The Canadian Pensioners Mortality Table: some results on mortality level and trends

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Laval University
45th Actuarial Research Conference
Vancouver, July 26th, 2010
Presentation Outline

1. Introduction: context
2. Data Used and Methodology
4. Comparisons
5. Short-term Projection Scale
7. Conclusion: Next Steps
Section 1

Introduction: context
Purpose of this Research

- Measure mortality levels and trends
- For Canadian pensioners
- With complete and reliable data
- Goal: reference table for Canadian pension plans
- Potential use: actuarial valuation, individual commuted value calculations
Context

- Previous work
- CIA Commission on Pension Plan Mortality Experience
- 2009 CIA Research grant

**Acknowledgements:** CIA
- Chaire d’actuariat, SOA, Régie des rentes du Québec, Office of the Chief Actuary
Project Phases

- Phase 1: Data collection and validation. 2009/07
- Phase 2: Preparation of report on mortality level for the triennial period 2005-2007. 2009/12- 2010/06 (ongoing)
- Phase 3: Mortality trend over time and other comparisons. Fall 2010
Previous Presentations

- Presentation (in French) on these results, mortality level and trends
- Goal: help establishing actuarial assumptions for QPP actuarial valuation
- CIA Annual Meeting, Vancouver, 2010-06
Section 2

Data used and methodology
Data Source

- 100 % Canadian
- 1967-2008 Period
- All individual pensions actually paid
- Retirement pensions only
- Quebec Pension Plan (source: Régie des rentes du Québec)
- Canada Pension Plan (source: Office of the Chief Actuary)
Originality

- Not a survey
- Not only members of currently existing plans (coverage ratio)
- Actual pensions paid, not census data
- Data includes dates and amount paid: precision and consistency over time
Relevance

- Measure of mortality based on a reliable source of high-quality data
- Common characteristic of pensioners: worked in Canada and earned pension entitlement
- Covered, or could have been covered, by a private pension
Quality of Data

- High: Pensions actually paid
- Administration: monthly pension $
- Individual records: all pensions
- Excellent collaboration with CPP/QPP
- Validation done by the researcher and CPP/QPP actuaries
- 2008 data excluded (under-reporting)
Nature of Data

- Dates: birth, retirement, death (year and month, not the day)
- Age, Calendar year/period
- Confidentiality: no S.I.N.
- $ of initial pension: Income level
- Consistent calculation of death and exposure over time
Volume of Data

- 7.85 M individual records (1967-2008)
  - CPP: 5.82 M  QPP: 2.03 M
  - Male: 4.47 M  Female: 3.38 M
- Including 3.03 M deaths
  - Male: 2.08 M,  Female: 0.95 M
- Alive as at July 1, 2007: 4.61 M
  - Male: 2.30 M,  Female: 2.31 M

★ A lot of data ! (in numbers and %)
Coverage by Age and Sex

Canadian Pensioners Data in % of Census Data on 2007-07-01

- Male
- Female

60 65 70 75 80 85 90+
40% 50% 60% 70% 80% 90% 100%
Classification Variables: 1

- **Source**: CPP, QPP, CAN=Canada
- **Sex**: Male, Female
- **Age**
  - Age *at last birthday*: integer
  - Precision: $1/24^{th}$ of a year
  - Adjustment for the day (middle of the month)
  - From 60 to 111 in 2007 (born in 1896 or later)
Classification Variables: 2

- **Calendar year/ 3-year period**
  - 1967 to 2007

- **Income Level and Income Class**
  - Pension $ translated into % of maximum pension
  - % at beginning of retirement = function (YMPE *)
  - Adjustment according to retirement date: source, early or late retirement, phasing-in formula

* YMPE = C/QPP Yearly Maximum Pensionable Earnings ➔ $ 39,100 in 2002, $ 43,700 in 2007
Data by Income Level (5%-interval): CAN, Male
Classification Variables: 3

- 5 income classes
  - 1: < 35 % maximum pension
  - 2: 35-94 % max. pension
  - 3: > 95 % max. pension (high income)
  - 4: > 35 % max. pension = 2 + 3
  - 5: All income = 1 + 2 + 3

Class 4: low pensions excluded
Data Limitations

- Volume varies by year: 1967, 1970, 1990...
- Year 2008: under-reporting of CPP deaths
- Retirees only: impact on data coverage for female
- No data below age 60
- Early retirement: data from age 60 to 64 since 1984 (QPP)/1987 (CPP)
- Maximum Age related to (Year – 1896)
  - 1967: ages 68 to 71
  - 1970: ages 65 to 74
  - 2000: ages 60 to 104
  - 2007: ages 60 to 111
Measured Values

- Death
- Exposure
- Central death rate
- Observed probability of death
- For each cell
  - Source/Age/Sex/Income Class/Year
- Graduated rate calculation (smoothing)
## Exposure by Class, CAN 2005-2007

<table>
<thead>
<tr>
<th>Class</th>
<th>Male (000 Life-Years)</th>
<th>Male (%)</th>
<th>Female (000 Life-Years)</th>
<th>Female (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>707</td>
<td>11</td>
<td>2,868</td>
<td>43</td>
</tr>
<tr>
<td>2</td>
<td>2,852</td>
<td>43</td>
<td>3,051</td>
<td>46</td>
</tr>
<tr>
<td>3</td>
<td>3,071</td>
<td>46</td>
<td>694</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>5,923</td>
<td>89</td>
<td>3,745</td>
<td>57</td>
</tr>
<tr>
<td>5</td>
<td>6,630</td>
<td>100</td>
<td>6,613</td>
<td>100</td>
</tr>
</tbody>
</table>
## Deaths by Class, CAN, 2005-2007

<table>
<thead>
<tr>
<th>Class</th>
<th>Male (#)</th>
<th>Male (%)</th>
<th>Female (#)</th>
<th>Female (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31,567</td>
<td>12</td>
<td>85,175</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>111,084</td>
<td>43</td>
<td>77,596</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>117,952</td>
<td>45</td>
<td>17,783</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>229,036</td>
<td>88</td>
<td>95,379</td>
<td>53</td>
</tr>
<tr>
<td>5</td>
<td>260,603</td>
<td>100</td>
<td>180,554</td>
<td>100</td>
</tr>
</tbody>
</table>
Section 3

Mortality Level:
2005-2007
# Deaths for CAN, Male, Age 70, Class 4 (>35 % Max. Pension)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1 (&lt;35%)</td>
<td>251.50</td>
<td>266.00</td>
<td>241.00</td>
<td>106.00</td>
<td>98.50</td>
<td>96.50</td>
<td>1059.50</td>
</tr>
<tr>
<td>2 (35-94%)</td>
<td>830.50</td>
<td>892.50</td>
<td>886.00</td>
<td>333.00</td>
<td>292.50</td>
<td>301.50</td>
<td>3536.00</td>
</tr>
<tr>
<td>3 (&gt;95%)</td>
<td>678.50</td>
<td>639.00</td>
<td>646.00</td>
<td>216.50</td>
<td>195.50</td>
<td>193.00</td>
<td>2568.50</td>
</tr>
<tr>
<td>4 (&gt;35%)</td>
<td>1509.00</td>
<td>1531.50</td>
<td>1532.00</td>
<td>549.50</td>
<td>488.00</td>
<td>494.50</td>
<td>6104.50</td>
</tr>
<tr>
<td>5 (all)</td>
<td>760.50</td>
<td>1797.50</td>
<td>1773.00</td>
<td>655.50</td>
<td>586.50</td>
<td>591.00</td>
<td>7164.00</td>
</tr>
</tbody>
</table>

2010-07-26  Louis Adam, 45th Actuarial Research Conference, Canadian Pensioners Mortality 2007-12-31
## Exposure: CAN, 4, M, Age 70

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1 (&lt; 35 %)</td>
<td>8 755.60</td>
<td>9 125.35</td>
<td>9 627.51</td>
<td>2 783.92</td>
<td>2 891.44</td>
<td>3 038.97</td>
<td>36 322.79</td>
</tr>
<tr>
<td>2 (35-94%)</td>
<td>33 572.65</td>
<td>34 415.65</td>
<td>34 404.01</td>
<td>11 674.07</td>
<td>12 004.36</td>
<td>12 306.19</td>
<td>138 376.944</td>
</tr>
<tr>
<td>3 (&gt;95%)</td>
<td>34 312.29</td>
<td>35 105.43</td>
<td>34 995.06</td>
<td>11 036.42</td>
<td>11 063.15</td>
<td>10 749.68</td>
<td>137 262.028</td>
</tr>
<tr>
<td>4 (&gt;35%)</td>
<td>67 884.94</td>
<td>69 521.08</td>
<td>69 399.07</td>
<td>22 710.49</td>
<td>23 067.51</td>
<td>23 055.88</td>
<td><strong>275 638.972</strong></td>
</tr>
<tr>
<td>5 (all)</td>
<td>76 640.54</td>
<td>78 646.43</td>
<td>79 026.58</td>
<td>25 494.40</td>
<td>25 958.96</td>
<td>26 094.85</td>
<td>311 861.76</td>
</tr>
</tbody>
</table>
Calculations: CAN, 4, M, Age 70

- Deaths: 6,104.50
- Exposure: 275,638,972
- Central Rate $\mu_{70}: 0.022147$
- Probability of Death $\hat{q}_{70}: 0.021903$
- Standard Deviation of $\hat{\mu}_{70}: 0.0002835$
- Standard Deviation of $\hat{q}_{70}: 0.000277$
- Coefficient of Variation: 1.27%
Calculations & Interpretation

- Observed Value $\hat{q}_{70}$: 0.021903
- Lower Bound (95 %): 0.021360
- Upper Bound (95 %): 0.022447
- Value obtained by smoothing (graduation) $q_{70}$: 0.021626
- Graduated value obtained takes into account results for several ages, but bounded by ± 1 standard deviation
Rationale \( \log(\hat{\mu}_x) , 65 \leq x \leq 85 \)

\[
\ln[ \text{Observed } \mu_x ] \\
\text{Canada Male 2005-2007 35%-100%}
\]

\[
y = 0.1066217x - 4.4658287 \\
R^2 = 0.9993192
\]
Graduation, with Constraints,
Ages 65-75

CAN, Male, Level 4, 2005-2007, Detailed calculation, age 65 to age 75

Age 70: 0.021626
Graduation, with Constraints, Ages 75-85

CAN, Male, Level 4, 2005-2007, Detailed calculation, age 75 to age 85

- Observed $q_x$
- Lower Bound $q_x$ (95%)
- Upper Bound $q_x$ (95%)
- Graduated $q_x$
- Graduated $q_x$, unbounded
Graduation, with Constraints, Ages 85-95

CAN, Male, Level 4, 2005-2007, Detailed calculation, age 85 to age 95

- Observed $q_x$
- Lower Bound $q_x$ (95%)
- Upper Bound $q_x$ (95%)
- Graduated $q_x$
Graduation, with Constraints, Ages 95-115

CAN, Male, Level 4, 2005-2007, Detailed calculation, age 95 to age 115
Terminal Values

- Male: 0.54 at age 115
- Female: 0.51 at age 115
- Values obtained by comparing combined data at extreme ages over several years (1991-2007)
- Materiality: less significant for pension
- Modification to an exponential model (Gompertz, with asymptotic limit)
\[ x \leq 95: \]
\[ \mu_x = Bc^x \]
\[ \log(\mu_x) = \log(B) + x \cdot \log(C) \]

\[ 95 \leq x \leq 115: \]
\[ \log(\mu_{115+}) = \text{constant (0.54 Male, 0.51 female)} \]
\[ \log(\mu_{95+k}) = \log(BC^{95} \cdot c_{96} \cdot c_{97} \cdots c_{95+k}) \]
\[ \log(c_{96}) > \log(c_{97}) > \ldots > \log(c_{115}) \text{ (linear decrease)} \]
\[ \log(\mu_{115}) - \log(\mu_{95}) = \sum_{k=1}^{20} \log(c_{95+k}) \]
End-of-Table Model

Male, Canada, Age ≥ 95: Central Rate of Death $\mu(x)$
Male: 0.54 at Age 115
Canada, Female, All Income, 2007-12-31 End of Table
Data Over Age 95 for Period 1991-2007

Female: 0.51 at Age 115
Values below age 65: extrapolation

- Tests not completed…
- No data below age 60
- Potention solution: blend of Statistics Canada with extrapolation of CPP-QPP (Age 60 to 65), Male Class 4, 2003-2005 Period
- Done here for 2003-2005 Period
Values under age 65

- Graduated Death Probabilities CPP-QPP
- Statistics Canada
- Extrapolation of CPP-QPP Probabilities of Death (Age 60 to 65)
- Mixture of Statistics Canada and Extrapolation of CPP-QPP (Age 60 to 65)
Section 4

Comparisons
Male/Female Comparison

Ratio of Probability of Death
Female/Male, CAN, 2005-2007, Level 4

65 70 75 80 85 90 95 100 105 110 115

50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%
Comparison by Income: Male 1,2,3,4/5

CAN, Male, 2005-2007, Comparison by Income Class
Ratio of Observed Probability of Death

- Ratio 1/5
- Ratio 2/5
- Ratio 3/5
- Ratio 4/5
Comparison by Income: Female 1,2,3,4/5

CAN, Female, 2005-2007, Comparison by Income Class
Ratio of Observed Probability of Death

- Ratio 1/5
- Ratio 2/5
- Ratio 3/5
- Ratio 4/5

60 65 70 75 80 85
60% 70% 80% 90% 100% 110% 120% 130% 140% 150% 160%
Comparison by Income: Male 2,3/4

CAN, Male, 2005-2007, Comparison by Income Class

- Ratio 2/4
- Ratio 3/4
Comparison by Income: Female 2,3/4

CAN, Female, 2005-2007, Comparison by Income Class

- Ratio 2/4
- Ratio 3/4

60 65 70 75 80 85
Comparison by Source: M

Comparison by Data Source, Male, Over 35% Max. Pension

- **CPP/CAN** (2005-2007)
- **QPP/CAN** (2005-2007)
- **CPP/CAN** (1995-1997)
Comparison by Data Source, Female, Over 35% Max.

- CPP/CAN (2005-2007)
- QPP/CAN (2005-2007)
Section 5

Short-term Projection Scale
Evolution of mortality, 1987-2007, Age 70: example
Can, Male, Over 35 % Max. Pension, Unweighted regression

\[ q(x+t) = q(x) \times (1-0.02352)^t \]
\[ y = 0.03652e^{-0.02380x} \]
\[ R^2 = 0.94282 \]
Reduction Rate

- Example: \( q_{2010} = q_{2005-2007} \times (1\text{-rate})^4 \)
- Rate = reduction (projection) scale
- Decreases over time the probability of death in a year (example: 2%/year)
- Calculated for various combinations of variables (source, age, sex, class)
- Here: CAN, 70, Male, >35% max. pension
Explanation on Reduction Rate

- Previous chart: same weight given to each calendar year figure for $q_{70}$
- Method used here: Average annual rate obtained by weighted linear regression
- Weight related to the quantity of data
- Different period ending in 2007
- Each rate varies according to: age/period
- 15-year rate for age 70: 2.78%/year
15-year Period, Ending in 2007

**Weighted Least-Square Regression Example for q_{70}**

Age 70, Male, Canada, Income > 35% Maximum Pension, 1992-2007 (15 years)

**Slope:** 2.78%, 95% Confidence Interval: 2.46% - 3.11%, $R^2=0.96$

Observed $q_{70}$ in 2007: 0.021680

Observed $q_{70}$ in 1992: 0.031584
M, Can, 4, Ages 60 to 70

Canada, Male, Over 35 % Max., Average Annual Rate of Decrease of Mortality Over Various Periods Ending in 2007
Short Term/Long Term Comparison

Canada, Male, Over 35 % Max. Pension, Various Periods ending in 2007
Short Term, with Bounds: M

Canada, Male, Over 35 % Max. Pension
Rate of Mortality Decrease per Year, Short Term (2007)

Last 15 years
Lower Bound
Upper Bound
Short Term
Scale AA
Short term, with bounds: F

Canada, Female, Over 35 % Max. Pension, Rate of Mortality Decrease per Year, Short Term (2007)

- Last 15 Years
- Lower Bound
- Upper Bound
- Short Term
- Scale AA
Long Term, with Bounds

Canada, Male, Over 35 % Max. Pension Rate of Mortality Decrease per Year, Long Term (2007)
Lon
ge term, with bounds: F

Canada, Female, Over 35 % Max. Pension Rate of Mortality Decrease per Year, Long Term (2007)

Min to 2007
Lower Bound
Upper Bound
Long Term
Scale AA
Section 6

Materiality:
Impact on Present Values
Impact on Actuarial Liabilities

- Change of mortality tables: from UP-94 to Canadian Pensioners Mortality (CPM)
- Male - Female
- without projection beyond 2006, or up to 2010, 2015, 2020
- Income class effect: not the same impact for upper income pensioners
Assumptions and notes

- UP-94 figures calculated using “Age last birthday” assumption for consistency: not typical
- I.e.: table UP-94 @2006 “LB”
- Present value of a $1,000/year life annuity-due, payable annually, interest rate = 6%
- Charts: % Increase from UP-94 to CPM
Male, 2006: $1,000 \times \ddot{a}_x$

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>65</td>
<td>10,828.25</td>
<td>10,605.38</td>
<td>11,138.05</td>
<td>10,871.85</td>
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<tr>
<td>70</td>
<td>9,480.96</td>
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<td>9,692.17</td>
<td>9,468.40</td>
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<tr>
<td>75</td>
<td>8,003.83</td>
<td>7,767.76</td>
<td>8,118.65</td>
<td>7,968.22</td>
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<tr>
<td>80</td>
<td>6,497.16</td>
<td>6,315.05</td>
<td>6,541.35</td>
<td>6,451.26</td>
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<tr>
<td>85</td>
<td>5,161.53</td>
<td>4,937.19</td>
<td>5,059.69</td>
<td>5,006.96</td>
</tr>
</tbody>
</table>
Male, 2006: % Change
Female, 2006: $1,000 \times \ddot{a}_x$

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>65</td>
<td>11,808.29</td>
<td>12,046.04</td>
<td>12,217.46</td>
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<tr>
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<td>9,380.01</td>
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<td>7,657.65</td>
</tr>
<tr>
<td>85</td>
<td>5,926.42</td>
<td>5,975.72</td>
<td>6,037.88</td>
<td>5,991.27</td>
</tr>
</tbody>
</table>
Female, 2006, % Change
Male, Class 4, with Projection

![Bar chart showing mortality rates for different age groups and years: 2010, 2015, 2020.](chart.png)
Female, Class 4, with Projection
Male, Class 3, with Projection

Chart showing mortality rates for different age groups.
Female, Class 3, with Projection

![Graph showing mortality rates for different age groups in 2010, 2015, and 2020. The x-axis represents ages 65 to 85, and the y-axis represents percentage. The bars are color-coded for each year: blue for 2010, red for 2015, and green for 2020.](image-url)
Section 7

Conclusion:
Next Steps
General Comments

- Canadian mortality rates affect many private and public pension plans.
- Mortality is significant, at least at high ages (unrealistic to conclude that all will live until age 120).
- Mortality varies according to: age, sex, income, year, source.
General Comments

- Study carried out with recent and reliable Canadian data
- The rate of decrease of mortality is not constant
- Multiple external factors must be considered, along with past data, to develop a suitable assumption for the intended purpose
Comments on Reduction Rate

- Varies from year to year
- Lower for female than for male
- Higher at age 65, close to 0 at age 90 (negative afterwards?)
- Proposal: linearly decreasing scale by age group
- Faster decrease in the recent past: troubling
- Slower decrease over a longer period
- Faster decrease than American AA scale
- The past may not be an indication of the future...
Thank you!

Questions?
Data by Income Level (5%-interval): CAN, Female