FinTech and the Traditional Insurer: Disrupt or Distract?

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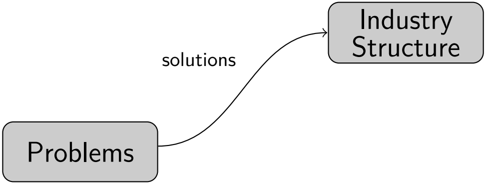
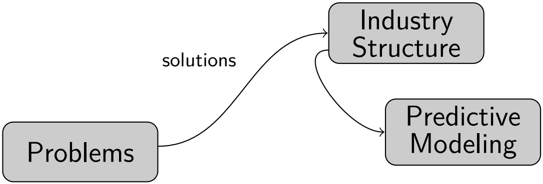
The insurance industry is prime for disruption in its current state.

*Managing change is a mix of art and science, especially in an **antiquated** sector such as Insurance.*

https://hackernoon.com/tradable-insurance-on-the-blockchain-why-we-should-think-about-it-part-1-of-2-b4e3109cd148


Industry
Structure
solutions
Problems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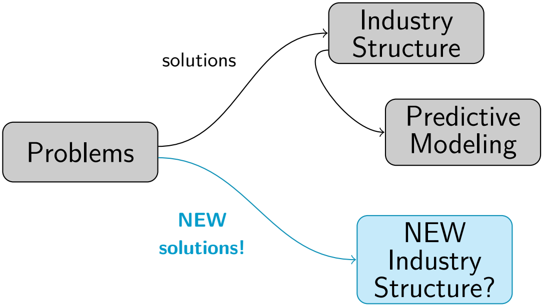
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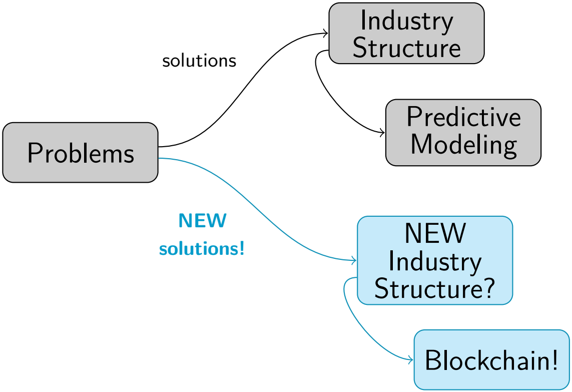
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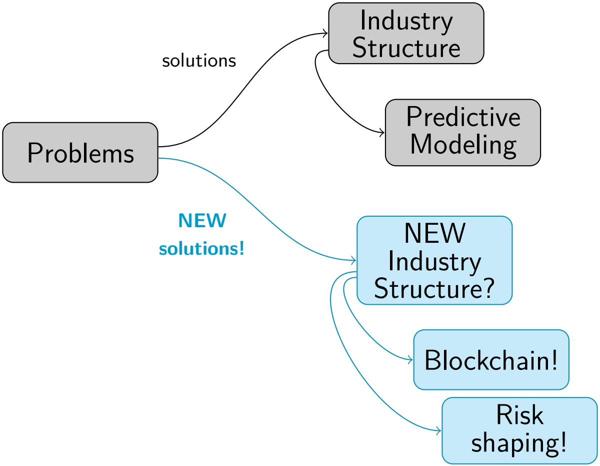
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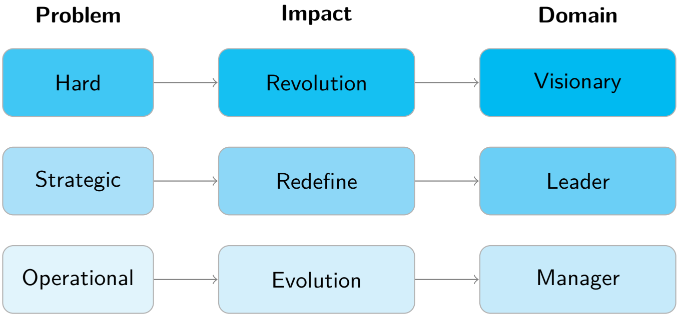
Hard Problem: Big Impact



The Hard Problems of Insurance

Theoretical Model of Insurance

If...

- we all **agree** on possible outcomes and their **probabilities**, and **if**...
- final states are known with certainty, **then**...
- there will be lots of risk trading **between** risk averse individuals
- The **mutuality principle**: everyone will **quota share** the **economy**
  - One decision variable: your participation percentage
  - Arrow, Debreu, Borch, 1960s

Assumptions Do Not Hold...

Ambiguity, uncertainty, opinions abound

- **Risk aversion** does cause agents to **share** risk, but...
- Behavioral economics and cognitive biases: framing, recency, zero-risk, status quo, optimism, outcome, illusion of control
- Ambiguity aversion: prefer bets with known probability distributions over ones where the probabilities are unknown
- **Ambiguity** provides an incentive to **bet** against each other, Tsanakas and Christofides (2006)

Even if Assumptions Did Hold...

...insurance has a behavioral dimension

The insurance policy might itself change incentives and therefore the probabilities upon which the insurance company has relied.

... it is clear that this principle explains the limitations of both insurance in particular and risk-shifting through the market in general.

Insurance, Risk and Resource Allocation, Kenneth J. Arrow (1971). Emphasis in original.

Hard Problems of Insurance

Information, information, information

- What do I know?
- What do you know?
- Will you tell me?
- How will knowing it change behavior?

Hard Problems of Insurance

Information driven problems

- Adverse selection
  - Insured to insurer
  - Insurer to capital markets
- Moral hazard
  - Ex ante: before the event, less care
  - Ex post: after the event, less remediation, claim padding
- Fraud

In Practice Management Preoccupied With Difficult Problems...

. . . but not hard information-related problems

- New market entrants
- Substitute products
- Buyer power
- Supplier power
- Competitors
- Growth
- IT
- Product differentiation
- Brand and image
- Business processes
- Efficiency
- Catastrophe risk
- Emerging risks
- ORSA & Regulation

KYC and Insurance Buying Motivations

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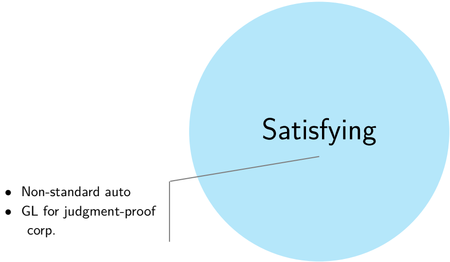
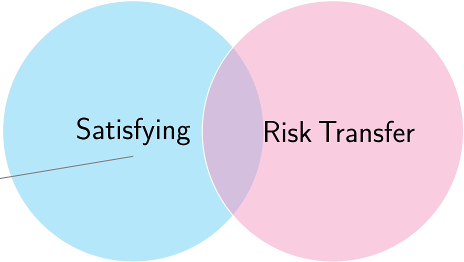


KYC and Insurance Buying Motivations



- Non-standard auto
- GL for judgment-proof corp.

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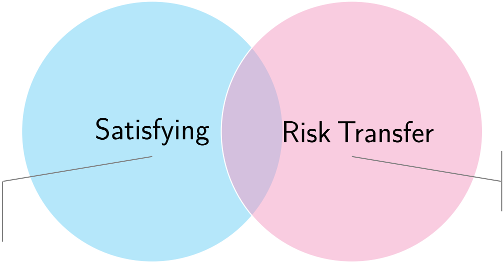

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- Cat re, outside rating agency PMLs
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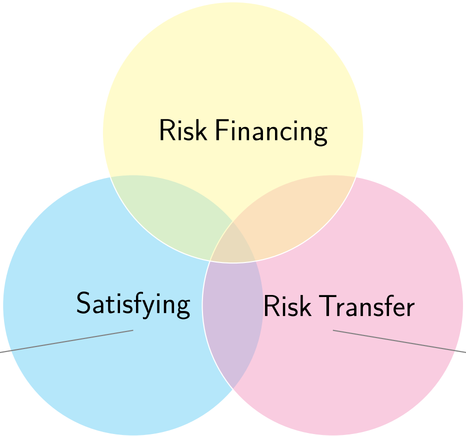

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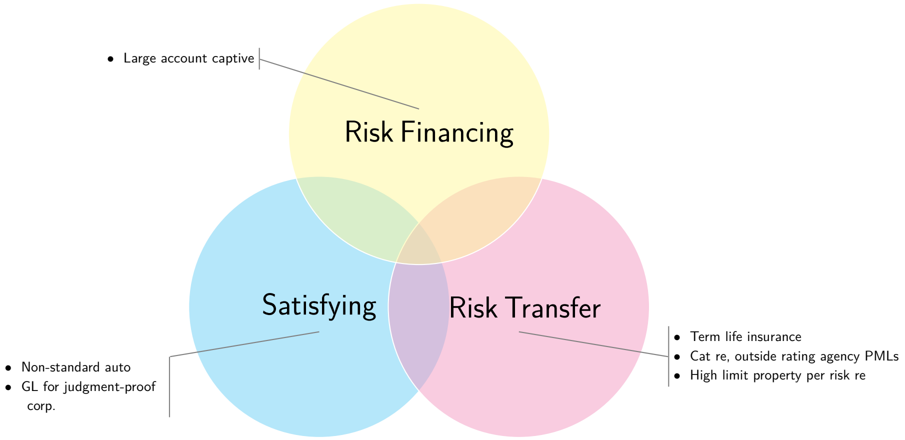

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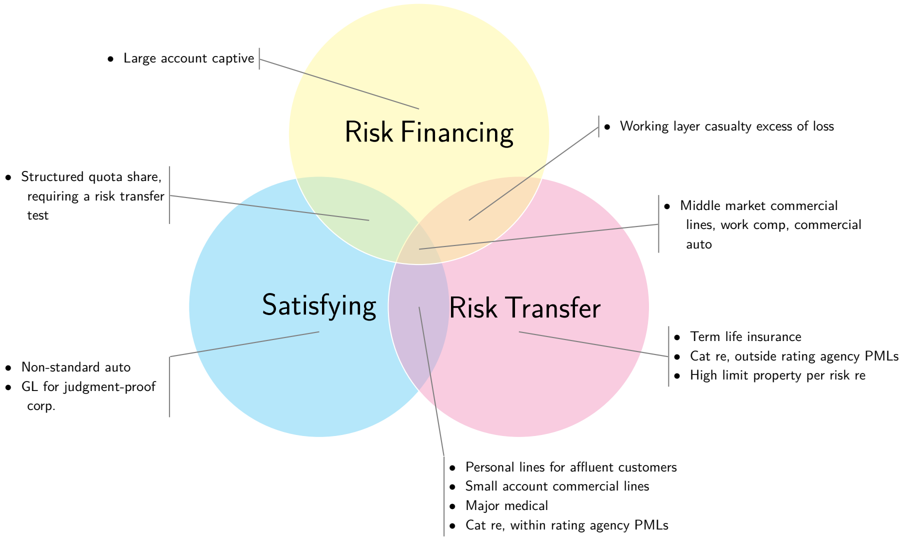

The Insurance Stack

The Insurance Stack

Lemonade could collapse the Insurance stack #insurtech

The current Insurance stack

The insurance industry works through a 3 layer stack:

- **Layer # 1: Brokers**. Their job is to gather premiums from customers.
- **Layer # 2: Insurance Companies**. Their primary job is claims processing. They take in premiums via brokers, invest the cash flow and pay out claims when needed.
- **Layer # 3: Reinsurance Companies**. They are the payers of last resort. They insure the insurance companies. Their job is to have enough capital to pay out claims, even if the models did not predict the volume of claims.

Figure 1: Tech view of insurance

https://dailyfintech.com/2016/02/25/lemonade-could-collapse-the-insurance-stack-insurtech/

The Insurance Stack

CUSTOMER	PAPER	CAPITAL	CLAIMS
• Education	• Pool management	• Guarantee solvency	• FNL
• Needs analysis	• Solvency	• Liquidity	• Investigation
• Sales, marketing	• Capital structure	• Reinsurance	• Litigation
• Origination	• Regulation	• ILS / Alternative	• SIU
• Distribution	• Compliance	• Debt	• Fraud
• Servicing	• Rating agency	• Hybrid	• Loss control
• Billing	• Product design	• Equity	• Bill review
• Loss control	• Pricing	• Frictional cost	• Payment
• Engineering	• Underwriting policy		• Assistance
• Risk management	• Line underwriting		

Figure 2: Four primary functions within the Insurance Stack

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Traditional insurer

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Quantifying Value by Stack Function

Table 1: Average customer, paper, reinsurance and claim function expenses as a percent of direct earned premium, calendar years 2007-2016. 2016 direct earned premium USD599 billion. Combined expenses **USD245 billion** excluding cost of capital.

Line	Customer	Paper	Net Re	Claim	Combined
All Lines	0.187	0.084	0.023	0.115	0.409
Commercial Auto	0.205	0.095	0.005	0.118	0.424
Commercial Property	0.211	0.093	0.096	0.060	0.460
Other	0.182	0.093	0.043	0.045	0.362
Other Liability	0.203	0.086	0.019	0.204	0.512
Personal Property	0.211	0.070	0.056	0.089	0.426
Private Passenger Auto	0.167	0.076	-0.009	0.119	0.354
Workers' Compensation	0.167	0.105	0.006	0.136	0.414

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Observations

- Stunningly high
- Stunningly stable

Figure 3: Reinsurance function expenses, calendar years 1996-2016. Non-proportional assumed reinsurance is included in Other.

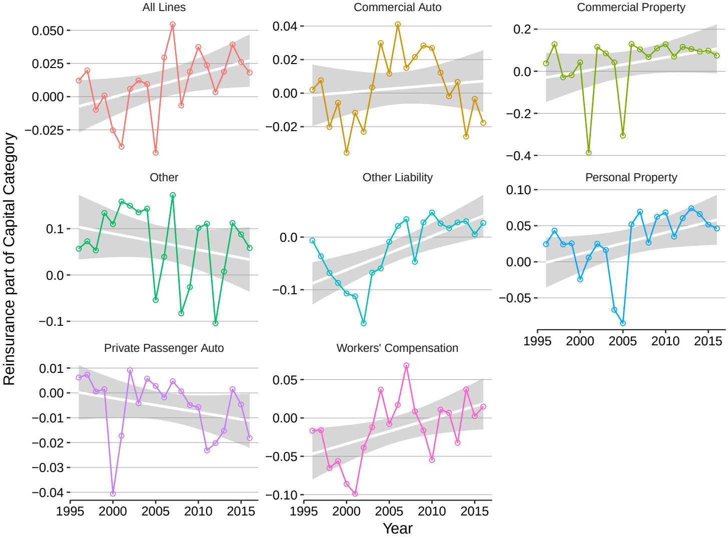

Figure 4: Reinsurance function expenses, separate scale by line, calendar years 1996-2016. Non-proportional assumed reinsurance is included in Other.

Structural Implications for Paper

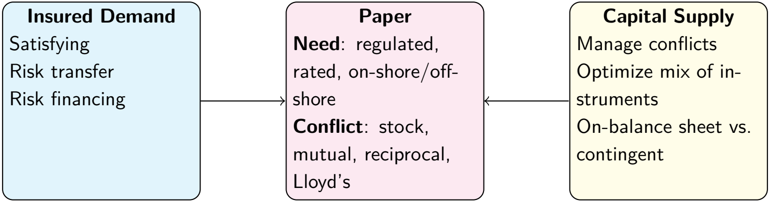

Figure 5: Insurance buying motivations and demand interact with Capital supply considerations within Paper function to determine form and organization.

X-Tech Enabled Solutions

Fin**Tech**, Insur**Tech**, **Financial**Tech Solutions

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Hardware

- Mobile
- Cloud
- Internet of Things (IoT)
- Home sensors
- Auto telematics
- Drones, micro satellites
- Augmented reality (AR)
- Alexa

Software

- Text analysis, semantics
- Voice recognition
- Chat bots, Siri, Alexa
- Image recognition
- Augmented reality
- Tensor Flow, Go
- Hadoop, MongoDo, Redis
- Python, R, Julia

Algorithms

- Neural networks
- Deep learning
- Artificial intelligence (AI)
- Hash functions
- Cryptography
- Clustering
- Compressed sensing

Data

- Big data
- Text, speech, image, video
- Behavioral data
- Social media
- Spending
- Credit
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- Blockchain
- No central authority
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Financial

- Lloyds
- ILS/Cat Bond
- ILW
- Collateralized
- Sidecars
- Hedge fund permanent
- P2P

FinTech, InsurTech

FinTech and InsurTech Narratives

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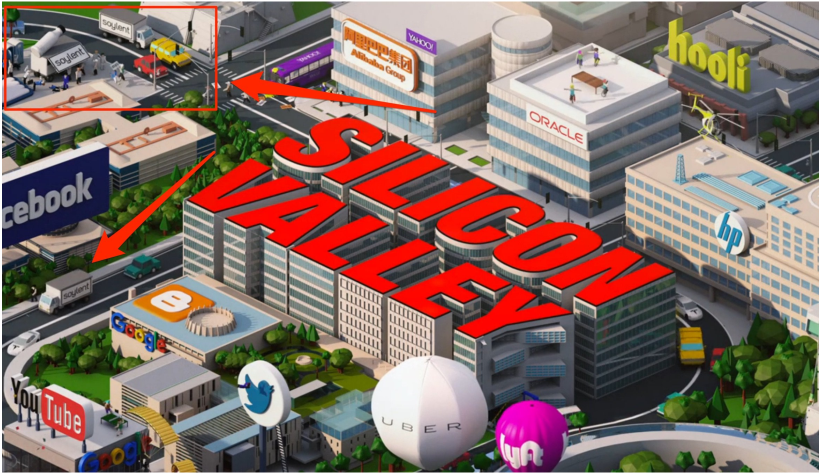

Figure 6: Silicon Valley: comedy with a serious message.

FinTech and InsurTech Narratives

Better experience, simpler process, comparison, guides

- {Mobile | Instant} personalized expert {assistance | recommendations | education | advice} simplifies the {experience | process} of {buying | finding} the most suitable insurance

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- **Rethinking** the relationship between insurers and their customers and the ways in which they interact

FinTech and InsurTech Narratives

Online and mobile insurance and insurance markets places

- **Online** simple { car, renter insurer | insurance supermarket | policy aggregator | claims reporting } platform

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- ... **automated** insurance agent... quicker, easier and **more personal**

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- . . . **automated** insurance agent. . . quicker, easier and **more personal**
- **Redefining** how insurance is priced and delivered

FinTech and InsurTech Narratives

Peer-to-peer insurance: back to the Arrow model!

- **Online** $\left\{ \begin{array}{c} \text{pool} \\ \text{peer-to-peer} \end{array} \right\}$ insurance. . . lowering annual insurance premiums by up to 50%

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- If you **submit a claim** within your team, your teammates **pay it**

FinTech and InsurTech Narratives

New coverages and risk products

- { On-demand / Micro-duration } insurance for your { smart phone, camera / laptop, tablet / standalone car rental / driving friend's car } entirely from your phone

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- Enable { bulk purchase | self-insurance } for { small groups | individuals }
- A **better way** to insure your gizmo

FinTech and InsurTech Narratives: Lessons

Within Sales and the Customer Function

- Simpler, faster, more engaging
- Game-ification, risk feedback
- Customizable: coverage, duration, location
- Perception: **serious distribution problems**

Within the Claims Function

- Less confrontational, on your side
- You or your team in control
- Algorithmic, deterministic, coverage certainty
- Perception: **serious willingness-to-pay problems**

FinTech and InsurTech Narratives: Lessons

Industry addresses claim payment meme

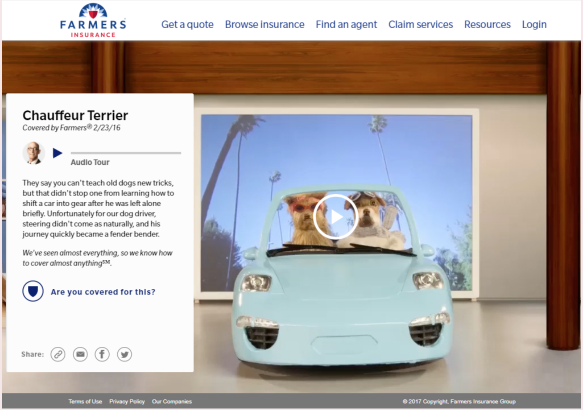

Figure 7: Farmers Insurance ad promoting claims paying.
https://www.farmers.com/hall-of-claims

FinTech and InsurTech Narratives: Lessons

Industry addresses claim payment meme

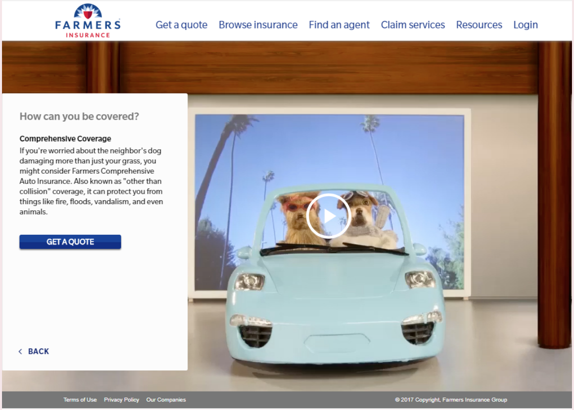

Figure 8: Farmers Insurance ad, coverage explanation and education.
https://www.farmers.com/hall-of-claims

FinTech and InsurTech Narratives: Lessons

Good news for incumbents: no one is going after auto

- **New product ideas have limited scale**
  - Phone, camera, renters
  - JIT-insurance
- Beware: disruption starts at low end
- Driverless cars will take care of auto in due course...

FinTech and InsurTech Narratives: Lessons

Bad news for incumbents: grow the slice can be devastating

- **New product ideas have limited scale**
  - No strong grow-the-pie concepts
  - Especially weak in mature markets
- **Stealing market share**, e.g. granular underwriting, auto telematics, can be very **effective** and **disruptive** to slow-reacting incumbents
  - UK motor has seen disruptive change since mid-1980s
  - US auto more gradual ascent of GEICO
- Though **traditional insurer** structure will persist, **specific** traditional insurers need not!
- Recommend **vigorous engagement** with FinTech

Insurance: Strong but Stealth Innovation Track-Record

Function	Innovation	Result
Customer	**Direct Response**	GEICO market share march since 1990s, #2 auto insurer today with strong growth trajectory.
Paper	**Credit Scoring**	Using big data since before there was big data; decline in auto residual markets, except NC
Capital	**Alternative Capital**	ILS, sidecars, collateralized solutions grown from almost nil in 2000 to nearly USD90 billion today; capital availability and speed-to-market has dampened underwriting cycle and lowered cost of cat reinsurance
Claims	**Digital Settlement**	Allstate QuickFoto app introduced 2013 for smaller claims; today 50 percent of all drivable vehicles inspected through two digital operating centers using QuickFoto. Video chat to review damage with body shops collapsed 5-7 day process to get "eyes on a vehicle" to hours. USD52 million restructuring charge, Q2 2017 call.

Figure 9: Insurance industry has a strong but stealth track-record of innovation!

Blockchain

Blockchain

Start-up narratives

- The vision is { more insurance / less admin }
- Blockchain empowers { immutable transactions / decentralised agreement } with audit history, **smart contracts**, high resilience and built in **fraud protection** mechanisms
- . . . { democratize access to / increase transparency of } reinsurance investments
- Think of the market for insurance products as broken into small **insure-bits**, each of which fundamentally represents an investment. There's an investor on one side; on the other side is a customer paying a premium. [**Arrow** again!]

Blockchain

Blockchain can refer to a combination of one or more of

Figure 10: Bitcoin combines four separate functions and some magic.

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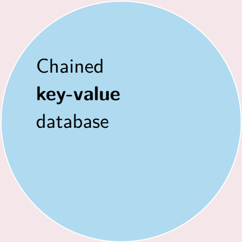

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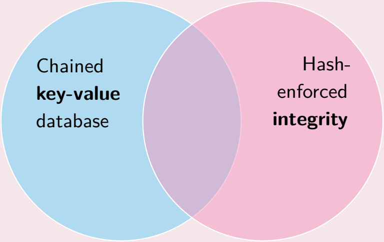

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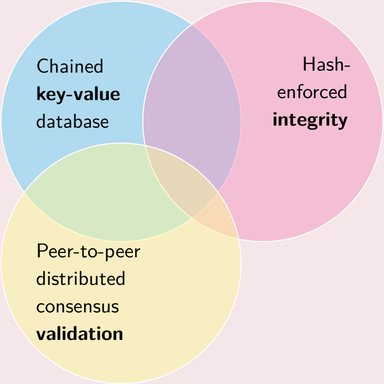

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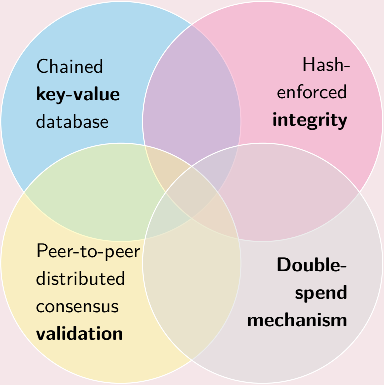

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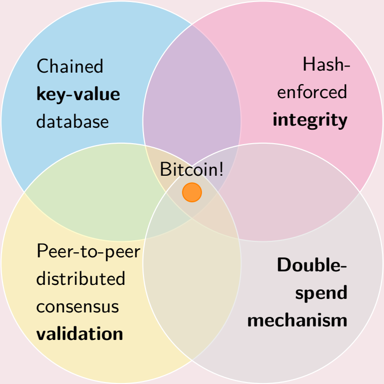

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Blockchain

Ingredient 1: Chained, key-value database

- Databases: more than just SQL
- Key-value stores: Redis, Oracle NoSQL, BerkeleyDB, LevelDB
- Key index allows fast access; flexible payload
- **Chaining** gives order to data, e.g. financial transactions

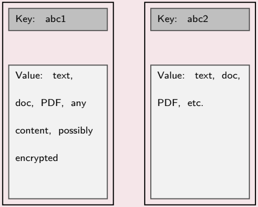

Figure 11: Chained, key-value database structure

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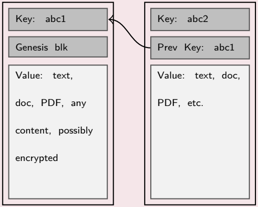

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- Key-value stores: Redis, Oracle NoSQL, BerkeleyDB, LevelDB
- Key index allows fast access; flexible payload
- **Chaining** gives order to data, e.g. financial transactions

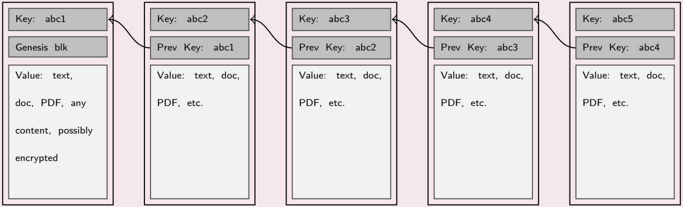

Figure 11: Chained, key-value database structure

Blockchain

Ingredient 2: Cryptographic hash functions

- Cryptographic Hash Functions are a magic ingredient
- A **hash** H maps data of arbitrary size to a fixed size such that
  - $H(x)$ is an easy to compute, deterministic function
  - If $x \neq y$ then $H(x) \neq H(y)$ with high probability
  - $H(x)$ appears random over its range as x varies
  - **Cryptographic**: given y it is very hard to find x with $H(x) = y$

- High probability = probability of collision is $\approx 10^{-40}$, not one in one hundred, see https://en.wikipedia.org/wiki/Birthday_attack

Blockchain

Ingredient 2: SHA256 cryptographic hash function

```
import hashlib

In[1]: hashlib.sha256(b'The quick brown fox jumps over the lazy dog').hexdigest()
Out[1]: 'd7a8fbb307d7809469ca9abcb0082e4f8d5651e46d3cdb762d02d0bf37c9e592'

In[2]: hashlib.sha256(b'The quick brown fox jumps over the lazy dog.').hexdigest()
Out[2]: 'ef537f25c895bfa782526529a9b63d97aa631564d5d789c2b765448c8635fb6c'
```

- Output of hash can be interpreted as a large integer

Blockchain

Ingredient 2: Hash-enforced **integrity**

- Set the key equal to the hash of the value concatenated with the previous key hash
- Knowing the key, i.e. hash, of the head-link in the chain allows to **determine** the whole chain and check for **tampering**!(!!)

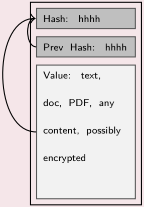

Figure 12: Hash enforced integrity

Ingredient 2: Hash-enforced **integrity**

- Set the key equal to the hash of the value concatenated with the previous key hash
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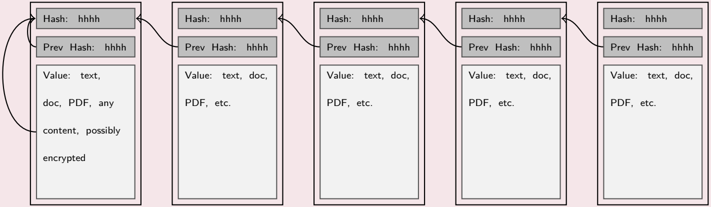

Figure 12: Hash enforced integrity

Blockchain

Ingredient 3: Peer-to-peer distributed **validation**

- **Integrity** verifies no value in the chain has changed since hashes last computed; it does not guarantee **validity**
- A **trusted authority** could maintain the current head node hash
  - Anyone can publish nodes
  - The authority accepts nodes, links them into the chain, and updates the current head node hash
  - Doesn't matter where nodes are stored
- Without authority chains are just **tamper-evident** not **tamper-proof**
- Quick-to-compute hash functions: just re-compute and assert your new head node hash

Blockchain

Peer-to-peer distributed validation and **proof-of-work**

- Need to make it difficult to re-compute the hashes in the chain
- Concept: require block hashes $<$ critical value: solve $H(n + \text{prev hash} + \text{value}) < c$ where n is the nonce, a **n**umber used **once**, to **seal** the block, $+$ means concatenation
- Smaller c, harder to find n, test $n = 1, 2, 3, \ldots$ by brute force
- Tie breaking rule: **majority decision** is represented by the **longest chain**, which has the **greatest proof-of-work** effort invested in it

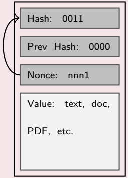

Figure 13: Proof of Work

Blockchain

Peer-to-peer distributed validation and **proof-of-work**

- Need to make it difficult to re-compute the hashes in the chain
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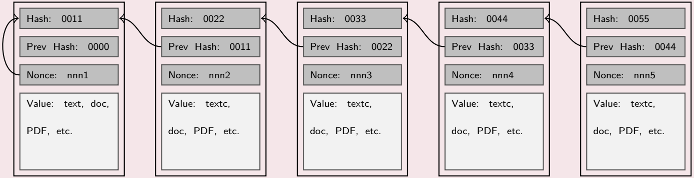


Figure 13: Proof of Work

Blockchain: Bitcoin Mining Network

Figure 14: Racks of machines mining Bitcoins and Ether at a server farm in Guizhou, China, June 2017. Current hash rate estimated at **10 million trillion** SHA256 hashes per second! Over USD1.1 billion of electricity consumed annually, about the use of Ecuador. Sources: photo Gilles Sabrié for The New York Times, https://blockchain.info/charts/hash-rate, https://digiconomist.net/bitcoin-energy-consumption

Blockchain

Ingredient 4: Double-spend mechanism

- A Bitcoin is a **public address** designated as the payment address of a previous valid transaction with consensus agreement
- All Bitcoins can be traced back to the coinbase that created them, the mining process
- To spend a Bitcoin the owner proves ownership by solving a complex puzzle and signing over ownership to the new owner
- Bitcoin network searches past nodes to check ownership has not already been transferred, forestalling double spending
- Public address is one half of a private/public key pair

Blockchain: A Public Address

1GhJGaWJbSsSDhbHhr9LqkMUEbDoW1tzG7

Figure 15: Donations gratefully received.

Blockchain: Finance and Insurance

R3 and Corda, Chain; B3i, Blocksure, Etherisc, TeamBrella

- Blockchain incorporating some, but not necessarily all, components of Bitcoin network would enable efficiencies
  - Shared view of truth: not my copy vs. your copy, no reconciliation; hash integrity and validation ensures we all have identical databases
  - Database can be private
  - Validation can involve authorities or decentralized consensus mining
- Effectiveness requires a willingness to change processes and behaviors
  - One party can post a contract and the other signs it to finalize
  - Definitive language available to both parties. . . but they sill have to do the work
- Blockchain: { a good tool to **enable** / won't magically **enforce** } contract certainty

Blockchain and the Future

Zero knowledge proofs

- It is possible to **verify** information without **revealing** it: a **zero knowledge proof**
- Where's Waldo? with a mat
- Distributed database of all private credit, health, behavioral data
  - One-time **read/verify-only** access
  - Read, **act** and **forget**, rather than read, act and **store**
  - User **cannot pass along** what they've learned
- No possibility of Equifax hack: data encrypted, you hold keys
- Central database of underwriting information: easier quotes
- Theoretic potential is huge: commercial model less clear

Risk Shaping and Efficient Use of Capital

Alternative Capital Addresses a Hard Problem

Frictional costs of holding capital

- Insurance risk is **costly to bear**, biasing insurers to remove risk
- Frictional carry-costs of capital
  - Corporate income tax
  - Agency costs
- Adjustment cost of capital
  - Manager-investor information asymmetry: raising capital **expensive** when capital **low**
- Credit sensitive customers with zero-risk bias
- Left-skew averse investors
- Froot JRI 2007
- Accounts for **underwriting cycles** and expensive cat reinsurance

Alternative Capital Addresses a Hard Problem

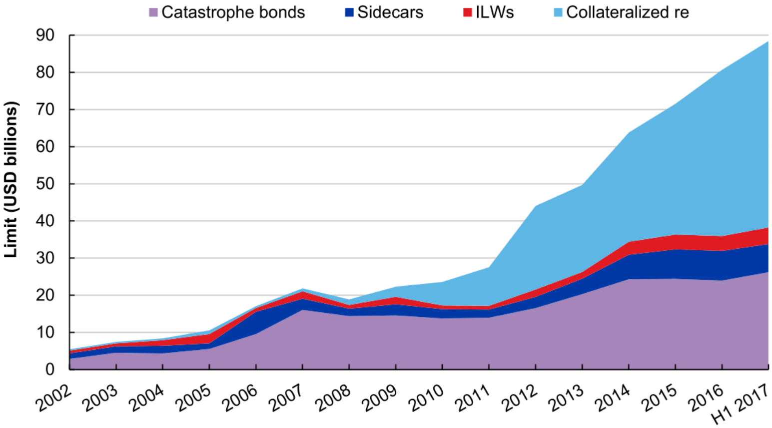


Figure 16: Deployment of alternative capital
Source: Aon Securities Inc.

Alternative Capital Addresses a Hard Problem

Lower cat bond pricing: increasing efficiency

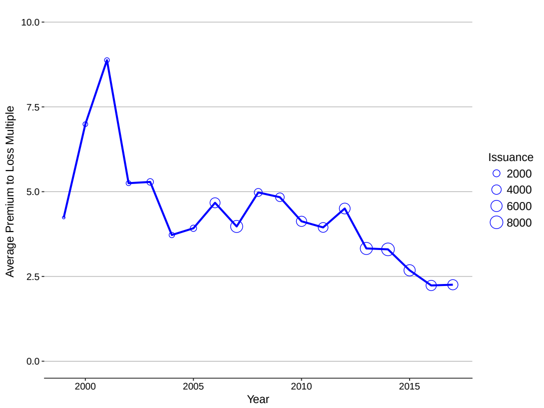
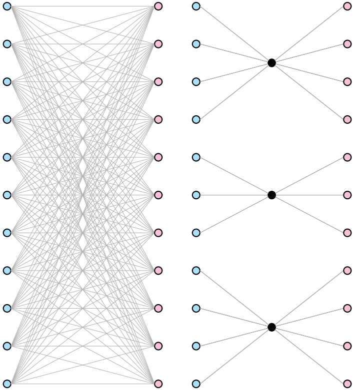


Figure 17: Clear long-term trend of lower cat bond prices shown as declining average premium multiple (reciprocal loss ratio) since 1999. Data Source: LaneFinancial LLC.

In Theory and In Practice... Why Warehouse Risk?



Individuals swap risks directly in the theoretical model. Actually insurers, black dots, act as risk warehousing intermediaries between insureds and investors.

- Why not trade directly insured-investor = Arrow again?
- Blockchain enabled **insure-bits**
- **Traditional insurers** have **comparative advantage** in **KYC**: risk **assessment** and **monitoring** for opaque risks
- Froot and O'Connell (2008)
- Evaluation and monitoring defines **Paper** function, value estimated at 8.4% of direct premium or **USD50 billion** annually

Expensive Capital Must be Used Efficiently

Do not hold too much capital

- Management has incentive to over-leverage
- Countered by **minimal capital regulation**
- **Rating agencies** binding for most companies

Use capital efficiently

- Optimal **risk shaping** of pooled portfolio to minimize cost-of-capital drag
- Efficiency clearly related to volatility, variance, tails
- But how? Want to **quantify** capital efficiency

One Period Insurance Pricing Model

$t = 0$ | $t = 1$

Premium $M(a)$ paid by insured. Residual value sold to investors for $Q(a)$. Total assets $a = M(a) + Q(a)$.

Losses $\min(X, a) = X \wedge a$ paid and any residual value $(a - X)^+$ given to investors.

- Assets of firm, a, are premium $M(a)$ and capital from investors $Q(a)$
- Capital is **consideration** paid by investors at $t = 0$ for the **residual value** cash flow at $t = 1$
- Return to investors is ρ, set $\nu = 1/(1 + \rho)$ and $\delta = \rho/\nu$, so $1 = \nu + \delta$
- There is one policy and no other liabilities
- Risk free interest rate zero, pricing is a spread over risk free rate
- No taxes or expenses

Basic Pricing Formula

Total assets a comprised of		
Loss $\mathsf{E}(X \wedge a)$	Not loss costs $N(a) = a - \mathsf{E}(X \wedge a)$	
$\mathsf{E}(X \wedge a)$	Risk margin $R(a)$	Capital $Q(a)$
$\mathsf{E}(X \wedge a)$	$\delta N(a)$	$\nu N(a)$
Premium $M(a) = \mathsf{E}(X \wedge a) + \delta N(a)$		$\nu N(a)$
$a \ = \ M(a) + Q(a) \ = \ \mathsf{E}(X \wedge a) + \delta N(a) + \nu N(a)$		

Figure 18: Decomposition of total assets a into loss cost, margin and capital. If investor return is ρ then $Q(a) = \nu N(a)$ and $R(a) = \delta N(a)$, since $\delta/\nu = \rho$ and $\delta + \nu = 1$. Schematic components not to scale!

Basic Pricing Formula by Layer: Differentiate

Concept and meaning

- Infinitesimal layer of loss from a to $a + da$, approximated by $[a, a + 1)$
- Very thin layer only has total losses
- Probability of loss to layer $\mathsf{Pr}(X > a) = S(a)$
- Probability of no loss $\mathsf{Pr}(X \le a) = F(a)$
- Investor payoff mirrors: residual value $= 1$ with probability $F(a)$
- Write $p = F(x)$ when investor is paid and no loss for insured
- Differentiate wrt a to obtain infinitesimal premium density
- $\mathsf{E}(X \wedge a) = \int_0^a S(x)dx$ has derivative $S(a)$

Basic Pricing Formula by Layer: Differentiate

Differentiate premium components with respect to a

Loss $\mathsf{E}(X \wedge a)$	$R(a) = \delta N(a)$	$Q(a) = \nu N(a)$
$\downarrow \dfrac{d}{da}$	$\downarrow \dfrac{d}{da}$	$\downarrow \dfrac{d}{da}$
$S(a)$	$\delta F(a)$	$\nu F(a)$

Premium density $m(a) = S(a) + \delta F(a)$	$\nu F(a)$

$$1 = m(a) + \nu F(a) = (S(a) + \delta F(a)) + \nu F(a)$$

Figure 19: Decomposition an infinitesimal layer at a into loss cost, margin and capital. The derivative of $N(a) = a - \mathsf{E}(X \wedge a)$ is $1 - S(a) = F(a)$. Total equals 1 because differential of a is 1.

The Investor Cost of Capital

Vary returns $\rho(p)$ by layer

- Model assumes a fixed investor return ρ across all layers
- Reinsurance and bond pricing: different spreads by layer
- High layers, remote from loss, have lower loss ratios $=$ more expensive
- Model $\rho = \rho(p)$ function of probability p investor paid $=$ no loss

The Investor Cost of Capital

Calibrating returns by layer: synthetic layers

- Appears to introduce continuum of required returns
- Assume return ρ^* on reference layer with probability $p = 0.5$ of no loss
    - $p = 0.5$ maximizes variance and entropy of layer; a good reference
    - Mathematically any layer can be used as reference
    - Investors can borrow, or obtain a letter of credit, or lend at a fixed rate i
- **By borrowing, to leverage and increase risk, or by partially investing and saving, to de-leverage and decrease risk, the investor can make the variance of rate of return on a layer with probability $p \neq 0.5$ equal to the variance of the rate of return on the reference layer with $p = 0.5$**
- Since investors are mean-variance maximizers the return on two investments with the same variance must be the same

The Investor Cost of Capital

Calibrating returns by layer: details

- Let $\rho(p)$ be the return on a layer with probability p of payoff
  - I.e. $p = F(x)$ is chance of no loss to layer at x
- Let $v = 1/(1+i)$ be **time value** discount, and $d_i = 1 - v$
- Let $\nu(p) = 1/(1+\rho(p))$ be the **risk** discount, and $\delta(p) = 1 - \nu(p)$
- Reference, unlevered return is $\rho^* = \rho(0.5)$; $\nu^* = \nu(0.5)$
- Some manipulation shows

$$\boxed{\nu(p) = v - (v - \nu^*)\sqrt{(1-p)/p}}$$

  driven by discount spread $v - \nu^*$
- Hence $\delta(p) = 1 - \nu(p) = d_i + (v - \nu^*)\sqrt{(1-p)/p}$

Implications for Pricing

Layer pricing formula

- Premium density, with $p = F(x)$, is

$$m(x) = S(x) + \delta(p)F(x) = S(x) + d_i F(x) + (v - \nu^*)\sqrt{F(x)S(x)}$$

- Premium density has three components
  - Loss cost $S(x)$
  - Minimum financing **face capital** costs just using debt, $d_i p = d_i F(x)$
  - Additional cost of equity finance $(v - \nu^*)\sqrt{pq} = (v - \nu^*)\sqrt{F(x)S(x)}$, varying with x
- C.f. Mango rented vs. consumed capital:
  - Capital rented has debt cost
  - Capital consumed has equity cost

Implications for Pricing

Pricing formula = integrate layer pricing

- For policy supported by assets a integrate to get premium

$$M(a) = \mathsf{E}(X \wedge a) + d_i N(a) + (v - \nu^*) \int_0^a \sqrt{F(x)S(x)}dx$$

where $N(a) = \int_0^a F(x)dx = a - \mathsf{E}(X \wedge a)$ is the **insurance savings**

- Premium has three components
  - Loss cost $\mathsf{E}(X \wedge a)$
  - Minimum financing costs using all debt, $d_i N(a) = d_i(a - \mathsf{E}(X \wedge a)$
  - Additional cost of equity finance $(v - \nu^*) \int_0^a \sqrt{F(x)S(x)}dx$

Implications for Cat Bond Pricing

Model has testable implications for cat bond pricing

- Model risk load as
$$R(x) = pd_i + (v - \nu^*)\sqrt{pq}$$
- OLS regression of cat bond risk load R against p and $r_{qp} = \sqrt{pq}$
- Risk load estimated as premium rate minus expected loss EL
- Probability no loss to investor, $p = F(x)$, estimated as $1 - EL$, proxy for no partial losses
- Expect i to be in the range 1% to 5% and ρ^* to be comparable to a high equity return
- LaneFinancial LLC cat bond database since 1996
- Peril, geography, layer, expected loss and pricing spread
- Certain issues removed, lacking data elements for controls
- 571 observations

Implications for Cat Bond Pricing: Modeling Results

	Dependent variable:						
	Risk Load						
	Base	Year:p	Year:rpq	Year	Controls	Year, Controls	No Outliers
r	0.010***		0.011***		0.021***		
	(0.003)		(0.003)		(0.004)		
r_{pq}	0.341***	0.347***			0.300***		
	(0.023)	(0.020)			(0.023)		
IssueSize					0.000	−0.000	0.000
					(0.000)	(0.000)	(0.000)
Indemnity					−0.016***	0.003	0.004*
					(0.003)	(0.002)	(0.002)
PredUSHurr					0.010**	0.009***	0.008***
					(0.004)	(0.003)	(0.002)
PredUSQuake					−0.010**	−0.009**	−0.009***
					(0.005)	(0.004)	(0.003)
PredEU					−0.020***	−0.024***	−0.023***
					(0.005)	(0.004)	(0.003)
PredJ					−0.017***	−0.018***	−0.018***
					(0.006)	(0.004)	(0.004)
Year Effect?	No	Yes	Yes	Yes	No	Yes	Yes
Observations	571	571	571	571	571	571	564
R^2	0.750	0.839	0.863	0.877	0.775	0.903	0.921
Adjusted R^2	0.749	0.833	0.859	0.868	0.772	0.895	0.914
Residual Std. Error	0.034	0.028	0.025	0.025	0.032	0.022	0.018
F Statistic	854.363***	143.721***	174.252***	100.055***	242.294***	111.743***	137.102***

Implications for Cat Bond Pricing: With Controls

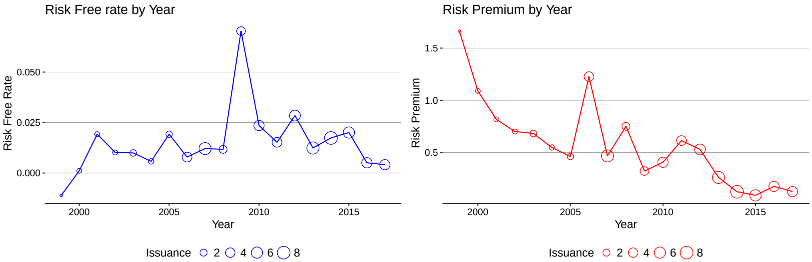


Figure 20: Risk factors i and ρ^* by year implied by model with controls and issue year effect; long-term decline in pricing evident in lower risk factor ρ^*. Spike in ρ^* in 2006 after Hurricane Katrina. Spike in i in 2009 during financial crisis. Negative i in 1999 is not statistically significant, $se = 0.067$. Data: LaneFinancial LLC

Implications for Risk Shaping

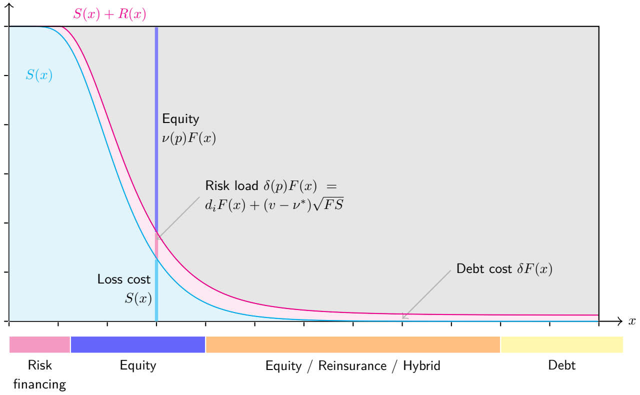


Figure 21: Survival function $S(x)$ and risk load $R(x)$ shown with relevant capital domains: risk financing for low aggregate loss amounts that are almost certain to be exceeded, equity and reinsurance or debt. Capital structure illustrated at $x = 3$ showing split between loss cost $S(x)$, risk load and equity.

Implications for Risk Shaping II

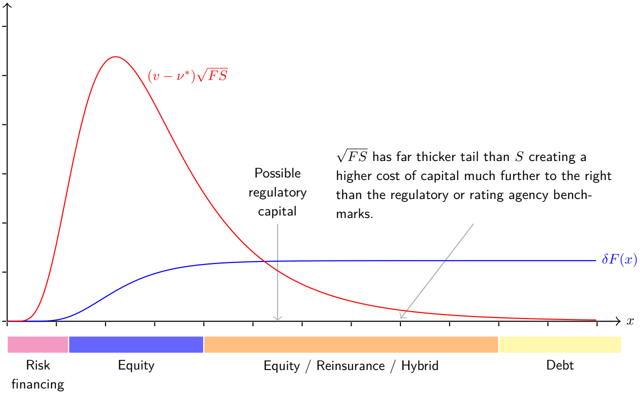


Figure 22: Marginal debt financing costs δF and equity costs $(v-\nu^*)\sqrt{FS}$ shown with relevant capital domains. Compared to previous view, this figure highlights the relative magnitudes of the two financing costs. Again the action of the square root pushes high equity costs far into the right hand tail.

Asset Risk

Asset Risk

Froot, JRI 2007

[F]inancial intermediaries should ***shed all liquid risks*** *in which they have* ***no ability to outperform*** *and devote their* ***entire risk budgets*** *toward an optimally diversified portfolio in exposures where they have an* ***edge****.*

Asset Risk

Froot, JRI 2007

*[F]inancial intermediaries should **shed all liquid risks** in which they have **no ability to outperform** and devote their **entire risk budgets** toward an optimally diversified portfolio in exposures where they have an **edge**.*

*For **insurers** specifically, this means **warehousing insurance risks**, where they arguably have informational advantages, and **shedding all others**.*

Asset Risk

Froot, JRI 2007

In practice, of course, insurance and reinsurance companies, do not seem to eliminate all liquid exposures.

*[A]s financial investors, insurers and reinsurers have a **real** or **perceived** ability to **outperform** capital market hurdles.*

*Realized insurer returns on their investment portfolios probably **do not provide evidence** that this ability is real, Berkshire Hathaway not withstanding.*

*This leaves **corporate overconfidence** concerning capital market investment opportunities as a possible explanation.*

Asset Risk

Malmendier and Tate (2005): CEO Overconfidence and Corporate Investment

We argue that ***managerial overconfidence*** *can account for* ***corporate investment distortions****.*

Overconfident managers ***overestimate*** *the returns to their investment projects and view external funds as* ***unduly costly****.*

Thus, they ***overinvest*** *when they have abundant internal funds, but* ***curtail*** *investment when they require external financing.*

We find that investment of overconfident CEOs is ***significantly more responsive*** *to cash flow, particularly in equity-dependent firms. [=****pro-cyclic****]*

Asset Risk

Time-frame conundrum

- In the short-run risky assets are too risky and should be avoided

  I can't afford to be in the market

- In the long-run you capital grows too slowly and premiums are too high and uncompetitive without asset risk

  I can't afford **not** to be in the market

Asset Risk

Asset risk impact on underwriting capacity

- Asset risk has an **indeterminate** impact on underwriting capacity
  - **Increases**: adds to **expected assets** at end of period
  - **Decreases**: adds to **risk** of assets at end of period
- Market price of assets balances risk and return for the **general** investor, but not necessarily for **insurers**
- Asset risk **increases** capacity in **long** run; **decreases** in **short**-run
- Capital models generally have one-year, short-run focus
- If asset risk decreases capacity it is reasonable to allocate cost of reduced **consumed** capacity to assets

Asset Risk for the Simple Model

Adding asset risk to the simple model surprisingly complex

- Basic pricing formula for thin layer:

$$1 = m(x) + \nu F(x) = S(x) + \delta F(x) + \nu F(x)$$

- Assumes assets held in safe instrument with no possibility of default
- Allow a risky asset R which pays 1 in a good state with probability g and 0 otherwise
- **Question**: what proportion f of assets should the insurer hold in the safe asset?

Asset Risk for the Simple Model

Decision variables

- Amount of starting assets a: still $a = 1$ or allow $a < 1$?
- Proportion f of assets held in the safe asset class
- Price of insurance now a function of
  - Insurance risk: unchanged
  - Starting assets a: now variable
  - Proportion of asset held in the safe class f
  - Characteristics of R

Asset Risk for the Simple Model

Order of decisions

- Characteristics of R given exogenously
- Insurer selects its investment philosophy by choosing f based on its CEO's level overconfidence
- Product market constraints determine starting assets a

Asset Risk for the Simple Model

Product market constraints

- **Regulatory constraint**: assets in the good state at $t = 1$ should be at least 1, otherwise promise to pay is not credible
  - Face capital constraint
  - Implies a **lower** bound on a, which decreases with f assuming positive return
- **Fairness constraint**: the market price of insurance, accounting for the possibility of default and the states of the world in which it occurs, should be no higher than in the case of a safe insurance, $f = 1$
  - Market value loss ratio with risky assets equals market value loss ratio when $f = 1$
  - When $f = 1$ market value loss ratio equals actuarial loss ratio
  - Market value of recoveries determined using state price density
  - Implies **upper** bound on a

Asset Risk for the Simple Model—Not so Simple!

Product market constraints

- Regulatory and fairness constraints produce a **unique** $a = a(f)$
- If $a > a(f)$ then the insured is paying in all states for extra protection that only benefits them in the bad states, which increases the market value loss ratio: the investor benefits at the expense of the insured
- If $a < a(f)$ then the investor and insured are in fair positions but the policy is not credible: it fails to pay fully even in the good state, which regulators will not allow
- If $a = a(f)$ then the investor and insured are in fair positions and the policy is pays in full in the good state
- Hence the rational solution is $a = a(f)$
- Illustrates complexities involved incorporating asset risk