The Ground for Negotiation: Zoning for Risk Reduction around Hazardous Plants

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2018 World Health Organisation Report
CHEMICAL RELEASES CAUSED BY NATURAL HAZARD EVENTS AND DISASTERS

WHO report in short

- Over the past 100 years of industrialization many chemicals have been buried in riverine, estuarine and coastal sediments
- Normally safe buildings and sites are concerned
- Difference between natural and man-made disasters is blurred
- Climate change contributes to the blurring, not the only factor
- Local history and conditions matter

BUT

- Nothing about liability in the report
- Nothing about prevention
- Not much on drought and heatwaves (focus on chemicals)
- All about description of risk, consequences and organization of intervention

Ajka

- Ajka alumina sludge spill: industrial accident at caustic waste reservoir chain
- Particularly wet summer
- On 4 October 2010, Northwestern corner reservoir #10 collapsed, freeing approximately 1 million cubic meters of liquid waste from red mud lakes
- Mud was released as a 1-2 m wave, flooding several nearby localities
- Ten people died — 150 people were injured
- About 40 square kilometers of land were affected

An ugly view of Ajka alumina sludge spill

A beautiful view of Ajka alumina sludge spill

Toulouse fertilizer plant after explosion

France, AZF, September 2001.

Toulouse fertilizer plant

Toulouse agglomeration has encircled the plant

France, ONIA/AZF plant and neighborhoods in the 1930's and in 2001

Red zones

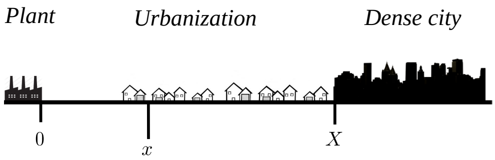
- To contain their liabilities, industrialists can purchase or rent land, establishing a red zone (private way)
  Example. In Louisiana, the Dow Chemical company in 1991 paid for a whole village of 300 inhabitants to move out of the vicinity of one of its plants
- The state also can delimit red zones (building forbidden or limited) (public way)
- **In practice**, red zones result from negotiation between the mayor and the firm
- Extending the red zone reduces total cost of risk but crowds households at the same time

Liability, insurance, and urbanization: all is entangled

- **Land-use regulation and insurance impact household location choices**
  If lax land-use regulation and insurance do not price the risk
  $\Rightarrow$ households locate inefficiently in exposed areas

- **Household location choices determine the cost of risk borne by the economy**
  Locating in exposed areas without paying for the cost
  $\Rightarrow$ external effect on the community or the firm
- **All in a linear urban model where people choose where they live**

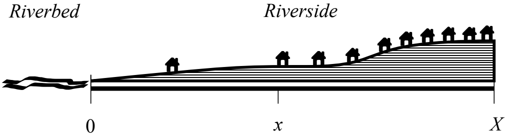
Space and risk



Risk

$p(x) = \rho \cdot f(x)$	loss prob. at x where ρ is a risk factor (comp. stat.)
$\lambda_S \cdot s$	part of damage proportional to surface held
λ_F	fixed part of damage per house

Space and risk



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Households

Households

- N people (a continuum of infinitesimal households)
- Same income
- Utility function: $U(z, s)$
  z: composite good
  s: housing surface
- Risk averse

Rent

- No opportunity cost for land: in empty areas, rent is null
- Rents are redistributed

Industrial disasters

Liability

- Firm fully responsible
- Limited liability assumed away
  (with limited liability households would be more careful)
- "Curse of unlimited liability": people unrestrained to inflict an external effect to the firm

Good quality of compensation is assumed

- Instantaneous repairs
- Works exactly like complete insurance

Markets and regulation of various types could restore efficiency

- How?
- Comparative statics?
- Predictions and recommendations?

Natural disasters

Liability

- No firm — or firm totally irresponsible
- "Curse of unlimited liability": people unrestrained to inflict an external effect to society = free-riding

Good quality of compensation is assumed

- Instantaneous repairs
- Works exactly like complete insurance

Markets and regulation of various types could restore efficiency

- How?
- Comparative statics?
- Predictions and recommendations?

Equilibrium

Households compete for space with the firm

- We endogenize density, rents, risk exposure/cost of risk
- People maximize their objectives given prices
- Budget constraints: individual, insurance sector, state
- Global resource constraints: space, correlated risk

Implementing the first best

Proposition

- Actuarial insurance pricing implements a Pareto optimum
- Density decreases with respect to risk
- Most risky locations can be unoccupied

- Actuarial insurance internalizes risk externalities
- Finely defined limitation of population density could also work
- In both cases, high informational cost

Red zone

- Firm does not need red zones per se but only to avoid it being occupied by potential victims
- Households value less the exposed areas than the firm does
- Opening markets for land creates value

Markets for red zones

Firm game. Firm holds bargaining power: it chooses rent and transfer to the community (two-part tariff)

Market game. Households and firm both price takers. Red zone determined by the equilibrium on land market

Mayor game. Mayor holds bargaining power. He sets rent for households and rent (possibly different) for firm

Natural/Integrated. The community pays for the risk (all is internalized by the mayor)

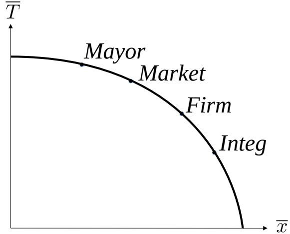
Sizing red zones

- x is the size of the red zone
- T is the monetary transfer from the firm to the people

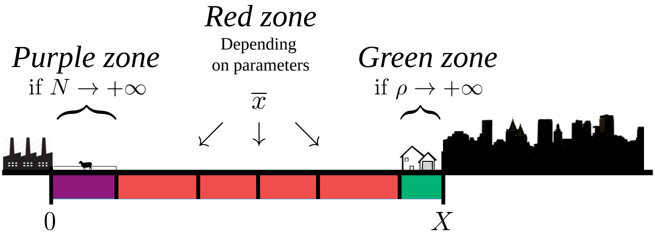
Proposition

The "richer" households are, the more expensive it is to "squeeze" them and the smaller the red zone is

$$x^*_{\text{Int}} \geq x^*_{\text{Firm}} \geq x^*_{\text{Market}} \geq x^*_{\text{Mayor}}$$



Purple and green zones



Green zone: a preserved space for households when $\rho \to +\infty$.
People may be forced instead onto safest place X.

Purple zone: a preserved red zone as $N \to +\infty$.
Otherwise it vanishes completely.

Examples

- Illustrate variety of theoretical predictions for increase in N
- Red zone expands as ρ increases in all scenarios
- Comparative statics of ρ and N around the basic scenario:

$$U(z, s) \text{ some simple form} \tag{1}$$

$$p(x) = \rho \cdot (X - x) \tag{2}$$

$$X = 1, \quad \lambda_F = 1, \quad \lambda_S = 1, \quad \alpha = 1, \quad \omega = 1.5 \tag{3}$$

  Note that $x = X = 1$ is safe
- Closed-form expressions for red zones in all scenarios

First example

Take a Cobb-Douglas utility function:

$$U(z, s) := \log(z) + \alpha \log(s)$$
$$p(x) := \rho \cdot (X - x)$$

Effect of risk intensity ρ

	Variations	Green zone $\lim x^*$ as $\rho \to +\infty$
x^*_{Mayor}	$\nearrow$	$\leq \frac{1}{1+\alpha} X$ (†)
x^*_{Market}	$\nearrow$	$\frac{1}{1+\alpha} X$
x^*_{Firm}	$\nearrow$	None
x^*_{Integ}	$\nearrow$	None

(†) More precisely, $\lim_{\rho \to +\infty} x^*_{\text{Mayor}} =$

$$X - \frac{(1+\alpha)}{2(2+\alpha)} \frac{\lambda_F N}{\lambda_S} \left(\sqrt{1 + 4 \frac{\alpha(2+\alpha)}{(1+\alpha)^2} \frac{\lambda_S X}{\lambda_F N} \left(\frac{\lambda_S X}{\lambda_F N} + 1 \right)} - 1 \right)$$

Effect of risk intensity ρ

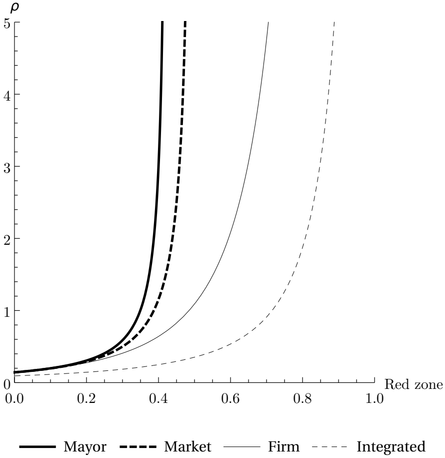


Figure: With $N = .1$, log-log and linear loss probability)

Effect of population N

$$\rho^2 \lambda_F^2 \,\overline{x}^2 - 4\alpha(\alpha+2)\omega\rho\lambda_F \,\overline{x} - 4\alpha(\alpha+2)\omega^2 > 0 \qquad \text{(COND)}$$

	Variations		Purple zone $\lim x^*$ as $N \to +\infty$
x^*_{Mayor}	if (COND) if not (COND)	$\nearrow$ $\searrow$	$\max\{\frac{1}{1+\alpha}X - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\}$
x^*_{Market}	$\searrow$		$\max\{\frac{1}{1+\alpha}X - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\}$
x^*_{Firm}	$\searrow$		$\max\{X - (\frac{2\alpha\omega X^\alpha}{\rho\lambda_F})^{\frac{1}{1+\alpha}}; 0\}$
x^*_{Integ}	$\searrow$		$\max\{X - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\}$

Effect of population N

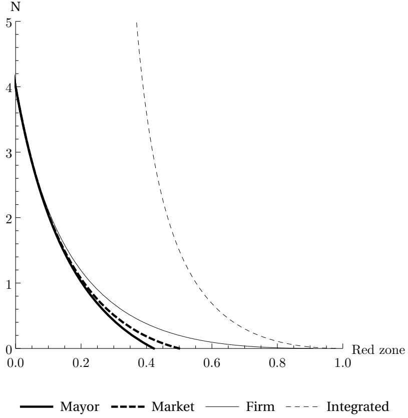


Figure: With $\rho = 2$.(COND) is true

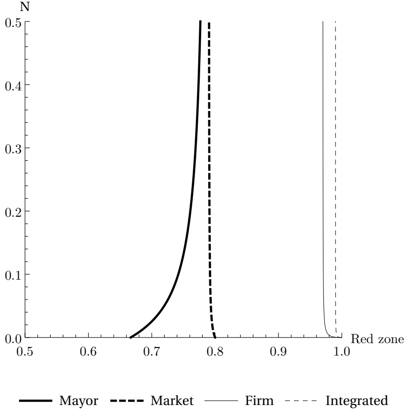


Figure: Parameters: $X = 1$, $\lambda_F = 5$, $\lambda_S = 0.3$, $\alpha = 0.25$, $\omega = 0.25$. (COND) is false

Second example

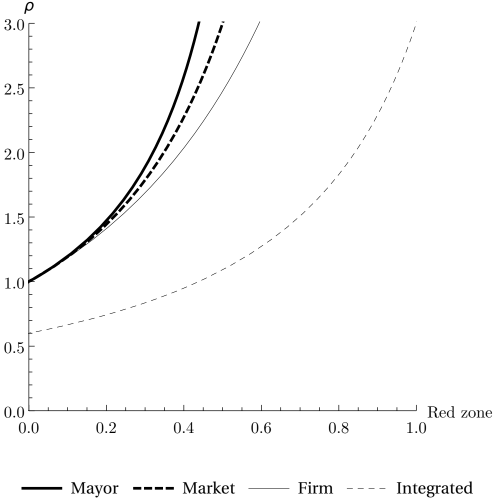
We take now a quasi-linear utility function:

$$U(z,s) := \log(z) + \alpha\ s$$
$$p(x) := \rho \cdot (X - x)$$

Effect of risk intensity ρ

	Variations	Green zone $\lim x^*$ as $\rho \to +\infty$
x^*_{Mayor}	$\nearrow$	$\leq X$
x^*_{Market}	$\nearrow$	$\leq X$
x^*_{Firm}	$\nearrow$	None
x^*_{Integ}	$\nearrow$	None

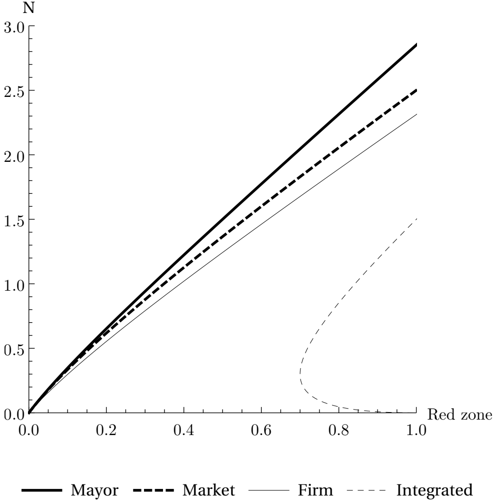
Effect of risk intensity ρ



Effect of population size N

	Variations	Purple zone $\lim x^*$ as $N \to +\infty$
x^*_{Mayor}	$\nearrow$	X
x^*_{Market}	$\nearrow$	X
x^*_{Firm}	$\nearrow$	X
x^*_{Integ}	$\searrow$ then $\nearrow$	X

Effect of population N



Final remarsk

- Public and private risk managements matter for insurance
- Liability law matters
- Frontiers between natural and industrial disasters are blurred
- Maps are critical public goods
- Decisions matter for a very long time

Return