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Modern Life-Care Tontines

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joint work with:

Dr. Nathalie Lucas (National Bank Belgium)

We want to thank Prof. Michel Denuit (UC Louvain) for many comments and discussions.

Short introduction

- ▶ @HEC Lausanne since 08/2021.
- ▶ Prior positions in **Ulm** (Germany)



in Munich (Germany), Brussels (Belgium),
Toronto (Canada).

- ▶ Research in **life and pension insurance**.
- ▶ peter.hieber@unil.ch



Long-term care needs more attention. . .

- ▶ Belgium: LTC spending (in terms of GDP) increased from **1.7% in 2000** to **2.3% in 2018** (source: Eurostat).
- ▶ United Nations projections: The number of **elderly people**, i.e. older than 65, is projected **to triple from 2020 to 2080** to reach 2.2 billion. The global **share of the elderly population** is expected to **rise from 9.4% in 2020 to 20.6% in 2080**.

Agenda

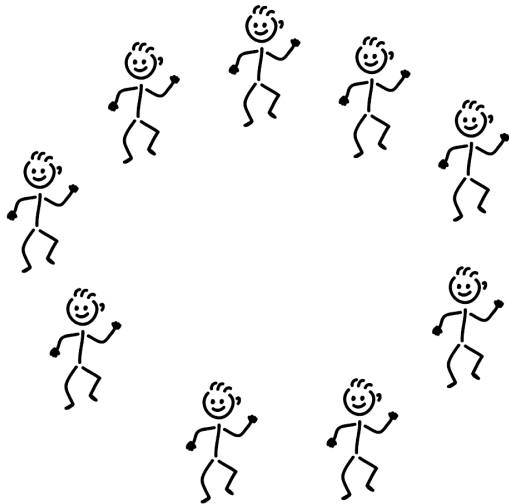
1. Motivation: Mutual insurance schemes in past and present
2. (Academic) research on mutual insurance schemes
3. Combining (mortality risk) and (**long-term care**) insurance
4. Why can this challenge traditional insurance business?

What is mutual insurance?

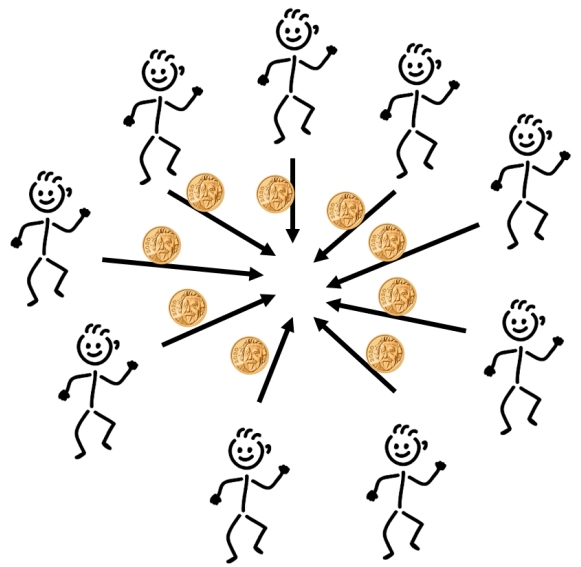
Definition: A **mutual insurance company** is an insurance company owned entirely by its policyholders.

- ▶ This usually avoids **risk charges** and **reduces administration, regulation**.
- ▶ Several hundred years ago, mutual insurance was the dominant form of insurance.
- ▶ Its popularity may again increase in the coming decades.

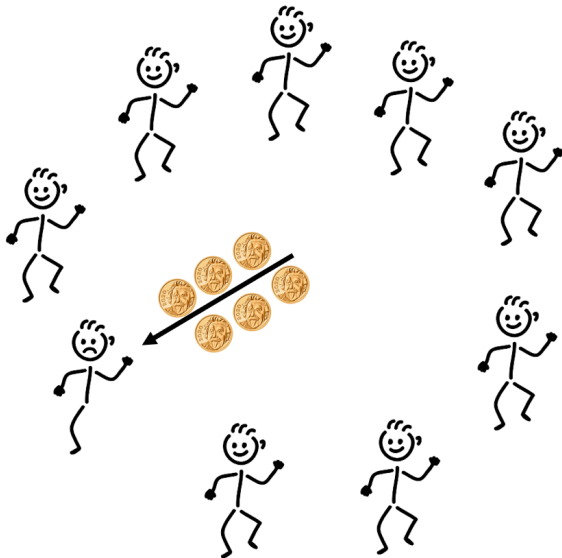
What is mutual insurance?



What is mutual insurance?



What is mutual insurance?



Mutual insurance schemes in past. . .

Historic tontines (17th-19th century)

- ▶ Plans to raise government money.
- ▶ Predefined income stream is paid to survivors of a pool.
- ▶ Charlotte Barbier: *Before dying in 1726 at the age of 96, in return for her 300 livres investment, she had received back 73,000 livres.*
- ▶ Li, Y., & Rothschild, C. (2020). Selection and redistribution in the Irish tontines of 1773, 1775, and 1777. **Journal of Risk and Insurance**, 87(3), 719-750.

18 juin 1792.

Certificat d'addition au brevet de quinze années, expédié le 25 avril dernier,

AU sieur DOUSSET, inventeur.

L'ÉTABLISSEMENT présenté au public est un de ceux que la confiance appelle et que le succès se plaît à couronner.

Il a pour objet, 1°. de procurer des facilités à ceux que la volonté engage à des ventes d'immeubles, ou que des besoins forcent à des emprunts; 2°. de procurer des placements utiles sur des garanties imperturbables; 3°. outre un accroissement annuel de l'intérêt des mises, de donner dans une des opérations proposées la chance d'une propriété.

Il offre un autre avantage, et que nul établissement de ce genre n'a atteint, celui de l'impérissabilité des placements: car, d'un côté, les intéressés auront contracté avec des particuliers solvables, et, aux termes de la loi, il n'en est aucun qui ne puisse être contraint; d'un autre côté, les intéressés n'auront à craindre ni dénaturation, ni suppression, ni retranchement de leurs créances, et, à moins de la chute du ciel ou du renversement de la terre, ils n'ont rien à redouter.

Cet établissement profitera au riche, à l'homme aisé, et, qui plus est, au pauvre, qui, en y plaçant les économies que la sagesse lui aura fait faire, trouvera dans les accroissements annuels

... start a revival today:

The New York Times

When Others Die, Tontine Investors Win



By Tom Verde

March 24, 2017

Living a long life is its own reward. But when you invest in a [tontine](#), there's an added benefit: You collect money that would have gone to people who have died.

That is part of the macabre appeal of the tontine, a 350-year-old investment vehicle that fell into disfavor more than a century ago but is now getting fresh consideration as a way to help people receive steady income in retirement.

Modern tontines: “Le conservateur”, France

- ▶ <http://www.conservateur.fr>
- ▶ Probably the first “modern tontine”.
- ▶ 20 year product, rolling.
- ▶ Upon death, money is distributed among survivors (“**mortality credits**”).

App-based insurance: “Friendsurance”, Germany

- ▶ For example: Household insurance (ménage).
- ▶ Small claims are covered in a **P2P-network of friends**.
- ▶ Big claims are covered by regular insurance.
- ▶ (Some) cost savings via **reduced fees, no risk charges**, easy administration.
- ▶ Hope to increase **“transparency”** (blockchain technology).
- ▶ “Friendsurance” is an internet company, no insurer!

Modern tontines: Occupational pension reform PEPP

- ▶ Reluctancy by companies to offer **long-term return guarantees**.
- ▶ Tackled by the **PEPP pension reform** in 2017-18 in EU (also Canada, Switzerland).
- ▶ Occupational pension without mortality / investment guarantees.
- ▶ Implementation may follow **tontine-like schemes**.
- ▶ Similar paths in other countries: e.g. public pension reform in Singapore.

Modern tontines: Xianghubao

Xianghubao mutual aid amount.

Age group	Mild critical illness	Severe critical illness
30 days to 39-year-old	50,000 yuan	300,000 yuan
40- to 59-year-old	50,000 yuan	100,000 yuan

- ▶ **Disability insurance.**
- ▶ Based on an **app in China**, founded 2018.
- ▶ After 1 year, **100 million users**.

See also:

- ▶ Abdikerimova, S., & Feng, R. (2022). Peer-to-Peer multi-risk insurance and mutual aid. **European Journal of Operational Research**, 299(2), 735-749.

Modern tontines: Nuovalò



- ▶ Founded 2020.
- ▶ Specializing in longevity risk pooling solutions.
- ▶ Peer-to-peer insurance software.

See also:

- ▶ Winter, P., & Planchet, F. (2022). Modern tontines as a pension solution: A practical overview. **European Actuarial Journal**, 12, 3-32.

This talk: Motivation

To sum up: **Digitalization, blockchain technology** nowadays ease the implementation of **mutual insurance schemes**. This may **replace (or add to) traditional insurance**.

But we also need the actuarial knowledge / research to discuss:

- ▶ The fairness of risk sharing schemes.
- ▶ The way surplus is distributed among the pool.
- ▶ The product design (also fraud, moral hazard).

Agenda

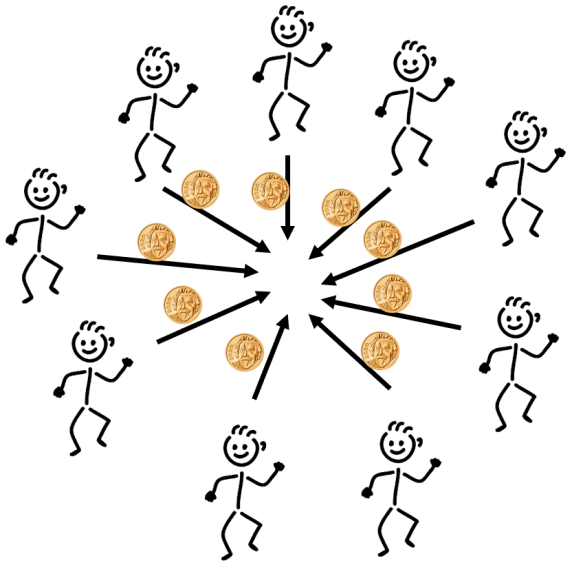
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This talk: Academic research

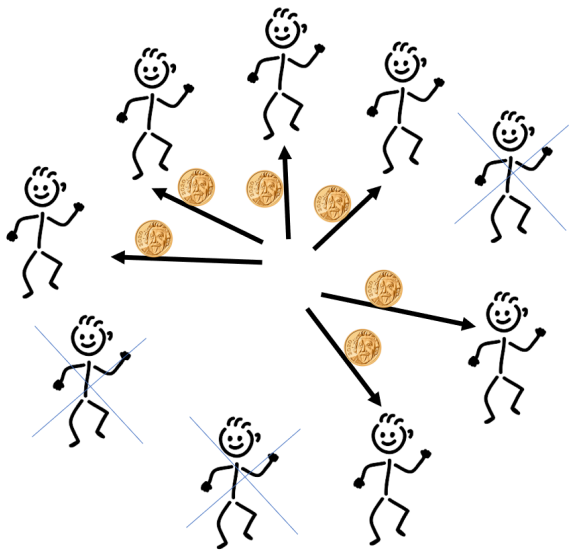
- ▶ Mutual risk-sharing schemes for **heterogeneous pools** (for example heterogeneous in age, health).
- ▶ We **pool mortality and morbidity** (long-term care) **risks**.
- ▶ Hieber, P., & Lucas, N. (2022). *Modern life-care tontines*. ASTIN Bulletin: The Journal of the IAA, 52(2), 563-589.
- ▶ Denuit, M., Hieber, P., & Robert, C. Y. (2022). *Mortality credits within large survivor funds*. ASTIN Bulletin: The Journal of the IAA, in press.

*Joint work with Nathalie Lucas (National Bank, Belgium),
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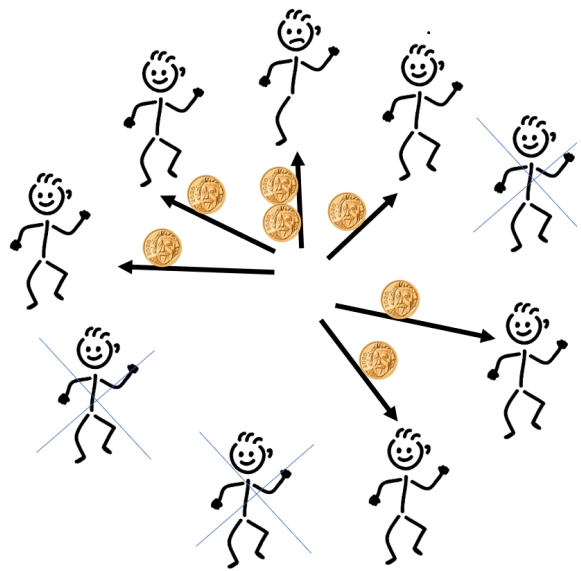
Life Tontine



Life Tontine



Life-Care Tontine



Tontine products and surplus distribution

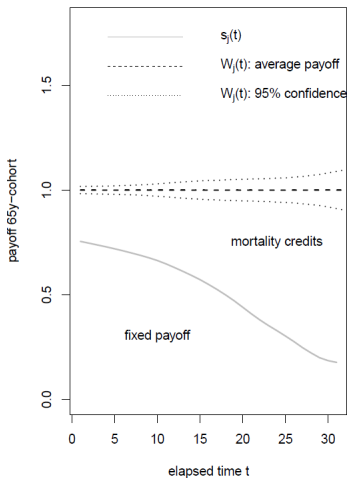
How do **modern tontines** work? Difference to pure financial investment?

We share insurance “gains”:

- ▶ **mortality credits**: As in traditional insurance, accounts of deceased are (maybe only partially) distributed to survivors.
- ▶ **morbidity credits** (see later slides): Long-term care risks (more dependent people, longer time in dependency) are shared.
This can be a surplus or a deficit!

All this comes on top of the regular financial return.

Multi-period heterogeneous tontine: Sketch/example



Fixed payoff (gray line) = “individual account”

Some notation

- ▶ Pool members $\mathcal{L}_0 = \{1, 2, \dots, n\}$. Time in periods $t = 0, 1, 2, \dots$
- ▶ Individual $j \in \mathcal{L}_0$ contributes **single premium** $c_j(0)$ at time 0.
- ▶ Deterministic, **risk-free rate** δ_t , $t \geq 0$.
- ▶ Remaining lifetimes $T_j, j \in \mathcal{L}_0$, are assumed to be independent.
- ▶ **Death probability**: q_{x_j} . **Maximal age** $\omega \in \mathbb{N}$.
- ▶ **Individual account value**, fixed payoff $s_j(t)$:

$$c_j(t) = \begin{cases} e^{\int_{t-1}^t \delta_s ds} c_j(t-1) - s_j(t), & j \in \mathcal{L}_t \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$(c_j(t))$ is the “individual account”, the gray line!

In case of death, the pool shares the remaining account value

$$X(t) := \sum_{j=1}^n \mathbb{1}_{j \in \mathcal{D}_t} \cdot e^{\int_{t-1}^t \delta_{sds}} c_j(t-1).$$

An individual $j \in \mathcal{L}_{t-1}$ receives a payoff of:

$$W_j(t) = \begin{cases} s_j(t) + \beta_j(X(t)), & \text{if } j \in \mathcal{L}_t \\ \beta_j(X(t)), & \text{if } j \in \mathcal{D}_t \end{cases} \quad (2)$$

decomposed of

- $s_j(t)$: individual, fixed withdrawal amount,
- $\beta_j(X(t))$: collective part of the benefits, i.e. the mortality credits.

What is a **fair** distribution of mortality credits?

Definition (Fair distribution rule: mortality credits)

A fair distribution rule $\beta_j(X(t))$ satisfies:

- ▶ **Self-sufficiency property:** $\sum_{j \in \mathcal{L}_{t-1}} \beta_j(X(t)) = X(t)$.
- ▶ **Positivity property:** $\beta_j(X(t)) \geq 0$.
- ▶ **Fairness property:**

$$\mathbb{E}_{t-1}[\beta_j(X(t))] = \underbrace{\mathbb{E}_{t-1}[\mathbb{1}_{j \in \mathcal{D}_t}]}_{\text{probability to die in } (t-1, t]} \cdot \underbrace{e^{\int_{t-1}^t \delta_s ds} c_j(t-1)}_{\text{amount at risk at time } t}, \quad (3)$$

where $\mathbb{E}_t := \mathbb{E}[\cdot | \mathcal{F}_t]$ is an expectation conditional on the information $\mathcal{F}_t := \sigma(\mathcal{L}_t)$.

Examples: Sharing rules

Share linearly according to (1) **amount invested** and (2) **death probability**.

Example (Linear risk sharing rule)

At time t , each individual $j \in \mathcal{L}_{t-1}$ receives the mortality credit (respectively death benefit):

$$\beta_j(X(t)) = \frac{q_{x_j+t-1} \cdot c_j(t-1)}{\sum_{j \in \mathcal{L}_{t-1}} q_{x_j+t-1} \cdot c_j(t-1)} \cdot X(t). \quad (4)$$

(see, e.g., [Donnelly, Guillén, Nielsen \[2013, 2014\]](#), [Schumacher \[2018\]](#))

Actuarial fairness: Insurer's view

For each $t = 0, 1, \dots$, the premium equivalence holds: (pool view)

$$\underbrace{\sum_{j=1}^n c_j(t)}_{\text{total account values}} = \sum_{j=1}^n \underbrace{\sum_{s=t+1}^{\omega-x_j} e^{-\int_t^s \delta_u du} W_j(s)}_{\text{discounted future benefits individual } j} . \quad (5)$$

- ▶ Right hand side: **random** (big letter!)
- ▶ Left hand side: **deterministic**.

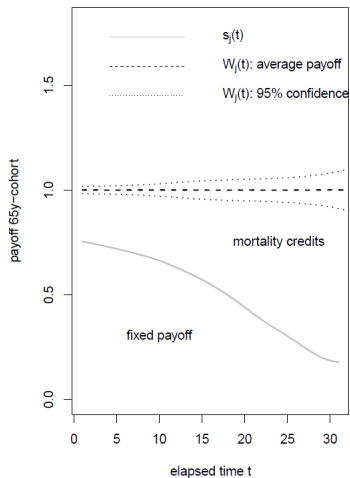
Actuarial fairness: Individual's view

For each $t = 0, 1, \dots$, the contract is fully-funded: (individual view)

$$\underbrace{c_j(t)}_{\text{retrospective reserve}} = \mathbb{E}_t \left[\underbrace{\sum_{s=t+1}^{\omega-x_j} e^{-\int_t^s \delta_u du} W_j(s)}_{\text{prospective reserve}} \right]. \quad (6)$$

The expected present value of future benefits equals the current account value.

Multi-period heterogeneous tontine: Sketch/example



Fixed payoff (gray line) = “individual account”

Backwards iteration

Individual $j \in \mathcal{L}_t$'s time- t account value is given by:

$$c_j(t) = \sum_{u=t+1}^{\omega-x_j} e^{-\int_t^u \delta_s ds} s_j(u). \quad (7)$$

How do we choose the gray line?

For example, choose the average payoff to be constant, equal to $b_j > 0$:

$$\begin{aligned} \mathbb{E}_{t-1}[W_j(t) | j \in \mathcal{L}_t] &= \mathbb{E}_{t-1}[\mathbb{1}_{j \in \mathcal{L}_t} \cdot s_j(t) + \mathbb{1}_{j \in \mathcal{L}_{t-1}} \cdot \beta_j(\mathbf{X}(t)) | j \in \mathcal{L}_t] \\ &= s_j(t) + \mathbb{E}_{t-1}[\beta_j(\mathbf{X}(t))] \\ &= s_j(t) + q_{x_j+t-1} e^{\int_{t-1}^t \delta_s ds} c_j(t-1) \stackrel{!}{=} b_j. \end{aligned} \quad (8)$$

((9) is a system of equations backwards in time!)

Theorem (Backwards iteration)

If an individual $j \in \mathcal{L}_t$ aims for an average payoff $b_j(t)$, the fixed payoff is given by:

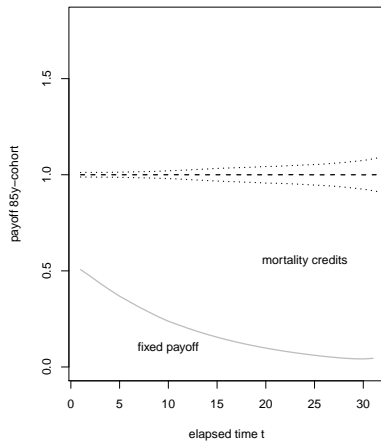
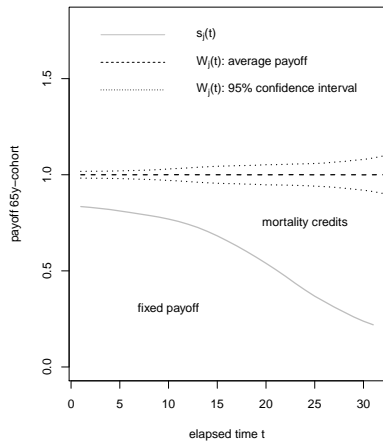
$$s_j(t) = \begin{cases} \frac{b_j(t)}{1+q_{\omega-1}}, & \text{for } t = \omega - x_j \\ \frac{b_j(t) - q_{x_j+t-1} \sum_{u=t+1}^{\omega-x_j} e^{-\int_t^u \delta_s ds} s_j(u)}{1+q_{x_j+t-1}}, & \text{for } t = \omega - x_j - 1, \omega - x_j - 2, \dots, 1 \end{cases} \quad (9)$$

We derive the individual's account value as

$$c_j(t) = \sum_{u=t+1}^{\omega-x_j} e^{-\int_t^u \delta_s ds} s_j(u) \quad (10)$$

and the initial single premium as $c_j(0)$.

Numerical example



Discussion

- ▶ The backwards iteration detects the split between **fixed payoff** $s_j(t)$ and **mortality credits** $\beta_j(X(t))$ that leads to an average payoff of $b_j(t)$.
- ▶ The backwards iteration can be carried out **individually** for each $j \in \mathcal{L}_0$ (modularity / flexibility).
- ▶ This allows **different age cohorts** to share mortality risks in a fair way.

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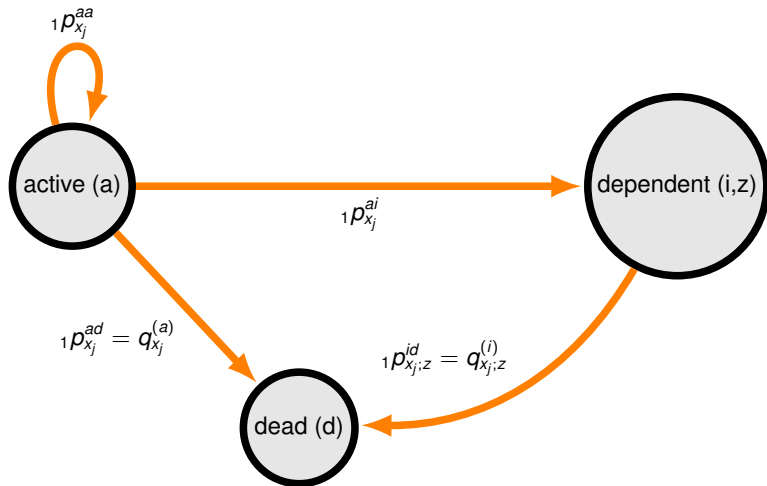
Why pool mortality and morbidity risks?

- ▶ People moving into dependency need more money but have a reduced life expectancy!
⇒ **Natural hedge, diversification!**

- ▶ Individuals in bad health cannot receive long-term care insurance!
⇒ **Combined product gives access to insurance for a larger share of the population!**

- ▶ Cost reduction due to **reduced adverse selection!**
⇒ Combined product is **attractive for people in bad health...**

Life-Care Tontine: semi-Markov model



z : time spent in dependency.

Modern Life-Care Tontine

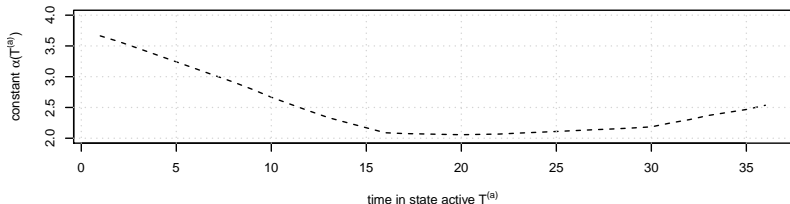
We move in two steps:

- (1) A **natural, actuarial fair increase** in payments **in dependency**: Higher payments “compensated” by lower life expectancy.
- (2) The **increase** in dependency **is fixed a priori**. Any gains / deficits are shared within the pool of active individual (“morbidity credits”).

We use the notation $\alpha(T^{(a)})$ where $T^{(a)}$ is the time where the individual moves into dependency to account for the increase in payments: $b_j(t)$ as an active; $\alpha(T^{(a)}) \cdot b_j(t)$ as a dependent person.

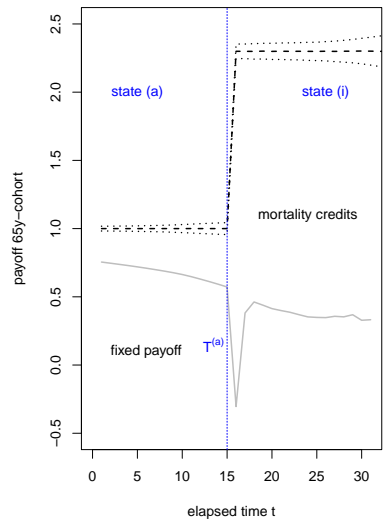
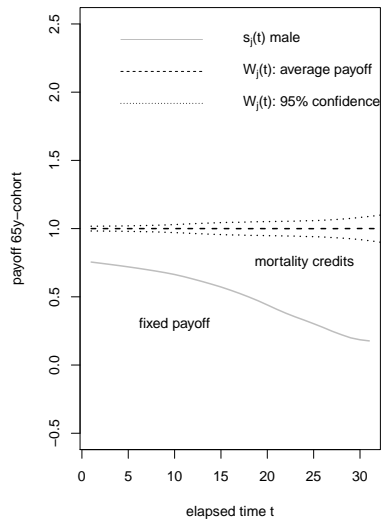
Modern Life-Care Tontine

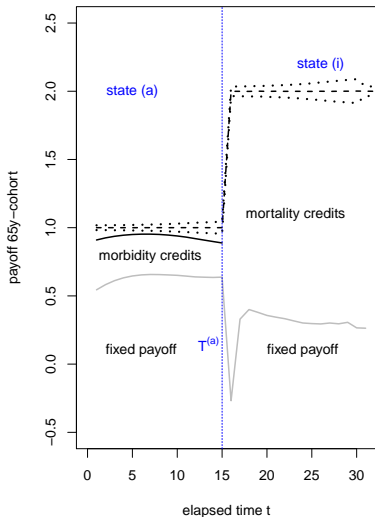
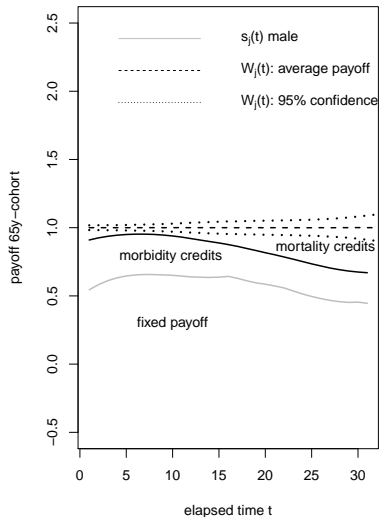
“Natural increase”: French mortality/disability data shows actuarially fair values for $a(T^{(a)})$:



Mortality credits of a dependent person depend on the death probability

$$q_{x_j+t-1}^{(i)} > q_{x_j+t-1}^{(a)}$$





Quick summary

- ▶ We propose a fair mutual insurance scheme ($b_j(t)$ for each individual j , we share the risk, the average payment is unaffected by pooling!).
- ▶ We show how this scheme can be adapted to a **life-care tontine** introducing the concept of **morbidity credits**, complementing the known concept of **mortality credits**.
- ▶ The scheme allows to pool different age cohorts.
- ▶ It is **fully-funded at all times**, allowing individuals to later join the scheme!

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Digital companies offer insurance? (01/2018)

The New York Times

Amazon, Berkshire Hathaway and JPMorgan Team Up to Try to Disrupt Health Care

Jan. 30, 2018

SEATTLE — Three corporate behemoths — Amazon, Berkshire Hathaway and JPMorgan Chase — announced on Tuesday that they would form an independent health care company for their employees in the United States.

Digital companies offer insurance? (09/2021)

Amazon to start offering insurance to UK businesses - broker

By Carolyn Cohn

LONDON, Sept 27 (Reuters) - Amazon.com Inc ([AMZN.O](#)) is to start offering insurance to small and medium-sized UK business customers, the technology giant's first foray into business insurance in the country, broker Superscript said on Monday.

Members of Amazon's Business Prime programme will be able to buy cover from Superscript such as [contents insurance](#), [cyber insurance](#) and [professional indemnity insurance](#), which a Superscript spokesperson said would be underwritten by "major UK insurers". They will be offered a discount of 20% to current rates as a way of enticing businesses over to them.

Discussion and implications

- ▶ Actuaries need to discuss the **actuarial fairness of heterogeneous sharing schemes** (like the **Xianghubao** disability insurance in China).
- ▶ We introduce a **collective defined contribution plan with disability rider**.
- ▶ Our results are very interesting also in **public pension design** (EU PEPP pensions), where investment and mortality guarantees are **forbidden**.
- ▶ It is beneficial to **pool mortality and long-term care (morbidity) risks**. In an ageing population, long-term care risks gain importance.
- ▶ Today's rise of digitalization (trading apps etc.) make the implementation of such schemes easy and accepted, starting with big success in Asia.

Question? Comments?



Thank you!

Hieber, P., Lucas, N. (2022). Modern life-care tontines. **ASTIN Bulletin**, 52(2), 563-589.

Denuit, M., Hieber, P., and Robert, C. Y. (2022). Mortality credits within large survivor funds. **ASTIN Bulletin**, in press.

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