Joint work with S. Abdikerimova and C. Liu

The Rise of Peer-to-Peer Insurance and Its Mathematical Modeling

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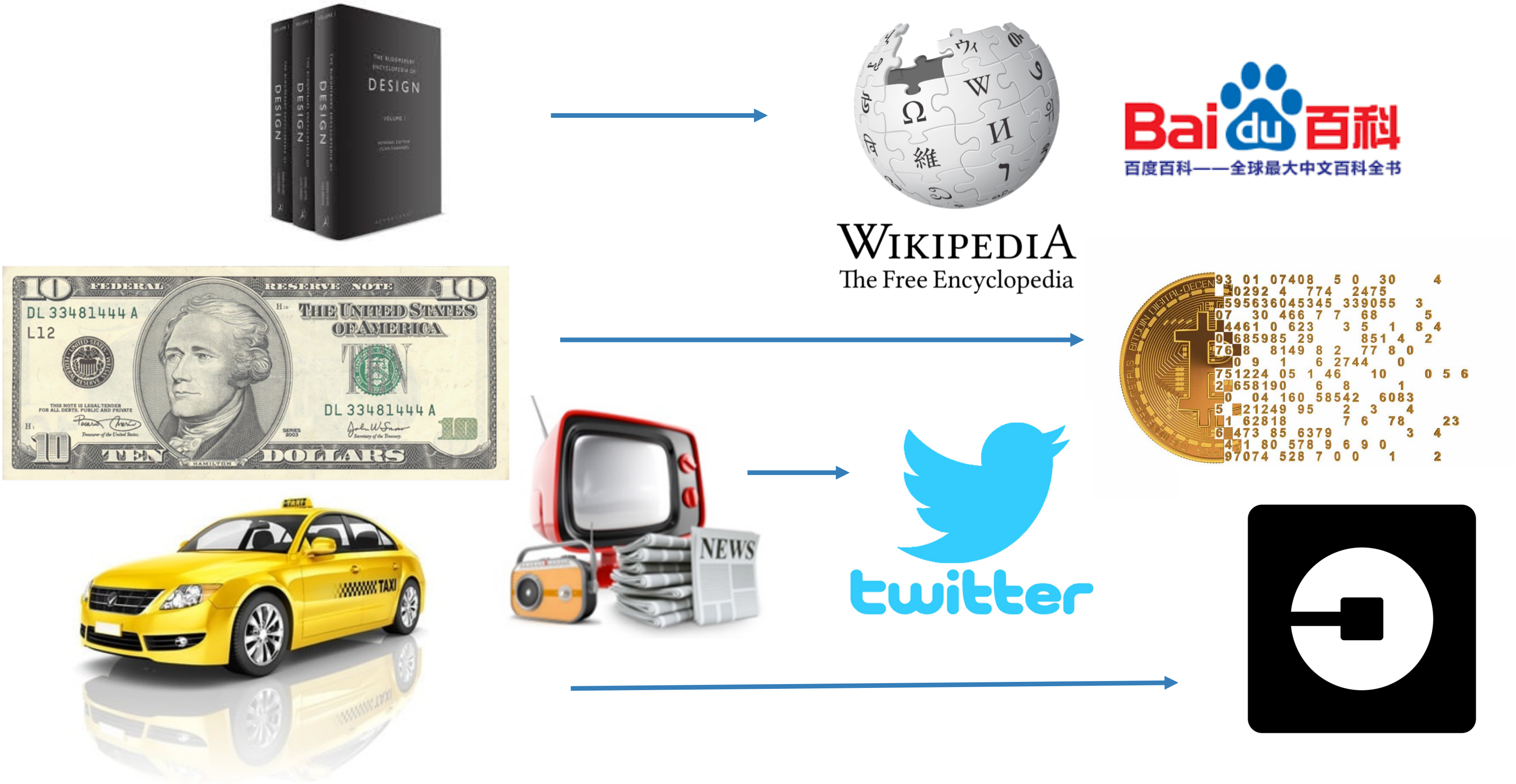
Decentralization / disintermediation

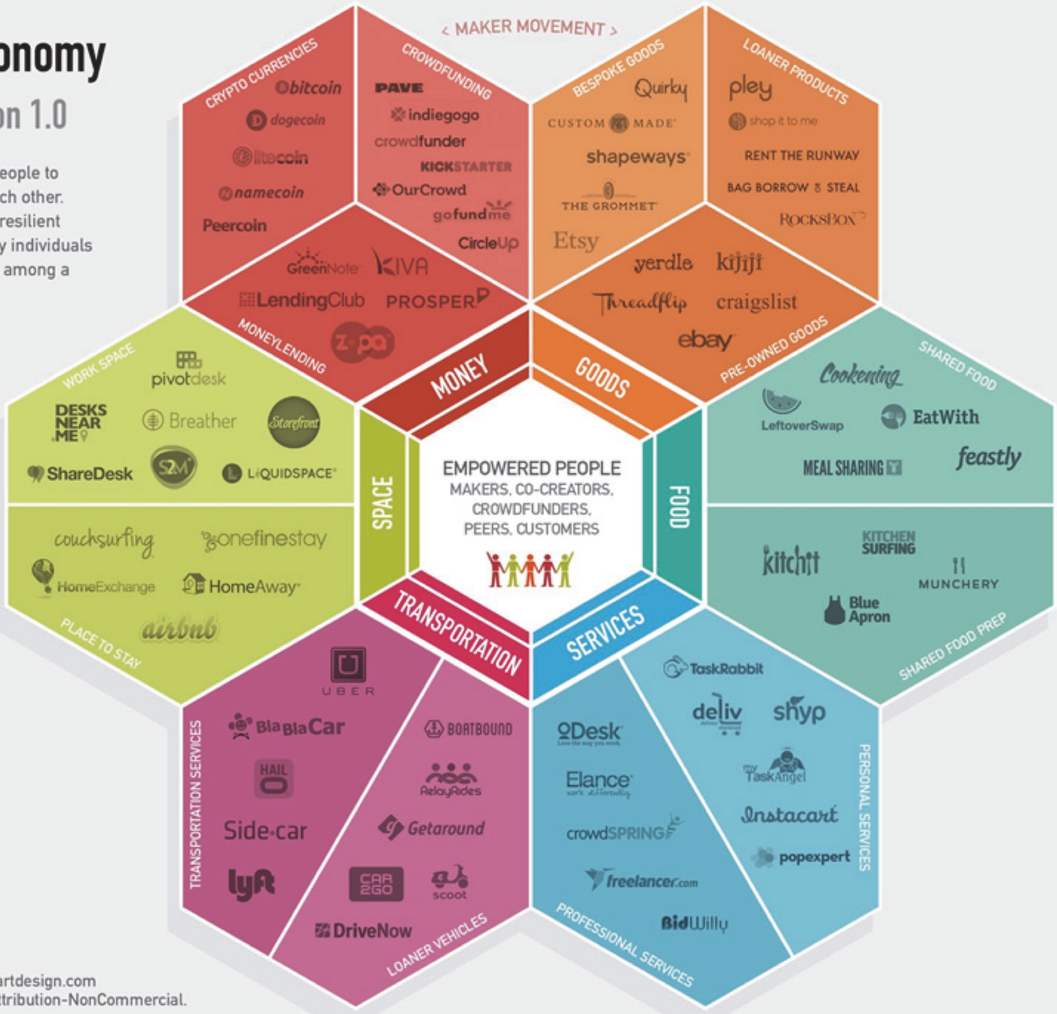


Collaborative Economy Honeycomb Version 1.0

The Collaborative Economy enables people to efficiently get what they need from each other. Similarly, in nature, honeycombs are resilient structures that efficiently enable many individuals to access, share, and grow resources among a common group.

In this visual representation, this economy is organized into discrete families, sub-classes, and example companies. To access the full directory of 9000+ companies visit the Mesh Index, at meshing.it/companies managed by Mesh Labs.

By Jeremiah Owyang
@Jowyang



KEY MARKET FORCES

SOCIETAL DRIVERS
- DESIRE TO CONNECT
- SUSTAINABLE MINDSET
- POPULATION INCREASE

ECONOMIC DRIVERS
- FINANCIAL CLIMATE
- UNTAPPED IDLE RESOURCES
- STARTUPS HEAVILY FUNDED

TECHNOLOGY ENABLERS
- INTERNET OF EVERYTHING
- MOBILE TECHNOLOGIES
- SOCIAL NETWORKS

With input from:
Neal Gorenflo (@gorenflo),
Lisa Gansky (@instigating),
Shervin Pishevar (@sherpa),
Mike Walsh (@mwalsh),
Brian Solis (@briansolis),
Alexandra Samuel (@awsamuel),
and Vision Critical (@visioncritical).

Design by Vladimir Mirkovic www.transartdesign.com

CROWD COMPANIES
www.crowdcompanies.com

Product Sharing

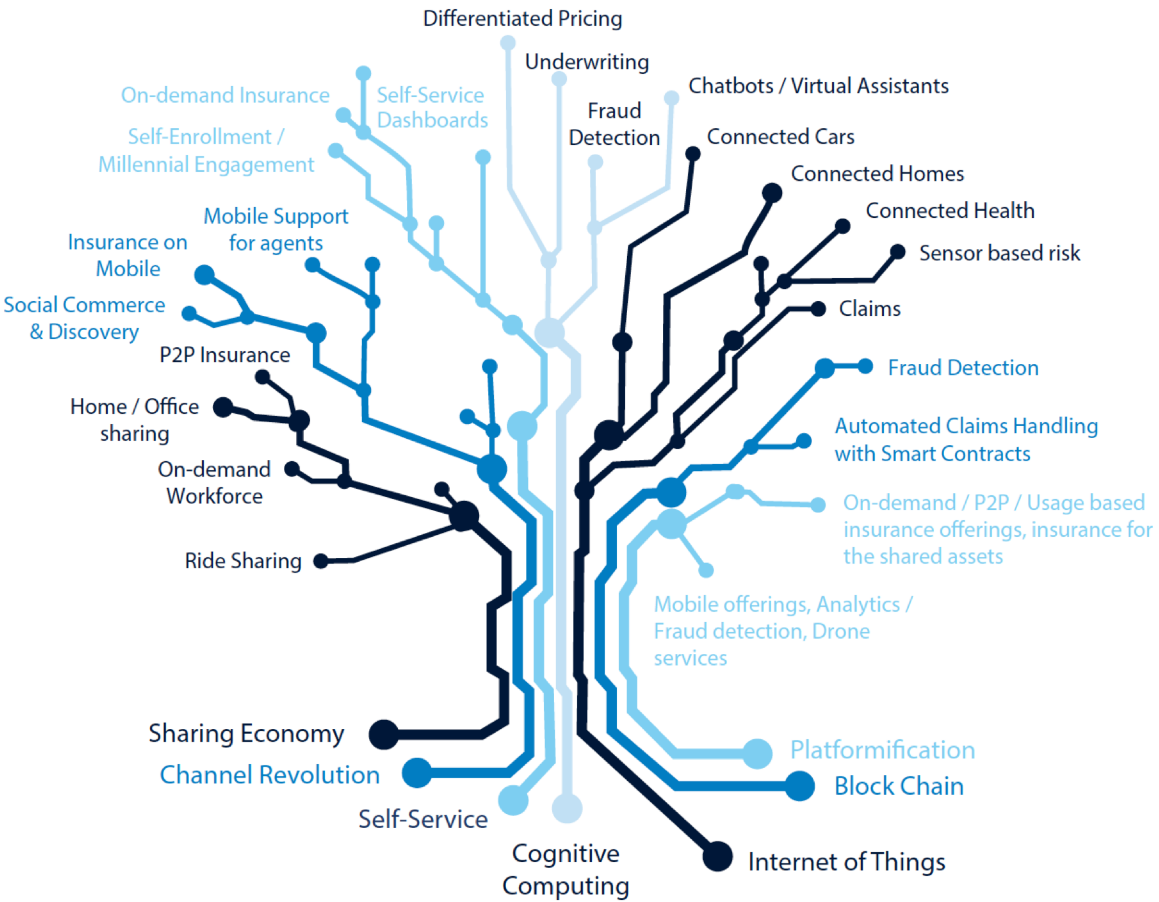
Service Sharing

Product Sharing

Service Sharing

Risk Sharing

Innovations in Insurance

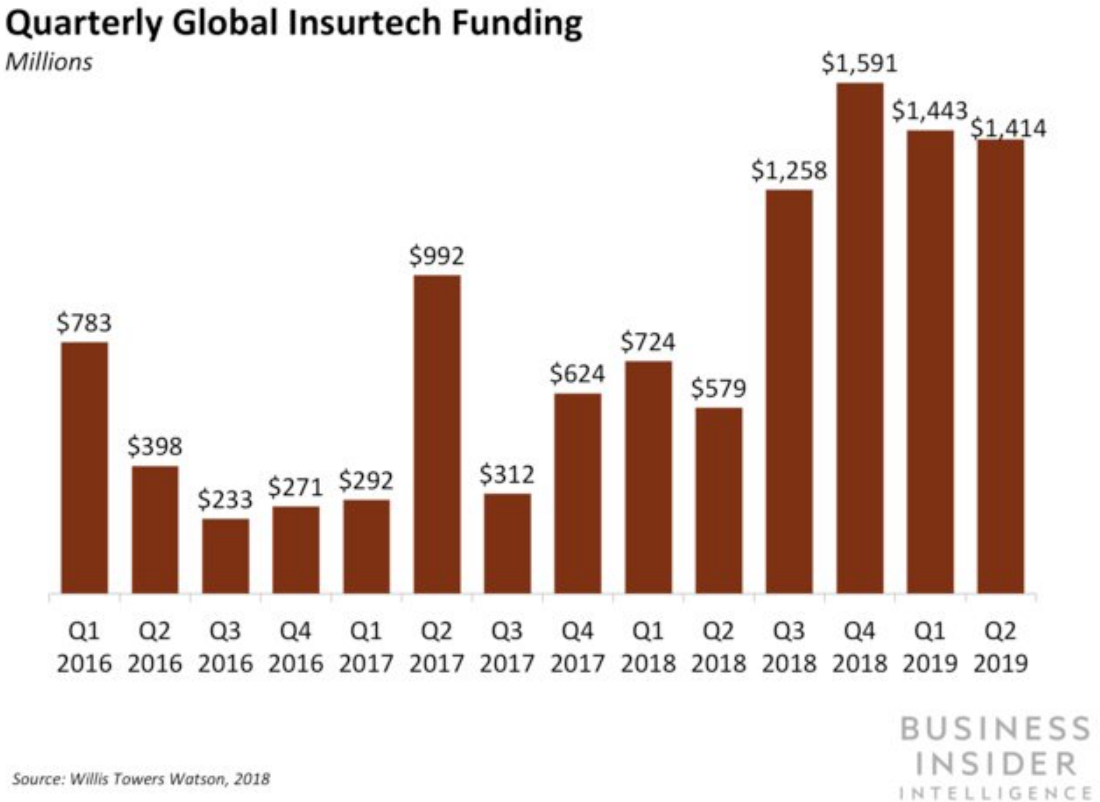


Source: Institute of International Finance

Peer-to-Peer Insurance

- A network of participants pool resources together to compensate each other for financial losses
- Revival of a centuries-old practice with modern adaptation
- Bring trust back to insurance – “law of small number”
- Transparent charging structure
- Reduction in regulatory cost
- Disintermediation allows new responsiveness to consumer needs

2019 Q2 Top 4 Deals



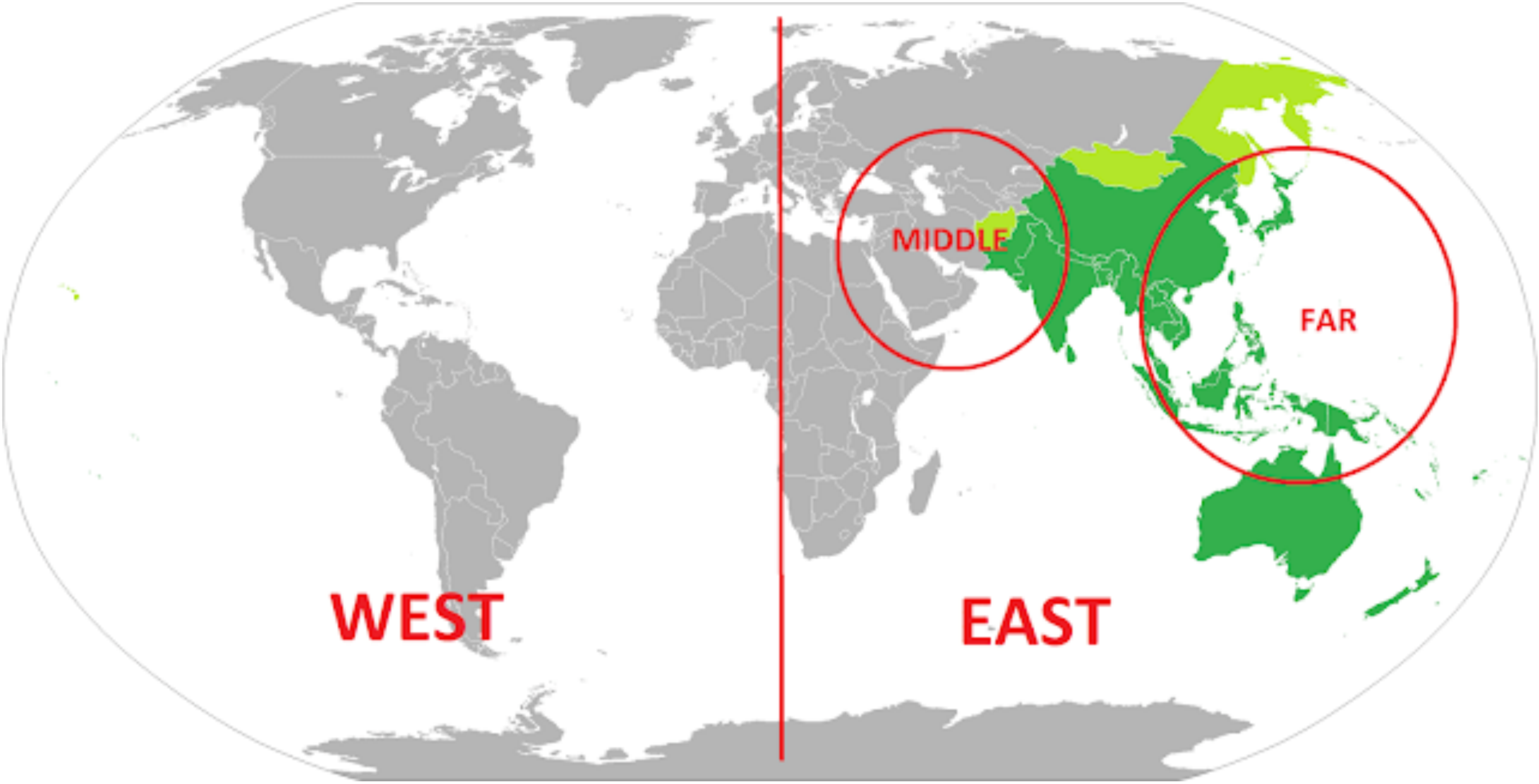
Lemonade 300 millions

Collective Health 205 millions

policybazaar 152 millions

水滴互助 145 millions

Peer to Peer Insurance Takaful Mutual Aid



friendsurance

Friendsurance: Friends with Benefits?

Buy insurance

We offer comprehensive Cashback Insurance products.

Connect with others

Your potential maximum premium Cashback is dependent on having 9 connections in your Network. **We can help you connect** with others, **or you can connect** with your friends – kinda like Facebook.

Need to make a claim?

Claims are handled like any other insurer, but more friendly-like. Don’t stress if you need to make a claim, you’ll never pay more than your original premium.

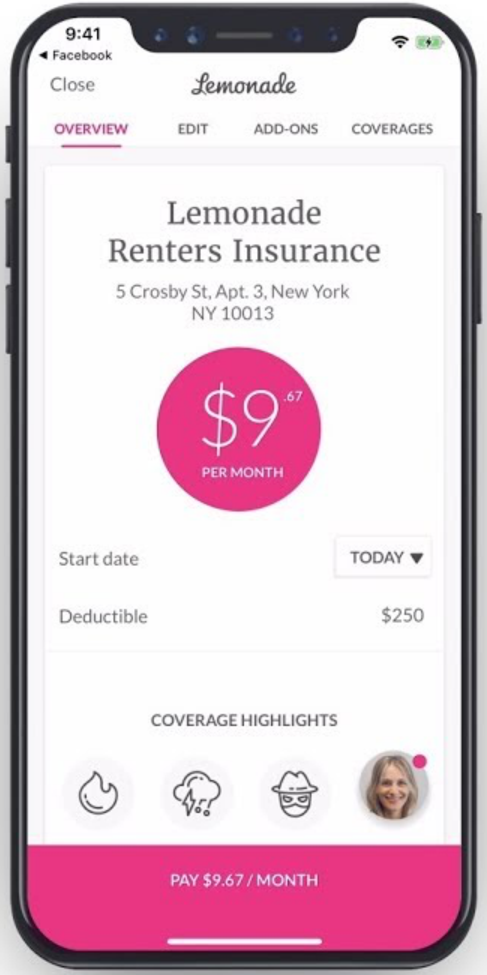
Stay claim free, get cash back

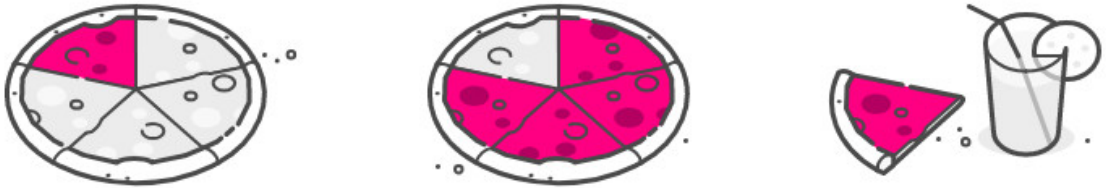
Every year, on our Cashback anniversary, we calculate your Cashback.

Broker model: a portion of premium goes to a mutual pool and the remainder goes to an insurer.

Lemonade

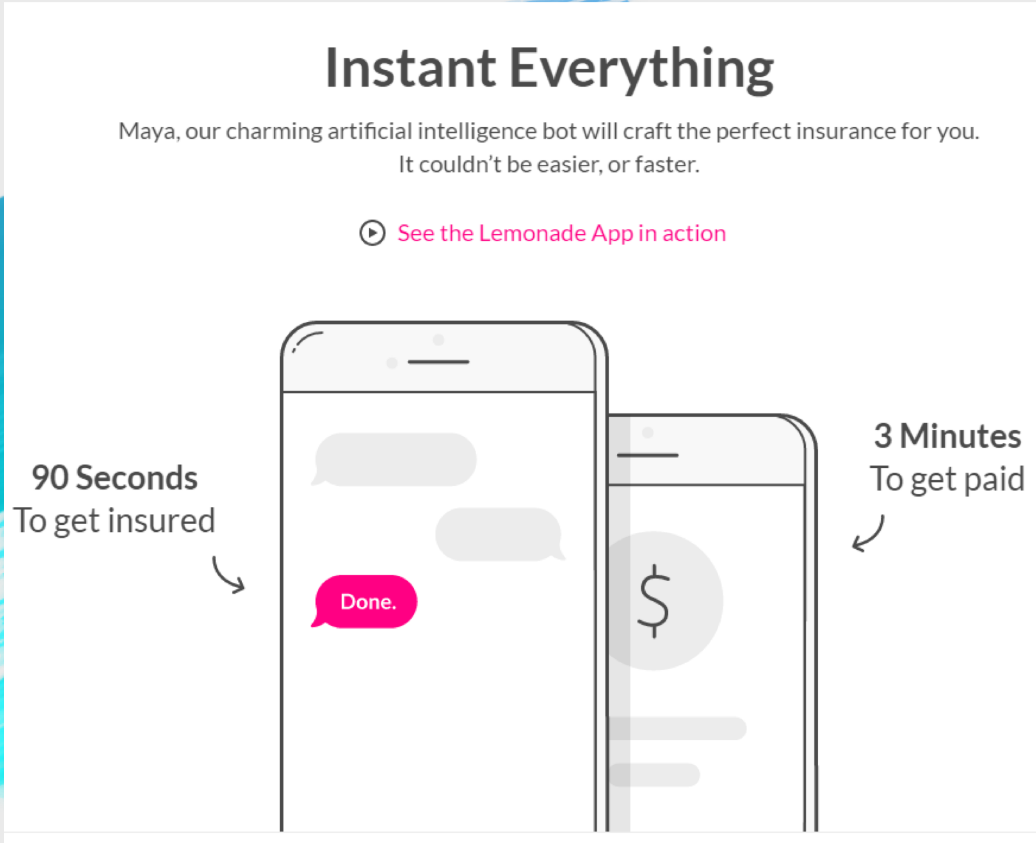
Get insurance in 90 seconds
with Lemonade's app





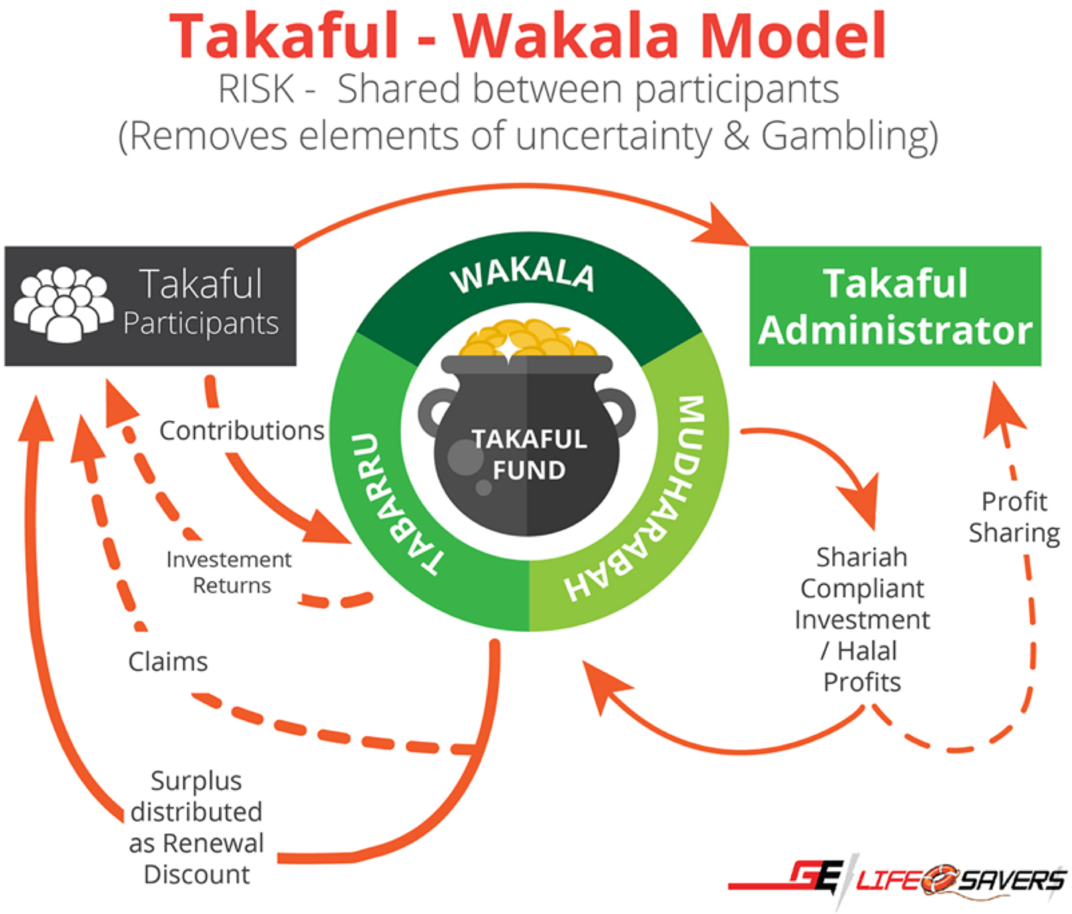
- Lemonade keeps a flat 20% fee of a customer's [premium] while setting aside the remaining 80% to pay claims and purchase reinsurance.
- Unclaimed premiums go to a nonprofit of the user's choosing in an annual "Giveback."

Carrier model: offer actual coverage directly to consumers.



- Artificial intelligence: Chatbots
- Machine learning
  - Insurance application
  - Claim processing (review claims, cross-reference, fraud detection, approval)

- Shari’ah compliant alternative to insurance
- Each contributes to the tabarru fund.
- When a participant makes a claim, the payment is made out of the tabarru fund.

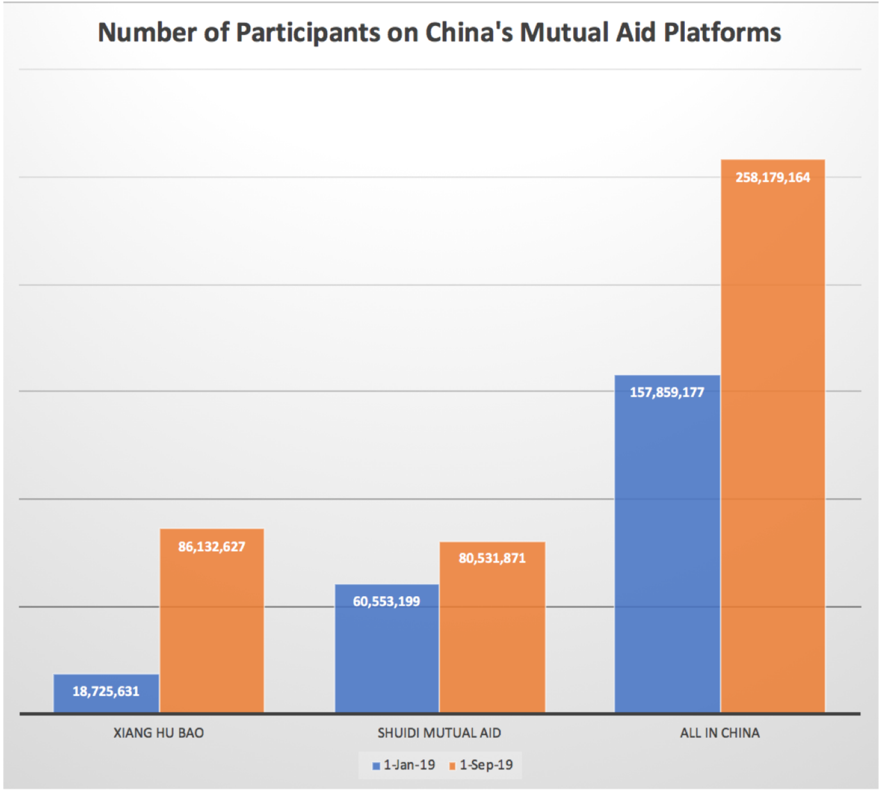


Online Mutual Aid（网络互助）

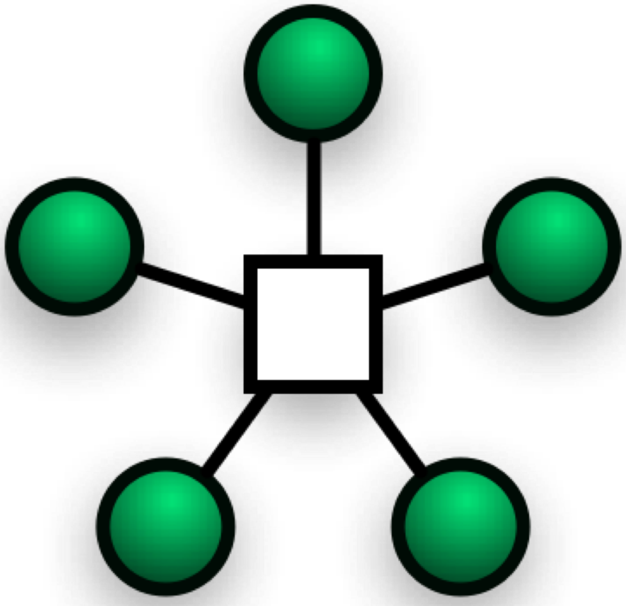
- Majority in healthcare
- Commercial health insurance considered too expensive
- Gap in coverage create an opportunity for startups
- No funding pool
- Payment in arrears
- As little as 20-50 Yuan per month for a coverage of 100,000-300,000 Yuan.

Online Mutual Aid（网络互助）

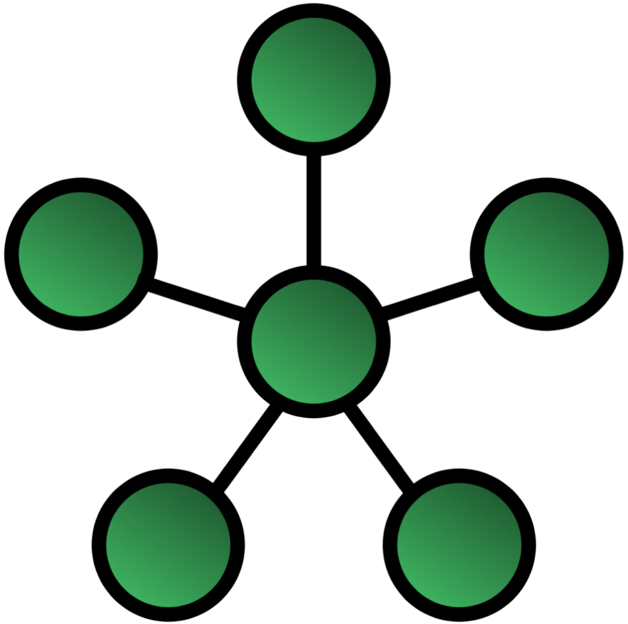
- Difficulty with gaining credibility?
  - Financing backing of China's largest tech firms (Alibaba, Tencent, DiDi)
  - Crowdfunding converts well educated about risks
- Regulation
  - Heavily regulated conventional insurance
  - Grey area



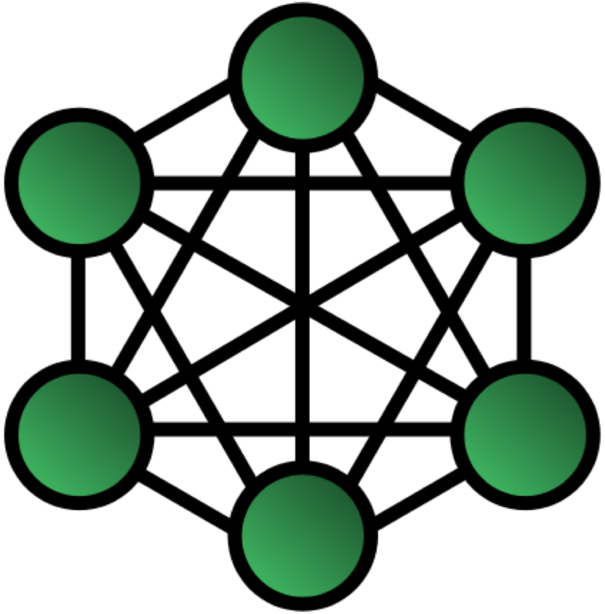
- Classic mutual insurance
- Self-managed pooled fund



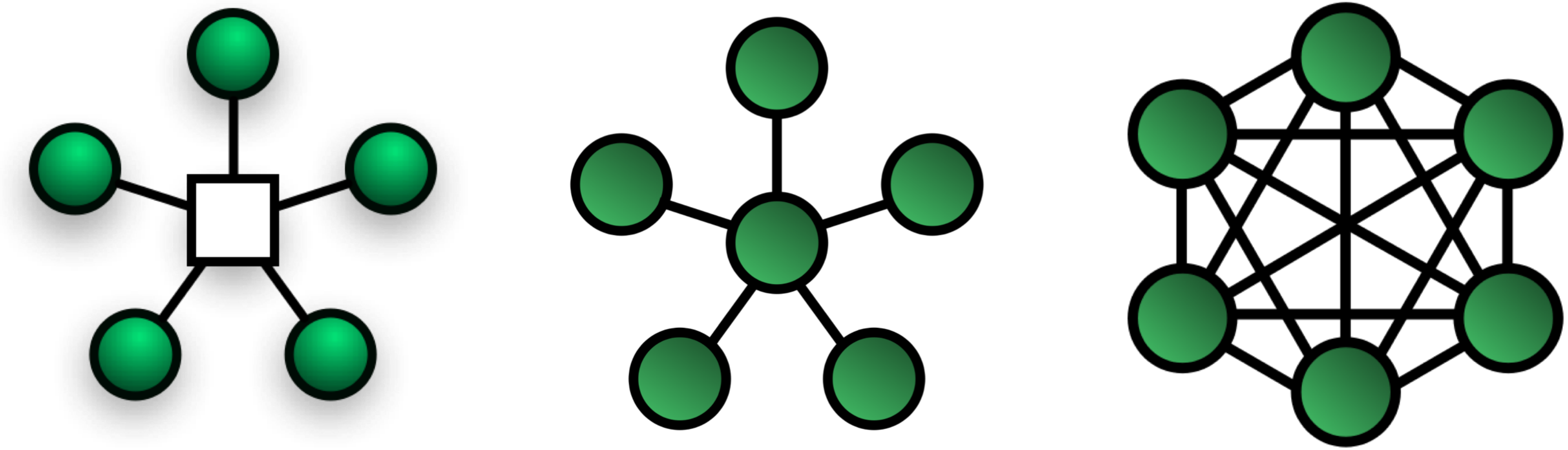
- Modern insurance
- Insurance as an intermediate
- Advantage:
  - Standardized contract
  - Professionalized service
  - Fixed premium & fixed benefit (by law of large numbers)
  - Insurer absorbs residual risk



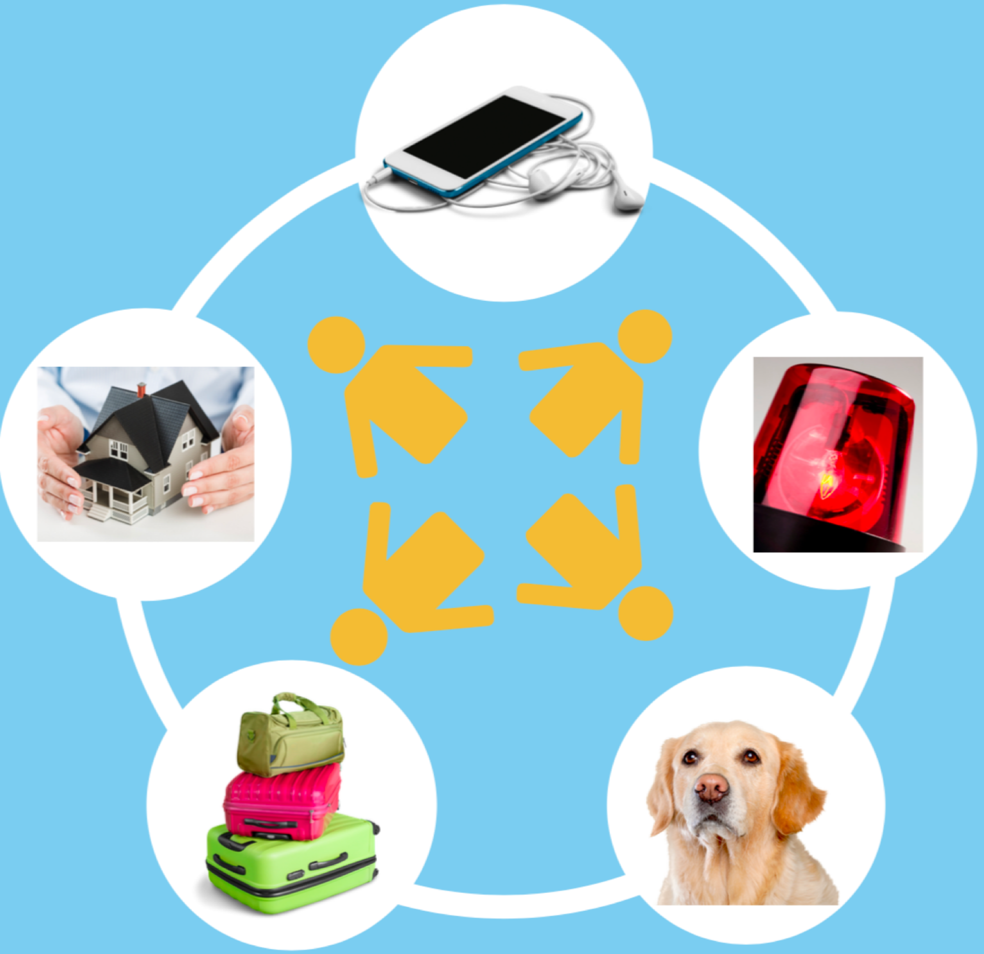
- Peer-to-peer insurance
- Decentralized organization
- Advantage:
  - Standardized contract
  - Transparency
  - Low administrative cost



◦ primitive -> centralized -> decentralized



◦ Benevolent society -> Mutual insurance -> P2P insurance



WHAT IS MULTI-RISK CROWD INSURANCE?

A group of individuals pool money together to insure against unique risks they have in mind.

Quantitative Principle of Peer-to-Peer Insurance

1. Pooled funding
   - Pool premium funds with known acquaintances
   - Remaining funds are refuned to its members
2. Mutual aid
   - Largely based on crowdfunding model
   - Charges are made after claims are made

Online Mutual Aid（网络互助）

- Adverse selection
- Differential pricing
- Two common methods
  - Equal cost sharing and differential benefit
  - Equal benefit and differential cost sharing

众托帮百万大病医疗互助计划

保障**111种**重大疾病和**77种**特定疾病

最高可获**50万元**

会员年龄	0–25周岁	26–50周岁	51–75周岁
2016年	0	0	0
2017年	2.39	3.70	6.05
2018年	6.42	12.84	25.68
2019年	6.80	13.60	27.20
累计分摊(元)	15.61	30.14	58.93

Modeling of existing business model for mutual aid

- Each claimant receives a monetary unit.
- Let I_j be the indicator of the j-th participant's survival over each period without any loss, p_j be the probability of survival and q_j be the probability of loss, i.e. $p_j = \mathbb{P}(I_j = 1)$, and $q_j = 1 - p_j$
- $w_j > 0$ be the weight for his/her cost sharing.
- Assume that loss distributions of all participants are independent of each other.

- Consider the j-th individual's benefit should he/she suffer a loss. Clearly, the individual can receive the specified mutual aid as long as at least one participant other than him/her is still alive. Therefore, his/her benefit can be written as
$$1 - \prod_{k=j,k=1}^{n} (1 - I_k).$$

Existing business model

If the j-th participant survives the period without any loss, then he/she is obligated to share the cost of mutual aids for other claimants. The total amount of payment can be represented as

$$\frac{w_j \sum_{k=1,k\neq j}^{n}(1 - I_k)}{w_j + \sum_{k=1,k\neq j}^{n} w_k I_k}.$$

A mutual aid plan is considered fair if the expected value of income (benefit) is equal to the expected value of outgo (cost). Therefore,

$$p_j \mathbb{E}\left[\frac{w_j \sum_{k=1,k\neq j}^{n}(1-I_k)}{w_j + \sum_{k=1,k\neq j}^{n} w_k I_k}\right] = q_j\left(1 - \prod_{k=1,k\neq j}^{n} q_k\right). \qquad (1)$$

The equation is not true except for a homogeneous group.

We can show that the mutual aid plan with equal distribution of cost is fair for a homogeneous group. When $p_1 = \cdots = p_n = p$ and $w_1 = \cdots = w_n$, then (1) holds true for all $j = 1, \cdots, n$. Let $M = \sum_{k=1,k\neq j}^{n} I_k$. Observe that M has a binomial distribution with parameters $n-1$ and p. Then, the left-hand side of (1) can be written as

$$p\mathbb{E}\left[\frac{(n-1)-M}{M+1}\right] = p\sum_{z=0}^{n-2}\frac{(n-1)-z}{z+1}\binom{n-1}{p}p^z q^{n-1-z}$$

$$= q\sum_{k=1}^{n-1}\frac{(n-1)!}{z!(n-1-z)!}p^z q^{n-1-z} = q[1-q^{n-1}],$$

which matches the right-hand side of (1).

Pooled Funding Model – Survivor-to-All Plan

- Consider a case where n individuals with different risks, each contributing the premium of 1 to a common fund.
- The interest rate is zero.
- Should an individual surives without any loss, his/her premium would be used to cover loss from others.
- Design a re-distribution algorithm in a fair manner.

Quantitative Principle of Crowd Insurance

- (Equivalence Principle) For each individual

$$\text{EPV of outgoes} = \text{EPV of incomes.}$$

- Let p_i be the probability that the i-th individual survives in a year without any loss and α_{ij} be the portion of the i-th individual's premium transferred to the j-th individual should the i-th individual survive without any loss. Then it is considered fair to the i-th individual that

$$\alpha_{1i}p_1 + \alpha_{2i}p_2 + \cdots + \alpha_{ni}p_n = p_i,$$

  where

  1. $0 \leq \alpha_{ij} \leq 1$ for $j \neq i, j = 1, 2, \cdots, n$
  2. $\sum_{j=1}^{n} \alpha_{ij} = 1$ for all $j = 1, 2, \cdots, n$.

Crowd Insurance

- Let p_i be the probability that the i-th individual survives in a year without any loss and α_{ij} be the portion of the i-th individual's premium transferred to the j-th individual should the i-th individual survive without any loss. Then it is fair to the i-th individual that

$$\alpha_{1i}p_1 + \alpha_{2i}p_2 + \cdots + \alpha_{ni}p_n = p_i,$$

- Note that, if one multiplies $(p_1, \cdots, p_n)$ by a constant, the equation still holds for all $i = 1, \cdots, n$. Therefore, we can normalize the vector $\mathbf{p} = (p_1, \cdots, p_n)$ so that $\sum_{i=1}^{n} p_i = 1$.

Connection to Markov chain

Given an n-dimensional row vector $\mathbf{p}$, find a transition probability matrix $\mathbf{A}$ such that

$$\mathbf{pA} = \mathbf{p}.$$

The vector $\mathbf{p}$ can be interpreted as the stationary distribution of the discrete-time Markov chain with the given transition probability matrix.

Special cases

1. The trivial case is when $\mathbf{A} = \mathbf{I}$ the identity matrix. It implies that everyone's own premium is returned when he/she survives without any loss. There is no exchange of cash flows. Nobody receives any survivor credit from others in this case.
2. If we specify that the portion α_{ij} is same regardless of who survives. Then $\alpha_{ij} = \alpha_j$ for all $i = 1, \cdots, n$ and the equivalence principle reduces to

$$\alpha_i \sum_{i=1}^{n} p_j = p_i.$$

   Therefore,

$$\alpha_i = \frac{p_i}{\sum p_j}.$$

Objective: minimized fluctuation

- We can show that the solution always exists but is not unique under the equivalence principle only.
- Consider the i-th claimant's net return.

$$R_i = \sum_{j \neq i} \alpha_{ji} I_j, \qquad \text{where } I_j = \begin{cases} 1, & \text{if no loss occurs} \\ 0, & \text{otherwise} \end{cases}.$$

- We are interested in a distribution algorithm for crowd insurance that minimizes

$$\sum_{i=1}^{n} \mathrm{Var}(R_i),$$

under the constraint of individual fairness.

Alternative objective

- Mean-variance optimization algorithm for crowd insurance without the equivalence principle.
- The algorithm aims to minimize

$$\sum_{i=1}^{n} \mathrm{Var}(R_i) - \mu \sum_{i=1}^{n} \mathrm{E}(R_i).$$

- Analytical solution: when n is small,

$$\alpha_{ji} = \begin{cases} \mu/(2q_j), & j \neq i \\ 1 - (n-1)\mu/(2q_i), & j = i \end{cases}.$$

For $n = 2$, assume that $q_1 \neq q_2$. Then solution to the optimization problem is given by

1. $\mu \leq \min\{2q_1, 2q_2\}$:

$$\alpha_{11} = 1 - \frac{\mu}{2q_1},\ \alpha_{12} = \frac{\mu}{2q_1},\ \alpha_{21} = \frac{\mu}{2q_2},\ \alpha_{22} = 1 - \frac{\mu}{2q_2};$$

2. if $q_2 > q_1$ and $2q_1 < \mu < 2q_2$:

$$\alpha_{11} = 0,\ \alpha_{12} = 1,\ \alpha_{21} = \frac{\mu}{2q_2},\ \alpha_{22} = 1 - \frac{\mu}{2q_2};$$

3. if $q_1 > q_2$ and $2q_2 < \mu < 2q_1$:

$$\alpha_{11} = 1 - \frac{\mu}{2q_1},\ \alpha_{12} = \frac{\mu}{2q_1},\ \alpha_{21} = 1,\ \alpha_{22} = 0;$$

4. $\mu \geq \max\{2q_1, 2q_2\}$:

$$\alpha_{11} = 0,\ \alpha_{12} = 1, \alpha_{21} = 1, \alpha_{22} = 0.$$

Survivor-to-Claimant Model

In this case, a survivor gives away part of his/her wealth to each participant who suffers a loss. A claimant would only receive transfers from survivors. Mathematically, we can represent the j-th participant's financial return net of his/her initial deposit by

$$R_j = \begin{cases} \sum_{i \neq j}^{n} s_i \alpha_{ij} I_i, & \text{if } j\text{-th participant makes a claim;} \\ -s_j \sum_{i \neq j}^{n} \alpha_{ji}(1 - I_i), & \text{otherwise.} \end{cases}$$

Survivor-to-Claimant Model

A payment plan is said to be fair to the j-th individual if the expected value of net return is zero, i.e. $\mathbb{E}[R_j] = 0$. It is easy to show that the individual fairness condition can be rewritten as

$$\sum_{i=1}^{n} s_i \alpha_{ij} p_i q_j = \sum_{i=1}^{n} s_j \alpha_{ji} p_j q_i.$$

The individual fairness equation has a simple interpretation. On the left-hand side, the factor $s_i \alpha_{ij}$ is the potential amount to be transferred from the i-th participant to the j-th participant, which is only materialized when i survives without any loss and j incurs a loss. The equation indicates that the expected value of the j-th participant's incomes should be equal to the expected value of his/her outgoes.

Technical details can be found in our papers.

- S. Abdikerimova and R. Feng. (2019) Peer-to-peer multi-risk insurance and mutual aid. Preprint.
- Z. Chen, C. Liu, R. Feng and L. Wei. (2019) Mathematical principles of peer-to-peer insurance. Preprint.

Thank you very much for your attention!