

# **Modelling and predicting the risk of extreme hospital bills in Singapore**

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# Key references

**Abeyasinghe, T., Himani, A., Lim, J. (2011) “Equity in Singapore’s healthcare financing”, *Challenges for the Singapore Economy After the Global Financial Crisis*, edited by P. Wilson, Singapore: World Scientific.**

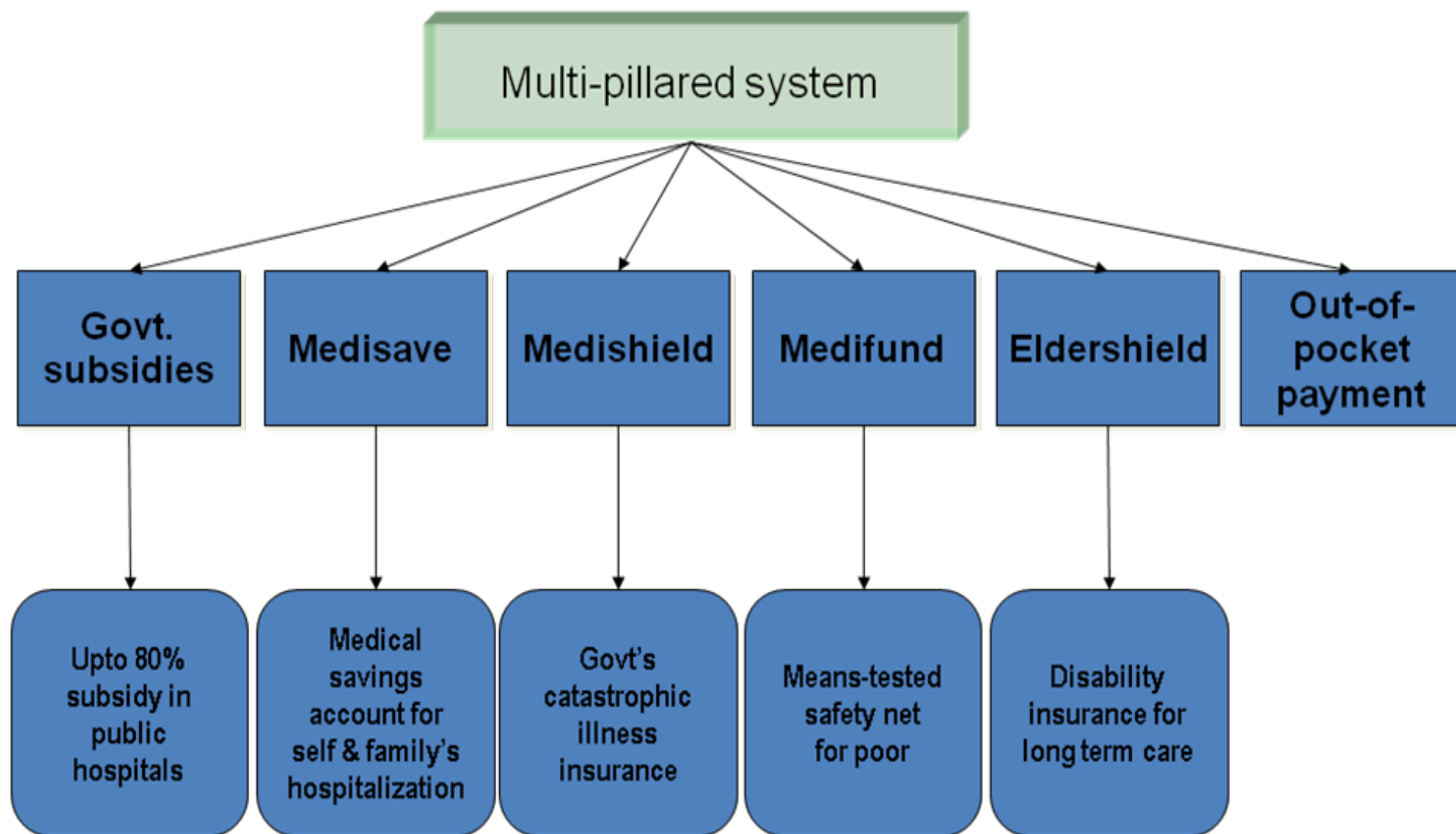
**Himani Aggarwal (2012) *Essays in modeling health expenditures with a focus on Singapore*. PhD Thesis, Dept of Economics, NUS**

# Singapore health care financing philosophy

## The National Health Plan (NHP) 1983

- Self responsibility (individual and family) – co-payment
- Affordable health care through a subsidy system

## The structure of Singapore's healthcare financing system



# Government subsidies and ward-class system

Ward Type	Subsidy	Beds per room	Attached Toilet & Shower	Air-con	T.V. & Phone
A	0	1	Yes	Yes	Yes
B1	20%	4	Yes	Yes	Yes
B2+	50%	5	Yes	Yes	No
B2	50 – 65%	6	No	No	No
C	65 - 80%	>6 (open ward)	No	No	No

# **Medical Savings Accounts (MSA) System**

## **Strengths:**

- Curbs overutilization by creating cost-conscious consumers; encourages healthy living**
- Eliminates efficiency losses arising from moral hazard in a third-party pre-paid system**
- Mobilizes non-budgetary resources to help pay for increasing medical expenditures**
- Resolves the problem of intergenerational transfers**

# Medical Savings Accounts (MSA) System

## Problems:

- Equity (individual income dependence)

- Adequacy - **Extreme bills**

Important for both

- \* Singaporeans

- \* Overseas private patients

(Spore a med hub – to attract 1 mn foreign patients)

# Data

**Hospitalization episodes from SGH Jan-Dec 2007**

**Sample size: 30,192 episodes**

**(18,935 patients 64+, Male 48%, Female 52%)**

**(better quality than survey-based data)**

**Information gathered:**

**Inpatient expenses**

**Modes of financing**

**Inpatient's characteristics such as age, gender**

**Length of stay**

**Diagnosis (primary and secondary)**

**Outcome of hospitalization**



# Distribution of **Gross** Inpatient Expenditure in Different Ward Classes

Ward Class	N	Mean (S\$)	Median (S\$)	90 <sup>th</sup> Percentile (S\$)	95 <sup>th</sup> Percentile (S\$)	99 <sup>th</sup> Percentile (S\$)	Min (S\$)	Max (S\$)
A	1,395	7,759	3,939	17,428	21,896	46,469	319	287,902
B1	2,324	7,053	3,901	15,704	19,970	36,440	256	144,735
B2+	822	5,412	4,014	11,042	15,532	26,944	256	38,479
B2	15,260	5,378	2,822	12,704	17,393	32,666	226	308,627
C	10,391	5,843	3,181	13,361	18,490	37,554	186	136,127
Total	30,192	5,778	3,104	13,517	18,222	35,519	186	308,627

# Distribution of **Net** Inpatient Expenditure

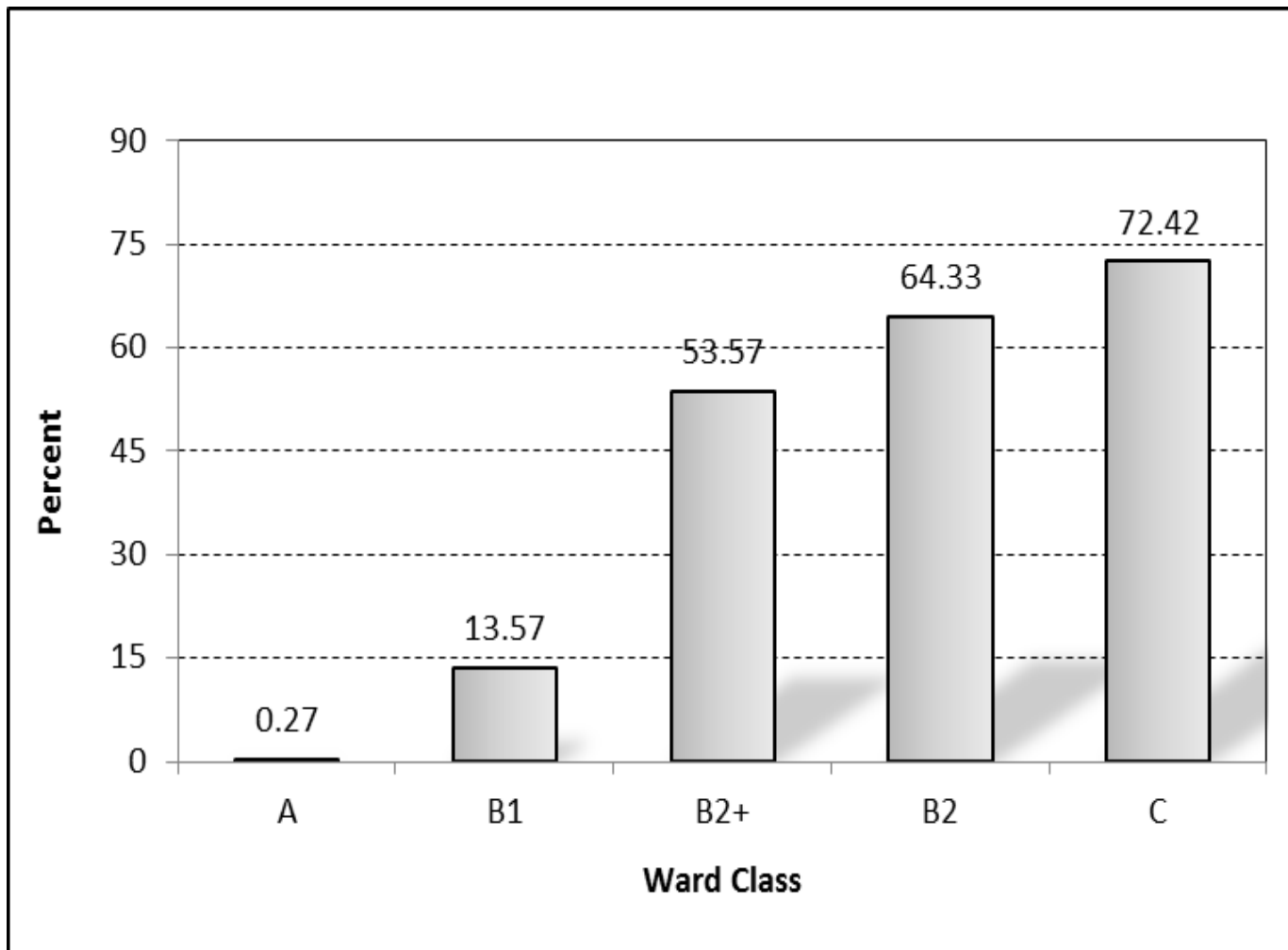
(Net = Gross – Govt subsidy + GST 7%)

Ward Class	N	Mean (S\$)	Median (S\$)	90 <sup>th</sup> Percentile (S\$)	95 <sup>th</sup> Percentile (S\$)	99 <sup>th</sup> Percentile (S\$)	Min (S\$)	Max (S\$)
A	1,395	8,108	4,180	18,326	23,266	48,793	341	207,741
B1	2,324	6,560	3,574	14,819	18,404	33,646	213	136,754
B2+	822	2,305	1,804	4,074	5,681	10,851	135	21,091
B2	15,260	1,727	986	3,989	5,257	10,083	68	95,615
C	10,391	1,466	842	3,257	4,431	9,004	38	38,721
Total	30,192	2,320	1,087	4,778	8,133	19,126	38	207,741

## Distribution of **Length of Stay (days)** in Different Ward Classes

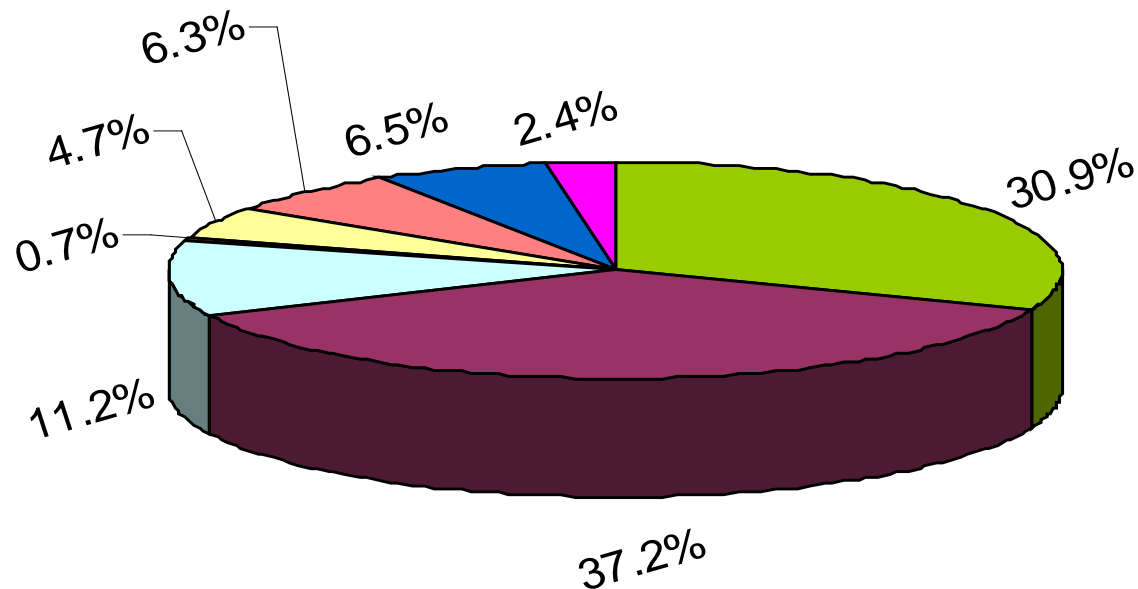
<b>Ward Class</b>	<b>Mean</b>	<b>Median</b>	<b>90<sup>th</sup> Percentile</b>	<b>95<sup>th</sup> Percentile</b>	<b>99<sup>th</sup> Percentile</b>
<b>A</b>	<b>6.9</b>	<b>4</b>	<b>15</b>	<b>25</b>	<b>53</b>
<b>B1</b>	<b>6.4</b>	<b>4</b>	<b>13</b>	<b>20</b>	<b>39</b>
<b>B2+</b>	<b>5.4</b>	<b>3</b>	<b>11</b>	<b>18</b>	<b>36</b>
<b>B2</b>	<b>6.7</b>	<b>4</b>	<b>15</b>	<b>22</b>	<b>44</b>
<b>C</b>	<b>8.6</b>	<b>5</b>	<b>19</b>	<b>28</b>	<b>57</b>
<b>Total</b>	<b>7.3</b>	<b>4</b>	<b>16</b>	<b>24</b>	<b>49</b>

# Actual govt subsidies (%)



# How **net** inpatient expenditure financed

(MSA of patient and family + OOP about 75%)

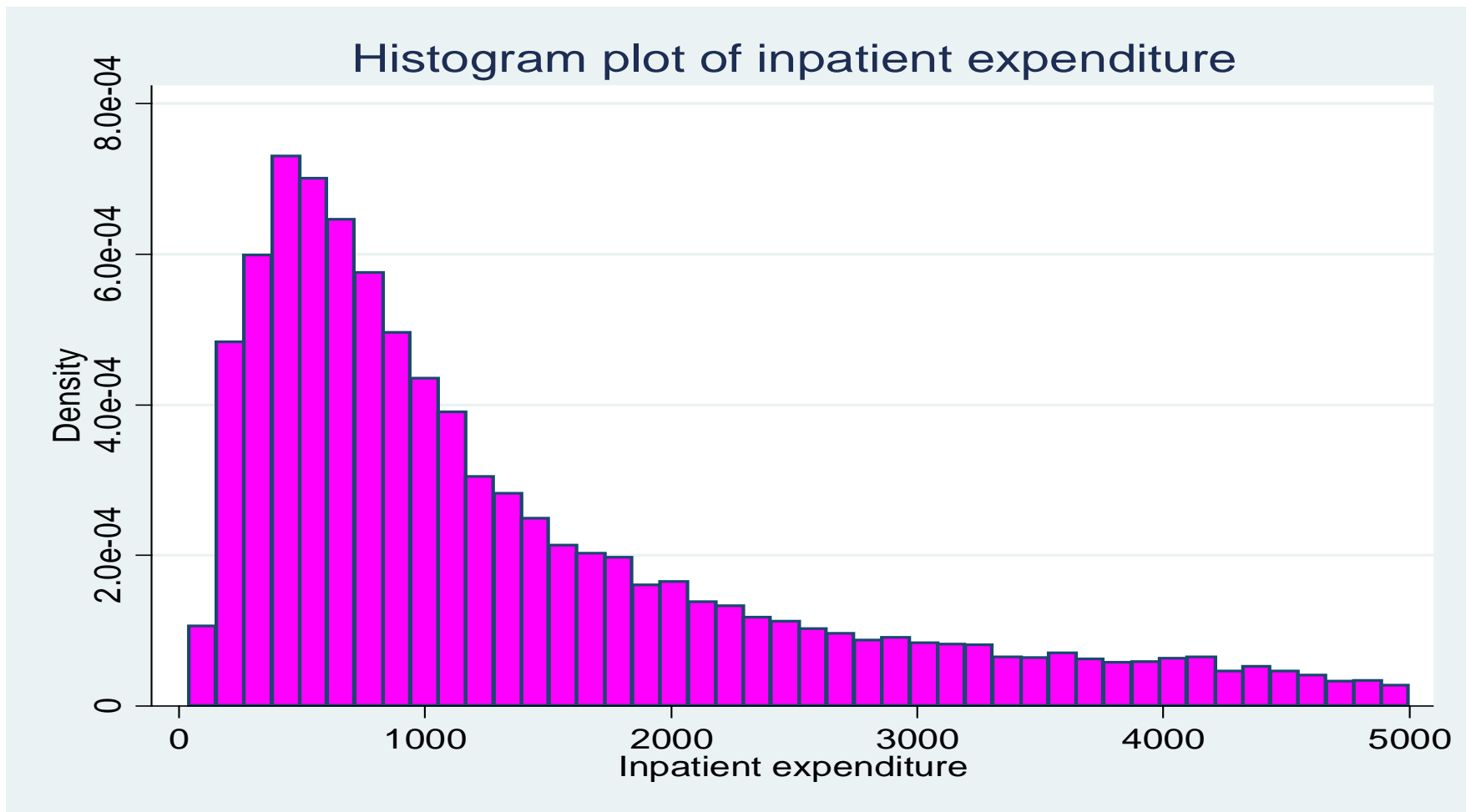


- |                          |                         |
|--------------------------|-------------------------|
| ■ MSA of patient         | ■ MSA of family members |
| ■ Govt. health insurance | ■ Medifund              |
| ■ Pvt. health insurance  | ■ OOP                   |
| ■ MCPS                   | ■ Others                |

# Distribution of net inpatient expenditure

## Tail cut off at \$5,000

Seven cases more than \$100,000. Maximum more than \$200,000



# Modelling the skewed net expenditure distribution

## Pareto and Lognormal distributions

- **Univariate model fitting is common**
- **Conditional distribution fit is not common.**

**This is what we want for predicting the probabilities of extreme bills conditional on diagnosis and other information**

# Pareto distribution

## Univariate Pareto:

$$f_Y(y) = \begin{cases} \alpha y_0^\alpha y^{-(1+\alpha)} & \text{for } y \geq y_0 > 0 \\ 0 & \text{for } y < y_0 \end{cases}$$

$\alpha > 0$  is shape parameter. Lower the value fatter the tail, higher the prob of extreme bills

## Conditional Pareto:

For  $i$ th patient,  $\mathbf{x}_i$  is a vector of covariates such that

$$\alpha(x_i) = \mathbf{x}_i' \boldsymbol{\beta} = X_{i1}\beta_1 + X_{i2}\beta_2 + \dots + X_{ik}\beta_k > 0$$

**ML estimation.**



# Lognormal distribution

**Univariate lognormal:**

$$f_Y(y) = \frac{1}{y\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2\sigma^2}(\ln y - \mu)^2\right], \quad y > 0, \sigma > 0$$

**$\sigma > 0$  is shape parameter.**

**Conditional lognormal:**

$$\sigma(x_i) = x_i' \beta = X_{i1}\beta_1 + X_{i2}\beta_2 + \dots + X_{ik}\beta_k > 0$$

**ML estimation.**

# Pareto-Lognormal comparison

Univariate fits show Pareto distribution over-estimates the right tail and lognormal under-estimates the right tail.  
Overall lognormal fit is bit better than Pareto.

We therefore fit both distributions conditional on covariates and provide a probability range for extreme bills:

Lognormal – lower bound of tail probability

Pareto – upper bound of tail probability

# Estimation of Conditional Lognormal Distribution

<b>INPATIENT EXPENDITURE</b>	<b>COEFF.</b>	<b>ROBUST Z-STAT.</b>
<b>Age 64-69</b>	0.061***	4.79
<b>Age 70-74</b>	0.052***	4.08
<b>Age 75-79</b>	0.035***	2.82
<b>Age 80-84</b>	0.037***	2.74
<b>Female</b>	-0.029***	-3.67
<b>Operation</b>	0.105***	8.08
<b>Implant</b>	0.561***	30.88
<b>Co-morbidities &gt;10</b>	0.087***	9.01
<b>Class A</b>	0.845***	32.18
<b>Class B1</b>	0.638***	31.16
<b>Class B2+</b>	0.072***	2.9
<b>Class B2</b>	0.011	1.2
<b>Dummy for death</b>	0.243***	10.65
<b>MediShield</b>	0.061***	5.1
<b>Pvt. health insurance</b>	0.097***	5.6
<b>Infectious and parasitic diseases</b>	0.122***	4.29

Positive significant coefficient implies more skewed expenditure dist and higher prob of extreme bills

Log likelihood = -256287.71  
Obs. = 30192

\*\*\* significant at 1%  
\*\* significant at 5%  
\* significant at 10%

# Estimation of Conditional Lognormal, contd.

<b>INPATIENT EXPENDITURE</b>	<b>COEFF.</b>	<b>ROBUST Z-STAT.</b>
<b>Malignant neoplasm</b>	0.107***	4.18
<b>Benign neoplasm</b>	-0.052	-1.18
<b>Thyroid gland disorders</b>	-0.107	-1.56
<b>Endocrine gland diseases</b>	0.034	1.03
<b>Nutritional disorders</b>	-0.036	-0.34
<b>Metabolic and immunity disorders</b>	-0.038	-1.32
<b>Blood and blood forming organs</b>	-0.060*	-1.73
<b>Mental disorders</b>	0.109**	2.07
<b>Disorders of central nervous system</b>	0.019	0.51
<b>Disorders of peripheral nervous system</b>	0.012	0.23
<b>Disorders of eye and adnexa disorders</b>	0.755***	13.95
<b>Diseases of ear and mastoid process</b>	0.172***	3.68
<b>Hypertensive diseases</b>	0.232***	5.58
<b>Ischemic heart diseases</b>	0.090***	3.04
<b>Other forms of heart diseases</b>	-0.062**	-2.06

\*\*\* significant at 1%

\*\* significant at 5%

\* significant at 10%

# Estimation of Conditional Lognormal, conted.

<b>INPATIENT EXPENDITURE</b>	<b>COEFF.</b>	<b>ROBUST Z-STAT.</b>
<b>Cerebro-vascular diseases</b>	0.077***	2.63
<b>Other circulatory system diseases</b>	0.061**	2.00
<b>Chronic obstructive pulmonary disease</b>	0.238***	8.43
<b>Other respiratory system diseases</b>	0.038	1.49
<b>Diseases of oral cavity, salivary gland and jaws</b>	0.006	0.04
<b>Gastrointestinal diseases</b>	-0.003	-0.10
<b>Liver, gall and pancreatic diseases</b>	-0.024	-0.74
<b>Urinary disorders</b>	-0.027	-1.02
<b>Genital disorders</b>	-0.174***	-4.64
<b>Congenital anomalies</b>	-0.351***	-4.41
<b>Ill defined conditions</b>	0.272***	10.60
<b>Injury and poisoning</b>	0.142***	5.42
<b>Musculoskeletal diseases</b>	0.173***	5.75
<b>Other diseases</b>	0.178***	4.06
<b>Constant</b>	0.662***	25.61

\*\*\* significant at 1%  
 \*\* significant at 5%  
 \* significant at 10%

## **Some Results from the fitted models**

**Insured have a greater probability of incurring substantial hospital costs**

**MediShield - Self-selection bias (less healthy chose insurance)**

**Pvt. Insurance - Moral hazard problem (over use)**

**Younger elderly compared to older elderly and males compared to females face higher chances of facing higher bills**

**Patients in ward A at max risk of extreme expenses, followed by ward B1 and ward B2+**

**Probability of extreme expenditure is greater in cases of death of patient during illness episode**

# Probability (%) of extreme hospital bills

	> S\$10,000	> S\$30,000	> S\$50,000	> S\$70,000	> S\$90,000	> S\$100,000
<b>Overall</b>	1.02-5.64	0.03-2.00	0.00-1.23	0.00-0.90	0.00-0.71	0.00-0.64
<b>With MediShield</b>	1.70-8.79	0.09-3.65	0.02-2.43	0.01-1.85	0.00-1.52	0.00-1.39
<b>W/o MediShield</b>	0.86-4.87	0.02-1.63	0.00-0.98	0.00-0.70	0.00-0.55	0.00-0.49
<b>With Pvt. insurance</b>	<b>2.86-10.83</b>	<b>0.27-4.85</b>	<b>0.07-3.34</b>	<b>0.03-2.61</b>	<b>0.01-2.17</b>	<b>0.01-2.01</b>
<b>W/o Pvt. Insurance</b>	<b>0.91-5.30</b>	<b>0.03-1.83</b>	<b>0.00-1.12</b>	<b>0.00-0.81</b>	<b>0.00-0.63</b>	<b>0.00-0.57</b>
<b>With malignant neoplasm</b>	1.27-8.32	0.05-3.39	0.01-2.23	0.00-1.69	0.00-1.38	0.00-1.27
<b>W/o malignant neoplasm</b>	0.99-5.35	0.03-1.86	0.00-1.14	0.00-0.82	0.00-0.65	0.00-0.58
<b>With IHD</b>	2.00-8.76	0.13-3.63	0.03-2.41	0.01-1.84	0.00-1.51	0.00-1.39
<b>W/o IHD</b>	0.95-5.42	0.03-1.89	0.00-1.16	0.00-0.84	0.00-0.66	0.00-0.60
<b>With musculoskeletal dis</b>	<b>5.55-13.99</b>	<b>0.98-6.88</b>	<b>0.37-4.94</b>	<b>0.18-3.97</b>	<b>0.10-3.38</b>	<b>0.08-3.16</b>
<b>W/o musculoskeletal dis</b>	<b>0.85-5.30</b>	<b>0.02-1.83</b>	<b>0.00-1.12</b>	<b>0.00-0.81</b>	<b>0.00-0.63</b>	<b>0.00-0.57</b>
<b>With injury</b>	2.00-8.06	0.13-3.24	0.03-2.12	0.01-1.61	0.00-1.31	0.00-1.20
<b>W/o injury</b>	0.96-5.49	0.03-1.92	0.00-1.18	0.00-0.86	0.00-0.67	0.00-0.61
<b>With other circulatory dis</b>	1.09-5.80	0.04-2.07	0.01-1.28	0.00-0.94	0.00-0.74	0.00-0.67
<b>W/o other circulatory dis</b>	1.02-5.64	0.03-1.99	0.00-1.23	0.00-0.89	0.00-0.71	0.00-0.64

# Summary Results

## **Prob(expenditure >S\$10,000):**

**With Pvt. Insurance: 2.9% - 10.8%.**

**With MediShield, 1.7% - 8.8%**

**For uninsured, 0.9% - 5.3%**

**Musculoskeletal diseases: 5.6% - 14%**

**Malignant neoplasm: 1.3% - 8.3%**

**Coronary diseases: 2% - 8.8%**

**Injuries: 2% - 8.1**

**Without any of these conditions, for other: 0.85% - 5.6%**



# Musculoskeletal Diseases: Prob (%) of extreme bills by ward class and age

	Age Group	> S\$10,000	> S\$30,000	> S\$50,000	> S\$70,000	> S\$90,000	> S\$100,000
Ward A	64-69 yrs	14.30-32.45	5.90-21.61	3.64-17.89	2.58-15.79	1.97-14.39	1.75-13.84
	70-74 yrs	14.99-37.25	6.44-26.07	4.06-22.09	2.93-19.80	2.27-18.25	2.03-17.64
	75-79 yrs	13.15-24.11	5.05-14.42	2.99-11.36	2.06-9.70	1.54-8.63	1.35-8.21
	80-84 yrs	13.24-31.81	5.12-21.03	3.04-17.35	2.10-15.28	1.57-13.90	1.38-13.36
	>84 yrs	<b>9.12-13.99</b>	<b>2.54-6.88</b>	<b>1.25-4.94</b>	<b>0.75-3.97</b>	<b>0.50-3.38</b>	<b>0.42-3.16</b>
Ward B1	64-69 yrs	12.86-35.38	4.84-24.30	2.84-20.41	1.94-18.19	1.44-16.70	1.26-16.11
	70-74 yrs	13.25-39.78	5.12-28.51	3.04-24.42	2.10-22.05	1.57-20.44	1.38-19.79
	75-79 yrs	11.87-30.60	4.17-19.95	2.35-16.35	1.56-14.34	1.13-13.01	0.98-12.48
	80-84 yrs	9.34-22.26	2.65-12.94	1.32-10.05	0.80-8.51	0.54-7.52	0.46-7.14
	>84 yrs	<b>6.30-17.91</b>	<b>1.25-9.62</b>	<b>0.50-7.21</b>	<b>0.26-5.96</b>	<b>0.16-5.17</b>	<b>0.13-4.87</b>
Ward B2	64-69 yrs	4.31-13.13	0.60-6.31	0.20-4.48	0.09-3.58	0.05-3.03	0.03-2.82
	70-74 yrs	3.98-12.06	0.51-5.61	0.16-3.93	0.07-3.11	0.04-2.61	0.03-2.43
	75-79 yrs	2.68-8.99	0.23-3.77	0.06-2.51	0.02-1.92	0.01-1.58	0.01-1.45
	80-84 yrs	2.05-7.87	0.14-3.14	0.03-2.05	0.01-1.55	0.00-1.26	0.00-1.15
	>84 yrs	<b>0.50-6.07</b>	<b>0.01-2.21</b>	<b>0.00-1.38</b>	<b>0.00-1.01</b>	<b>0.00-0.80</b>	<b>0.00-0.73</b>
Ward C	64-69 yrs	3.65-9.31	0.43-3.95	0.13-2.65	0.05-2.04	0.03-1.67	0.02-1.54
	70-74 yrs	3.18-8.35	0.33-3.40	0.09-2.24	0.04-1.70	0.02-1.39	0.01-1.27
	75-79 yrs	1.60-6.08	0.08-2.21	0.02-1.38	0.00-1.01	0.00-0.80	0.00-0.73
	80-84 yrs	1.65-8.06	0.09-3.25	0.02-2.13	0.00-1.61	0.00-1.31	0.00-1.20
	>84 yrs	<b>0.41-4.08</b>	<b>0.01-1.29</b>	<b>0.00-0.75</b>	<b>0.00-0.53</b>	<b>0.00-0.41</b>	<b>0.00-0.36</b>

# Malignant Neoplasm: Prob (%) of extreme bills by ward class and age

	Age Group	> S\$10,000	> S\$30,000	> S\$50,000	> S\$70,000	> S\$90,000	> S\$100,000
Ward A	64-69 yrs	9.53-19.89	2.76-11.10	1.39-8.46	0.85-7.08	0.58-6.19	0.49-5.85
	70-74 yrs	9.35-19.05	2.66-10.46	1.32-7.92	0.80-6.59	0.54-5.75	0.46-5.43
	75-79 yrs	8.91-15.40	2.43-7.83	1.18-5.72	0.70-4.65	0.47-3.99	0.39-3.74
	80-84 yrs	8.51-16.89	2.22-8.89	1.05-6.59	0.62-5.41	0.40-4.67	0.34-4.40
	>84 yrs	8.77-19.23	2.35-10.60	1.13-8.04	0.67-6.70	0.44-5.84	0.37-5.52
Ward B1	64-69 yrs	7.19-21.44	1.61-12.29	0.70-9.49	0.38-8.01	0.24-7.05	0.19-6.68
	70-74 yrs	7.09-21.46	1.57-12.31	0.68-9.51	0.37-8.02	0.23-7.06	0.19-6.69
	75-79 yrs	6.99-18.46	1.52-10.03	0.65-7.55	0.35-6.26	0.22-5.45	0.18-5.14
	80-84 yrs	6.44-20.47	1.30-11.54	0.53-8.84	0.28-7.42	0.17-6.50	0.13-6.16
	>84 yrs	6.31-18.30	1.25-9.91	0.50-7.45	0.26-6.17	0.16-5.36	0.13-5.06
Ward B2	64-69 yrs	0.75-7.24	0.02-2.80	0.00-1.80	0.00-1.35	0.00-1.09	0.00-0.99
	70-74 yrs	0.74-7.44	0.02-2.91	0.00-1.88	0.00-1.41	0.00-1.14	0.00-1.04
	75-79 yrs	0.62-7.04	0.01-2.70	0.00-1.73	0.00-1.29	0.00-1.03	0.00-0.94
	80-84 yrs	0.62-8.14	0.01-3.29	0.00-2.16	0.00-1.63	0.00-1.33	0.00-1.22
	>84 yrs	0.31-6.85	0.00-2.60	0.00-1.66	0.00-1.23	0.00-0.99	0.00-0.90
Ward C	64-69 yrs	0.64-5.57	0.01-1.96	0.00-1.21	0.00-0.88	0.00-0.69	0.00-0.63
	70-74 yrs	0.75-5.81	0.02-2.08	0.00-1.29	0.00-0.94	0.00-0.74	0.00-0.67
	75-79 yrs	0.53-5.67	0.01-2.01	0.00-1.24	0.00-0.90	0.00-0.71	0.00-0.65
	80-84 yrs	0.51-5.89	0.01-2.12	0.00-1.31	0.00-0.96	0.00-0.76	0.00-0.69
	>84 yrs	0.41-5.63	0.01-1.99	0.00-1.23	0.00-0.89	0.00-0.70	0.00-0.64

# Summary Results

## Musculoskeletal disease

Face highest risk of catastrophic expenditure.

Prob(expenditure >S\$10,000) : 13.8% - 27.9% in ward A &  
2.2% - 7.2% in ward C.

Even in lower ward classes, there is a slight probability of hospital costs > S\$30,000 & >S\$50,000, especially for younger elderly.

Oldest old face the smallest likelihood of extreme expenditure

## Malignant neoplasm

Prob(expenditure >S\$10,000) : 9.2% -18.1% in ward A &  
0.6% - 5.7% in ward C.

For higher threshold expenditure (>S\$30,000), probability range is 2.6%-9.8% in ward A, 0-2.9% in ward B2 & 0-2% in ward C.

# What more needs to be done

- Obtain data over different years covering more ages and examine how stable the slope coefficients are. As health care costs increase the intercept is expected to shift.
- If slope coefficients are stable and only intercept shifts occur then figure out how the intercept is related to average bill size.
- Then come up with an easy to use excel worksheet that the hospitals can use to inform patients about expected bill size given the diagnosis and other info.
- Since subsidy structure is likely to change, model gross expenditure and then factor in subsidies.

