Premium indexing in lifelong health insurance[1]

2013 Astin Colloquim, The Hague

W. Vercruysse, J. Dhaene, M. Denuit, E. Pitacco, K. Antonio

KU Leuven, Belgium

May 22, 2013

[1] KU Leuven AG Chair on Health Insurance.

Outline

Introduction

Research background

Complementary health insurances:

- outside social security system
- occupational or non-occupational.

Belgian legislation:

- lifelong contract,
- fixed technical basis,
- premium adaptation only with fixed medical index.

Medical inflation is impossible to predict
–> ongoing monitoring

Indexing for medical inflation

Notations and assumptions

Notation:

- x: age at policy issue;
- t: time since policy issue;
- $^{(t)}$: time at which quantities are valuated.

Assumptions:

- level premiums,
- non-transferrable reserves,
- apart from inflation, all assumptions made in the technical basis are met.

Health insurance contract:

- APV of the benefits:

$$B_x^{(0)} = \sum_{k=0}^{\infty} c_{x+k}^{(0)} v(0,k) \; {}_k p_x .$$

- Non-exit probability:

$$\begin{aligned} {}_k p_{x+t} &= \exp\left(- \int_0^k \left(\mu_{x+t+s} + \lambda_{x+t+s} \right) ds \right), \\ &= \left(1 - {}_k q_{x+t}^{[d]} \right) \left(1 - {}_k q_{x+t}^{[w]} \right). \end{aligned}$$

- Level premium:

$$\pi_x^{(0)} = \frac{B_x^{(0)}}{\ddot{a}_x}, \text{ where } \ddot{a}_x = \sum_{k=0}^{\infty} v(0,k) \; {}_k p_x.$$

- Initial reserve:

$$V_0^{(0)} = B_x^{(0)} - \pi_x^{(0)} \ddot{a}_x = 0.$$

Indexing for medical inflation

time t=1

- Reserves:
  - Assets (retrospective reserve):

$$V_1^{(0)} = \left[\pi_x^{(0)} - c_x^{(0)}\right] \left[v(0,1)\ {}_1p_x\right]^{-1}.$$

  - Liabilities (prospective reserve):

$$V_1^{(0)} = B_{x+1}^{(0)} - \pi_x^{(0)} \ddot{a}_{x+1},$$

$$B_{x+1}^{(0)} = \sum_{k=0}^{\infty} c_{x+1+k}^{(0)} v(1,1+k)\ {}_kp_{x+1},$$

$$\ddot{a}_{x+1} = \sum_{k=0}^{\infty} v(1,1+k)\ {}_kp_{x+1}.$$

- Medical inflation during $[0, 1]$:

$$B_{x+1}^{(1)} = (1 + j_1^{[B]}) B_{x+1}^{(0)}.$$

- Inequality:

$$\textit{Assets} \neq \textit{Liabilities}$$

$$V_1^{(0)} \neq (1 + j_1^{[B]}) B_{x+1}^{(0)} - \pi_x^{(0)} \ddot{a}_{x+1}.$$

- Restore actuarial equivalence:
  - premium increase, $j_1^{[P]}$;
  - reserve increase, $j_1^{[V]}$;

- Following Pitacco (1990):

$$(1+j_1^{[V]})V_1^{(0)} = (1+j_1^{[B]})B_{x+1}^{(0)} - (1+j_1^{[P]})\pi_x^{(0)}\ddot{a}_{x+1},$$

or, equivalently,

$$V_1^{(1)} = B_{x+1}^{(1)} - \pi_x^{(1)}\ddot{a}_{x+1}.$$

Indexing for medical inflation

time t=2,3,...

- Reserves:
  - Assets (retrospective reserve):

$$V_t^{(t-1)} = \left[V_{t-1}^{(t-1)} + \pi_x^{(t-1)} - c_x^{(t-1)}\right]\left[v(t-1,t)\ {}_1p_{x+t-1}\right]^{-1}.$$

  - Liabilities (prospective reserve):

$$V_t^{(t-1)} = B_{x+t}^{(t-1)} - \pi_x^{(t-1)}\ddot{a}_{x+t},$$

$$B_{x+t}^{(t-1)} = \sum_{k=0}^{\infty} c_{x+t+k}^{(t-1)} v(t,t+k)\ {}_kp_{x+t},$$

$$c_{x+t+k}^{(t-1)} = c_{x+t+k}^{(0)} \prod_{h=1}^{t-1}(1+j_h^{[B]}),$$

$$\pi_x^{(t-1)} = \pi_x^{(0)} \prod_{h=1}^{t-1}(1+j_h^{[P]}).$$

- Medical inflation during $[t-1, t]$:

$$B_{x+t}^{(t)} = (1 + j_t^{[B]}) B_{x+t}^{(t-1)}.$$

- Inequality:

$$\textit{Assets} \neq \textit{Liabilities}$$

$$V_t^{(t-1)} \neq (1 + j_t^{[B]}) B_{x+t}^{(t-1)} - \pi_x^{(t-1)} \ddot{a}_{x+t}.$$

- Restore actuarial equivalence:

$$(1+j_t^{[V]})V_t^{(t-1)} = (1+j_t^{[B]})B_{x+t}^{(t-1)} - (1+j_t^{[P]})\pi_x^{(t-1)}\ddot{a}_{x+1},$$

or, equivalently,

$$V_t^{(t)} = B_{x+t}^{(t)} - \pi_x^{(t)}\ddot{a}_{x+t}.$$

Application of the indexing mechanism

Relationships

$$j_t^{[B]} = \left(\frac{V_t^{(t-1)}}{B_{x+t}^{(t-1)}} \right) j_t^{[V]} + \left(\frac{\pi_x^{(t-1)} \ddot{a}_{x+1}}{B_{x+t}^{(t-1)}} \right) j_t^{[P]}.$$

Question:

How to share the additional cost arising from unanticipated benefit inflation between the policy holder ($j_t^{[P]}$) and the insurer ($j_t^{[V]}$)?

Application of the indexing mechanism

Possible procedures

1. $j_t^{[V]} = 0$:
   - advantages:
     - simple and transparant;
     - intuitive;
   - disadvantage:
     - $j_t^{[P]}$ may fluctuate heavily from year to year.

2. $j_t^{[P]} = (1+\alpha) j_t^{[B]}$:

$$\begin{aligned} \alpha &= 0 \Longrightarrow j_t^{[P]} = j_t^{[B]} = j_t^{[V]}, \\ \alpha &> 0 \Longrightarrow j_t^{[P]} > j_t^{[B]} > j_t^{[V]}, \\ \alpha &< 0 \Longrightarrow j_t^{[P]} < j_t^{[B]} < j_t^{[V]}. \end{aligned}$$

How to determine α such that the contract remains fair?

1. Optimal α for a given age at policy issue:

$$APV_x(\alpha_x^*) = 0, \text{ with } APV_x(\alpha) = \sum_{t=1}^{\infty} j_t^{[V]} V_t^{(t-1)} p_x v(0,t).$$

2. Optimal α for a given portfolio of new entrants:

$$APV(\alpha^*) = 0, \text{ with } APV(\alpha) = \sum_{x=x_0}^{\omega-1} n_x \cdot APV_x(\alpha).$$

where $\sum_{x=x_0}^{\omega-1} n_x \cdot \left[\sum_{t=1}^{\infty} j_t^{[V]} V_t^{(t-1)} p_x v(0,t)\right] = 0$ to find the optimal α, can be written as an initial equation of equilibrium similar to the one that determines the premiums.

Numerical illustration

Technical basis

- Non-exit probability:

$$p_y = \left(1 - q_y^{[d]}\right)\left(1 - q_y^{[w]}\right)$$

  - independent survival rates based on the mortality function of the first Heligman-Pollard Law:

$$\frac{q_y^{[d]}}{1 - q_y^{[d]}} = A^{(y+B)^C} + De^{-E(\ln y - \ln F)^2} + GH^y,$$

    with market parameters:
    $A = 0.00054$, $B = 0.017$, $C = 0.101$, $D = 0.00013$,
    $E = 10.72$, $F = 18367$, $G = 1.464 \times 10^{-5}$ and $H = 1.11$.

  - independent lapse rates:

$$q_y^{[w]} = \begin{cases} 0.1 - 0.002(y - 20), & y = 20, 21, \ldots, 70 \\ 0, & \text{else} \end{cases}.$$

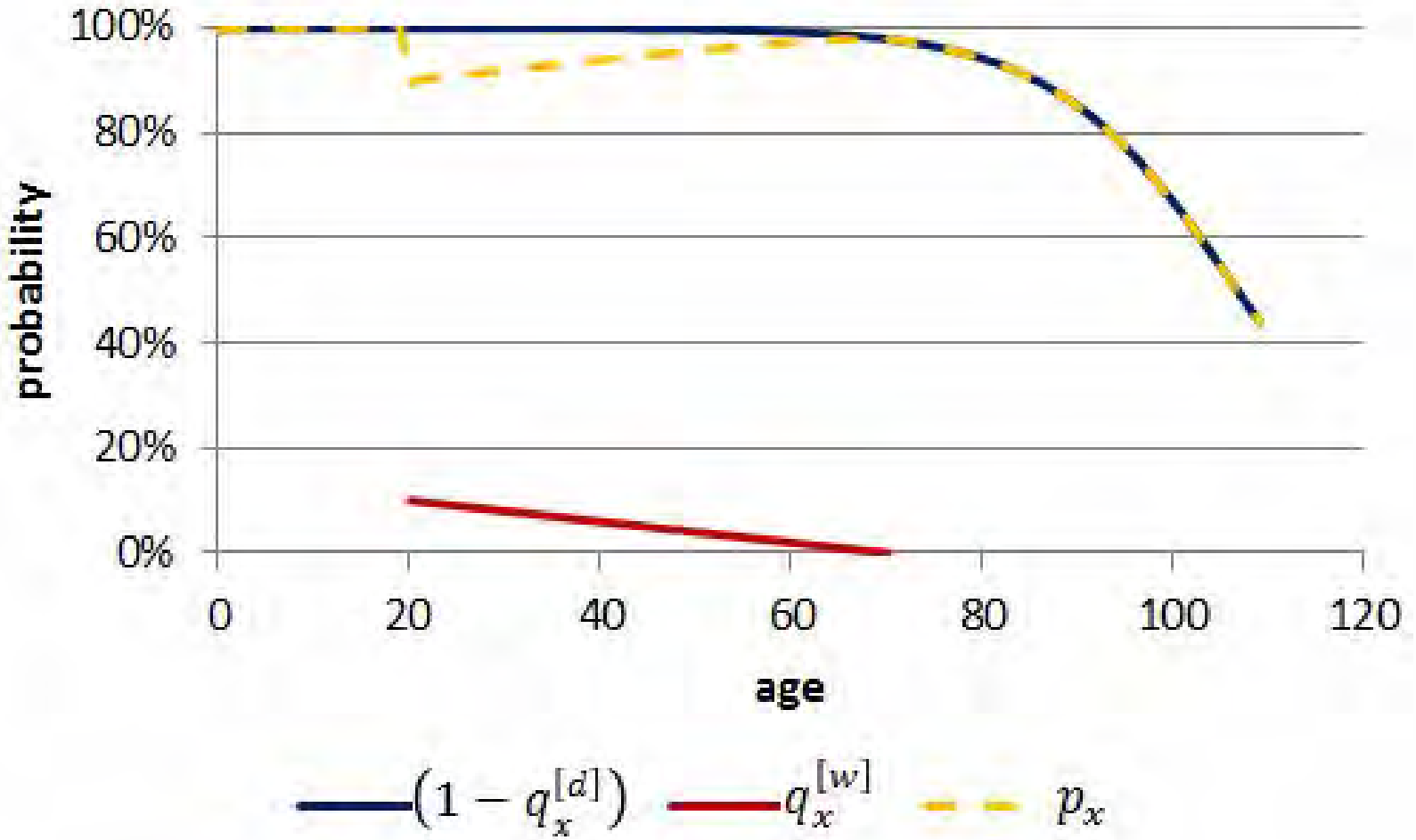

Figure: One-year non-exit, survival and lapse probabilities.

- interest rate: $i = 2\%$
- annual claim amount:

$$c_y^{(0)} = 0.204476472 \times \exp(0,038637y), \;\; y \geq 20.$$

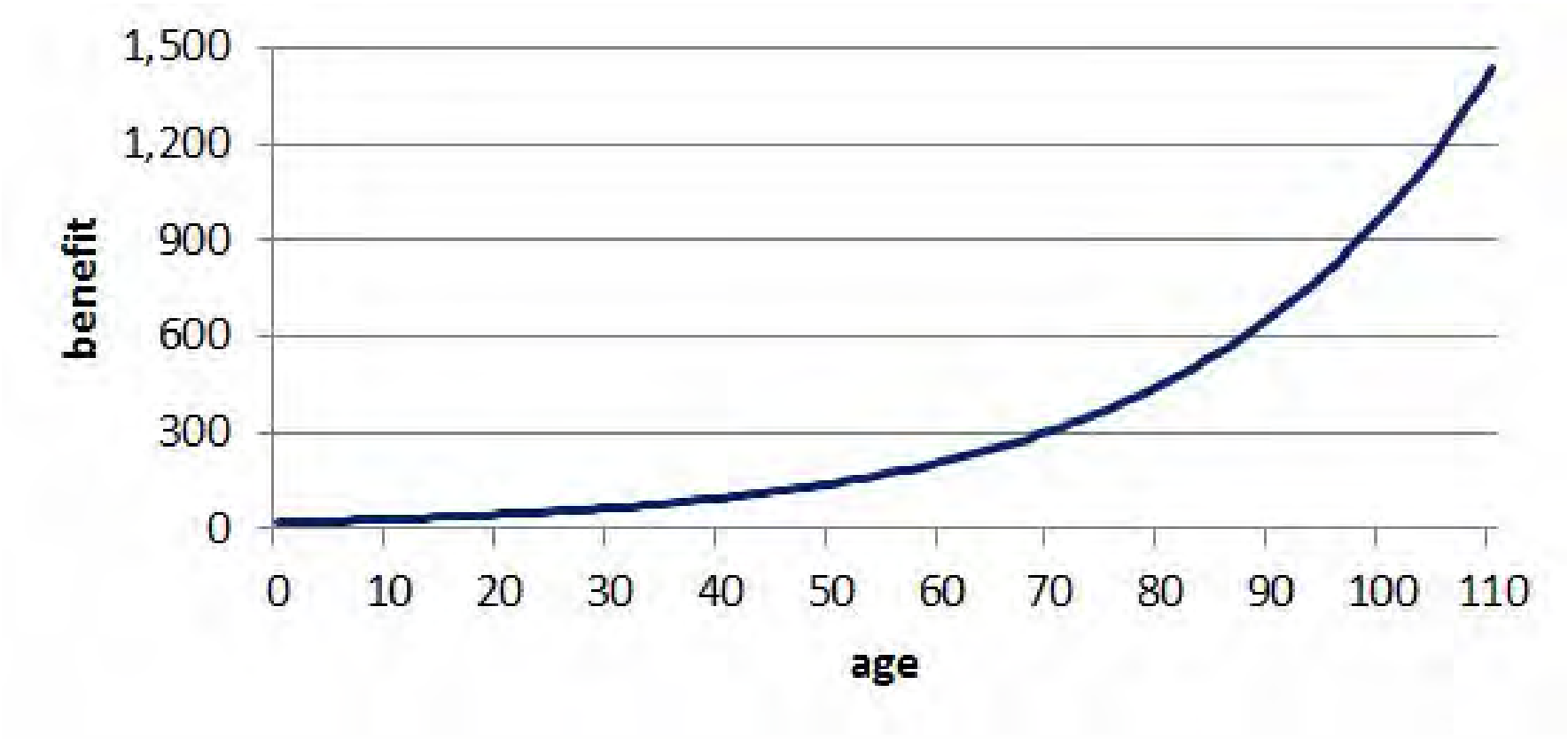

Figure: Yearly claim amounts for a person aged x.

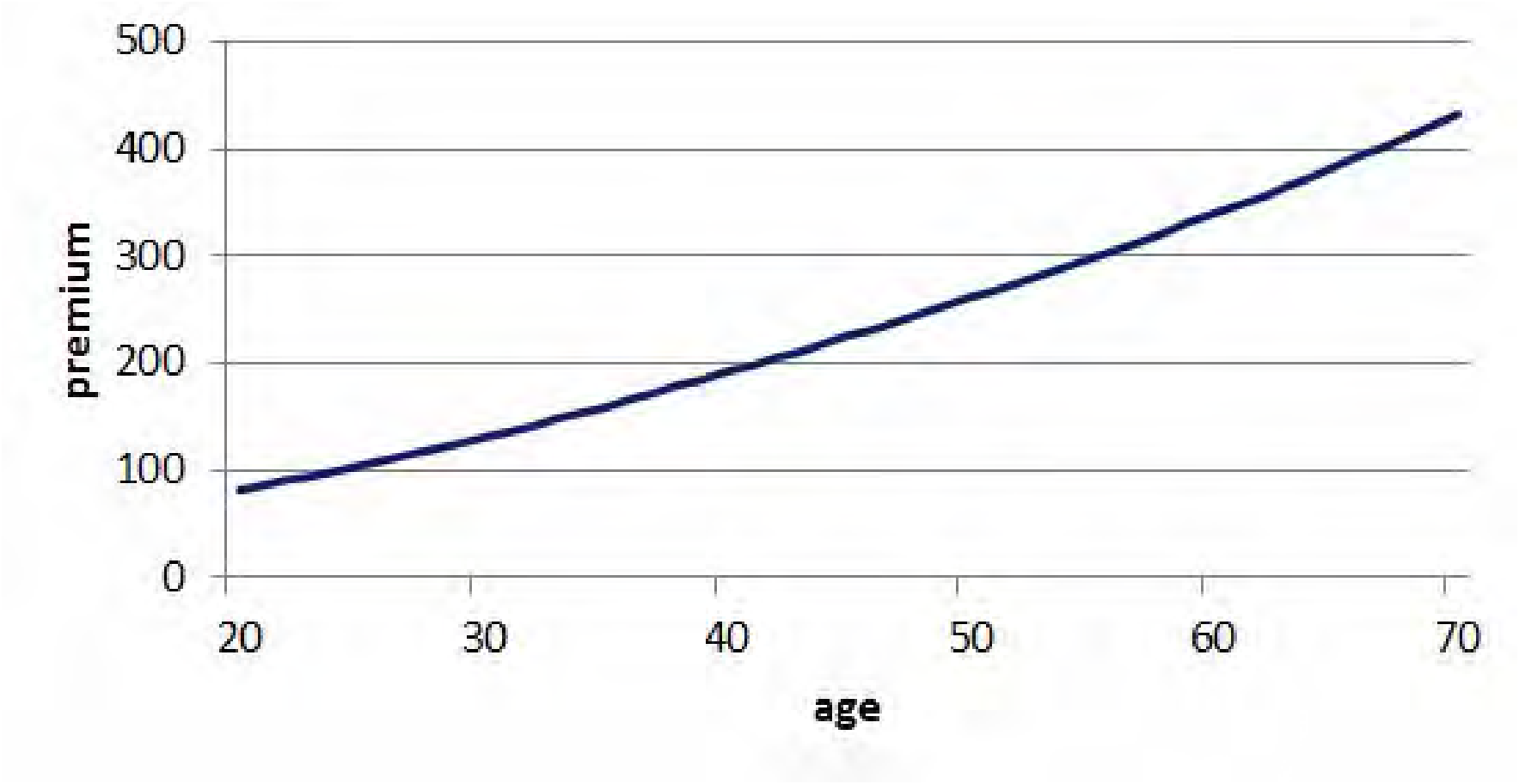

Figure: Level premiums $\pi_x^{(0)}$ for different ages.

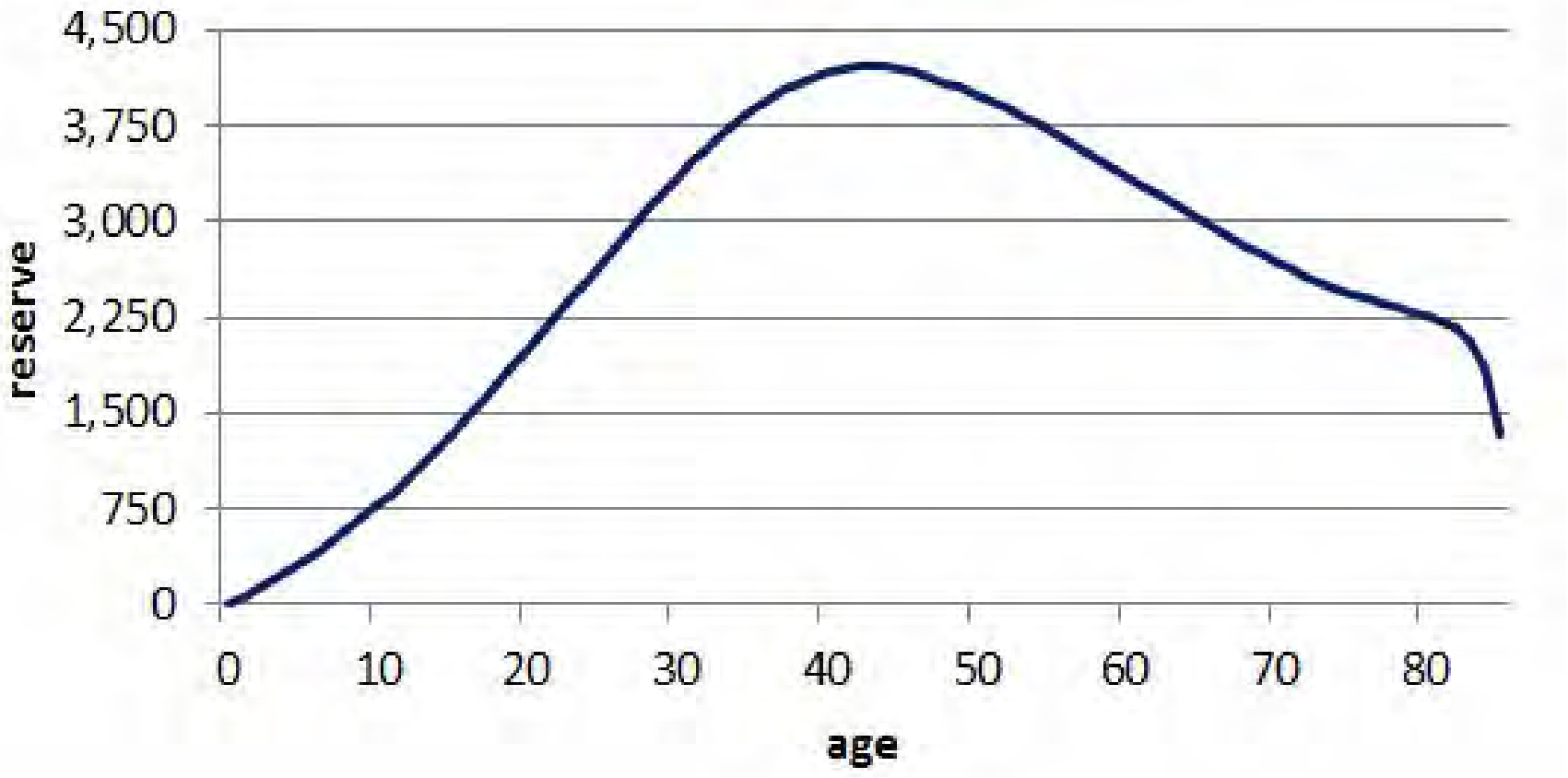

Figure: Reserves $V_t^{(0)}$ for a person aged 25 at policy issue when $j_t^{[B]} = 0$.

Numerical illustration

Optimal alpha as a function of the age at entry

1. Calculate $APV_x(\alpha)$ for different values of α.
   E.g. take $x = 25$:

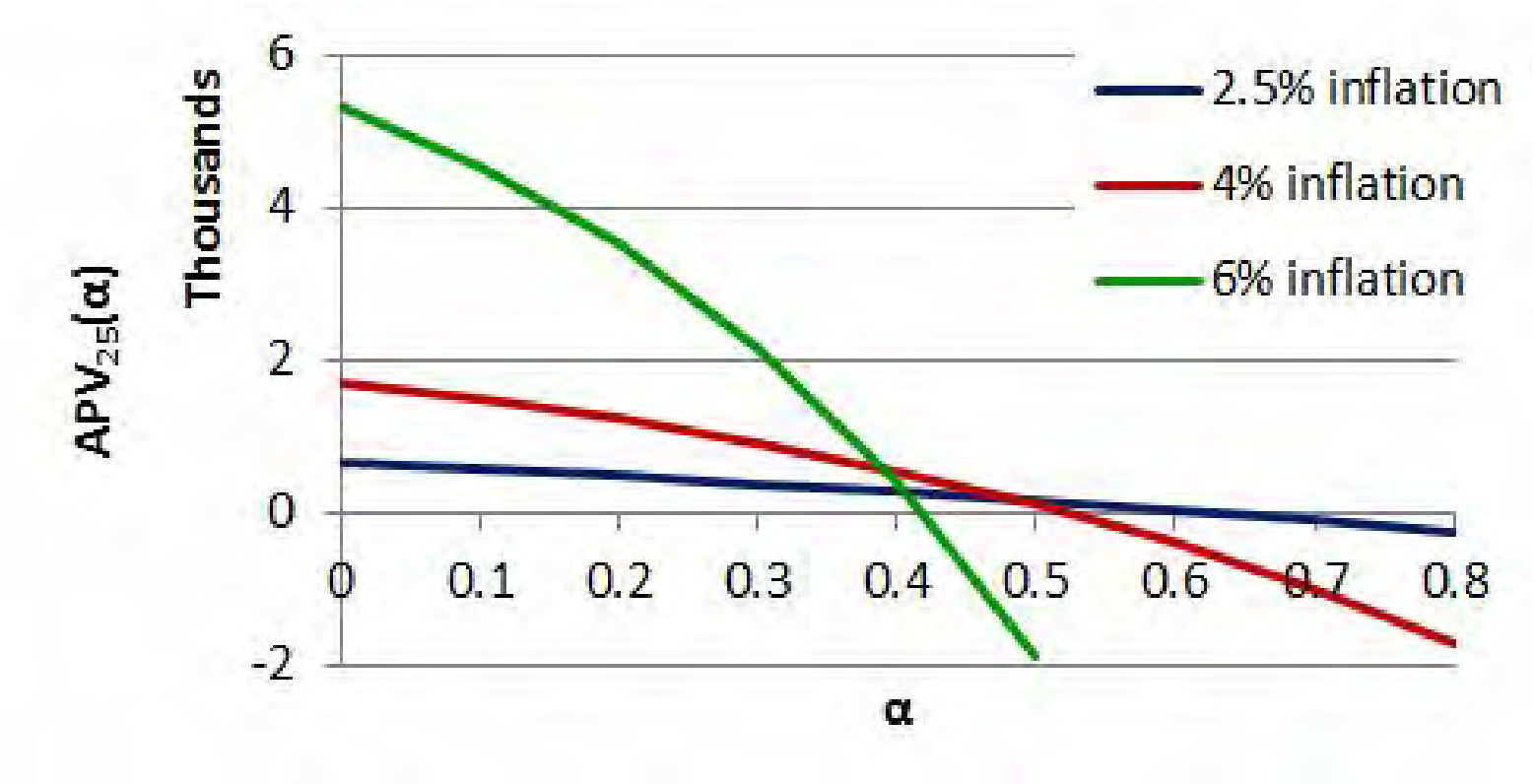

Figure: $APV_{25}(\alpha)$ when $j_t^{[P]} = (1+\alpha) j_t^{[B]}$.

2. Select α_x^* for which $APV_x(\alpha_x^*) = 0$.

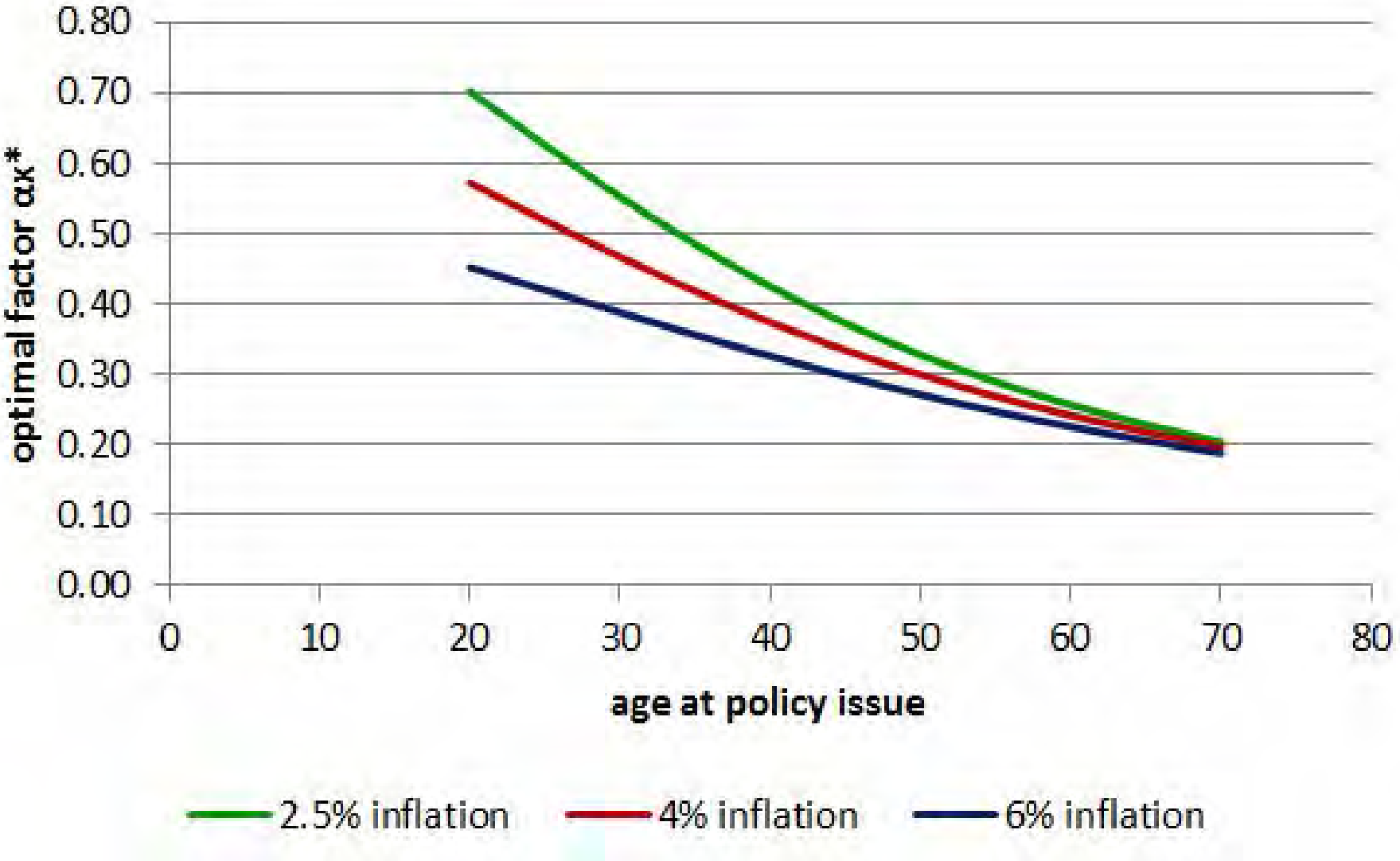

Figure: The optimal factor α_x^* as a function of the age at policy issue.

Numerical illustration

Optimal alpha for a given portfolio of new entrants

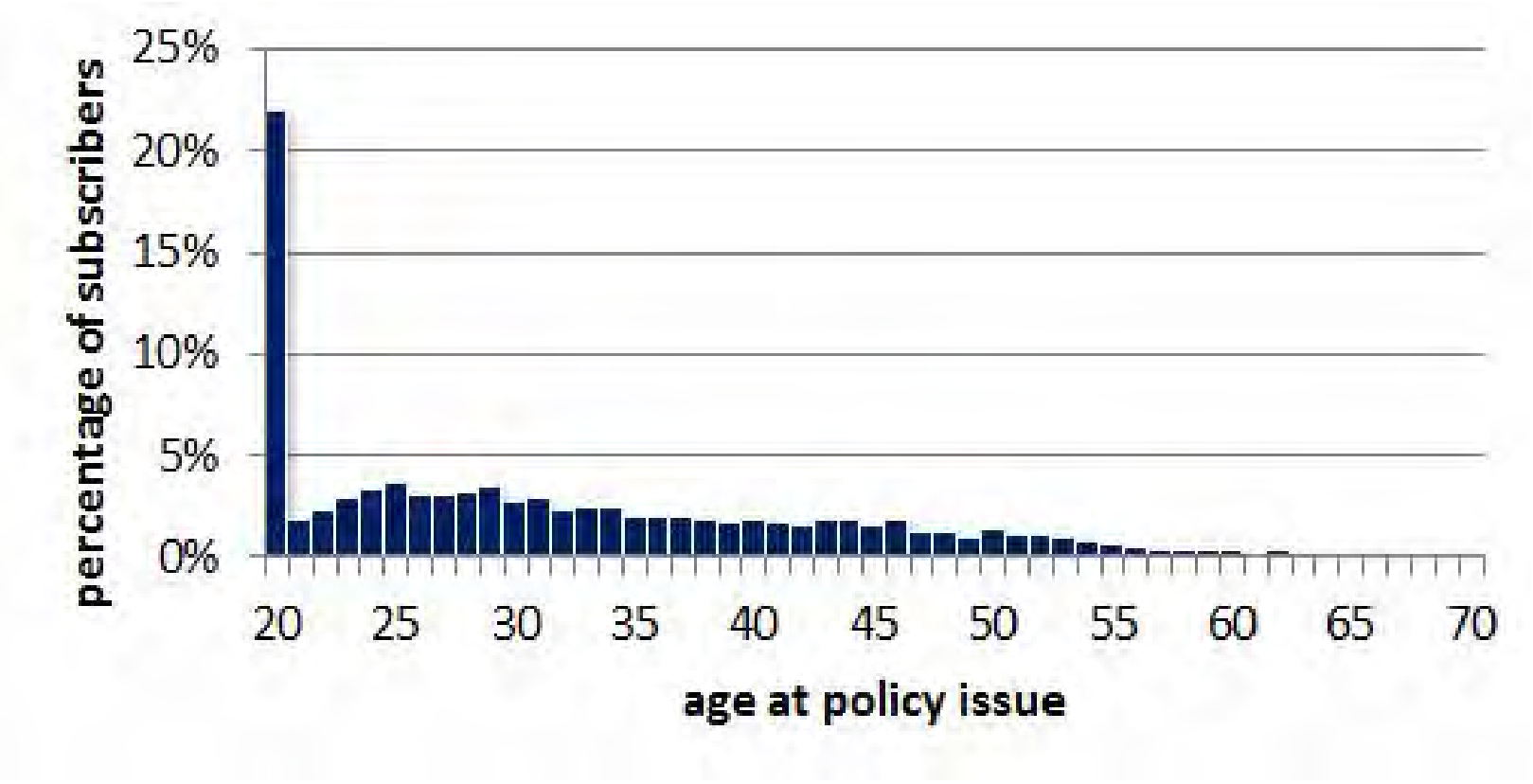

Figure: Distribution of the age of new entrants.

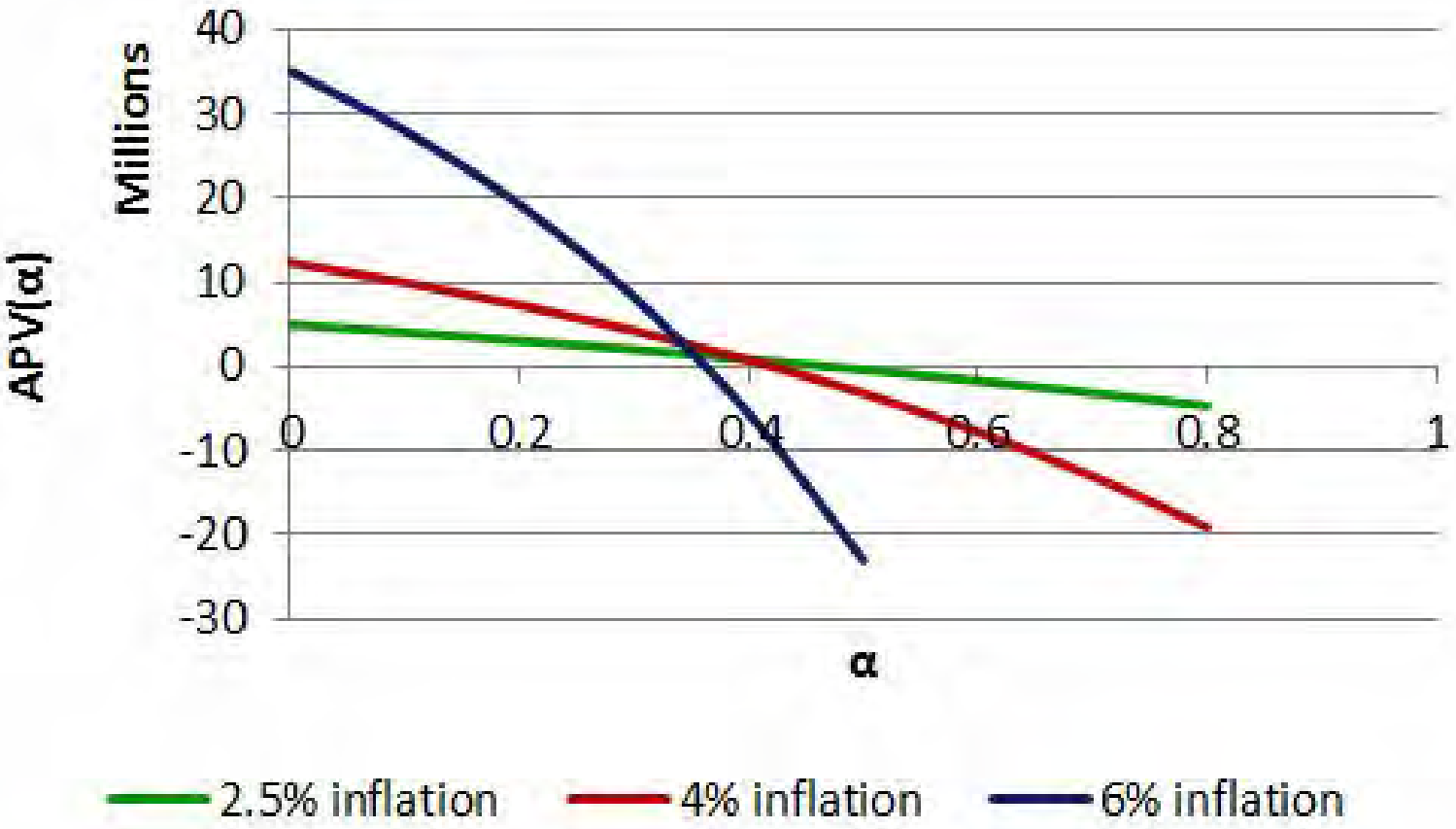

Figure: $APV(\alpha)$ as a function of α in case $j_t^{[P]} = (1+\alpha) j_t^{[B]}$.

Conclusion

- premium indexing mechanisms to restore the actuarial equivalence:

$$j_t^{[B]} = \left(\frac{V_t^{(t-1)}}{B_{x+t}^{(t-1)}} \right) j_t^{[V]} + \left(\frac{\pi_x^{(t-1)} \ddot{a}_{x+1}}{B_{x+t}^{(t-1)}} \right) j_t^{[P]}.$$

1. on policy-per-policy and year-to-year basis with $j_t^{[V]}$ constant or $j_t^{[V]} = 0$.
2. with $j_t^{[P]} = (1+\alpha) j_t^{[B]}$ such that the actuarial present value of the future reserve increases equal 0. α can be choosen:
   - 2.1 for a given age at policy issue;
   - 2.2 for a given portfolio of new entrants.

References

- Pitacco, E. (1999). Multistate models for long-term care insurance and related indexing problems. *Applied Stochastic Models in Business and Industry* 15, 429-441.
- Vercruysse, W., Dhaene, J., Denuit, M., Pitacco, E.& Antonio, K. (2013). Premium indexing in lifelong health insurance. working paper.

Contact

Ward Vercruysse:	Ward.Vercruysse@kuleuven.be
Jan Dhaene:	Jan.Dhaene@kuleuven.be
Michel Denuit:	michel.denuit@uclouvain.be
Katrien Antonio:	Katrien.Antonio@kuleuven.be

Website: www.econ.kuleuven.be/insurance/AGchair.htm