SAPHIR – SAfety Preferences for Health-Related Industrial Risks

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SAPHIR: How to do benefit cost analysis (BCA) of catastrophic risks?

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- Example: Evaluation of a public project (e.g., a new power plant)
    i. Construction cost
    ii. Benefit (e.g., low-cost energy, less CO_2 emissions)
    iii. The possibility of a catastrophe?

- How to value the possibility of a big accident as opposed to many small accidents?

Two risky social situations: *A* and *B*

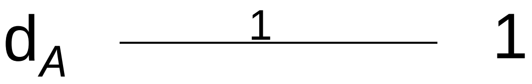
A society with two individuals *i*, and two equiprobable states *s*:

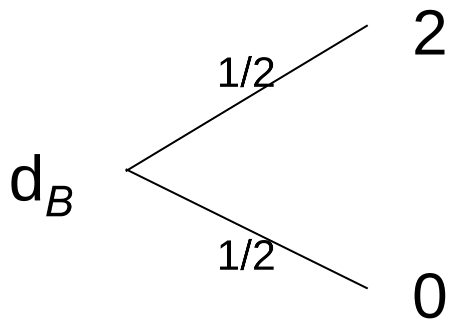
« 1 »: dead
« 0 »: alive

A	i=1	i=2
s=1	1	0
s=2	0	1
p_i	1/2	1/2

B	i=1	i=2
s=1	1	1
s=2	0	0
p_i	1/2	1/2

Distribution of fatalities:





Situation B is « more catastrophic » than situation A

Note that the expected number of fatalities is the same in A and B

Is BCA catastrophe-averse?

- No, standard BCA is catastrophe neutral
  - In the previous example: Each individual *i* faces an individual probability of dying $p_i = 1/2$ in both situations *A* and *B*
  - Standard BCA is based on individual WTP, and thus only depends on individual risk (and not on the risks of others)

Regulatory agencies' practices

- Some regulatory agencies display catastrophe aversion
  - Higher weighting for big accidents using « frequency-number lines » used in the UK, Norway, Switzerland and the Netherlands (Evans & Verlander 1997, Rheinberger 2010)
  - The disutility of N lives lost in a single accident is a function of N^{α} with $\alpha > 1$ (Slovic et al. 1984, Bedford 2013)

- But, these practices raise conceptual questions:
  - Are these practices well grounded conceptually?
  - How to compare in the same setting different criteria (e.g., the cost, the number of lives saved) to catastrophe aversion?

Catastrophe averse or prone?

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- Catastrophe averse: The U.S. President and Vice President do not travel together on Air Force One in order to avoid what is called a “decapitation strike”

- Catastrophe prone: Schelling (1968, in “The life you save may be your own”)
    - *« If a family of four must fly, and has a choice among four aircraft, of which it is known that one is defective but not known which one, it should be possible to persuade them to fly together. The prospects for each individual’s survival are the same, no matter how they divide themselves among the aircraft, but the prospect for bereavement are nearly eliminated through the correlation of their prospects. Society’s interest, in support of the family’s interest, should be to see that they are permitted and encouraged to take the same plane together. »*

Are we catastrophe averse?

- No, based on survey studies
  - Neither lay people nor hazard experts display catastrophe aversion (Jones-Lee & Loomes 1995, Rheinberger 2010)

Which of these two roads would you protect from avalanches?

	Road A	Road B
Expected accidents during 20 years	4	2
Expected number of fatalities per accident	3	6
I would protect:	❑ Road A	❑ Road B

Fig. 1. Example of one choice task faced by a part of the participants.

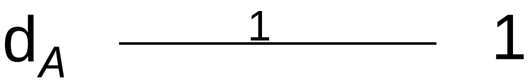
Source: Rheinberger (2010)

Catastrophe aversion is in conflict with risk equity!

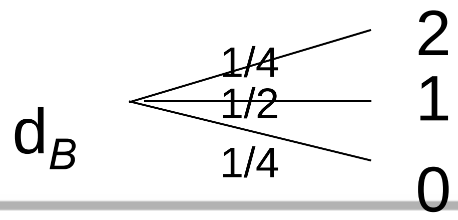
- Under independent risks more risk equity always induces a more catastrophic situation, and vice versa (Keeney 1980)

- A simple example illustrating Keeney's result:

A	i=1	i=2
s=1	1	0
s=2	1	0
s=3	1	0
s=4	1	0
p_i	1	0



B	i=1	i=2
s=1	1	1
s=2	1	0
s=3	0	1
s=4	0	0
p_i	1/2	1/2



The research paper: dependent risks

The paper essentially addresses two questions:

1. Does **« more risk dependence »** induce a « more catastrophic » situation?

2. Allowing for risk dependence, does **« more risk equity »** induce a « more catastrophic » situation? (i.e., Keeney's question)

Source: Carole Bernard, Christoph Rheinberger and Nicolas Treich, 2014, "*Catastrophe aversion and risk equity under dependent risks*". See at: http://www2.toulouse.inra.fr/lerna/treich/indextreichd.htm

More catastrophic, and more variable

- **Definition 1 (« more catastrophic »)**
  - **A distribution of fatalities d_A is more catastrophic than a distribution d_B iff for any concave function $f(.)$, $Ef(d_A) \leq Ef(d_B)$**
- **Definition 2 (« more variable »)**
  - **A distribution of fatalities d_A is more variable than a distribution d_B iff $var(d_A) \geq var(d_B)$**
- Remark: Def. 1 is simply Rothschild & Stiglitz (1970)'s def. applied to the distribution of fatalities in the population

A preview result

- **Proposition 1: Under N=2, the four following statements are equivalent:**
  i. **The probability of simultaneous deaths increases**
  ii. **The correlation ρ between the individual risks increases**
  iii. **The distribution of fatalities is more catastrophic (definition 1)**
  iv. **The distribution of fatalities is more variable (definition 2)**

- Simple proof, using:
  - Proba (simultaneous deaths)= $p_1 p_2 + \rho\, [p_1(1-p_1)p_2(1-p_2)]^{1/2}$
  - $var(d)= p_1(1-p_1)+ p_2(1-p_2) + 2\rho\, [p_1(1-p_1)p_2(1-p_2)]^{1/2}$

Intuition: initial example

A society with two individuals *i*, and two equiprobable states *s*:

« 1 »: dead
« 0 »: alive

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B	i=1	i=2
s=1	1	1
s=2	0	0
p_i	1/2	1/2

Distribution of fatalities:

Situation B is « more catastrophic » than situation A

An example where Keeney's result fails

A	i=1	i=2
s=1	1	1
s=2	1	0
s=3	1	0
s=4	1	0
s=5	0	1
s=6	0	0
s=7	0	0
s=8	0	0
p_i	1/2	1/4

$\rho_A = 0$

Equity-increasing risk transfer δ=1/8

B	i=1	i=2
s=1	1	0
s=2	1	0
s=3	1	1
s=4	0	1
s=5	0	1
s=6	0	0
s=7	0	0
s=8	0	0
p_i	3/8	3/8

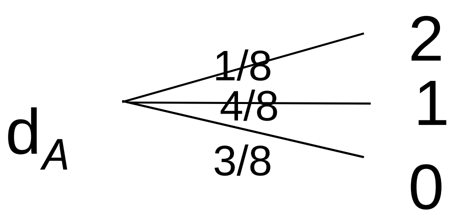
$\rho'_B = -0.06$

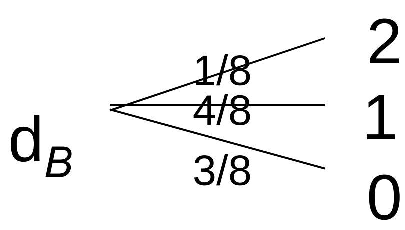
C	i=1	i=2
s=1	1	0
s=2	1	0
s=3	1	0
s=4	0	1
s=5	0	1
s=6	0	1
s=7	0	0
s=8	0	0
p_i	3/8	3/8

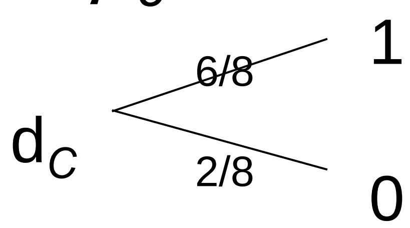
$\rho'_C = -0.6$

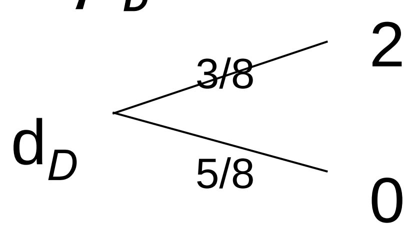
D	i=1	i=2
s=1	1	1
s=2	1	1
s=3	1	1
s=4	0	0
s=5	0	0
s=6	0	0
s=7	0	0
s=8	0	0
p_i	3/8	3/8

$\rho'_D = +1$









Conclusion

- **Motivation**: Catastrophic risks (e.g., storms, industrial accidents, terrorist attacks) are dependent social risks

- **The research paper:** Examines the relationship between « more catastrophic », « more dependent » and « more equitable » risks?

- **Two more deliverables**: Literature survey on catastrophe aversion + Implications for risk management

- **Broader research program**: Optimal safety provision in a setting sensitive to (risk) equity and/or catastrophe aversion