Digital Finance

COMP0164

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In this lecture

We will learn

- the fundamentals of insurance
- the basic actuarial formulae for life insurance
- the InsurTech landscape

Insurance fundamentals (Rejda, McNamara, and Rabel 2020)

What is insurance

Insurance is the pooling of *fortuitous losses* by transfer of such risks to insurers, who agree to indemnify insureds for such losses, to provide other pecuniary benefits on their occurrence, or to render services connected with the risk

Basic Characteristics of Insurance

- Pooling of losses
- Payment of fortuitous losses
- Risk transfer
- Indemnification

Pooling

Pooling involves spreading losses incurred by the few over the entire group

Example of Pooling

Two business owners own identical buildings valued at $50,000
There is a 10% chance each building will be destroyed by a peril in any year
Loss to either building is an independent event
Expected value *and* ***standard deviation*** *of the* ***loss*** *for each owner?*

$$\mu = 0.9 \times 0 + 0.1 \times 50,000 = 5,000$$

$$\sigma = \sqrt{0.9 \times (0 - 5,000)^2 + 0.1 \times (50,000 - 5,000)^2} = 15,000$$

If the owners instead pool (combine) their loss exposures, and each agrees to pay an equal share of any loss that might occur?

$$
\begin{aligned}
&\mu \\
=&\underbrace{0.81}_{0.9^2} \times 0 + \underbrace{0.09}_{0.9\times 0.1} \times \underbrace{25,000}_{50{,}000/2} + 0.09 \times 25,000 + 0.01 \times 50,000 \\
=&5,000
\end{aligned}
$$

$$
\begin{aligned}
&\sigma \\
=&\sqrt{0.81 \times (0 - 5,000)^2 + 2 \times 0.09 \times (25,000 - 5,000)^2 + 0.01 \times (50,000 - 5,000)^2} \\
=&10,607
\end{aligned}
$$

As additional individuals are added to the pool, the standard deviation continues to decline while the expected value of the loss remains unchanged

Law of Large Numbers

- Risk reduction is based on the **Law of Large Numbers**
- According to the **Law of Large Numbers**, the greater the number of exposures, the more closely will the actual results approach the probable results that are expected from an infinite number of exposures.

Basic Characteristics of Insurance (cont.)

- **Payment of fortuitous losses**: A fortuitous loss is one that is unforeseen, unexpected, and occur as a result of chance
- **Risk transfer**: A pure risk is transferred from the insured to the insurer, who typically is in a stronger financial position
- **Indemnification**: The insured is restored to his or her approximate financial position prior to the occurrence of the loss
- **Large number of exposure units**: to predict average loss based on the law of large numbers
- **Accidental and unintentional loss**: to assure random occurrence of events
- **Determinable and measurable loss**: to determine how much should be paid

Adverse Selection and Insurance

- **Adverse selection** is the tendency of persons with a higher-than-average chance of loss to seek insurance at standard rates
- If not controlled by underwriting, adverse selection results in higher-than-expected loss levels
- Adverse selection can be controlled by:
  - careful **underwriting** (selection and classification of applicants for insurance)
  - policy provisions (e.g., suicide clause in life insurance)

Insurance and Gambling Compared

Insurance

- Handles an already existing pure risk
- Is always socially productive:
  - both parties have a common interest in the prevention of a loss

Gambling

- Creates a new speculative risk
- Is not socially productive
  - The winner's gain comes at the expense of the loser

Insurance and Hedging Compared

Insurance

- Risk is transferred by a contract
- Involves the transfer of pure (insurable) risks
- Moral hazard and adverse selection are more severe problems for insurers

Hedging

- Risk is transferred by a contract
- Involves risks that are typically uninsurable
- Fewer problems of moral hazard and adverse selection for entities who buy or sell futures contracts

Types of Insurance

Insurance can be classified as either **private** or **government** insurance

- **Private insurance** includes **life and health** insurance as well as **property and liability** insurance
- **Government insurance** includes **social** insurance programs and other government insurance plans

Private insurance coverages can be grouped into two major categories

- **Personal lines**: coverages that insure the real estate and personal property of individuals and families or provide protection against legal liability
- **Commercial lines**: coverages for business firms, nonprofit organizations, and government agencies

Life and Health

- **Life insurance** pays death benefits to beneficiaries when the insured dies
- **Health insurance** covers medical expenses because of sickness or injury

Property and Liability

- **Property insurance** indemnifies property owners against the loss or damage of real or personal property
- **Liability insurance** covers the insured's legal liability arising out of property damage or bodily injury to others
- **Casualty insurance** refers to insurance that covers whatever is not covered by fire, marine, and life insurance

Social Insurance Programs

- Financed entirely or in large part by contributions from employers and/or employees
- Benefits are heavily weighted in favor of low-income groups
- Eligibility and benefits are prescribed by statute
- Examples: Social Security, Unemployment, Workers' Compensation

Other Government Insurance Programs

- Found at both the federal and state level
- Examples: Federal flood insurance, state health insurance pools

Benefits of Insurance to Society

- Indemnification for Loss
- Reduction of Worry and Fear
- Source of Investment Funds
- Loss Prevention
- Enhancement of Credit

Costs of Insurance to Society

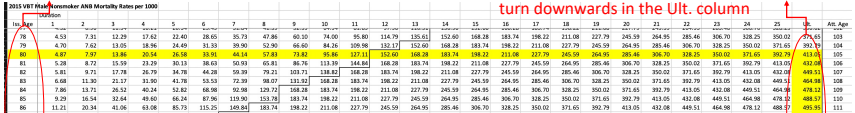
- Cost of Doing Business
  - An expense loading is the amount needed to pay all expenses, including commissions, general administrative expenses, state premium taxes, acquisition expenses, and an allowance for contingencies and profit
- Fraudulent Claims
- Inflated Claims
- Higher premiums to cover additional losses reduce disposable income and consumption of other goods and services

Life insurance

Economics of permenant life insurance

- *Insured* pays premiums starting insurance issuance until death to *insurance company*
- *Insurance company* pays death benefit at *insured*'s death to *beneficiary*

Mortality table



Issue Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Ult.	Att. Age
78	4.53	7.31	12.29	17.62	22.40	28.65	35.73	47.86	60.10	74.00	95.80	114.79	135.61	152.60	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	103
79	4.70	7.62	13.05	18.96	24.49	31.33	39.90	52.90	66.60	84.26	109.98	132.17	152.60	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	104
80	4.87	7.97	13.86	20.54	26.58	33.91	44.14	57.83	73.82	95.86	127.11	152.60	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	105
81	5.28	8.72	15.59	23.29	30.13	38.63	50.93	65.81	86.76	113.39	144.84	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	106
82	5.81	9.71	17.78	26.79	34.78	44.28	59.39	79.21	103.71	138.82	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	107
83	6.68	11.30	21.17	31.90	41.78	53.53	72.39	98.07	131.92	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	108
84	7.86	13.71	26.52	40.24	52.82	68.98	92.98	129.72	168.28	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	109
85	9.29	16.54	32.64	49.60	66.24	87.96	119.90	153.78	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	110
86	11.21	20.34	41.06	63.08	85.73	115.25	149.84	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	111
87	13.43	24.96	51.42	80.59	110.70	146.02	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	112
88	15.68	30.11	63.26	100.74	139.60	183.74	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	113
89	18.01	35.21	76.25	123.29	170.18	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	114
90	20.69	41.16	91.34	150.97	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	115
91	26.11	64.28	137.80	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	500.00	116
92	37.21	96.57	198.22	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	500.00	500.00	117
93	55.33	139.86	211.08	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	500.00	500.00	500.00	118
94	81.49	163.70	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	119
95	116.33	227.79	245.59	264.95	285.46	306.70	328.25	350.02	371.65	392.79	413.05	432.08	449.51	464.98	478.12	488.57	495.95	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	120

Figure 1: Excerpt of 2015 VBT Male Nonsmoker ANB Mortality Rates

Source: www.soa.org/files/research/exp-study/2015-vbt-smoker-distinct-alb-anb.xlsx.
Full table also downloadable from Moodle.

Table 1: Excerpt of 2015 VBT Male Nonsmoker ANB Mortality Rates, $x = 80$

Duration ($n+1$, in years)	1	2	3	4	5	6	7	8	$\cdots$
Mortality rates ($_{n\|}q_x$)	0.00487 ($_{0\|}q_{80}$)	0.00797 ($_{1\|}q_{80}$)	0.01386 ($_{2\|}q_{80}$)	0.02054 ($_{3\|}q_{80}$)	0.02658 ($_{4\|}q_{80}$)	0.03391 ($_{5\|}q_{80}$)	0.04414 ($_{6\|}q_{80}$)	0.05783 ($_{7\|}q_{80}$)	$\cdots$ $\cdots$

$_{n|}q_x$: one-year conditional mortality rate, the probability that a person aged x will die in one year, deferred n years, i.e. the person is dead at the end of the $(n+1)^{\text{th}}$ year given that the person is alive at the end of the n^{th} year

Important formulae

${}_{n|}q_x$: one-year conditional mortality rate, the probability that a person aged x will die in one year, deferred n years, i.e. the person is dead at the end of the $(n+1)^{\text{th}}$ year given that the person is alive at the end of the i^{th} year

${}_np_x$: the probability that a person aged x is alive at the end of the n^{th} year

$$ {}_np_x = \begin{cases} 1, & n \leq 0 \\ \prod_{m=0}^{n-1}(1 - {}_{m|}q_x), & n \geq 1 \end{cases} $$

$\mathbb{P}_n$: the probability that the death benefit will be paid out at the end of n^{th} year, i.e. the probability that the person dies between year $n-1$ and n

$$ \mathbb{P}_n = {}_{n-1}p_x \times {}_{n-1|}\, q_x $$

Table 2: Probabilities of death, (conditional) survival, and death benefit payment

n	0	1	2	3	4	5	6	7	8	$\cdots$
${}_{n-1\|}q_x$	0	0.00487	0.00797	0.01386	0.02054	0.02658	0.03391	0.04414	0.05783	$\cdots$
$1-{}_{n-1\|}q_x$	1	0.99513	0.99203	0.98614	0.97946	0.97342	0.96609	0.95586	0.94217	$\cdots$
${}_np_x$	1	0.99513	0.98720	0.97352	0.95352	0.92818	0.89670	0.85712	0.80755	$\cdots$
$\mathbb{P}_n$	0	0.00487	0.00793	0.01368	0.02000	0.02534	0.03147	0.03958	0.04957	$\cdots$

Full table and calculations downloadable from Moodle.

Note: everyone will die eventually, i.e.

$$\lim_{n\to\infty} {}_np_x = 0 \qquad \sum_{n=0}^{\infty} \mathbb{P}_n = 1$$

The person's life expectancy LE (expected number of years to live from **now** to death) can be calculated as

$$LE = \sum_{n=0}^{\infty} {}_np_x - 0.5$$

From the perspective of insurance company, the present value of a permanent life insurance policy PV is:

$$PV = \sum_{n=0}^{\infty} \frac{{}_{n}p_x \cdot \pi_n - \mathbb{P}_n \cdot DB}{(1+r)^n}$$

π_n: premium to be paid at time n (up-front payment, from time 0)

DB: death benefit amount

r: valuation interest rate

InsurTech

InsurTech taxonomy (Braun and Schreiber 2017)

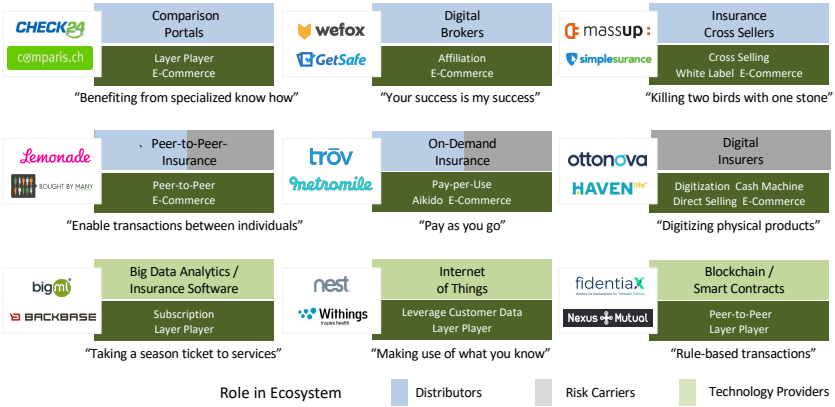


Figure 2: Business Model Patterns and InsurTech Categories

Thank you!

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References I

Braun, Alexander, and Florian Schreiber. 2017. *The Current InsurTech Landscape: Business Models and Disruptive Potential*. 62. I. VW HSG Schriftenreihe. https://www.ivw.unisg.ch/~/media/internet/content/dateien/instituteundcenters/ivw/studien/ab-insurtech_2017.pdf.

Rejda, George E, Michael J McNamara, and William H Rabel. 2020. *Principles of Risk Management and Insurance*. Pearson.