Slide 1

Actuarial Research Centre
Institute and Faculty of Actuaries

Longevity Trends, Past and Future:
A Deep Dive into CPP and QPP Mortality

Andrew Cairns
Director, Actuarial Research Centre,
      Institute and Faculty of Actuaries; and
Heriot-Watt University, UK

Joint work with Dr Torsten Kleinow and Jie Wen

HERIOT WATT UNIVERSITY

Canadian Institute of Actuaries / Institut canadien des actuaires

28 September 2018

Slide 2

Actuarial Research Centre
Institute and Faculty of Actuaries

Plan

- Motivation and background
- National and international mortality
- CPP and QPP socio-economic mortality
- Impact of:
    - pension level
   - evolving plan rules
    - immigration

13 September 2018

Slide 3

Motivation

- Pension plans and life insurers
    - Seek to project future mortality
    - Value future liabilities, measure risk and manage risk
- Improved models for making projections using
    - Mortality data for specific socio-economic (or other) subgroups
    - Especially datasets with longer historical runs of data
    - Quantify and understand differences in level and trend
- Mortality rates:
    - Canadian national level
    - *Zoom out:* International comparisons
    - *Zoom in:* Canadian sub-populations

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018   3

Slide 4

Historical Death Rates: Canada up to 2011

13 Se   4

Slide 5
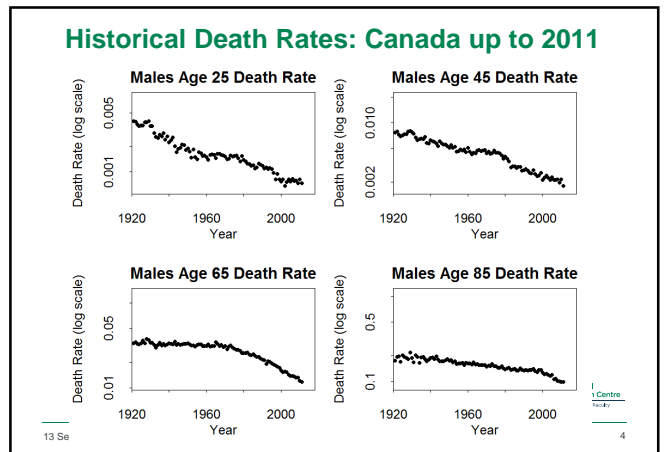
How to Process and Interpret Crude Mortality Data?

- How to improve the signal to noise ratio

- Empirical measures: ages standardised mortality rates

- Model-based methods

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018   5

Slide 6

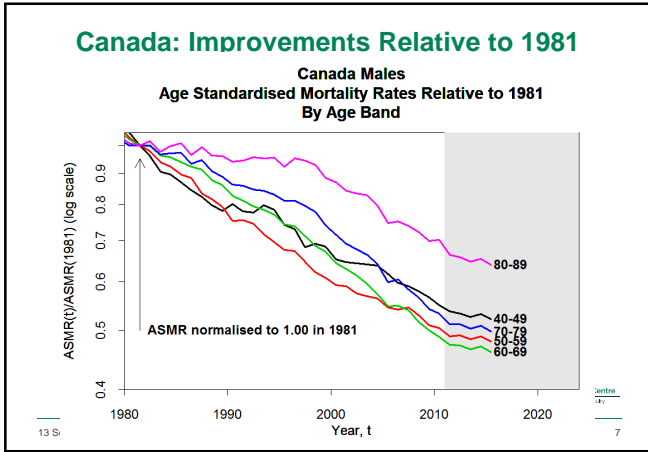### Age Standardised Mortality Rates (ASMR)

- 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 population" exposures
- Use of ASMR facilitates comparison of populations
- Use also reduces the impact of sampling variation

Actuarial Research Centre
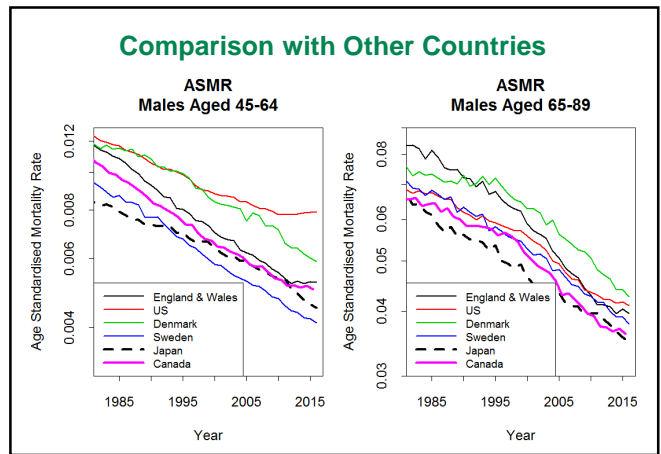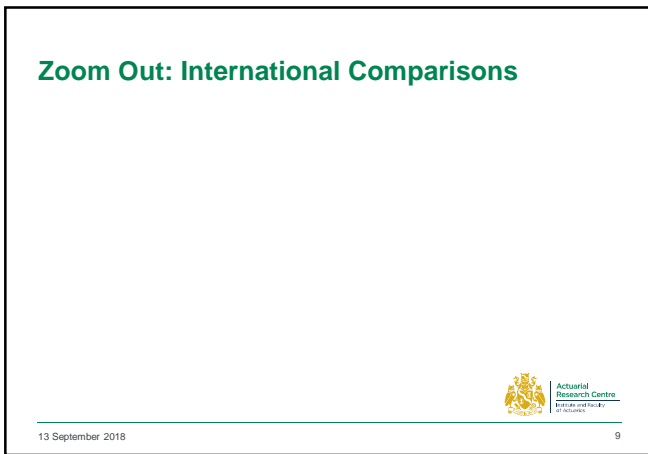Institute and Faculty of Actuaries

13 September 2018   6

1

Canada: Improvements Relative to 1981

Canada Males
Age Standardised Mortality Rates Relative to 1981
By Age Band

ASMR normalised to 1.00 in 1981

Recent Improvement Rates: Canadian Males

Age Group	2001-2011	2011-2015	vs	2000-2010	2010-2015
30-39	2.0%	0.5%		2.1%	1.0%
50-59	1.9%	0.5%		1.6%	1.0%
70-79	2.4%	0.9%		2.2%	1.9%

Table 1: Annual mortality improvement rates by age group and over different time periods.
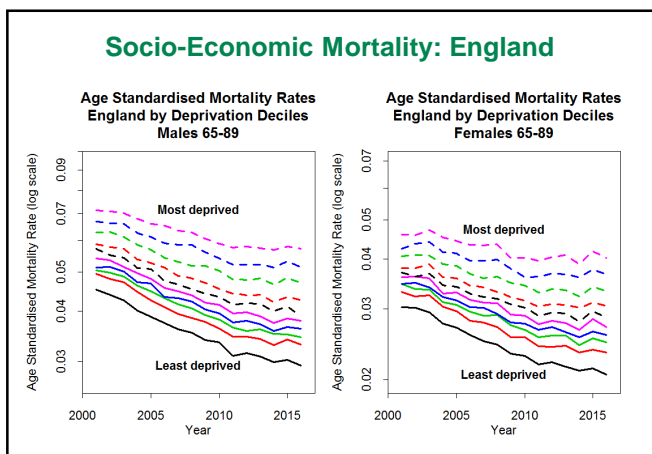
- A trend change seems likely
- But was the change in 2010 or 2011 or gradual?
- Makes a big difference when estimating and setting future improvement rates

---

Zoom Out: International Comparisons

Comparison with Other Countries

ASMR Males Aged 45-64

ASMR Males Aged 65-89

International Comparison

- Slowdown in Canada, England $ Wales, USA
- No slowdown in Japan, Sweden, Denmark
- Denmark is in a catch up phase
- Japan and Sweden have amongst the lowest mortality rates
- Hence
  - Will Japan and Sweden also slow down? Or
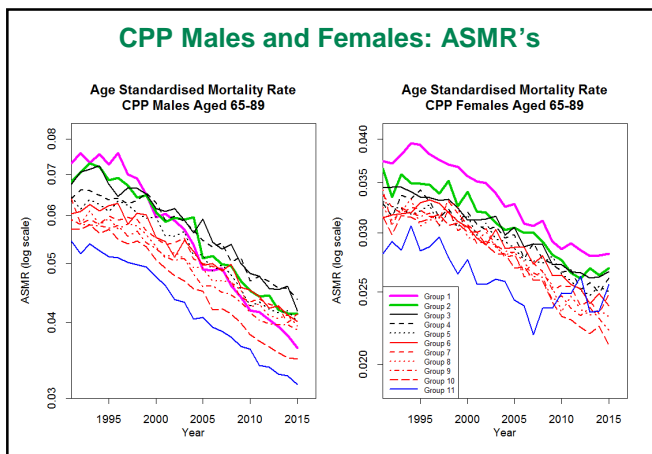 - Is the Canadian slowdown temporary?

Zoom In: Socio-Economic Sub-Populations

- Introduction: English data by deprivation
- Canadian data:
  - Canada Pension Plan (CPP)
  - Québec Pension Plan (QPP)
- Data acquisition facilitated by Canadian Institute of Actuaries project oversight group

Socio-Economic Mortality: England

**Age Standardised Mortality Rates
England by Deprivation Deciles
Males 65-89**

Most deprived

Least deprived

**Age Standardised Mortality Rates
England by Deprivation Deciles
Females 65-89**

Most deprived

Least deprived

CPP and QPP data

- Crude death rates for males and females
- Individual calendar years 1968-2015; and ages 65-89
- Subdivided into 11 pension bands
  - Group 1: 0-9% of the cohort maximum pension
  - Group 2: 10-19%
  - :   :   :
  - Group 10: 90-99%
  - Group 11: 100%
- Cohort maximum pension: contributing for at least 40 years with earnings above the Yearly Maximum Pensionable Earnings (YMPE: 2018 – CAD 55,900)

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018   14

CPP Males and Females: ASMR's

**Age Standardised Mortality Rate
CPP Males Aged 65-89**

**Age Standardised Mortality Rate
CPP Females Aged 65-89**

Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
Group 11

CPP Males: ASMR's

**Age Standardised Mortality Rate
CPP Males Aged 65-89**

Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
Group 11

- Initially "good" rankings"
- Group 11 stands clear
  - Heterogeneity at top end
  - Conscientiousness (?)
- Middle groups behave well
- Smaller groups more volatile
- Inequality gap widens slightly
- Strange behaviour: Groups 1, 2
  - Supports the *healthy immigrant effect*

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018   16

CPP Females: ASMR's

**Age Standardised Mortality Rate
CPP Females Aged 65-89**

Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
Group 11

- Similar spread to males
- Slightly slower improvements
- Group 1 stands clear
  - Large heterogeneous group
- Ordering of groups looks okay until 2006
- Strange behaviour: After 2006 Group 11 worsens significantly relative to other groups
- Reasons for this are not clear, although Group 11 is quite small.

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018   17

CPP Females: Group 11 Heterogeneity

**Age Standardized Mortality Rate
CPP Females Age 65-89**

Group 11 All
Group 11 No DSBCONV
Group 11 No DSBCONV & no other >100%

2018-07 DATA

Source: Office of Chief Actuary calculations, OSFI

- Includes beneficiaries who get more than 100%:
  - converted from disability at age 65 or,
  - were already survivors at time of benefit uptake.
- These two groups (higher than average mortality) have gradually increased over time.
- Removing data for these two groups results in a "well behaved" plot.

Actuarial Research Centre
Institute and Faculty of Actuaries

18

3

QPP Males and Females: ASMR's

Age Standardised Mortality Rate
QPP Males Aged 65-89

Age Standardised Mortality Rate
QPP Females Aged 65-89

- No obvious anomalies, unlike CPP
- Inequality gap widens more than CPP

Group 11 Stands Clear (Males)

- Heterogeneous group:
  - Well paid through to very well paid
  - Low mortality through to very low mortality
- Conscientiousness (1 of the 5 main character traits)
  - Thorough, careful, hard working, diligent, accurate
  - In working life
    - (???) More likely to exceed YMPE in a greater number of years
  - (✓) Higher life expectancy
  - Conjecture: Group 11 has a greater proportion than Groups 1-10 of conscientious individuals, who live longer

CPP Males: Group 1

- Groups 1 contains a mixture of
  - Low paid workers, long term unemployed, etc. ⇨ high mortality
  - People who migrated to Canada in the later part of their working lives
  - ⇨ Group is potentially heterogenous
- The healthy immigrant effect
  - E.g. Vang et al. (2017)
  - Immigration permitted if:
    - *Healthy*
    - *Fit to work*
  - Selection effect diminishes over time
  - But income level does not diminish

Deeper Dive

- To understand better
  - The differences between groups
  - Trends over time
- Helpful to consider
  - How big is each group?
  - How has the calculation of pension benefits evolved over time?
  - How significant is immigration?

CPP Males: Pension Level By Cohort

CPP Males Age 65
Proportions of Pensioners by Group

- E.g. 1990 age 65 retirees:
  - Group 11: 26%
  - Group 10: 36%
  - Group 1: 2%
- Pre 1977 transition phase
- Groups 10, 11 largest
- Lower pension groups very small
- Gradual decline in numbers attaining high pensions
  - *This might artificially push up group-specific improvement rates*

CPP Females: Pension Level By Cohort

CPP Females Age 65
Proportions of Pensioners by Group

- Much lower pensions than males
- Likely reasons:
  - *Career breaks; part time working; gender pay gap*
- Declining Group 1 later
- Large Group 1 might explain why Group 1 mortality much worse than Group 2:
  - *Heterogeneity within group*

4

Males: Decline in Proportion With High Pensions

Stylised Earnings Profile

- Earnings Profile
- YMPE
- 1990 Retiree
- 2010 Retiree
- Legend: Earnings; 1990 retiree contribution period; 2010 retiree contribution period

- Eligible contribution period 1966 to retirement; max 47 years
- Contributions: % of Earnings capped at Yearly Maximum Pensionable Earnings (YMPE)
- Pension based on best 85%
- 1990 age 65 retiree: best 20 out of 1966 to 1989
- 2010 age 65 retiree: best 37 out of 1966 to 2009
  - *Lower earnings early in career mean less likely to attain the maximum*

13 September 2018   25

Immigrant Pensions

Immigrants Best Possible Group Allocation

- 1925 Birth Cohort
- 1948 Birth Cohort
- Immigrant A
- Immigrant B
- Best Possible Group 1,3,5,7,9
- Best Possible Group 2,4,6,8,10
- Best Possible Group 11

- Immigrant A:
  - Enters at age 58 in 1983
  - Even if he/she pays maximum contributions:
    - *Can't do better than Group 4*
- Immigrant B:
  - Enters at age 58 in 2006
  - *Can't do better than Group 2*

- Conclusion:
  - Assuming immigration is stable
  - Group allocations of immigrants will have shifted towards lower groups (stable from 2013)

13 September 2018   26

Immigration: Canada Excluding Québec (CPP)

Contributing Years From Date of Immigration to Age 65 (Males) Canada Excluding Quebec

Legend: 0-10 y, 10-20 y, 20-30 y, 30-40 y, 40+ y

- E.g. 1990:
  - 75% of retirees (age 65 in 1990) in Canada for at least 40 yrs
  - 5% of retirees arrived after age 55
- Estimates based on past patterns of net immigration (warning: => NOT reliable!)
- Volatile but also "stable"

- 2015 retirees:
  - Immigration in the last 0-4 years => Group 1 (at 65): ~1.3% of all retirees
  - Potentially 30% of Group 1 are recent *healthy* immigrants

13 September 2018   27

Immigration: Québec versus Rest of Canada

Contributing Years From Date of Immigration to Age 65 (Males) Canada Excluding Quebec

Legend: 0-10 y, 10-20 y, 20-30 y, 30-40 y, 40+ y

Contributing Years From Date of Immigration to Age 65 (Males) Quebec

Legend: 0-10 y, 20-30 y, 30-40 y, 40+ y

13 September 2018   28

Immigration

- Québec
  - Significantly lower immigration
  - So healthy immigrant effect is not easily identified in QPP Group 1
- Both: Females
  - Similar patterns of migration in both regions
  - But for CPP females Group 1 is much bigger
  - So a healthy immigrant effect is not easily identified in Group 1
- CPP Group 1 has a high proportion of late retirals
  - Significant late retirement into mid 70's
  - (?) Earning and contributing between 65 and late retirement
  - (?) Possibly late retirees are mostly immigrants
  - "Lifetime" Canadians unlikely to benefit

13 September 2018   29

Zoom In Even Closer: CPP Males 2015

CPP Males Fitted Period Mortality Curves

Legend: Group 1, Group 2, Groups 3-10, Group 11

- Smoothed mortality curves
- Spread:
  - Wide spread at low ages
  - Covergence at high ages: typical of most socio-economic analyses
- Group 11: well below other groups <80
- Group 1:
  - Age 65: similar to Groups 2-5
  - Older ages: gradual cross over
  - Age 80+: similar to Group 11
- Conclusion: Pattern is consistent with considerable heterogeneity in Group 1
  - A: low-income, lifetime contributors who die off quickly
  - B: very (!) healthy immigrants

13 September 2018   30

Conclusions

- For forecasting it can be useful to
  - Zoom out – exploit the wider international context
  - Zoom in – understand the detail of your own data
- Healthy immigrant effect – implicit but important
- Evolving accrual rules can impact on pension level
  - Shift towards lower pensions can inflate historical group-level improvement rates
- Overall: if forecasting subgroup mortality, it is important to understand the nuances in the underlying data
- Some evidence for a widening inequality gap
- So don't lose sight of what is happening at the national level!

13 September 2018   31

Questions   Comments

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

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

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

HERIOT WATT UNIVERSITY   Canadian Institute of Actuaries / Institut canadien des actuaires   Actuarial Research Centre Institute and Faculty of Actuaries

13 September 2018   32

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 Actuarial Research Centre, and co-funded by the Society of Actuaries and the Canadian Institute of Actuaries.

www.actuaries.org.uk/arc

Modelling, Measurement and Management of Longevity and Morbidity Risk

- Major research programme funded by the Actuarial Research Centre of the Institute and Faculty of Actuaries running from 2016 to 2020
- Significant supporting funding from the Society of Actuaries and the Canadian Institute of Actuaries
- Themes
  - Development of new single and multi-population models for mortality and new sub-population mortality datasets
  - Drivers of mortality and cause of death analysis
  - Longevity risk management
  - Stochastic models for critical illness insurance

HERIOT WATT UNIVERSITY   Canadian Institute of Actuaries / Institut canadien des actuaires   SOCIETY OF ACTUARIES   Actuarial Research Centre Institute and Faculty of Actuaries

13 September 2018   34

Appendix

13 September 2018   35

CPP and QPP data

- $D(g,i,t,x)$ death counts
- $E(g,i,t,x)$ exposures

$$\left.\begin{array}{c}\end{array}\right\} \quad \hat{m}(g,i,t,x) = D(g,i,t,x)/E(g,i,t,x)$$
crude death rate

- g =gender
- i =pension band (0-9%, 10-19%,…90-99%, 100% of *max*)
- t =calendar year
- x =age last birthday (at date of death)
- Cohort maximum pension: contributing for at least 40 years with earnings above the Yearly Maximum Pensionable Earnings (YMPE: 2018 – CAD 55,900)
- Years 1968-2015;   Ages 65-89

Actuarial Research Centre Institute and Faculty of Actuaries

13 September 2018   36

Smoothing and Projecting Mortality

- Stochastic mortality models
  - E.g. Lee-Carter, CBD
  - Socio-economic data requires multi-population models
  - Smoothing within calendar years: fitted $m(i, t, x)$
  - Genuine volatility from year to year
  - Many models considered: "common age effect" model best overall
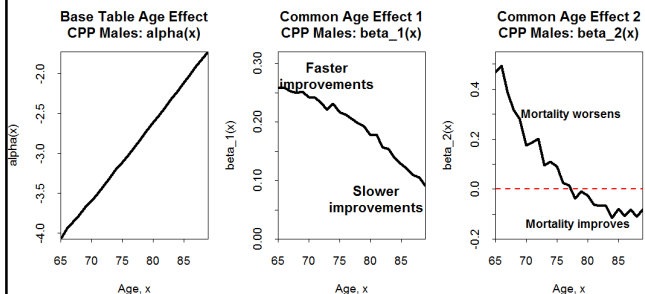- Common Age Effect Model:
  $$\log m(i, t, x) = \alpha(x) + \beta_1(x)\kappa_1(i, t) + \beta_2(x)\kappa_2(i, t)$$
  - $\alpha(x)$: common "base table"
  - $\beta_1(x)$: changes in the level of mortality at all ages
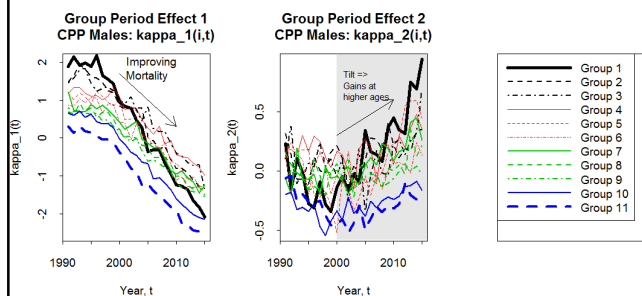 - $\beta_2(x)$: changes in the slope of the mortality curve

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018

37

Parameter Estimates: Common Age Effects

Base Table Age Effect
CPP Males: alpha(x)

Common Age Effect 1
CPP Males: beta_1(x)

Faster improvements

Slower improvements

Common Age Effect 2
CPP Males: beta_2(x)

Mortality worsens

Mortality improves

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018

38

Group-Specific Period Effects

Group Period Effect 1
CPP Males: kappa_1(i,t)

Improving Mortality

Group Period Effect 2
CPP Males: kappa_2(i,t)

Tilt => Gains at higher ages

Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
Group 11

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018

39

Fitted Period Mortality: E.g. CPP Males 2015

CPP Males
Fitted Period Mortality Curves

Group 1
Group2
Groups 3-10
Group 11

- Spread:
  - Wide spread at low ages
  - Covergence at high ages: typical of most socio-economic analyses
- Group 11: well below other groups <80
- Group 1:
  - Age 65: similar to Groups 2-5
  - Older ages: gradual cross over
  - Age 80+: similar to Group 11
- Conclusion: Pattern is consistent with considerable heterogeneity in Group 1
  - A: low-income, lifetime contributors who die off quickly
  - B: very (!) healthy immigrants

Actuarial Research Centre
Institute and Faculty of Actuaries

13 September 2018

40

7