Trends in Mortality by Pension Level: Evidence from the CPP and QPP

Andrew J.G. Cairns

Heriot-Watt University, Edinburgh

Director, Actuarial Research Centre, IFoA

Canadian Institute of Actuaries, Annual Meeting, June 2018

Actuarial
Research Centre
Institute and Faculty
of Actuaries

The Actuarial Research Centre (ARC)

A gateway to global actuarial research

The Actuarial Research Centre (ARC) is the Institute and Faculty of Actuaries' (IFoA) network of actuarial researchers around the world.

The ARC seeks to deliver cutting-edge research programmes that address some of the significant, global challenges in actuarial science, through a partnership of the actuarial profession, the academic community and practitioners.

The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the Canadian Institute of Actuaries and the SoA.

www.actuaries.org.uk/arc

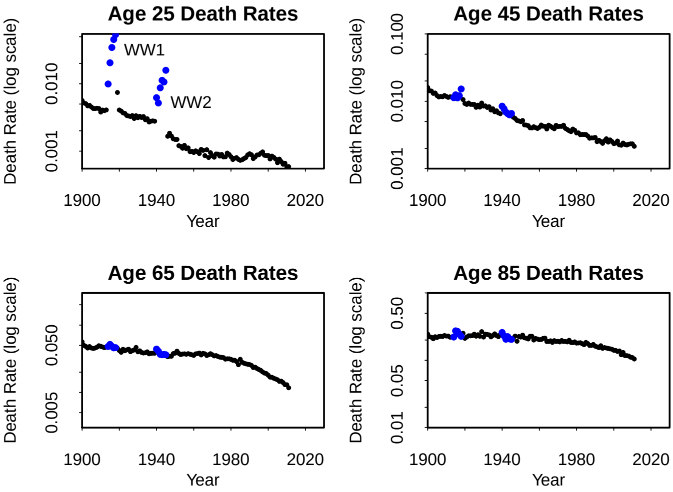
ARC Research Programme Themes

- Improved models for mortality; better data
- Key drivers of mortality
- Management of longevity risk
- Morbidity risk modelling for critical illness insurance

Plan

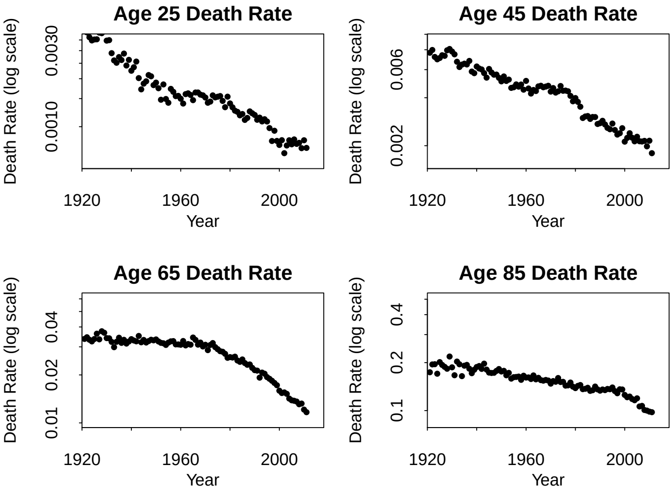
- Introduction and background
- National and international trends
- Subgroups: CPP, QPP, international
- Underlying demographic trends; immigration
- Stochastic mortality models; clustering
- Conclusions

Historical Death Rates: Males, England and Wales



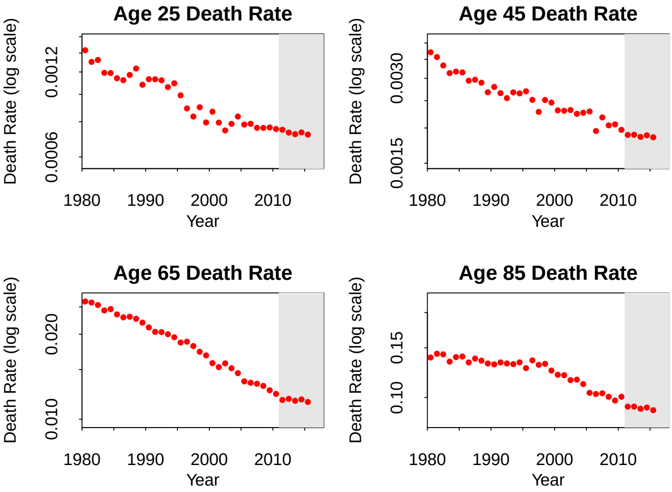
Future forecasts $\Rightarrow$ need for stochastic mortality models

Historical Death Rates: Canada Males (up to 2011)



(Source: Human Mortality Database)

Historical Death Rates: Canada Males (1980 to 2015)



(Source: Statistics Canada)

How to process and interpret crude mortality data?

- How to improve signal to noise ratio?

- Empirical measures: age standardised mortality rates
- Model based methods
- Clustering

Age Standardised Mortality Rates (ASMR)

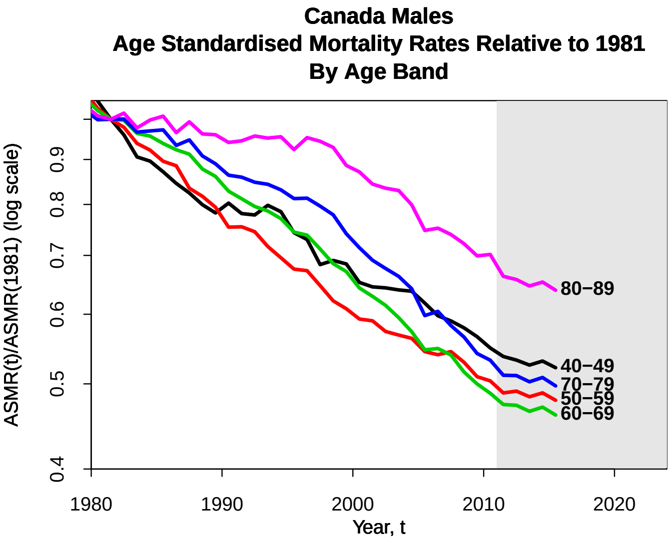
- The ASMR is a weighted average of the crude death rates over a defined age range
- Age range $x_0, \ldots, x_1$, year t:

$$ASMR(t) = \frac{\sum_{x_0}^{x_1} \hat{m}(t,x)\tilde{E}(x)}{\sum_{x_0}^{x_1} \tilde{E}(x)}$$

- $\hat{m}(t,x) =$ crude death rate in year t at age x
- $\tilde{E}(x)$ "standard" exposures (e.g. European Standard Population, 2013)

- Use of ASMR facilitates comparison of populations
- ASMR also reduces impact of sampling variation

Canada Males: Improvements Relative to 1981



Questions

- How significant is the slowdown observed at some ages?
- How do Canadian trends compare with other countries?
- Do we observe different trends amongst different socio-economic groups?

Actuarial Research Centre
Institute and Faculty of Actuaries

Recent Improvement Rates: Canadian Males

Average mortality improvement rates per annum:

Age Group	2001-2011	2011-2015
40-49	1.8%	0.7%
50-59	1.9%	0.5%
60-69	2.8%	0.7%
70-79	3.0%	0.7%
80-89	2.4%	0.9%

Actuarial Research Centre
Institute and Faculty of Actuaries

Recent Improvement Rates: Canadian Males

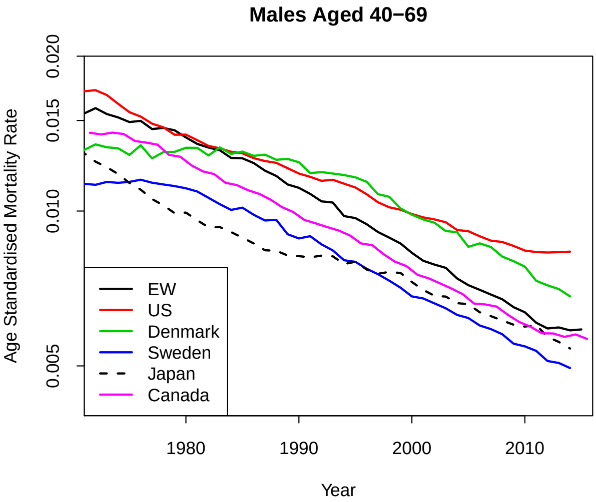
Beware of noise in the data:

Age Group	2001-2011	2011-2015	2000-2010	2010-2015
40-49	1.8%	0.7%	1.7%	1.0%
50-59	1.9%	0.5%	1.6%	1.0%
60-69	2.8%	0.7%	2.8%	1.1%
70-79	3.0%	0.7%	2.9%	1.3%
80-89	2.4%	0.9%	2.2%	1.9%

- 2010: generally high mortality
- 2011: generally low mortality

Actuarial Research Centre
Institute and Faculty of Actuaries

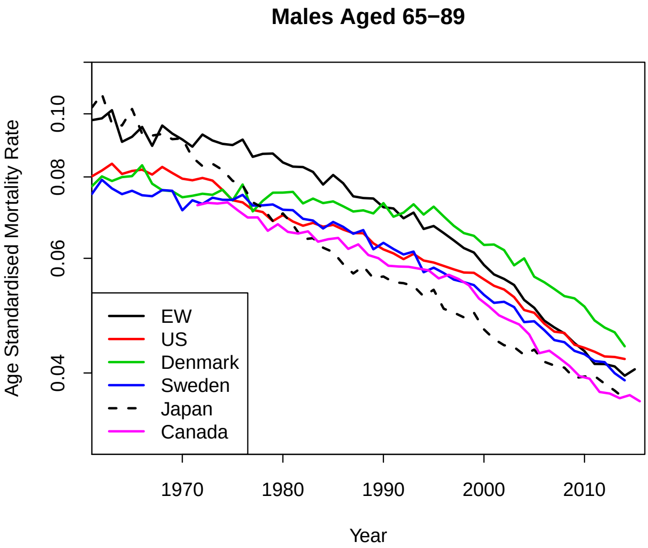
Comparison With Other Countries: ASMR 40-69



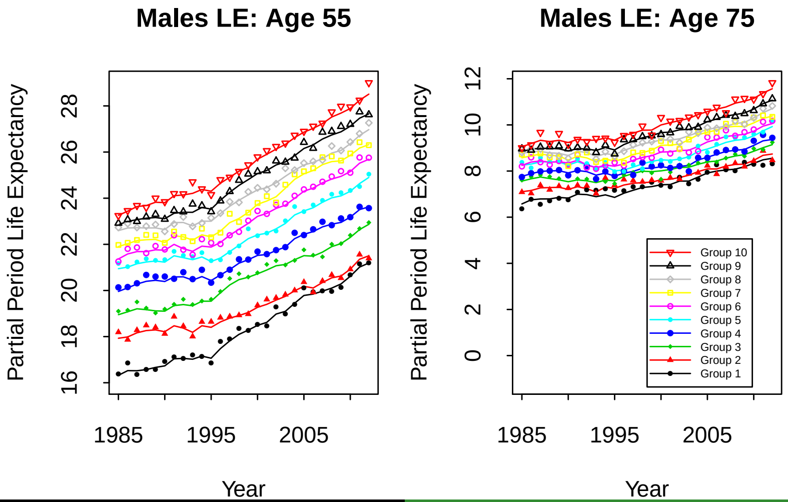
- Canada, England & Wales, US:
  $\Rightarrow$ slowdown
- Japan, Sweden, Denmark:
  $\Rightarrow$ no slowdown

Actuarial Research Centre
Institute and Faculty of Actuaries

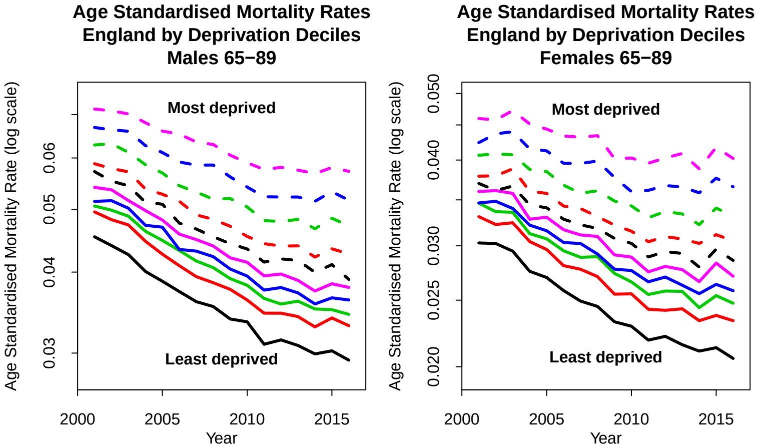
Comparison With Other Countries: ASMR 65-89



Denmark: life expectancy by *affluence* decile



England: mortality by *deprivation*



Socio-Economic Differences in Mortality: Canada

- Data acquisition facilitated through the research programme Project Oversight Group at the CIA
- Canada Pension Plan
- Québec Pension Plan
- Pensions in payment
- Deaths and exposures: $D(g, i, t, x)$, $E(g, i, t, x)$
- $g =$ gender
- $i =$ pension band
- $t =$ calendar year
- $x =$ age last birthday (at date of death)

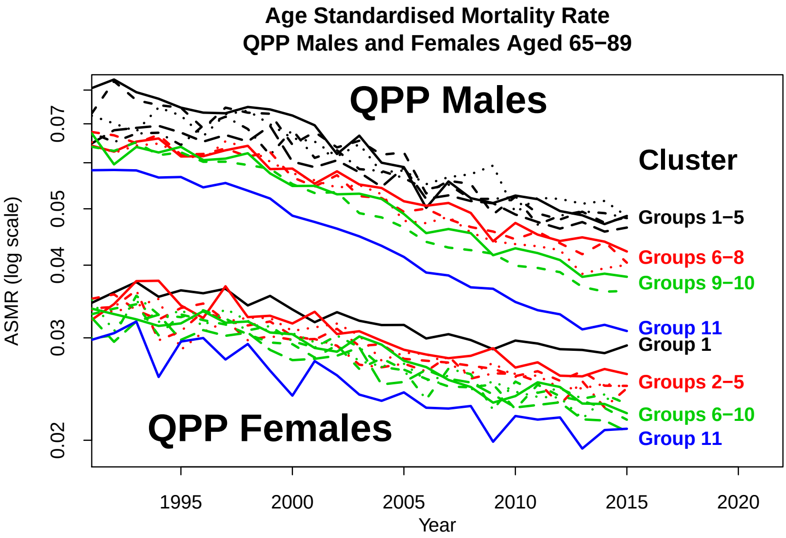
CPP and QPP data: 11 Groups by Pension Band

- Pension as a % of Cohort Maximum Pension
- Cohort Max $\Rightarrow$
  contributing to CPP/QPP for at least 39 years with earnings above *Yearly Maximum Pensionable Earnings* (YMPE; 2018: CAD 55,900)
- Group $i = 1 \Rightarrow$ 0% to 9% of Cohort Max
- Group $i = 2 \Rightarrow$ 10% to 19% of Cohort Max

  $\vdots \qquad \vdots$
- Group $i = 10 \Rightarrow$ 90% to 99% of Cohort Max
- Group $i = 11 \Rightarrow$ 100% of Cohort Max

- Years: 1968-2015
- Ages: 60-64 / 65+

QPP Mortality



Actuarial Research Centre
Institute and Faculty of Actuaries

QPP Mortality

- Group 11 stands clear of others
  - Group 11 is quite heterogeneous (comfortable → wealthy)
  - Achieving *max* requires conscientiousness
- Females Group 1 also stands clear
  (Why not males also? Females Group 1 much larger???)
- Widening gap might reflect shrinkage of Group 11 (later slides)
- Clustering creates larger, ‘similar’ groups with less sampling variation
- Different rates of improvement before and after 2011 in all groups (although results are noisy)

Actuarial Research Centre
Institute and Faculty of Actuaries

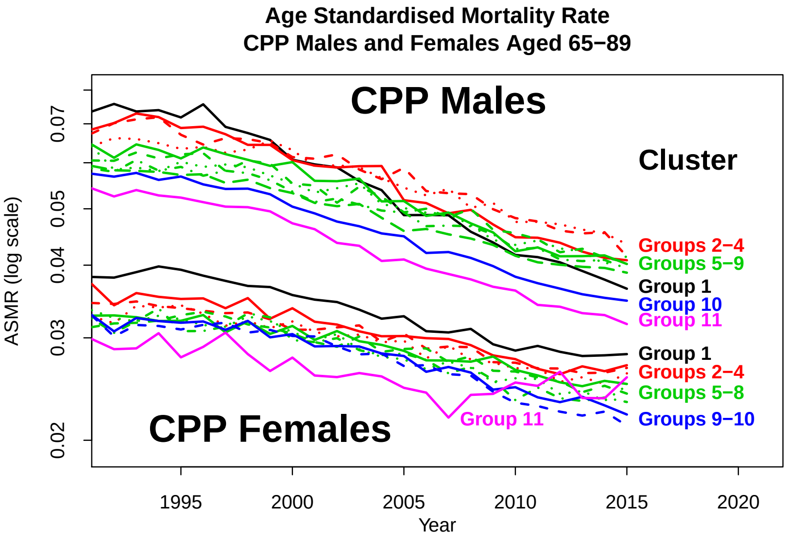
Conscientiousness

Meanings and associations:

- wishing to do one's work or duty well and thoroughly
- careful; diligent; hard working; dedicated; accurate

- Correlated with (???):
  - sustained success in employment
  - more likely to have maximum years with earnings above YMPE
  - more likely to visit doctor early
  - more likely to follow doctor's orders

CPP Mortality

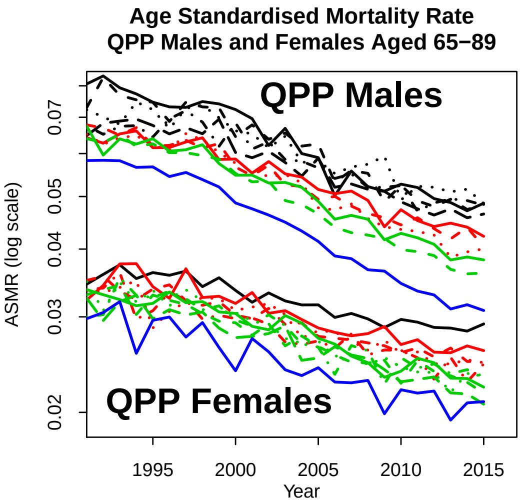


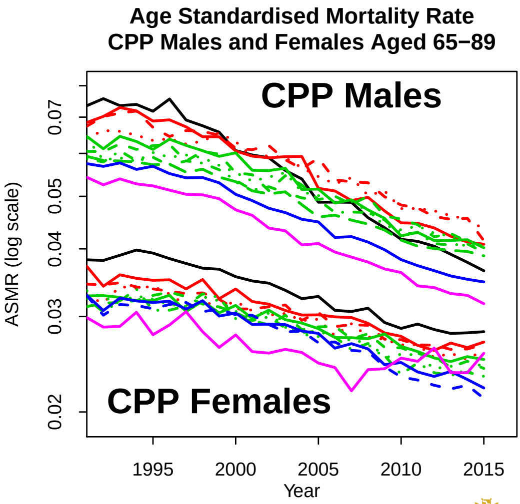
Actuarial Research Centre
Institute and Faculty of Actuaries

CPP Mortality

- Group 11 stands clear of others
- Females Group 1 also stands clear
- Stable inequality spread
- Strange behaviour needing further investigation:
  - Males Group 1: possibly immigration in late middle age of wealthier and healthier people
  - Females Group 11

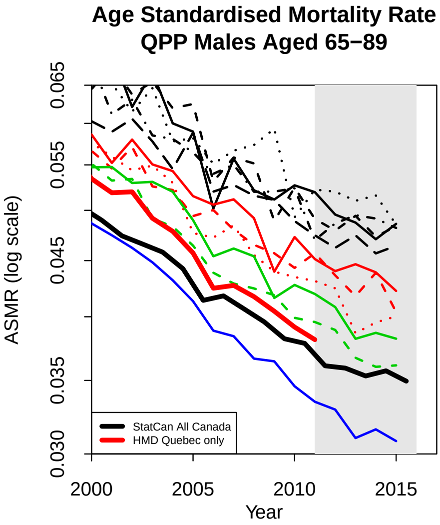
QPP vs CPP Mortality: (broadly similar)

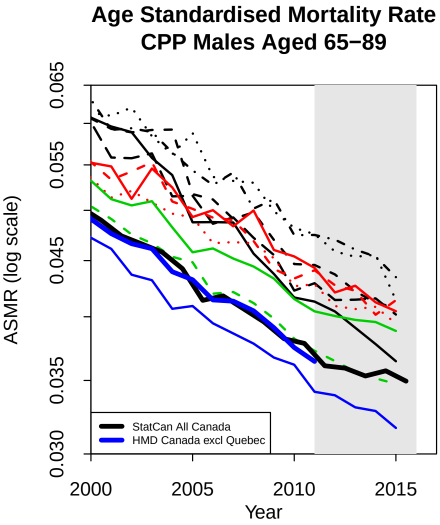




Actuarial Research Centre
Institute and Faculty of Actuaries

QPP vs CPP vs All Canada Mortality: Slowdown???



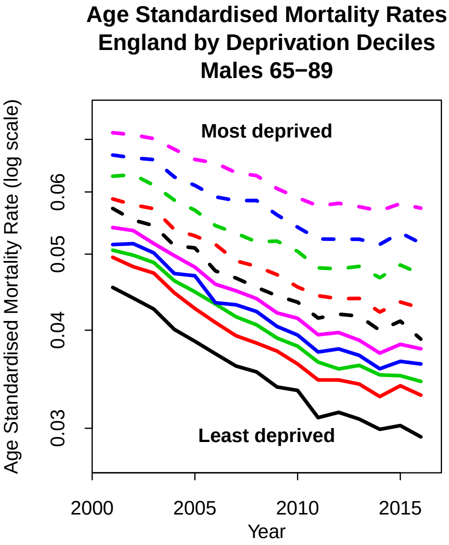


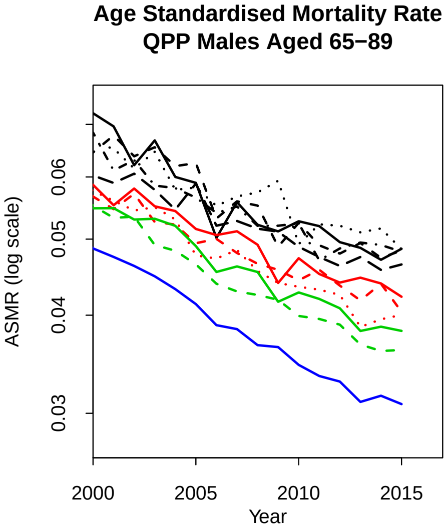
QPP vs CPP vs All Canada Mortality: Slowdown???

- QPP starts with higher mortality
- But QPP catches up by 2015
- Without pension bands, CA/Q/CxQ regional ASMR appear low but Groups 10+11 have ∼50% of the pensioner population
- Source of Canadian slowdown is difficult to pinpoint

- CA: All Canada
- Q: Québec only (HMD data by province)
- CxQ: All Canadian provinces apart from Québec

QPP Pensions Bands vs English Deprivation Deciles





Factors Influencing Group Mortality

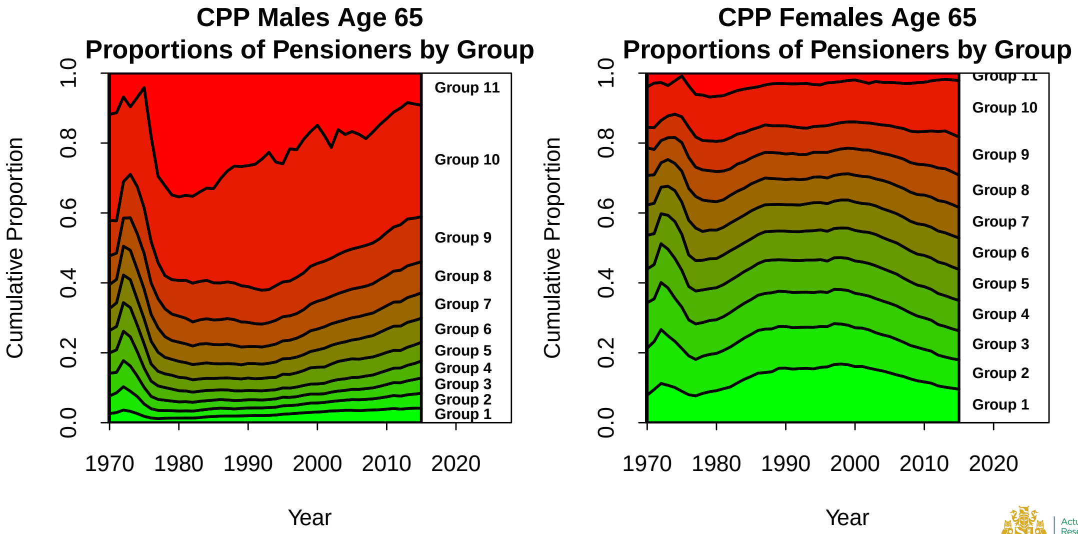
Everything else being equal:

- 10% in Group 11 (max) $\Rightarrow$ lower mortality compared to
- 20% in Group 11 (max) $\Rightarrow$ higher mortality

In practice:

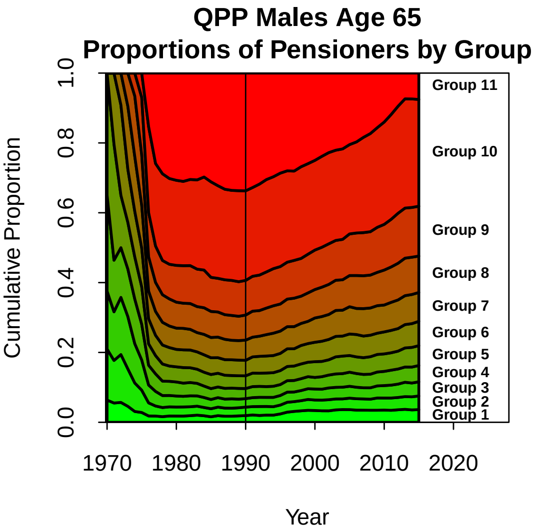
- Group 11 is shrinking cohort by cohort
- Artificially high mortality improvements (?)
- Although checks suggest numerical impact is small (groups 10+11; 9+10+11)

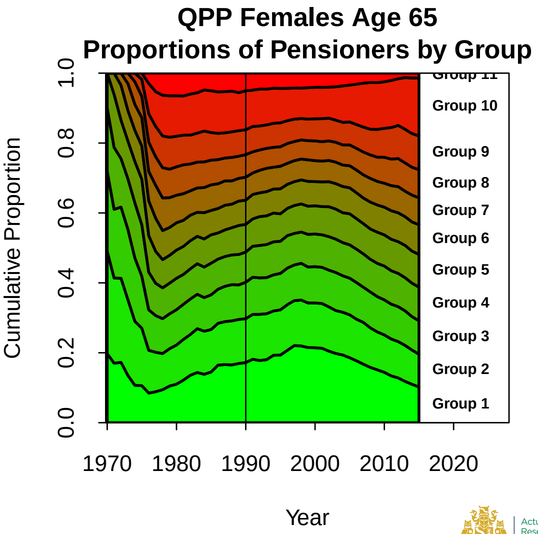
Proportions in Each Group: CPP Males vs Females



Actuarial Research Centre
Institute and Faculty of Actuaries

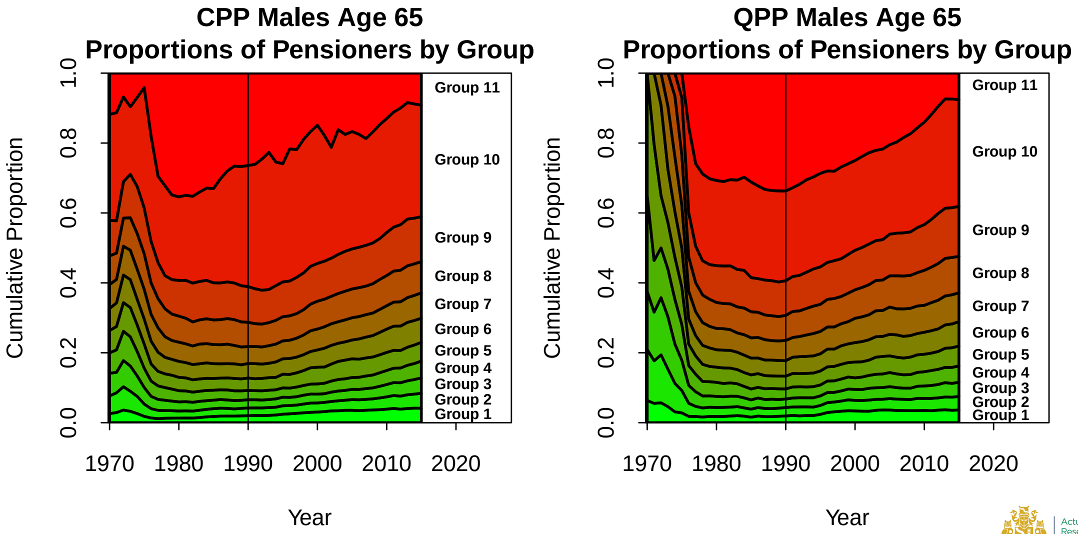
Proportions in Each Group: QPP Males vs Females





Actuarial Research Centre
Institute and Faculty of Actuaries

Proportions in Each Group: CPP Males vs QPP Males



Actuarial Research Centre
Institute and Faculty of Actuaries

Varying Group Sizes

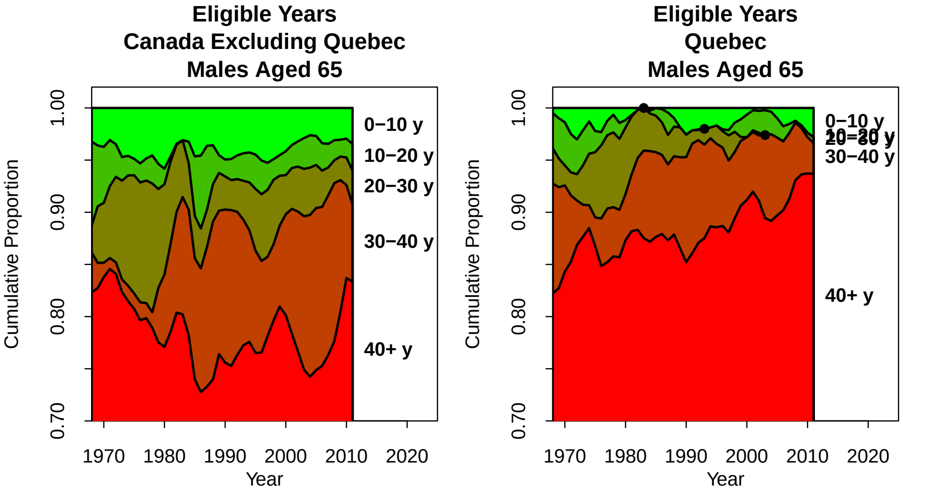
- Ability to attain a high pension depends on
  - Career salary profile
  - Career breaks
  - Real growth of the YMPE over time
  - Immigrants: age on arrival in Canada

- YMPE: growth >> CPI and median earnings growth
- ⇒ declining proportion in Group 11

- Migration: Eligible Years = 65—Age on Arrival (or 18)
- Indirect estimation using HMD Canadian Province population and deaths
- Estimation requires lots of assumptions!

Actuarial Research Centre
Institute and Faculty of Actuaries

Eligible Years by Cohort at Age 65



E.g. Québec **dots** link to low immigration around 1980

Actuarial Research Centre
Institute and Faculty of Actuaries

Immigration Remarks

- Québec (Q) immigration in adulthood much lower than the rest of Canada (CxQ)
- CxQ: highly variable immigration through time
- Q: declining immigration
- CxQ: significant levels of immigration amongst 55-65 year olds
- Peaks and troughs: link to periods of high/low immigration
- E.g. Québec **dots** link to low immigration around 1980

Actuarial Research Centre
Institute and Faculty of Actuaries

Motivation for Stochastic Mortality Models

- Data ⇒ uncertain future
- Modelling and measuring longevity risk is important in many actuarial applications
  - General risk assessment
  - Pricing: margin for systematic risk
  - Reserving: systematic risk in runoff
  - Reserving: systematic reserving risk over a 1-year horizon
  - Reserving: diversification benefit between two populations
  - Assessment of risk reduction in longevity hedges
- How do the results for different populations and sub-populations compare?

Mortality and Longevity Modelling & Risk Assessment

- Central forecasts
- How much uncertainty around central forecasts?

- Understand and document how stochastic models are currently used in practice: identify gaps
- New single population models: e.g.
  - wider age range
  - flexible and robust estimation procedures
  - greater flexibility in modelling central forecasts
- New multipopulation models: e.g.
  - Data driven modelling
  - How to handle smaller populations?
  - Robust models
  - Realistic correlation term structure

Multipopulation Stochastic Mortality Models

Genealogy:

- Single population:

$$\begin{array}{lrcl} \text{Lee-Carter} & \log m(t,x) & = & \alpha(x) + \beta(x)\kappa(t) \\ & \downarrow & & \downarrow \\ \text{Renshaw-Haberman} & \log m(t,x) & = & \alpha(x) + \beta_1(x)\kappa_1(t) + \beta_2(x)\kappa_2(t). \end{array}$$

- Multi-population Renshaw-Haberman

$$\log m(i,t,x) = \alpha(i,x) + \beta_1(i,x)\kappa_1(i,t) + \beta_2(i,x)\kappa_2(i,t)$$

- Many simpler special cases investigated
E.g. Common Age Effect (CAE) Model

$$\log m(i,t,x) = \alpha(x) + \beta_1(x)\kappa_1(i,t) + \beta_2(x)\kappa_2(i,t)$$

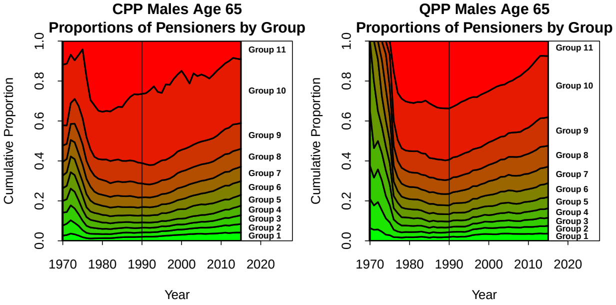
Actuarial Research Centre
Institute and Faculty of Actuaries

The Common Age Effect Model (CAE)

$$\log m(i,t,x) = \alpha(x) + \beta_1(x)\kappa_1(i,t) + \beta_2(x)\kappa_2(i,t)$$

- CAE gives the best balance between
  - Goodness of fit
  - Model complexity (number of parameters to estimate)

How Much Data to Use?



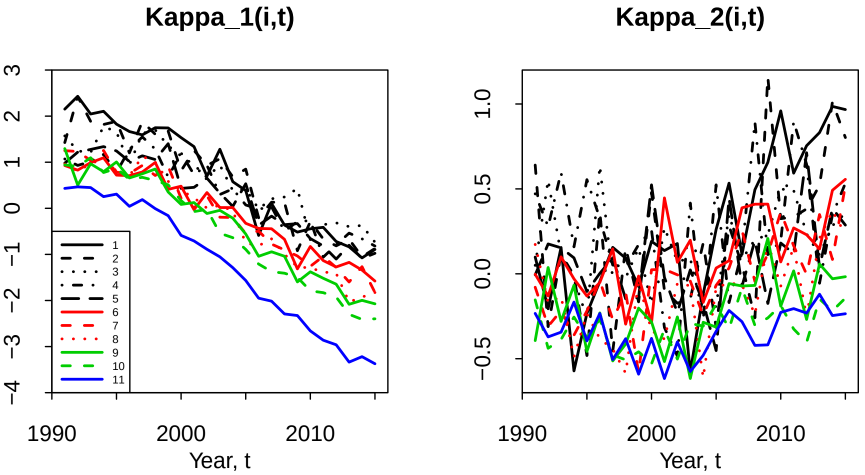
- Stability in *new* retirees from late 1970's
- Takes time to filter through to higher ages
- Compromise: 1991-2015
- Some immature early cohorts but models can cope

Actuarial Research Centre
Institute and Faculty of Actuaries

Common Age Effects: QPP Males

Actuarial Research Centre
Institute and Faculty of Actuaries

Group Specific Period Effects: QPP Males



Period Effects

- $\kappa_1(i,t)$
  - Picks up the main changes over time
  - Very similar to the ASMR plots

- $\kappa_2(i,t)$
  - Much more noisy (sampling variation in deaths)
  - Slight upwards trend
    $\Rightarrow$ additional improvements at high ages

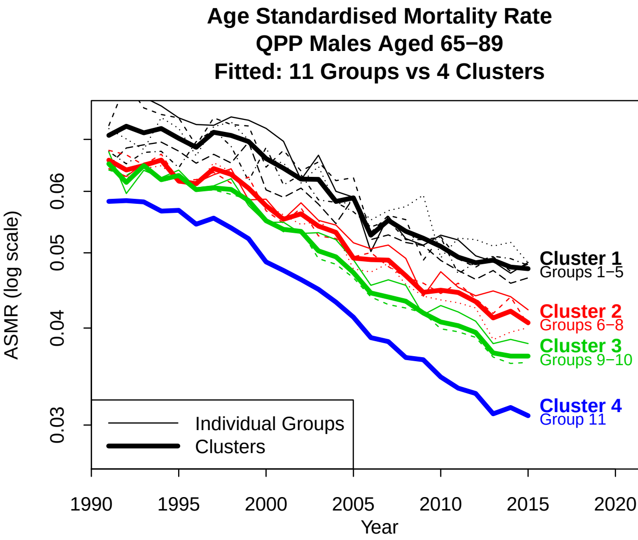
Clusters

- Some lower groups only 2-4% of total cohort
- Smaller groups:
  - Higher levels of sampling variation in deaths
  - Higher levels of sampling variation in estimated period effects $\kappa_1(i,t)$ and $\kappa_2(i,t)$
  - Introducing bias in forecast levels of uncertainty
- Clustering mitigates this problem
- Optimisation $\Rightarrow$ (e.g. QPP males, 65-89, 1991-2015)

Cluster	Groups	Exposures
1	1-5	1.745 M
2	6-8	2.069 M
3	9-10	3.861 M
4	11	2.743 M

Actuarial Research Centre
Institute and Faculty of Actuaries

ASMRs For QPP Clusters (Males)



Actuarial Research Centre
Institute and Faculty of Actuaries

Conclusions

- Analysis of CPP/QPP data by pension level provides insight into combined mortality
  - mortality rates
  - varying group sizes
  - immigration
- Further insight can be gained by looking outside Canada
- Multipopulation stochastic models will help assess future levels of uncertainty:
  - future funding levels
  - future contribution rates
- Clustering helps to improve signal to noise ratio
  $\Rightarrow$ more reliable forecasts

Actuarial Research Centre
Institute and Faculty of Actuaries

Thank You & Questions/Discussion

E: A.J.G.Cairns@hw.ac.uk

W: www.macs.hw.ac.uk/~andrewc/ARCresources

Summary

This presentation provides an analysis and discussion of pensioners’ mortality data provided by the Canada Pension Plan (CPP) and the Québec Pension Plan (QPP). The presentation covers three aspects of the ongoing analysis of the CPP and QPP data: empirical analysis of historical data and comparison of CPP/QPP; process of fitting multi-population mortality models to the historical CPP/QPP data to determine the best choice of model, number of subgroups needed, and most appropriate historical period for calibration; and insights into forecasting mortality improvements at the subgroup level.

The underpinning research is part of the Modelling, Measurement and Management of Longevity and Morbidity Risk research program funded by the Actuarial Research Centre of the Institute and Faculty of Actuaries, and co-funded by the Canadian Institute of Actuaries.