot about socio-demographic status.
- Google Street View impractical for thousands of postcodes in PRT transaction.
- Need systematic mapping of postcode to socio-demographic profile.

## Definition

Geodemographic segmentation works on the basis that people living in the same small neighbourhood share characteristics.

Mosaic family tree.





# 4 Mosaic profiles

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**EH11 3NP. K47: Municipal  
Challenge, Streetwise  
Singles.**



**EH4 1PJ. A01: City  
Prosperity, World Class  
Wealth.**



Same approach works with hierarchical postcodes in:

- Canada,
- the Netherlands,
- UK, and
- USA.

For other countries we need the full address, not just the postcode.

# 5 Significance

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Assessing significance from adding a risk factor:

- For statistical significance, use the drop in AIC.
- For financial significance, use change in liability valuation.

# 5 Impact of risk factors

Change in model fit and discounted cashflow valuation from adding risk factors. Period rates until the model in the last line of the table.

Model	AIC	Change in AIC	PV (£m)	Change in PV (£m)
Hermite I, age only	27279.4	n/a	835.3	n/a
+gender	27192.5	-86.9	816.4	-18.9
+widow(er) status	27177.6	-14.9	824.3	7.9
+early-retirement status	27161.7	-15.9	810.2	-14.1
+pension size	27099.5	-62.2	872.1	61.9
+selection	27082.1	-17.4	863.0	-9.1
+season	27045.8	-36.3	859.1	-3.9
<i>change from period mortality to forecast mortality:</i>				
+age-related time trend	27044.0	-1.8	932.4	73.3

Source: Richards [2019].

Risk factors vary in statistical and financial significance:

	Drop in AIC	Change in PV
Pension size	62.2	£61.9m
Time trend	1.8	£73.3m
Season	36.3	£3.9m

# 6 Convergence

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- Mortality differentials not constant.
- Most differentials reduce with increasing age, a.k.a. convergence.
- Modelling convergence can be tricky.



Gompertz [1825] model:

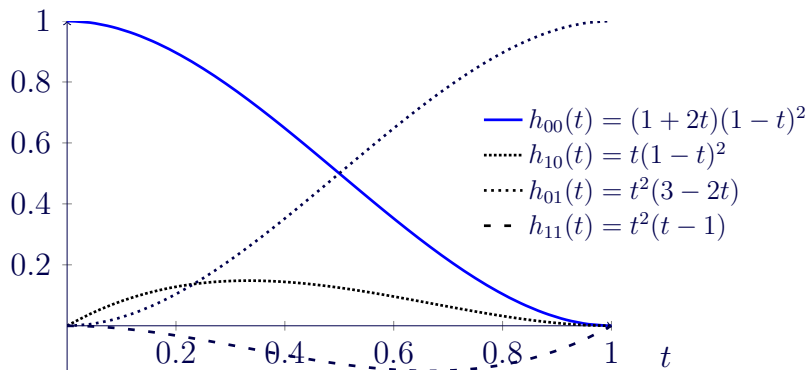
$$\log \mu_x = \alpha + \beta x$$

- Estimate  $\alpha$  and  $\beta$  from data.
- Can vary  $\alpha$  and  $\beta$  for each risk factor...

Gompertz model:  $\log \mu_x = \alpha + \beta x$ .

- Two-parameter approach produces undesirable crossover.
- With convergence around 90–95,  $\beta$  is technically redundant.
- Is there a one-parameter approach without crossover?

Hermite basis splines for  $t \in [0, 1]$ .



$$\begin{aligned}\log \mu_x &= \alpha h_{00}(t) + \omega h_{01}(t) \\ &\quad + m_0 h_{10}(t) + m_1 h_{11}(t)\end{aligned}$$

where  $t = (x - x_0)/(x_1 - x_0)$  for some age range  $[x_0, x_1]$ .

- Estimate  $\alpha$ ,  $\omega$ ,  $m_0$  and  $m_1$  from data.
- Only vary  $\alpha$  for each risk factor...

Hermite model for  $\log \mu_x$  with varying  $\alpha$ .

- Hermite-spline model yields convergence without crossover.
- No redundant parameters.
- Reduces minimum data needed for bespoke portfolio models.
- Ideally suited to PRT transactions.
- See Richards [2019] for details.

# 7 Conclusions

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- Use portfolio's own experience data for PRT.
- Risk varies by more than just age, gender and pension size.
- Can use geodemographic profile...  
... or other portfolio-specific features.
- Statistical significance and financial significance quite different.
- New models allow convergence without crossover.

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Creating portfolio-specific mortality tables: a case study. *European Actuarial Journal*, 3 (2):295–319, 2013. doi:  
<https://doi.org/10.1007/s13385-013-0076-6>.
- The Economist. The ferment of finance. *Special report on financial innovation*, February 25th 2012:8, 2012.

More on longevity risk at [www.longevity.co.uk](http://www.longevity.co.uk)

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# 9 About Longevity

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- Founded 2006.
- Based in Edinburgh, Scotland.
- Provides tools to analyse, price and manage longevity risk.
- Research partnership with Heriot-Watt University.

- Used in UK, USA, Canada and Switzerland.
- Used by insurers, reinsurers and consultancies.