

Methodological economic assessment of Tsunamis impact in the Mediterranean area

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0. Objects and objectives

- This paper is an interdisciplinary on-going research between geologists, earth observation scientists and economists,
- Methodological reflexion about how integrate the physical aspects and economic consequences of tsunamis is needed, this to avoid « *ad hoc* » economic modelization which is always detrimental to interdisciplinary approaches.
- Thus, the goals, that is to say the final objectives, of this paper are the following ones:

0. Objects and objectives

- Evidences of the occurrence of potential catastrophic tsunamis in the Mediterranean area are quite strong and the question of how to deal with them is raised.
- The present study is an attempt to supply an economic methodology to assess economic and financial consequences for Tsunami occurrence in The Mediterranean area.
- The economic methodology needs an economic assessment of the economic losses induced by a tsunami occurrence.
- Hence, this research has the objectives:

0. Objects and objectives

- First, to **supply an economic assessment** of vulnerability (based on the actualization of flows of the different sources of income generated on the considered area).
- Second to **define the costs of prevention**. This will be made by applying real options models,
- Third, to define **the market organisation** of insurance linked securities to have a clear idea of what may be insured by private insurance and how national solidarity may evolve in the future to cover catastrophic events.

0. Objects and objectives

- Collaboration with other sciences is necessary to define realistic and probable scenarios about the occurrence of tsunamis.

- Geist and Parsons (2006) :

"Probabilistic analysis of tsunamis is therefore not only important in determining an annualized risk as with insurance applications, but it is also important in explicitly defining the probability associated with individual scenarios."

1. Preventive action or precautionary principle?

- Tsunamis risk may be defined. So preventive actions could be undertaken without referring to the precautionary principle

BUT

- Tsunamis have a paradoxical status because they are under-evaluated by decision makers in most coastal countries, because of its very probability (perhaps)
- Consequently, we need to refer to the **precautionary principle** to enforce and implement preventive measures

1. Preventive action or precautionary principle?

- Why is it relevant to associate tsunamis with the precautionary principle ?
- Tsunamis combines two fundamental components of the precautionary principle
 - ***Uncertainty***
 - ***Irreversibility***

(this point is developed in my paper)

1. Preventive action or precautionary principle?

- The weakest version of the precautionary principle suggests that
 - *"a lack of decisive evidence of harm should not be a ground for refusing to take preventive action".*
- The 1992 Rio Declaration is more stringent and states,
 - *"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

2. Real Option Theory applied to tsunamis: methodological precautions

- ❑ Investing in prevention policy is typically a public decision with irreversible consequences: real options theory is relevant "*En principe*",
- ❑ That needs assessing the cost of flexibility based on newer risk measures and more sophisticated determination of the forecast risks.
- ❑ An economic analysis of the impact of tsunami of a coastal area involves defining both the set of prevention policies and their effective costs.

2. Real Option Theory applied to tsunamis: methodological precautions

- **Usual models used for this kind of analysis:**
 - Statistical/actuarial models, where past experience is used to estimate the consequence of future events,
 - Physical models, where, for example, the consequence of a landslide or submarine earthquake is estimated from a scaled down model in a laboratory,

2. Real Option Theory applied to tsunamis: methodological precautions

- Simulation or catastrophe models, depending on computer simulations of events which include pre-determined parameters and physical constraints for example in weather forecasts.
- Catastrophe models tend to make use of statistical and formulated physical models.

2. Real Option Theory applied to tsunamis: methodological precautions

- Risk is a complex function of time and space. Hazards can appear in a quasi-instantaneous way:
 - *The probability of occurrence of an event can change in time. The occurrence of a hazard can have short, medium and long term consequences,*
 - *Vulnerability and capacity have specific temporal dynamics. Their effects are not produced in a simultaneous way and a given hazard can have a local, regional or global impact.*

2. Real Option Theory applied to tsunamis: methodological precautions

- Under uncertainty, variances often do not provide adequate risk measures. Experience with financial risk measurement shows that using variances or covariances may underestimate (and in some cases overestimate) the actual risk by a sizeable factor.
- The emphasis is now on extreme behaviour which is often measured using value-at-risk, shortfall, etc. in the upper tail and lower tail separately. This matter of fact involves using Poisson or Levy process.

2. Real Option Theory applied to tsunamis:methodological precautions

- These new forms of risk measurement should be useful tools to assess risk in situations that go beyond financial or third-party risk.
- This is particularly true because life support networks composed of civil infrastructure are closely linked together.

2. Real Option Theory applied to tsunamis: methodological precautions

- Here options may be considered as the financial amount that should be invested to protect the whole area.
- This activity depends on several factors:
 - One may consider direct activity associated to industry, agriculture, tourism and all commercial activities. This is linked with our direct costs assessment. This has to be assessed by local data supplied by national institutes.

2. Real Option Theory applied to tsunamis: methodological precautions

- However, if a tsunami may have direct consequences, BUT indirect ones may be expected too.
- Network and transport infrastructures are very sensitive about it.
- A tsunami may paralyse the activity of an economic zone broader than that where the tsunami impact was exerted.
- They can be grouped according to the following categories (Isenberg 1991; Lau 1995):

2. Real Option Theory applied to tsunamis: methodological precautions

- Electricity (generation, transportation, distribution infrastructure, etc.)
- Natural gas and liquid fuels (storage, transportation, distribution infrastructure, etc.)
- Potable water and wastewater (collection, treatment, storage, transportation, distribution infrastructure, etc.)
- Telecommunications (broadcasting, cable transmission, distribution infrastructure, etc.)
- Transportation (road systems, public transportation systems, etc.).

2. Real Option Theory applied to tsunamis: methodological precautions

- *Direct and indirect costs (DC) (IC) and Long term economic costs*
 - Direct impacts and costs of a catastrophe are closely connected to the hazards (e.g. storms surges, commercial and industrial structures, public buildings, commercial and industrial structures, public buildings, water and waste treatment facilities, power generation or transmission facilities, communication facilities, automobiles, equipment of all types, bridges and surge, high winds, rain), and the resulting physical damage Pielke (1997).

2. Real Option Theory applied to tsunamis: methodological precautions

- Short term costs come from losses that occur at the time of the event. They may be compensated quite quickly, while long term costs are incurred far after the catastrophe. They include permanent job loss for the population and loss of tax revenues for the State and the region.
- Economic categorization may be assessed following the economic activity of the considered area: tourism, housing, industrial and commercial activities.
- Other hidden costs have to be added as household and family cost, health cost and natural ecosystems failure... Generally these costs are underestimated, by they may weight heavily on the recovery policies.

2. Real Option Theory applied to tsunamis: methodological precautions

- *Tsunami is a kind of catastrophic risk which is characterised by insurability.*
 - *In particular, if insurance offers temporal diversification, the insurance sector usually doesn't offer a sufficient geographic diversification for catastrophe risk. Gollier, (1997)*
 - *Solvency implies to ban temporal diversification.*

2. Real Option Theory applied to tsunamis: methodological precautions

- This involves to follows two goals:
 - The first one examines how reinsurance coupled with new financial instruments and perhaps civil state can expand coverage to resident people in areas subject to catastrophic losses;
 - The second shows how reinsurance and new financial instruments can be combined so that the price of protection can be lowered from its current level

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- A tsunami may be induced by different physical causes some of them are recurrent as for instance earthquake causes, or very hazardous for human temporality as asteroid, etc.
- Every origin of tsunami may induce different probability distribution. Japanese made great improvement in the analysis of tsunami hazard from volcanic activity Acharya (1989), (1990), Rikitake and Aida (1988).
- Previous work was brought by Iida, Cox, and G. Pararas-Carayannis (1967) or Newhall and Self (1982),

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- The main difficulty with tsunami lies in the fact that their sources of occurrence are several. To deal with an unified view with this point we will refer to the Geist and Parsons (2006) view.
- The object here is to define a methodology that may induce an economist to choose scientific pre-determined probability distribution by geo-physician rather than "*ad hoc*" distributions to describe a tsunami occurrence.

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- Building distribution probabilities from geophysical data Geist and Parsons (2006) consider three main sources of Tsunami:
 - Far-field seismogenic tsunamis,
 - Asteroid-impact tsunamis,
 - Landslide tsunamis.
 - Each of them has some impact on the probability distribution

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- *Geist and Parsons (2006) assume that a tsunami phenomenon follows a Poissonian arrival time process and the probability that a tsunami with amplitude h_c or greater occurring in time period T is given by the exponential function*

$$P(r, T, h_c) = 1 - \exp[-\lambda(r, h_c)T]$$

3. The needs of probabilistic tsunamis assessment analysis for real option theory

$$\lambda(r, h_c)$$

- The represents the rate or number of tsunamis per year at which wave heights are exceeded at a coastal location
- r : expresses both the magnitude of the source and distance between the source and site.
- h_c given amplitude of the tsunami

3. The needs of probabilistic tsunamis assessment analysis for real option theory

These three potential sources involve

The definition of three probability distributions

$$\lambda(r, h_c) = \begin{cases} 10^{a+bM} & \text{(a)} \\ n(r, s) & \text{(b)} \\ \text{empirical} & \text{(c)} \end{cases}$$

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- (a) are far-field seismogenic tsunamis, and

$$10^{a+bM}$$

represents the Gutenberg-Richter distribution,

- where M is the earthquake magnitude and a and b given parameters,
- (b) for the asteroid tsunamis, represents the annual impact rate per square meter of ocean for bodies of variable radii,
- (c), the landslides, parameters are considered as empirically distributed and highly randomly stochastic.

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- Let be a variable $x(t)$ corresponding to a given index of activity (global income) on a determined coastal area.
- $x(t)$ is a stochastic quantity varying in time. Following traditional methodology in analysing investment under uncertainty, see Dixit and Pyndick (1994), we can assume that $x(t)$ follows a geometric Brownian motion.

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- Thus, the continuous movement of $x(t)$ in time will be combined when tsunami appear with down jumps. Injuries are by definition rare events and therefore a Poisson process J seems to be appropriate to model the jumps. Thus, the movement of a given activity index is a combination of a continuous component described by a geometric Brownian motion and an infrequent component described by a Poisson process

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- The brownian geometric function that expresses the evolution of activity under tsunami threat is

$$dx(t) = \underbrace{ax(t)dt + \sigma x(t)dz(t)}_{\text{continuous}} + \underbrace{g(x, t)dJ}_{\text{discrete}}$$

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- Where a is the rate of growth of the index;
- $dz(t)$ is a Wiener process with zero mean and variance equal to dt ;
- and σ^2 is the variance of $dx(t)/x(t)$.
- For the discrete part, $g(x, t)$ is a function that affects in a pre-specified manner the change $dx(t)$ over periods of time dt only if an injury occurs during that time interval, otherwise it has no effect.
- The jump process J is a Poisson process with rate of arrival of events λ . This means that during a very small interval of time dt an event can occur with probability λdt , in which case there is a jump of size u , or the catastrophic event will not occur and the probability of this is $1 - \lambda dt$.

3. The needs of probabilistic tsunamis assessment analysis for real option theory

- Then the model has to be solved according the probability distribution linked to the tsunami event that has to be considered.

4. CONCLUSION

- ❑ Even if Tsunamis are rare events, their consideration is necessary.
- ❑ They show us the limits of non intervention in the planning of coastal zones.
- ❑ Their permanent threat should be a guide-line for coastal planning.
- ❑ This result is concordant with the conclusions of other presentations that emphasize the impact of over-crowded coastal areas and the consequent increase in their vulnerability.