Natural and Industrial Disasters: Land Use and Insurance

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Paris, 25 October 2013

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Disasters

France, Xynthia, February 2010.

France, AZF, September 2001.

A study of major risks

Our questions

- How do insurance and urbanization policies interact?
- What is the impact of liability rules on this interaction?

Our framework

- Urban model
- Perfect information
- Risk averse households
- Insured households

Liability, insurance and urbanization

- *Liability determines household insurance.*

Disasters	Liability	Household insurance
Natural	Community	State insurance
Industrial	Firm	Free insurance

- *Household insurance impacts household location choices.*
  If the insurance does not price the risk, households locate in exposed areas

- *Household location choices determine the cost of risk borne by the liable party.*
  By locating in exposed areas, households create externalities on the community / firm

Examples

France, Xynthia, February 2010. Source: Reuters

In France, natural disasters insurance does not price the risk. Households locate in flood plains.

France, ONIA/AZF plant and neighborhoods in the 1930's and in 2001. Source: IGN

We want to assess the public policies and the firm's strategies to limit these external effects

Literature

Urban economics and risk

- Theoretical urban models:
  Fujita and Thisse (2002), Tatano et al. (2004)
  With insurance: Frame (1998), Frame (2001)
- Applications of the hedonic prices method:
  Natural risks: Harrison et al. (2001), Bin et al. (2008)
  Industrial risks: Sauvage (1997), Travers (2007)

Insurance and prevention

- Insurance and mitigation of natural disasters: Picard (2008)
- Law and economics: Sanseverino-Godfrin (1996), Shavell (1982), Demougin and Fluet (2007)

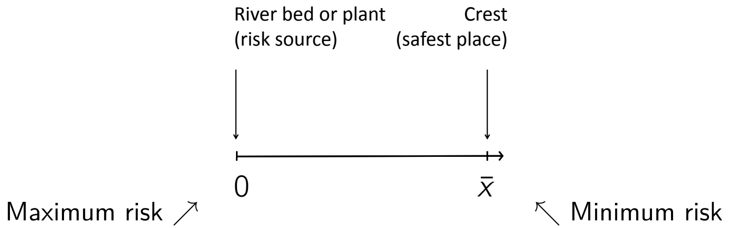
Timing

Stage 1: Regulation
Restrictions are imposed on insurance tariffs and (in some versions) on land use

Stage 2: Markets
Insurers choose a pricing in these tariffs

Stage 3: Individual choices
Households decide their location

Space and risk (1/2)



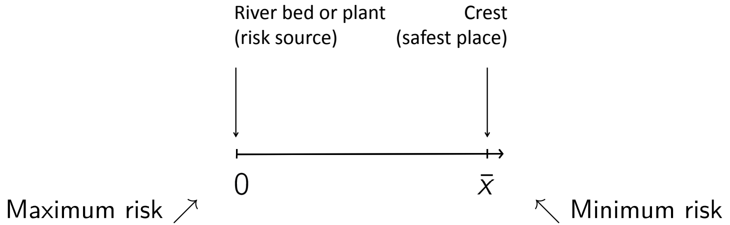
Space

- Surface per house at each location
- Density of households
- Space constraints: local and global

Risk

- Loss probability depends on location
- Cost of damage depends on location and surface used

Space and risk (2/2)



Risk

$p(x) = \rho \cdot f(x)$ probability of loss at x

$\lambda_S \cdot s$ part of damage proportional to surface held

λ_F fixed part of damage per house

Insurance

Good quality is assumed

- Instantaneous repairs
- Complete insurance

Natural disasters: state insurance

- Risk correlated inside a community. Mutualization between numerous communities $\Rightarrow$ we assume risk neutrality
- Insurance premium depends on location and surface used
- Zero profit

Industrial disasters: free insurance by the firm

- Risk neutrality of the firm
- Firm identified and solvent

Households

Households

- Same income
- Risk averse and insured households
- Utility function: $U(z, s)$
  Concave with respect to the quantity of the composite good z and to housing surface s

Rent

- No opportunity land cost. In empty areas, rent is null
- Rents are redistributed

Equilibrium

Households compete for space and less risky locations

- Density, rents, risk exposure, insurance prices
- Budget constraints: individual, insurance sector, state
- Liability rules:
  - Natural disasters: state insurance
  - Industrial disasters: free insurance by the firm

Actuarial insurance

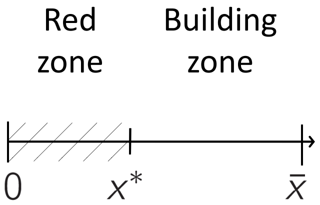
Proposition

Actuarial insurance pricing implements a Pareto optimum

- Trade-off between insurance cost and land price
- Actuarial insurance internalizes risk externalities
- Finely defined limitation of population density could also work
- In both cases, high informational cost

Uniform insurance

The building zone is fully and uniformly used
⇒ The government defines a red zone



Definition: constrained optimality

A red zone is said to be *constrained-optimal* if it is Pareto optimal under the constraint that land use by households is uniform

Second-best efficiency of red zone

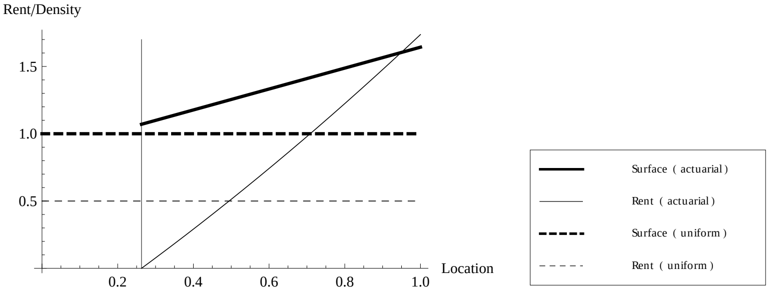
CR: total expected cost of risk

Proposition

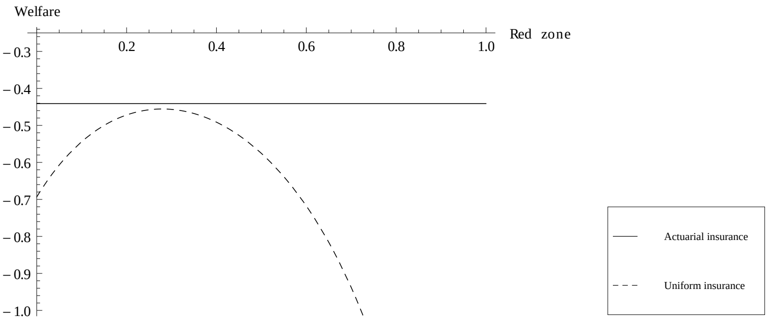
The constrained-optimal red zone x^* maximizes the utility. For an interior solution $x^* \in (0, \bar{x})$, x^* equals the marginal risk reduction (MRR) with the marginal rate of substitution (MRS) of households.
For corner solutions, the MRR is smaller (respectively larger) than the MRS if $x^* = 0$ (respectively $x^* = \bar{x}$)

The constrained-optimal red zone is denoted x^*_{Nat}

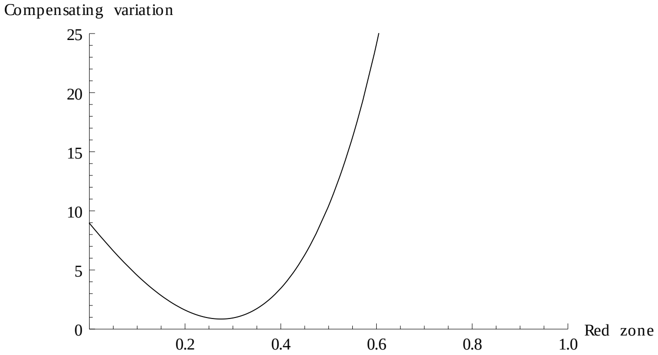
Equilibria with actuarial rates and uniform rates



Welfare as a function of the Red Zone



Compensating variation (percentage of initial wealth)



Refining policy zoning (1/3)

- Risk classification rather gross in practice
- Insurers use simple maps delineating location-based risk segments (same tariff for all in zone)
- Policy zoning shapes durably real estate market and insurance

Definition: policy zoning

A policy zoning is a partition of space in zones such that building is either prohibited or authorized on each zone; if zone is authorized, premium is uniform and actuarial zone-wise

Examples: uniform insurance with a red zone; actuarial insurance

Refining policy zoning (2/3)

Definition: refinement

Policy zoning Z_2 is a refinement of policy zoning Z_1 if every zone of Z_2 is a subset of a zone of Z_1 and is authorized if it belongs to an authorized zone of Z_1

Z_2 is a further fragmentation of Z_1 and building prohibition is (weakly) less restricted

In this sense, Z_2 is finer than Z_1

Refining policy zoning (3/3)

Proposition

Refining the policy zoning is Pareto improving

Proof

Consider two policy zonings, Z_2 being finer than Z_1. $\hat{p}(\cdot)$ is the unique function such that, for every zone of the partition Z_2, $\hat{p}(\cdot)$ is constant over this zone and equals the mean of $p(\cdot)$ over this zone. Z_2 is the actuarial zoning for $\hat{p}(\cdot)$ and so leads to a Pareto optimum. Z_1 imposes additional constraints and thus can only lead to a Pareto inferior allocation

Economics and politics of transition towards finer maps

- Fine policy zoning requires costly risk assessment
- Optimal insurance fineness (in the long run) somewhere between uniform and actuarial insurance
- Transition requires destructions and reconstructions
- Short term costs and benefits likely to dominate public debate
- In the short term, people only see their insurance premium increase or decrease
- Lengths of impacted zones key for majority acceptance

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

Markets and regulation of various types could restore efficiency

- How?
- Comparative statics?
- Predictions and recommandations?

Implementation

Implementing the first best

- Location-dependent taxes
- Finely defined limitation of population density could also work
- Both solutions are informationally demanding

Red zones

- Firm does not need this red zone 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
- Households are landowners: they are likely to benefit from red zones but to an extent that depends on market organization

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

- Firm game: the firm directly captures all the surplus. Indeed, utility guarantee deprives in effect households of the exchange gains
- Market game: the created value is partly recovered by households via rents
- Mayor game: the created value is entirely recuperated by households

Red zones are denoted x^*_{Firm}, x^*_{Market} and x^*_{Mayor}

Second-best efficiency of red zones

Proposition

For the three games, the equilibrium allocation (T_i^*, x_i^*) is constrained optimal and is the solution of

$$\begin{cases} x_i^* = 0 & \text{and } \mathrm{MRR}(0) \leq \mathrm{MRS}_{sz}\left(\omega + \frac{T_i^*}{N}, \frac{\bar{x}}{N}\right) & \text{or} \\ x_i^* \in (0, \bar{x}) & \text{and } \mathrm{MRR}(x_i^*) = \mathrm{MRS}_{sz}\left(\omega + \frac{T_i^*}{N}, \frac{\bar{x}-x_i^*}{N}\right) & \text{or} \\ x_i^* = \bar{x} & \text{and } \mathrm{MRR}(\bar{x}) \geq \mathrm{MRS}_{sz}\left(\omega + \frac{T_i^*}{N}, 0\right), \end{cases} \quad (1)$$

where the net transfer T_i^* from the firm to households is

$$T^*_{\text{Firm}} \text{ such that } U\left(\omega + \frac{T^*_{\text{Firm}}}{N}, \frac{\bar{x} - x^*_{\text{Firm}}}{N}\right) = U\left(\omega, \frac{\bar{x}}{N}\right) \quad (2)$$

$$T^*_{\text{Market}} = rx^*_{\text{Market}} \text{ where } r = \mathrm{MRS}_{sz}\left(\omega + \frac{rx^*_{\text{Market}}}{N}, \frac{\bar{x} - x^*_{\text{Market}}}{N}\right), \quad (3)$$

$$T^*_{\text{Mayor}} = \mathrm{CR}(0) - \mathrm{CR}(x^*_{\text{Mayor}}). \quad (4)$$

For the firm game and the mayor game, the equilibrium allocation is unique.

Sizing red zones

Proposition

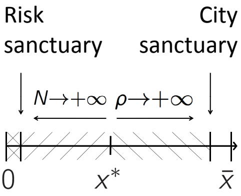
The “richer” households are, the more expensive it is to “squeeze” them and the smaller the red zone is

$$x^*_{\mathrm{Nat}} \geq x^*_{\mathrm{Firm}} \geq x^*_{\mathrm{Market}} \geq x^*_{\mathrm{Mayor}}$$

Sanctuaries

Variations and limits of the size of the red zone with respect to

- ρ: risk intensity
- N: demographic pressure

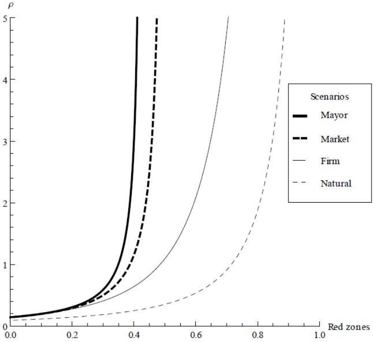


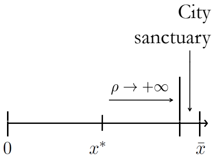
Sizing red zones

Effect of risk change in the case of a log-log utility function and a linear loss probability

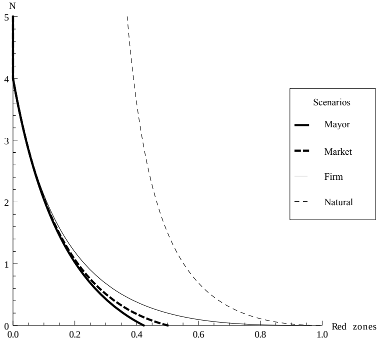
	Variations w.r.t. ρ	Variations w.r.t. N	Risk sanctuary $\lim_{N\to+\infty} x^*$	City sanctuary $\lim_{\rho\to+\infty} x^*$
x^*_{Nat}	$\nearrow$	$\searrow$	$\max\left\{\bar{x} - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\right\}$	$\bar{x}$
x^*_{Firm}	$\nearrow$	$\searrow$	$\max\left\{\bar{x} - \left(\frac{2\alpha\omega\bar{x}^{\alpha}}{\rho\lambda_F}\right)^{\frac{1}{1+\alpha}}; 0\right\}$	$\bar{x}$
x^*_{Market}	$\nearrow$	$\searrow$	$\max\left\{\frac{1}{1+\alpha}\bar{x} - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\right\}$	$\frac{1}{1+\alpha}\bar{x}$
x^*_{Mayor}	$\nearrow$	$\searrow$ or $\nearrow$	$\max\left\{\frac{1}{1+\alpha}\bar{x} - \frac{2\alpha}{1+\alpha}\frac{\omega}{\rho\lambda_F}; 0\right\}$	$\lim_{\rho\to+\infty} x^*_{\mathrm{Mayor}} < \bar{x}$

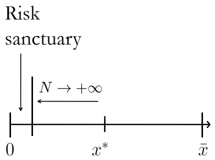
Red zones as a function of ρ and city sanctuaries





Red zones as a function of N and city sanctuaries





Natural disasters. The optimal policy zoning is a trade-off between information cost and long-term benefits

Industrial disasters. Red zones depend on market organization. Key role of mayor

Comparative statics. Red zones increase with respect to in risk parameters. Important exceptions depending on the nature of the parameter, risk structure and market organization

New Orleans, August 2005 after Hurricane Katrina.

Source: Colligan Worldpress

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