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L'assicurazione del rischio idrogeologico: una valutazione economico-finanziaria di strategie resilienti

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Research motivation

The description of possible strategies that a public administration can put in place to deal with hydrogeological risk:

- an absolute passivity (paying damages as they occur)
- a standard insurance scheme
- a resilient and innovative insurance scheme

Multidisciplinary approach:

- the regulatory framework
- hydraulic engineering expertise
- actuarial schemes
- the (potential) role of IT in various steps of the risk mitigation process

Agenda

1. Hydrogeological risk in Europe and in Italy
2. The regulatory framework for managing risks for p.a's: Sustainable Energy and Climate Action Plan (SECAP)
3. Engineering expertise
4. A quantitative comparison among different risk management strategies
5. A numerical example (based on data of hydrogeological risk in Italy)
6. I.T.'s role (big data, blockchain, smart contracts)
7. Conclusions and further research

1) Hydrogeological risk in Europe (climate extreme events)

European Environment Agency

“Between 1980 and 2019, climate-related extremes caused economic losses totalling an estimated EUR 446 billion in the EEA member countries. … climate-related extremes are becoming more common and, without mitigating action, could result in even greater losses in the coming years. The EU adaptation strategy aims to build resilience and ensure that Europe is well prepared to manage the risks and adapt to the impacts of climate change, thus minimising economic losses and other harms.”

The average annual (inflation-corrected) losses were around EUR 6.6 billion in 1980-1989, 12.3 billion in 1990-1999, 13.2 billion in 2000-2009 and 12.5 billion in 2010-2019.

Around 27 % of total losses were insured, although this also varied considerably among countries, from 1 % in Romania and Lithuania to 60 % in Belgium and Liechtenstein.

1) Hydrogeological risk in Italy: the state of the art

«Istituto per la Protezione e la Ricerca Ambientale» (ISPRA), 2018’s report

- 91% of italian municipalities is at risk (88% in 2015), more than 3 milions of families (more than 7 millions people)

- 20.808 franes in an area of 23.700 km^2, 7,9% of national territory

- 600.000 business units (12,4% of the total), more than 2 milions workers

- Cultural heritage: 38.000 goods, 40.000 monuments in franes area (more than 31.000 in floodable area even in medium probability scenarios)

- 9 regions (Valle D’Aosta, Liguria, Emilia-Romagna, Toscana, Umbria, Marche, Molise, Basilicata e Calabria) 100% of municipalities are at risk

1) Hydrogeological risk in Italy: costs for public administrations

Various sources of information.

- From 2013 to 2019 the **total damage for franes and floods in Italy is 20,3 billions, for an average of almost 3 billions each year**: the regions most affected have been Emilia-Romagna, Campania, Toscana, Abruzzo, Liguria.
- **Anbi** (Associazione nazionale dei consorzi per la gestione e tutela del territorio e acque irrigue) has presented a report focused on the reduction of hydrogeological risk in Italy ‘Manutenzione Italia – Azioni per l’Italia sicura’ in which it is stated that « … a cost of 2,5 billions each year is the cost for the hydrogeological risk»**.**
- **Only 10% of damages was reimbursed by the State Government** to regions: in the period (2013-2019), for estimated 20,3 billions of damages, only **2,07 billions were reimbursed.**
- “Natural disaster in Italy: evolution and economic impact”, a research by Prometeia, **states that the total cost suffered for franes and floods from 1945, is 160 (so more than 2 billions each year).**

1) Hydrogeological risk in Italy: prevention financing

Various sources of information.

- In the period 2013 - 2019 expenses for prevention were 2,1 billions, roughly 10% of the total damage.
- With the DPCM 20/2/2019 a hydrogeological risk mitigation national plan is approved: the amounts allocated were 11 billions for the period 2019-2021.
- Even PNRR provides investments for further 8,5 billions.
- Report ReNDiS by ISPRA: in 20 years the Environment Ministry has spent almost 7 billions for more than 6000 projects. The same report states that on the platform for monitoring the risk mitigative projects, the amount needed is for further 36 billions.
- Another source states that 26 billions can be the amount needed for completing the defense from hydrogeological risk.

Total damage, amount allocated by the, ratio allocation/damages, expenses for prevention, ratio expenses on damages (period 2013-2019):

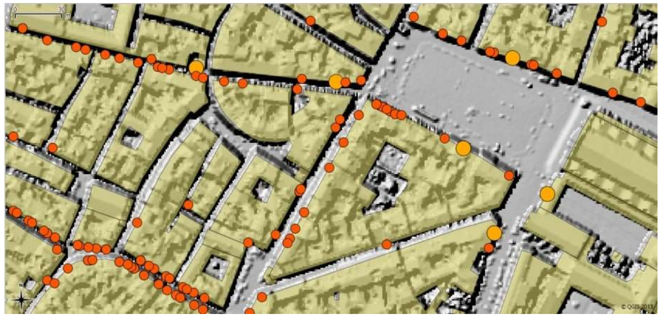
Regions	Damages	Amounts allocated	% All./Dam.	Exp for Prev.	% Exp./Dam.
Emilia-Romagna	€ 2,424,497,964.66	€ 202,561,573.11	8.35%	€ 159,352,270.92	6.57%
Campania	€ 1,808,047,930.56	€ 61,117,531.40	3.38%	€ 87,749,078.72	4.85%
Toscana	€ 1,802,219,554.15	€ 230,343,112.36	12.78%	€ 198,397,799.79	11.01%
Abruzzo	€ 1,772,062,188.25	€ 74,896,793.36	4.23%	€ 111,069,118.18	6.27%
Liguria	€ 1,712,026,540.07	€ 109,909,194.41	6.42%	€ 338,591,861.76	19.78%
Veneto	€ 1,695,911,743.75	€ 133,801,727.53	7.89%	€ 151,933,863.19	8.96%
Marche	€ 1,485,055,994.46	€ 69,497,985.90	4.68%	€ 59,457,088.30	4.00%
Puglia	€ 1,481,682,788.50	€ 55,407,270.85	3.74%	€ 83,827,798.27	5.66%
Piemonte	€ 1,274,290,764.98	€ 159,747,919.40	12.54%	€ 108,260,946.92	8.50%
Calabria	€ 976,641,426.25	€ 50,887,769.43	5.21%	€ 51,481,669.93	5.27%
Lazio	€ 890,255,735.93	€ 49,314,891.23	5.54%	€ 54,494,309.32	6.12%
Sicilia	€ 733,479,176.60	€ 80,495,533.42	10.97%	€ 158,287,955.17	21.58%
Sardegna	€ 682,741,449.81	€ 55,163,043.27	8.08%	€ 86,457,993.78	12.66%
Basilicata	€ 480,709,404.43	€ 55,006,087.71	11.44%	€ 51,975,729.09	10.81%
Lombardia	€ 422,399,590.63	€ 32,284,471.66	7.64%	€ 188,726,946.47	44.68%
Molise	€ 412,910,828.70	€ 12,317,599.64	2.98%	€ 57,873,422.61	14.02%
Umbria	€ 213,311,593.17	€ 15,397,252.32	7.22%	€ 31,733,515.91	14.88%
Valle d'Aosta	€ 22,522,571.00	€ 11,110,077.34	49.33%	€ 5,476,667.87	24.32%
Friuli Venezia Giulia	€ 0.00	€ 4,000,000.00		€ 63,302,801.29	
Trentino Alto Adige	€ 0.00	€ 0.00		€ 27,676,900.75	
Total	**€ 20,290,767,245.90**	**€ 1,786,266,157.07**	8.80%	**€ 2,076,127,738.24**	

1) Hydrogeological risk in Italy: insurance market

- Catastrophe insurance is quite rare in Italy, only 4.5% of properties are insured against natural disasters (landslides, floods and earthquakes) and only 2% against floods.
- A Greenpeace report states that taking out insurance against extreme events has become the last resort for citizens exposed to the risk of a disaster. “In the situation we live in in Italy, with outdated structures and a changing climate, insurance is becoming more and more important. For example, for those who live near a landslide or in an area subject to flooding, private insurance should be mandatory".
- The solution, for ANIA is a public-private partnership: to avoid that insuring those who are really in danger is too expensive, we need a compulsory insurance system controlled and controlled by the state. “Most of the countries, European and non-European, which like ours have a territory with a high seismic / hydrogeological risk, have implemented a compulsory or semi-compulsory national coverage scheme ".

Different scales of risk assessment: urban micro scale (Florence)

OpenData
I dati aperti del Comune di Firenze



Vertical distribution of the value

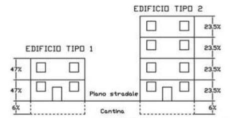
Development of Stage-damage curves D%=D(h)

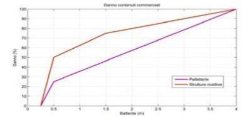
Flood depth mapping for census units

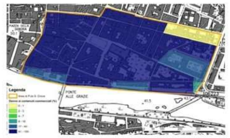
Damage assessment (%)

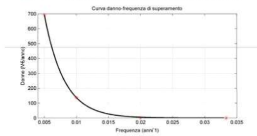
Economic assessment and Monetary damage (€/m²)

Risk assessment (€/year·m²)

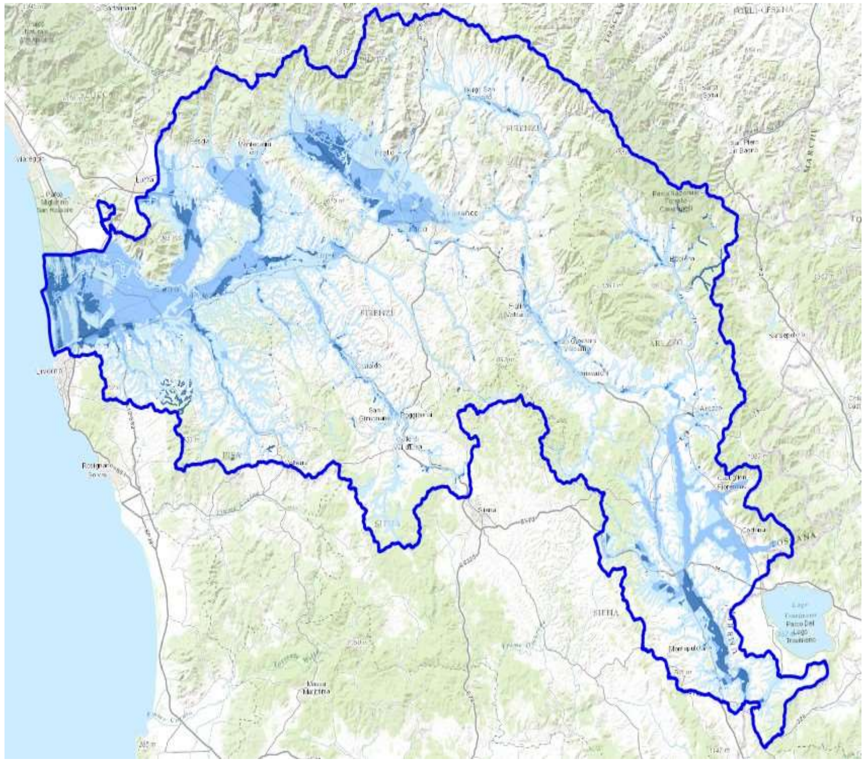


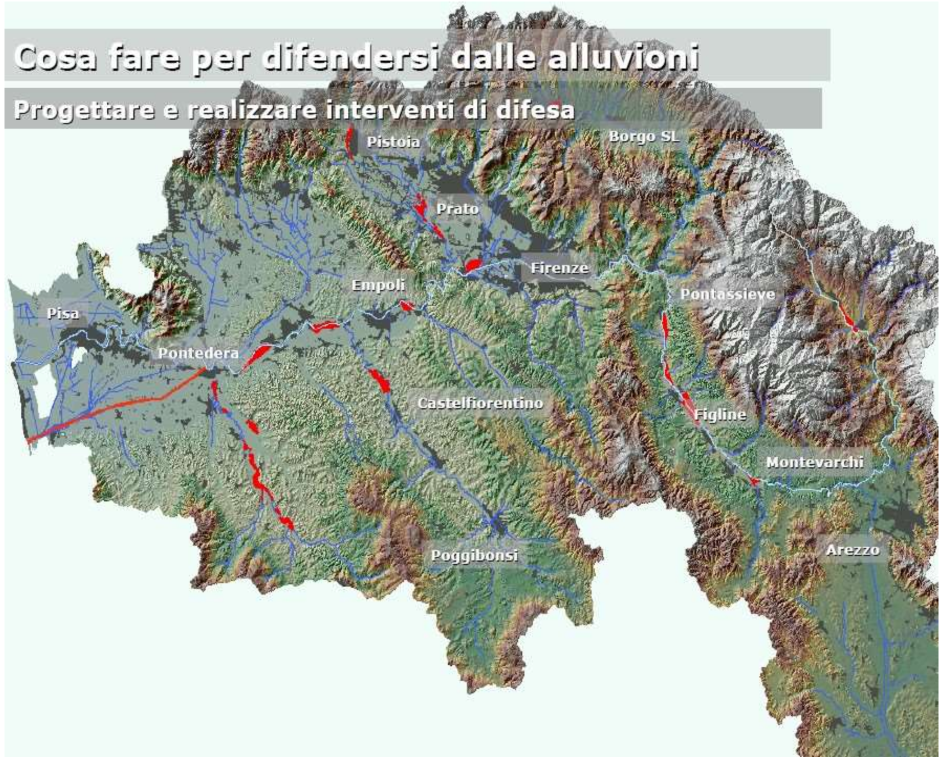






Different scales of risk assessment: basin scale (Arno river)





2) The regulatory framework for managing risks for p.a's: Sustainable Energy and Climate Action Plan (SECAP)

The regulatory framework: SECAP Covenant of Mayors for Climate and Energy (2008) is a voluntary-based initiative focused on the proactive role of local authorities for making territories (more) resilient to the impacts of climate change, produced Sustainable Energy and Climate Action Plan (SECAP) in 2015

One key point of the SECAP is Risk and Vulnerability Assessment (RVA), which is an analysis of the relevant risks and vulnerabilities, by analyzing climate hazards and assessing vulnerability (of urban sectors):

1. Municipal buildings, equipment/facilities
2. Tertiary (non-municipal) buildings, equipment/facilities
3. Residential buildings
4. Transport.

3) Engineering expertise

- Risk assessment and costs-benefits (in terms of mitigation respect the original level of risk) of the infrastructures that could be used for hydrogeological risk mitigation (embankments, dams, expansion tanks, ...)

- Within this process is required the risk assessment through engineering modeling, including the estimation of potential losses before and after the realization of a mitigation project and the overall costs and the time required to build the mitigative infrastructures.

Obs. The assessment of risk reduction by engineering expertise, could be an hard task, since it cannot be evaluated using historical series of damages (the mitigative infrastructures did not exist before).

4) A quantitative comparison among different risk management strategies

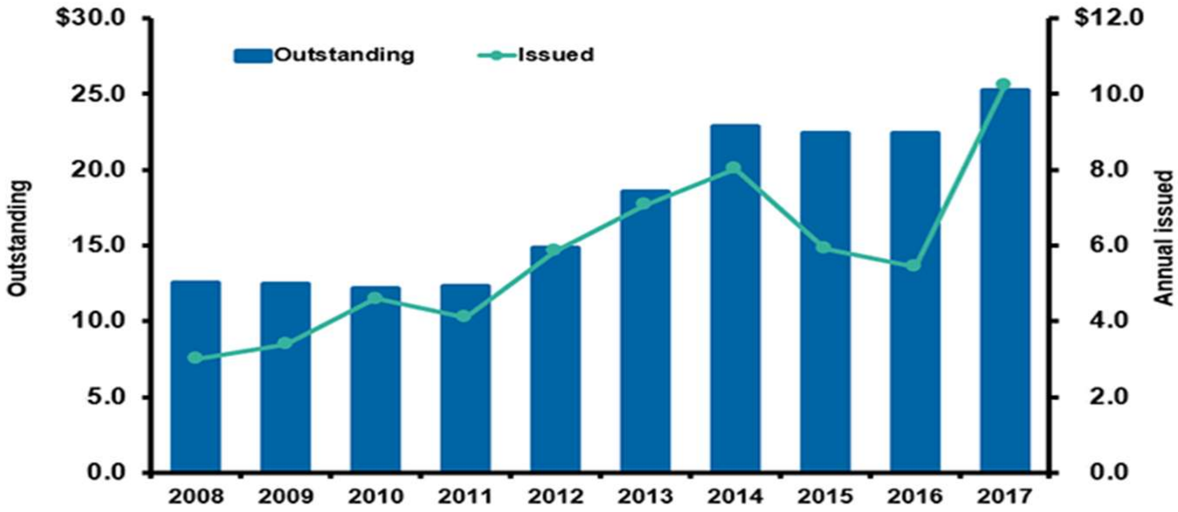
Three different strategies for dealing with hydrogeological risk by the public administration:

1) the **passive strategy**, provides for the payment of damages as they occur,

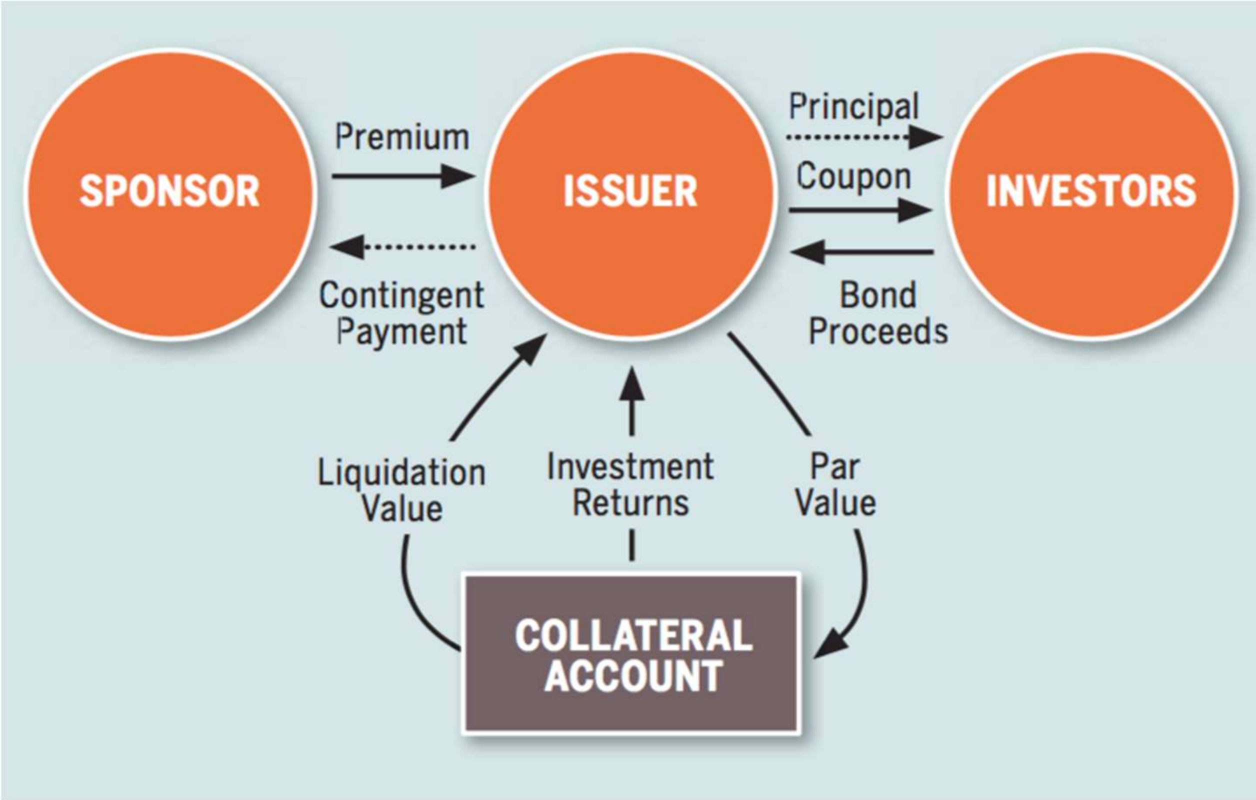
2) the **standard insurance strategy** (even with Cat Bond schemes),

3) the **innovative insurance resilient strategy**, combining the standard insurance scheme with the financing of mitigative infrastructures, which will reduce risk exposure once completed.

Catastrophe Bonds, Risk Capital Outstanding And Annual Issued, 2008-2017(US$ billions)



Cat Bonds cash flows scheme



4.1) The model of risk exposure

• $X(h)$, i.i.d for $h = 1, 2, \dots$ yearly random payment for hydrogeological damages, with $\forall h$ d.f. $f(X) = f(X(h))$, and $E[X^r]$, for $r = 1, 2, \dots$

• Insurance premium $P = g(f(X)) > E[X]$
we assume a full coverage of the damages by the insurance contract

• $v = (1+i)^{-1}$ annual discount rate.

Obs. We may consider trends in yearly damages due to climate change process.

4.2) The model for risk reduction

Mitigative infrastructure with cost W and completion time n which provides that the r.v. which describes the yearly damage for following years is X_R such that

$$E[X_R] < E[X] \qquad \text{and} \qquad \sigma[X_R] < \sigma[X]$$

from which for the insurance premium with the same function g, it holds

$$g(f(X_R)) = P_R < P.$$

Obs. The assessment of risk reduction by engineering expertise, could be an hard task, since it cannot be evaluated using historical series of damages (the mitigative infrastructures did not exist before).

4.3) Passive strategy

Passive strategy, the random present value of the total payment by the public administration, fixed a generic time horizon of m years, $C_P(0,m)$, is

$$C_P(0,m) = \sum_{h=1}^{m} x_h v^h$$

with

$$E[C_P(0,m)] = E[X]\,\frac{1-v^m}{i}$$

4.4) Standard insurance strategy

Standard insurance strategy, the present value of the total expenditure (deterministic) for the public administration is an annuity with installment P

$$C_I(0,m) = \frac{1-v^m}{i}\, P$$

For risk aversion principle P>E[X], we have

$$E[C_P(0,m)] < C_I(0,m) \qquad (1)$$

Obs. The passive strategy could incur in annual compensation so high as to endanger the financial solidity of the public administration, which with the insurance strategy, can conversely plan a constant yearly payment equal to P.

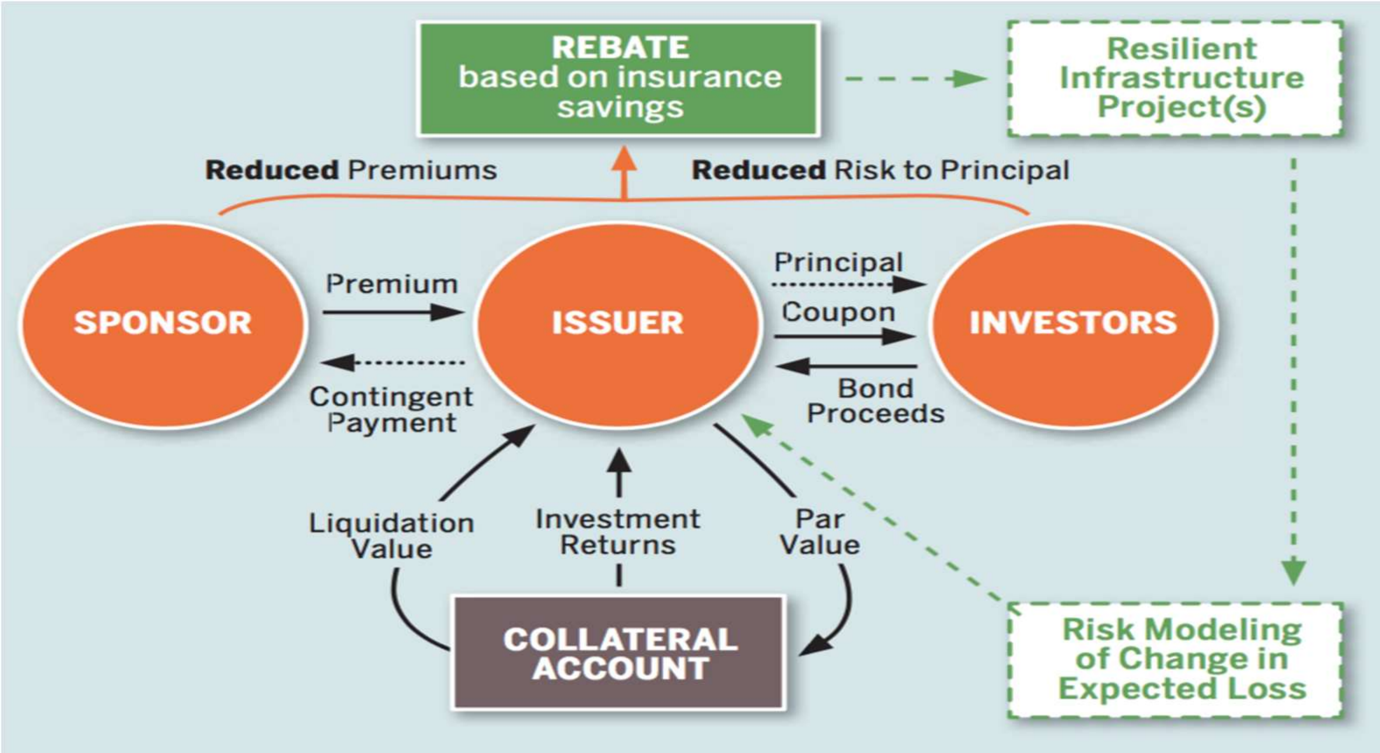
4.5) Innovative insurance resilient strategy

Resilient strategy provides that for n years it will be necessary to pay the insurance coverage P and to finance the mitigative infrastructures for which the cost W was assumed, while after completion time the annual insurance cost decreases to the level P_R.

Q annual installment assuming that it has to be paid for the entire duration of the construction of the mitigative infrastructure, that is n years

$$W = \frac{1-v^n}{i} Q$$

Resilience Bonds cash flows scheme



4.5) Innovative insurance resilient strategy

Present value of the total expenditure (deterministic) for the first n years

$$C_R(0,n) = \frac{1-v^n}{i}\,(P + Q)$$

and the following chain of inequalities

$$E[C_P(0,n)] \quad < \quad C_I(0,n) \quad < \quad C_R(0,n)$$

4.6) Break-even point

Break-even point: the minimum time horizon such that the resilient strategy becomes more convenient than the others, m>n

$$C_R(0,m) = \frac{1-v^n}{i}\,(P+Q) + v^n\,\frac{1-v^{m-n}}{i}\,(P_R)$$

$\mathbf{m_I}$ is the break-even point respect to the standard insurance strategy and $\mathbf{m_P}$ respect to the passive strategy

$$m_I = min_{m=n+1,n+2,\ldots}\; C_R(0,m) < C_I(0,m) \qquad (2a)$$

$$m_P = min_{m=n+1,n+2,\ldots}\; C_R(0,m) < E[C_P(0,m)] \qquad (2b)$$

4.7) Break-even point with different mitigative infrastructures

A further development.

- A possible range of mitigating infrastructures, with costs and times given by pairs W(j) and n(j), in the case of the generic j-th option, j = 1, 2, …, J, from which the ex-post risk exposure distribution is described by the random variable $X_R(j)$ and the corresponding reduced premium $P_R(j)$.

- In this case the problem of optimizing the choice of the mitigative action could concern the minimum $P_R(j)$ fixed a maximum level of infrastructure cost, and/or the minimum in terms of break-even point provided by the different choices, that is the minimum m(j), with $j \in 1, 2, \ldots, J$.

5) Numerical example: the original risk and the reduced risk premiums

- X yearly random damage lognormally distributed with parameters μ and σ.

- After mitigative infrastructures completion time, the reduced risk X_R, is lognormally distributed with parameters

$$\mu_R=(1-d_1)\mu \text{ and } \sigma_R=(1-d_2)\sigma$$

- Insurance premium loading is assumed a proportion α>0 of the volatility of the random damage even for reduced risk

$$P = E[X] + \alpha\sigma[X]$$

$$P_R = E[X_R] + \alpha\sigma[X_R]$$

5) Numerical example: standard parametrization

Based on total damage in Italy (for year)

E[X]=2 billions, σ[X]=1 billion, so that $\mu=0.58$, $\sigma=0.47$

W=3E[X]=6 billions, given that a “full coverage” is around the level 30 billions,
we can consider a “proportional risk reduction” of 20%, $d_1=0.2$, $d_2=0.2$,
but in this point the assessment of engineering expertise is crucial.

Premium loading $\alpha\sigma[X]$, with $\alpha=0.05$

$$E[X]=2.00,\ \sigma[X]=1, \text{ from which } P=2.05$$

$$E[X_R]=1.71,\ \sigma[X_R]=0.67 \text{ from which } P_R=1.74$$

W=6, n=5, i=0.02
from which Q=1.27 (it has to be payed for the planned n years of completion time).

We proceed to a sensitivity analysis of the break-even points m_I and m_P, according to (2a) and (2b)

5.1) Break-even point sensitivity respect to volatility of the original risk

σ[X]	m_I	m_P
1	26	31
1,2	26	31
1,5	25	31
2	24	31

As the volatility increases the break-even point with respect to the standard insurance strategy gets shorter, since the weight of risk reduction is relatively more important.

it could indicate an upward trend in damages

5.2) Break-even point sensitivity respect to trends in the expected value of the original risk

E[X]	m_I	m_P
2	26	31
2,1	26	31
2,5	20	23
3	16	18

The increasing of E[X] could indicate an upward trend in hydrogeological risk damages, and we highlight that the effect of risk reduction could have a greater impact and shorten the break even point.

5.3) Break-even point sensitivity respect to costs and corresponding risk reductions

- We assume a risk reduction expressed by a proportional reduction of the parameters that describe the original risk, μ and σ, expressed by $d_1 = d_2$, corresponding to the ratio of the cost of the mitigative infrastructures W respect to the total estimated in 30 billions.

W and d_1=d_2	**m_I**	**m_P**
6 and 0,2	26	31
8 and 0,266	27	31
10 and 0,333	28	31
15 and 0,5	30	32

It must be highlighted the role of engineering expertise in order to assess the function of risk reduction corresponding to different costs of the mitigative infrastructures.

5.3) Break-even point sensitivity respect to loading of insurance premium

The modulation of insurance premium loading can be analyzed in two directions:

- the request for profitability of insurance companies to participate in the coverage of hydrogeological risk,
- willingness of the state government to incentivize coverage of the same risk.

α	m_I	m_P
0,05	26	31
0,1	25	36
0,2	23	…
0,4	21	…

The comparison with the passive strategy is not significant, but it should be observed that as the loading increases, the break-even point is shortened compared to the standard insurance strategy.

6) I.T.'s role (potential)

The various steps of the process are:

- Big data: climate phenomena and claims data collection (blockchain certification and machine learning techniques for estimation)
- Smart Contract (through blockchain’s tools): the stipulation of the contract both in the insurance part and in the financing part of the mitigation work
- Certification of the timetable for the construction of the mitigation work (contractual clauses may be linked to any delays with respect to the settled timetable)
- Change in the regime of the insurance contract once the completion of the works has been certified, without the need for a new agreement on the actual exposure to risk, once this had been fixed at the signing of the contract (to be validated ex post by engineering expertise)

7) Conclusions and further lines of research

• Comments:

this paper presents an innovative approach on a resilient insurance scheme for hydrogeological risk reduction by a multidisciplinary approach (legal, engineering, quantitative actuarial).

• Further research:

- analysis of the variability of the results in order to highlight how the uncertainty of the cost of claims of the passive strategy may produce much more critical scenarios for public finance than other strategies, which provide a deterministic flow for managing risk
- real case data.

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