An Actuarial Model for Hospitalization Insurance with Limited Benefit: Cancer Impaired Risk

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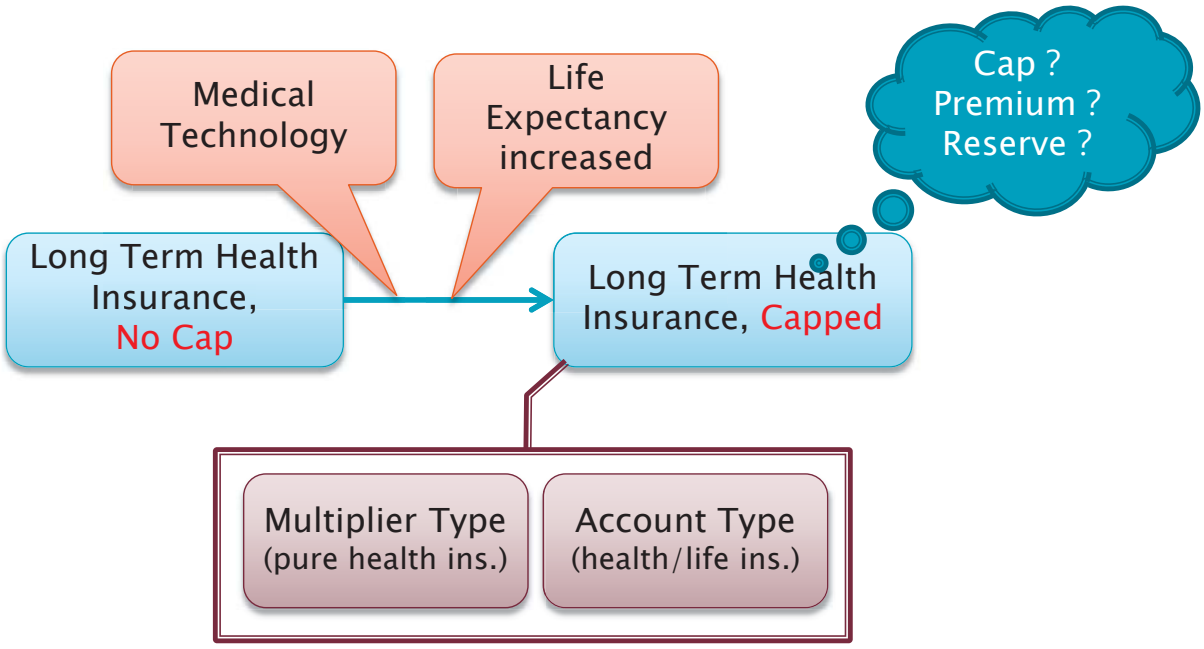
Motivation

- Cancer has become more like a chronic disease
  - CNN Larry King Live Show (Dec. 9, 2010)
  - Suppress cancer by activating certain genes
  - Go for a strong immunity
  - Embrace Eastern medicine
  - See cancer more as a chronic disease rather than a terminal illness
  - Delay death
- Cancer impair risk in Taiwan
  - Over 87,000 new cases - Cancer Registration (2009)
  - Population of 23 millions
  - Aging fast

Motivation



Goal

- Hospitalization insurance design for cancer patients
  - Long term
  - Capped
- Modeling the inpatient days each year from cancer onset
- Hospital income insurance for cancer patients
- Net premium calculation for multiplier type and account type insurance
  - Single premium
  - Level premium

Data

- Taiwan's National Health Insurance Research Database
- Files used
  - Inpatient expenditures by admissions (DD)
  - Registry for catastrophic illness patients (HV)
  - Registry for beneficiaries (ID)
- 1/1/'97-12/31/'09 (13-year longitudinal data)
- New Cancer patients
  - Male : 389,669 patients; 1,791,134 inpatient records
  - Female : 306,309patients; 1,463,748 inpatient records
  - No hospital stay cases were also included

Our observations

- Average hospital stay after cancer diagnosis

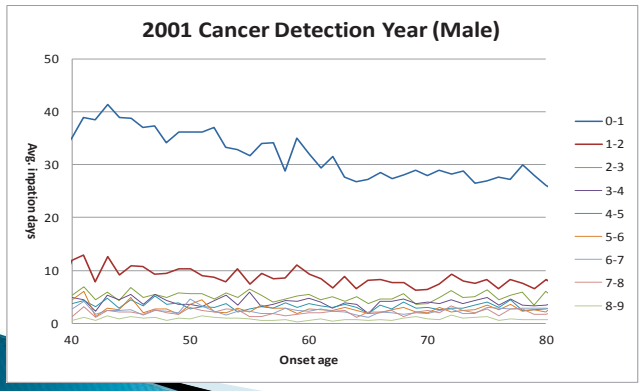
Inpatient days					
Years from onset	Average	Years from onset	Average	Years from onset	Average
0-1	29.17	5-6	5.72	10-11	4.06
1-2	9.83	6-7	5.33	11-12	3.68
2-3	8.04	7-8	4.97	12-13	2.30
3-4	7.01	8-9	4.77		
4-5	6.36	9-10	4.37		

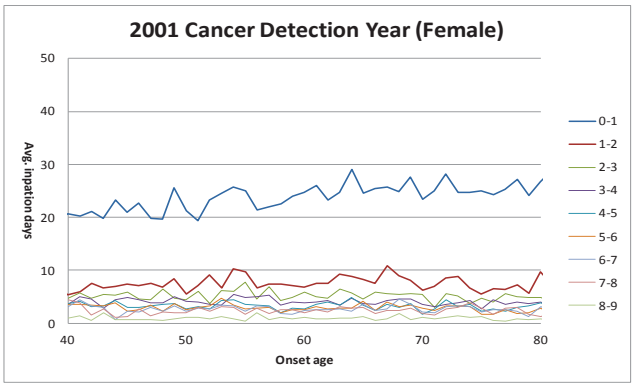
- Length of hospital stay each year are positive correlated

Correlation Coefficient	0-1	1-2	2-3	3-4
0-1	1	0.18	0.15	0.11
1-2	0.18	1	0.32	0.26
2-3	0.15	0.32	1	0.36
3-4	0.11	0.26	0.36	1

Our observations

- Average hospital inpatient days
  - Male > Female
  - First year from cancer onset > Second year > Third year ≈ Forth year ≈…
  - Same for all cancer onset detection year (’97–’09)





Methodology and findings:

- Actuarial Model
  - Generalized Linear Model (GLM)
  - Generalized Estimating Equation (GEE)
- Results:
  - Negative Binomial distribution is selected
  - Canonical link
  - $g(\mu_{sex}) = \beta_0 + \beta_1 age + \beta_2 iyear1 + \beta_3 iyear2$
    - μ: average inpatient days per year from cancer onset
    - sex: gender
    - age: age-of-onset
    - iyear1: affect by the years from onset
    - iyear2: not affect by the years from onset

Results (Model Selected)

- Models :

$$g(\mu_M) = 3.7249 - 0.0420 * \text{age} - 1.0837 * \text{iyear1} - 1.2329 * \text{iyear2}$$

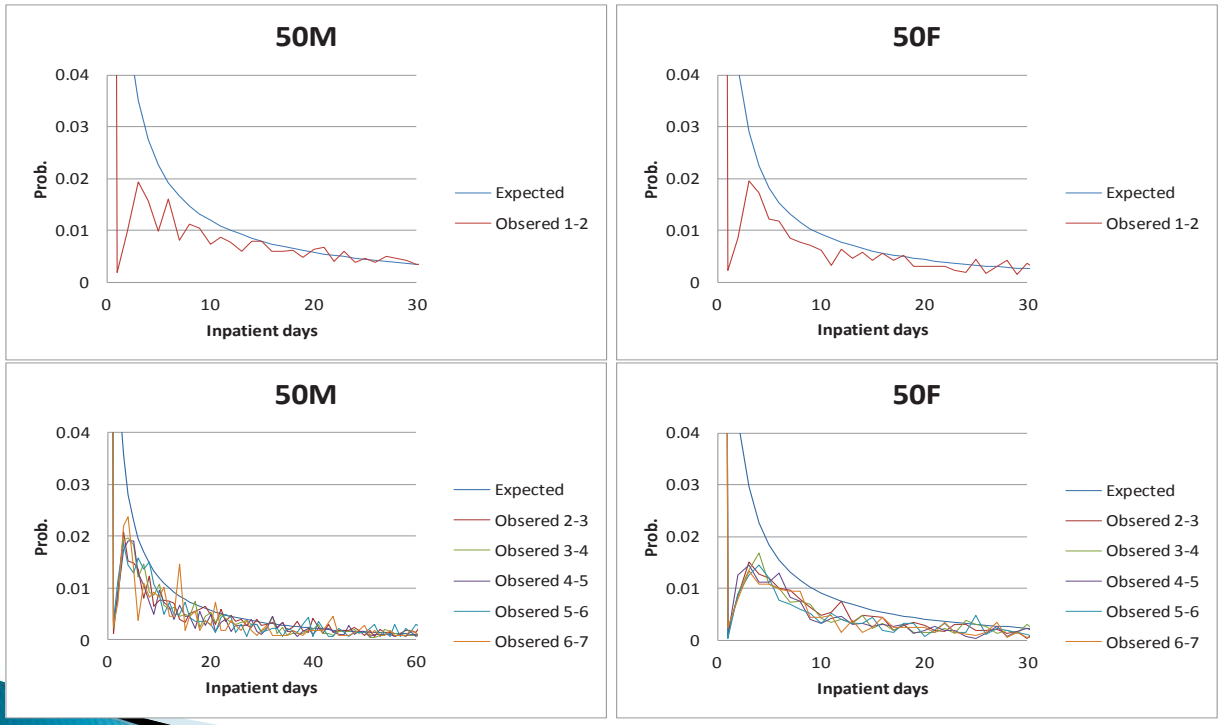
$$g(\mu_F) = 2.9994 + 0.0041 * \text{age} - 1.0761 * \text{iyear1} - 1.3134 * \text{iyear2}$$

  - All parameters are significant at .00001 level
- Correlation coefficient
  - Equal correlation model (or, exchangeable model) fits best
  - Male: 0.2387, Female: 0.2472
- Kapa estimation* :
  - Male: 5.4781, Female: 7.6424
  - Estimated by assuming independence observations

Results (Model fitting)

Avg. days	Age-of-onset							
	50 M		50 F		70 M		70 F	
Yr. from onset	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
0–1	35.7171	33.6126	23.4750	24.6407	28.7104	30.9044	26.0741	26.7464
1–2	12.0753	11.3725	7.8594	8.4006	9.8974	10.4563	9.1570	9.1185
2–3	9.5578		6.0686		8.8262		7.8788	
3–4	7.8447		4.7685		8.3722		7.3046	
4–5	7.1292		3.9266		7.7257		5.8082	
5–6	7.1091		4.2137		6.9541		6.4490	
6–7	7.0779		3.5693		6.7529		4.9843	
7–8	5.6925	9.7963	3.0480	6.6260	6.7508	9.0070	5.1853	7.1922
8–9	4.5759		2.5706		6.7256		6.9606	
9–10	4.1448		2.1469		6.6125		6.8053	
10–11	4.6146		2.4232		7.0899		6.2565	
11–12	3.8588		1.6844		8.1328		4.4921	
12–13	1.7656		1.2083		2.2377		3.8558	

Results (Model fitting)



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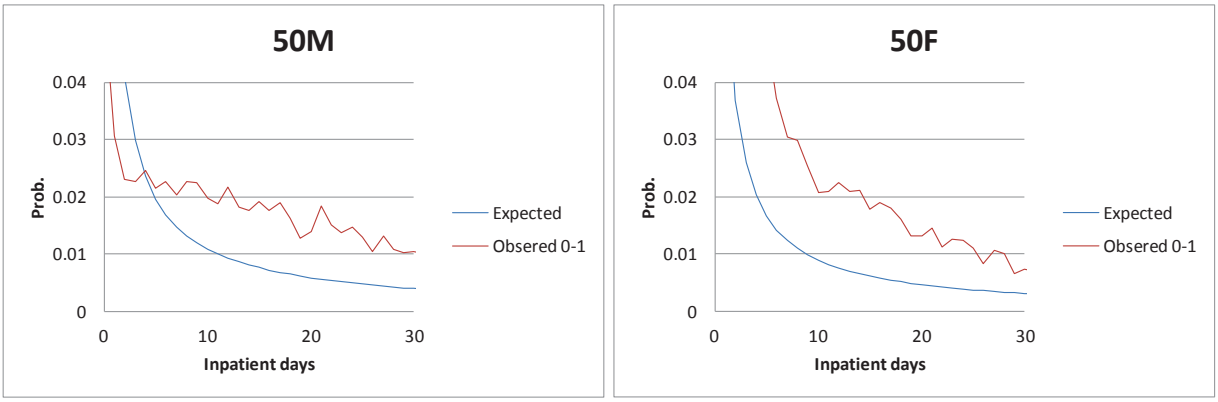
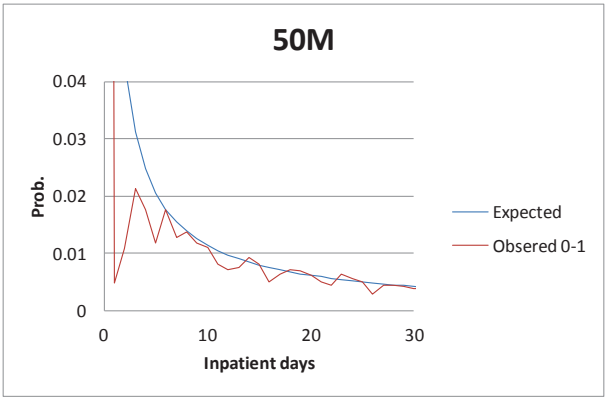
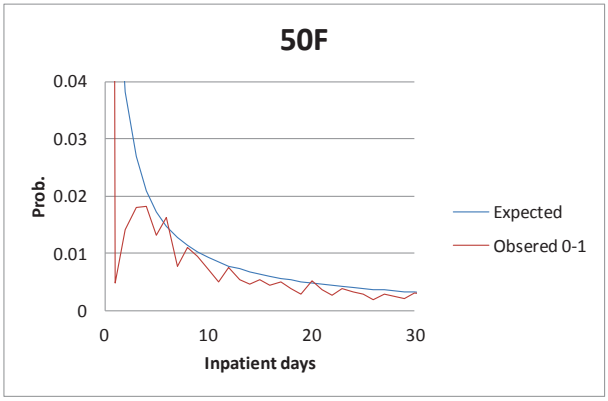


P(0 day inpatient)		Male			Female		
		0–1	1–2	2+	0–1	1–2	2+
50	Observed	0.0530	0.6375	0.6890	0.0708	0.7389	0.7858
	Expected	0.3856	0.4690	0.4817	0.5035	0.5789	0.5968
70	Observed	0.0746	0.6315	0.6467	0.0904	0.6549	0.6762
	Expected	0.3915	0.4761	0.4890	0.4982	0.5728	0.5906

Results (Model fitting–180 days waiting)





P(0 days inpatient)		Male			Female		
		0–1	1–2	2+	0–1	1–2	2+
50	Observed	0.6342	0.6375	0.6890	0.7395	0.7389	0.7858
	Expected	0.4045	0.4690	0.4817	0.5209	0.5789	0.5968
70	Observed	0.6784	0.6315	0.6467	0.7051	0.6549	0.6762
	Expected	0.4081	0.4761	0.4890	0.5177	0.5728	0.5906

Net single premium – Capped effect

- Early lapse due to cap(L)
- Example: (x), L=5, account type

Inpatient days

Patient\time	0–1	1–2	2–3	3–4
A	1	0	1	0
B	1	1	0	1
C	1	1	1	0
D	1	2	0	1
E	2	0	0	2
F	1	6	3	0
G	4	0	1	0

Account balance

Patient\time	0	1	2	3
A	5	4	4	3
B	5	4	3	3
C	5	4	3	2
D	5	4	2	2
E	5	3	3	3
F	5	4	n/a	n/a
G	5	1	1	n/a

Net single premium – Capped effect

- Average inpatient days paid calculation

# of days paid

Patient\time	0–1	1–2	2–3	3–4
A	1	0	1	0
B	1	1	0	1
C	1	1	1	0
D	1	2	0	1
E	2	0	0	2
F	1	4	n/a	n/a
G	4	0	1	n/a

Account balance

Patient\time	0	1	2	3
A	5	4	4	3
B	5	4	3	3
C	5	4	3	2
D	5	4	2	2
E	5	3	3	3
F	5	4	n/a	n/a
G	5	1	1	n/a

$$\bar{d}_0 = \frac{1+1+1+1+2+1+4}{7} = \frac{11}{7}$$

$$\bar{d}_1 = \frac{0+1+1+2+0+4+0}{7} = \frac{8}{7}$$

$$\bar{d}_2 = \frac{1+0+1+0+0+1}{6} = \frac{3}{6}$$

$$\bar{d}_3 = \frac{0+1+0+1+2}{5} = \frac{4}{5}$$

Net single premium – Capped effect

- Avg. death benefit each year

Account balance

Patient\time	0	1	2	3
A	5	4	4	3
B	5	4	3	3
C	5	4	3	2
D	5	4	2	2
E	5	3	3	3
F	5	4	n/a	n/a
G	5	1	1	n/a

$$\bar{R}_0 = \frac{5+5+5+5+5+5+5}{7} = 5$$

$$\bar{R}_1 = \frac{4+4+4+4+3+4+1}{7} = \frac{24}{7}$$

$$\bar{R}_2 = \frac{4+3+3+2+3+1}{6} = \frac{16}{6}$$

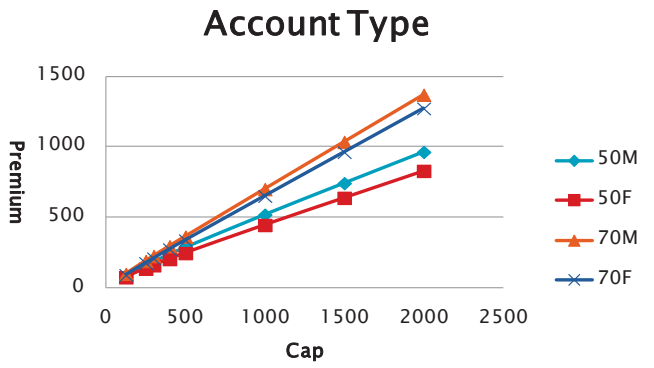
$$\bar{R}_3 = \frac{3+3+2+2+3}{5} = \frac{13}{5}$$

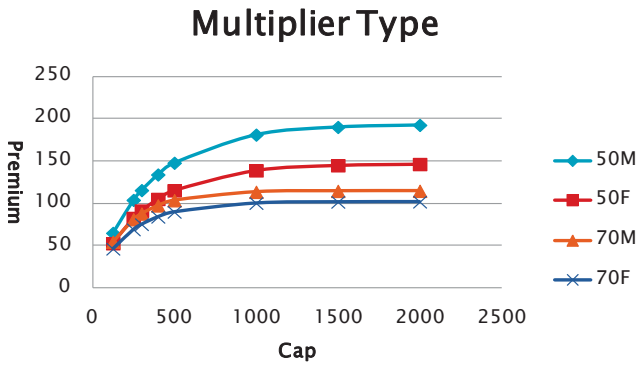
Net single premium – Capped effect

- Whole life hospitalization income insurance + 180-day waiting period
- TSO2011, i=3%, L=250, Correlation coefficient : 0.24, income benefit $1/day
- Result of 100,000 simulation
- NB + equal correlation → Clayton copula of Archimedean copula family

Onset Age	50		70	
Type	Male	Female	Male	Female
Account Type	160.3220	139.3698	192.2154	178.2968
Multiplier Type	104.1468	84.0725	82.8168	70.5166

Net single premium – Capped effect





Net single premium sensitivity study – correlation coefficient

Base-Correlation coefficient:0.24 · i=3% · TSO2011 · L=250

Onset Age	Type	Account Type						
	Corr. Coeff.	0	0.05	0.1	0.15	0.2	0.24	0.3
50	Male	180.1323	174.5477	170.4829	166.9669	163.5809	160.3320	158.3172
		12.35%	8.87%	6.33%	4.14%	2.03%	-	-1.26%
	Female	160.9115	152.4381	148.7822	144.9365	141.7722	139.3698	136.8370
		15.46%	9.38%	6.75%	3.99%	1.72%	-	-1.82%
Onset Age	Type	Multiplier Type						
	Corr. Coeff.	0	0.05	0.1	0.15	0.2	0.24	0.3
50	Male	151.6627	137.5993	127.5935	118.9310	110.8326	104.1468	98.6456
		45.62%	32.12%	22.51%	14.20%	6.42%	-	-5.28%
	Female	133.7780	114.6579	105.7100	96.5278	89.3044	84.0725	78.3796
		59.12%	36.38%	25.74%	14.81%	6.22%	-	-6.77%

Net single premium sensitivity study – death rate

Base-Correlation coefficient:0.24 · i=3% · TSO2011 · L=250

Onset age	Type	Account Type				
	TSO2011*	0.8	0.9	1	1.1	1.2
50	Male	157.0283	158.7441	160.3320	161.8121	163.1998
		-2.06%	-0.99%	-	0.92%	1.79%
	Female	136.3492	137.9199	139.3698	140.7185	141.9811
		-2.17%	-1.04%	-	0.97%	1.87%
Onset age	Type	Multiplier Type				
	TSO2011*	0.8	0.9	1	1.1	1.2
50歲	Male	105.9024	105.0009	104.1468	103.3337	102.5569
		1.69%	0.82%	-	-0.78%	-1.53%
	Female	85.0499	84.5471	84.0725	83.6222	83.1929
		1.16%	0.56%	-	-0.54%	-1.05%

Net level premium – Capped effect

- Early rational surrender due to cap
- Example: (x)=107, L=5, w=110, whole life, multiplier type, annual premium, # of premium payments=3
- Net annual premium=1.3952
- Calculation was done by iteration account for the rational surrender

# of days paid

Patient\time	0-1	1-2	2-3	3-4
A	1	0	1	0
B	1	1	0	1
C	1	1	1	0
D	1	2	0	1
E	2	0	0	2
F	1	4	0	0
G	4	0	0	0

Account balance

Patient\time	0	1	2	3
A	5	4	4	3
B	5	4	3	3
C	5	4	3	2
D	5	4	2	2
E	5	3	3	3
F	5	4	0	0
G	5	0	0	0

Net level premium=1.3952, G will surrender at time 1 before the 2nd premium paid.

Net level premium

- TSO2011, i=3%, L=250, Correlation coefficient : 0.24, income benefit $1/day, annual premium, #0f premium payment=20
- c=future premium/account balance =1

Onset Age	50				70			
	Male		Female		Male		Female	
Rational Surrender	With	Without	With	Without	With	Without	With	Without
Account Type	11.7237	12.7351	9.6771	10.1428	17.5050	18.9777	14.2699	15.6487
Multiplier Type	7.7105	8.3606	5.8473	6.1185	7.5348	8.1766	5.8690	6.1891

Net level premium sensitivity study – rational surrender

Base-Correlation coefficient:0.24 · i=3% · TSO2011 · L=250, annual premium, # of premium payment=20,
c=future premium/account balance =1

Onset Age	Type	Account Type				
	H	1	0.9	0.8	0.7	0.6
50	Male	11.7237	11.3635	10.8746	10.8508	10.7521
		-	-3.07%	-7.24%	-7.45%	-8.29%
	Female	9.6771	9.5338	9.3132	8.9158	8.3238
		-	-1.48%	-3.76%	-7.87%	-13.98%
Onset Age	**Type**	**Multiplier Type**				
	H	1	0.9	0.8	0.7	0.6
50	Male	7.7105	7.5599	7.3598	7.0824	6.6947
		-	-1.95%	-4.55%	-8.15%	-13.17%
	Female	5.8473	5.7845	5.6982	5.5707	5.3904
		-	-1.07%	-2.55%	-4.73%	-7.81%

Conclusion-Modeling

- Suggest length of inpatient day per year from onset using negative binomial distribution
- GEE + Waiting period fit well for inpatient days data
- Length of hospital stay are equally and positively correlated between any two year from cancer onset

Conclusion – net single premium

- Both account type and multiplier type
  - Obvious
    - Early lapse should be considered
    - High cap yields high premium
      - Cap should be set upon the affordability of premium
    - Low interest rate yields high premium
  - Not so obvious
    - Death rate has the lowest impact among all the rating factors
  - Obscure
    - High correlation yields low premium
    - Correlation impact is higher in multiplier type than in account type
- For multiplier type, premium increasing is limited after certain high cap

Conclusion – net level premium

- Rational surrender should be considered
- Premium will be reduced account for the rational surrender
- Early rational surrender reduces the premium
- Computation intensive process

To be improved

- The estimation of death rate for cancer patients
- Ways to measure rational surrender is unclear to the authors

Thanks for your attention!