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Nadia Netti * , Martina de Cristofaro , Domenico Ferrara

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Managing Natural Hazard Risks. A Multi-Stakeholder Approach for De-Risking

Nadia Netti [1,*], Martina de Cristofaro [2] and Domenico Ferrara [3]

[1] Department of Economics Management Institutions (DEMI)/ University of Naples "Federico II", Italy
[2] Department of Engineering/University of Campania "Luigi Vanvitelli", Italy; martina.decristofaro@unicampania.it
[3] Technology Transfer Office/University of Campania "Luigi Vanvitelli", Italy; domenico.ferrara@unicampania.it
* Correspondence: netti@unina.it

Abstract: As a result of decades of austerity, the economies of the Eurozone are experiencing underinvestment and crumbling infrastructures in an era of extremely severe emergencies as the climate change and aggressive global competition. The private savings glut of the rich and the strict fiscal rules suggest a crowding-in approach in partnership with big finance in a new age of infra-structures. If governments mint public infrastructures into investable assets, they can generate steady returns for investors and asset managers who look after pensions and insurances schemes and unlock trillions now devoted to welfare state. For the big finance to accept to be partner, however, governments must take the task of de-risking returns. Innovation technology and macro-financial literacy can synergically act to enhance this new de-risking role to address in a financially sustainable way the intense phenomena of Natural Hazards (NHs) that can severely compromise economic growth. This is precisely the aim of our Public-Private Partnership (PPP) among the Department of Economics, Management and Institutions of the University of Naples and a Knowledge Transfert Management, the Department of Engineering and the Aca-demic Spin-Off "STRAIN", of the University of Campania. Our PPP has been contributing to the evaluation and mitigation of NHs such as floods, landslides and earthquakes since 2012. The extremely advanced results of this multi-stakeholder partnership ensure a better knowledge of NHs which, as evidenced in the paper, is the fundamental input for the desired Public-Private Insurance Programmes (PIPPs).

Keywords: climate change and natural hazards; global financial markets and risk management; economic policy; economic development; innovation technology; derisking; insurance and re-insurance; landslide and seismic risk assessment; floods and soil liquefaction risk assessment

1. Introduction

In Macroeconomics and Finance literature the de-risking approach is everything but new. The de-risking role of financial institutions as the Central Bank is well described in making efficient financial markets and safe assets to satisfy "Liquidity Preference as Behavior Towards Risk" (J. Tobin, 1958) [1], and the need for money capital in the firm (D. Vickers, 1987) [2]. Different components of risk can be managed, not only financial risk but even operative and technical ones (S. A. Ross, 1976) [3]. Innovation technology plays in this a fundamental role nowadays allowing what just a decade ago was not possible.

In a speech at Lloyd's of London given by Mark Carney (2015) [4], the former Chairman of the Financial Stability Board and Governor of the Bank of England, on September 29, 2015, the UK insurance industry was invited to reflect on how urgent was to take into much more serious account the threat of climate change posed to the financial stability and hence longterm prosperity. Since the 1980s the number of registered weather-related loss events had tripled and NatCatSERVICE of Munich Re evidenced the extraordinary increase of inflation-adjusted insurance losses from these events. It was precisely then that Carney's "Tragedy of the Horizon" gave the start to a new point of view going well beyond the traditional horizon. Most actors used not to look further than a business

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cycle, a political cycle a credit cycle and a technocratic mandate in the case of monetary policy while climate change and its consequences became a matter of financial stability that the current generation had to fix to give a future to next generations. The speech even clarified the extreme importance of a better information to assess risks and to produce new insurance and re-insurance profitable products, and remembered that "an old adage is that which is measured can be managed" and that "supply creates demand" as recited in macroeconomics by the Say's Law. It is just following this point of view that it is possible to understand the very important role of innovation technology and technical information to correctly define realistic consequences of NHs and effects of climate change. This enables to reduce uncertainty which underlies a correct definition of the risk-return profiles of whatever physical, economic and financial investment performed in uncertainty conditions, therefore enhancing the chances for more resilient and sustainable growth across various sectors (economics, finance, engineering, green economy, etc.).

More recently, following the financial aspects of the debate about climate policy, it has been proposed a new theory of macro-financial regimes as a combination of mone-tary, fiscal and financial institutions that presides the creation and allocation of credit and money, therefore influencing the speed and the nature of green transition (Gabor D., Braun B., 2023) [5]. These "de-risking regimes", considered nowadays hegemonic, can be seen as those in which "the soft budget constraint syndrome has penetrated capital-ism" (Kornai, 2012) [6]. These regimes can therefore be confronted with "big green state regimes" (Gabor D., Braun B., 2023) [5] where the coordination mechanism is State-led planning with a genuine "soft budget constraint" that can be devoted to the protection of its own economy from the NHs. However, as well evidenced by Kornai (2012), this State-led planning approach may suffer from the inconsistency in the decision-making behavior, and therefore being much less reliable and even auto-disruptive, especially in a context of the very high uncertainty of the NHs.

Therefore, in de-risking regimes, multiple stakeholders must be effectively involved through Public-Private Partnerships (PPPs) and Public-Private Insurance Pro-grammes (PPIPs). As evidenced in "High-Level Framework for Public-Private Insur-ance Programmes" presented in May, at G7 Italia 2024 [7], global financial markets and particularly insurance markets can accomplish the extremely important role to absorb damage and losses from Natural Hazards.

According to OECD (2023a) [8] "Recommendation on Building Financial Resilience to Disaster Risks", for a sustainable development to be guaranteed it is necessary to prevent new disaster risks, to reduce the existing and managing the residual ones. All this must be done even "Leveraging technology in insurance to enhance risk assessment and policyholders risk reduction" and "Enhancing Financial Protection Against Catastrophe Risks" through "the Role of Catastrophe Risk Insurance Programmes" (OECD, 2023a) [9]. The International Association of Insurance Supervisors, then, underlies in its Report "A call to action", "the role of insurance supervisors in addressing natural catastrophe protection gaps" (IAIS, 2023) [10]. It's evident in this context the extremely effec-tive role of technology and innovation to measure the effects and reduce uncertainty for whatever NH and degree of climate change. This is to some extent what it is done by Aladdin (BlackRock), to cite the biggest example in the new era of investment management tech. Aladdin is a tech platform that unifies the insurance investment management processes; the software enables to manage portfolios across both public and private market investments. Aladdin Climate, then, helps to understand and act upon the effect of climate change on investments and quantify climate risks in financial terms, arriving at climate adjusted valuations and risk metrics through climate science, policy scenarios, asset data and financial models. Our PPP fits precisely into this area, as the engineering component implements advanced modeling techniques in the defi-nition of NHs and the effects of climate change (floods, landslides and earthquakes); the Patent Office and the KTM of the University of Campania "Luigi Vanvitelli" technically and financially sustain the development of new sensors and transducers, projected by DI of the University of Campania, to follow the physical phenomena at the base of catastrophic events in order to significantly reduce uncertainty and to enable DEMI, of the University of Naples, to manage and circumscribe the effects of NHs and climate change so to be able to give a fundamental input to insurance and re-insurance industry.

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2. Methodology

As far as the economic and financial aspects in the 2.1, we mainly refer to the Italian approach that is going to start on 31 December 2024. It is a new Smart Climate Risk Protection policy specifically implemented for catastrophic damages characterized by a compulsory scheme, circumscribed, by now, to a limited target of policyholders made of enterprises and households. We will refer to the last Italian Budget Law 2024 [11] to describe its perimeter and the role of each stakeholder involved in it; namely the Italian government, insurance industry and its Supervisory Authority (IVASS), the Italian insurance-financial group directly controlled by the Ministry of Economy and Finance (SACE), and the national reference price comparison site for the insurance sector (Facile.it). The Italian approach we will be briefly compared to a Lloyd's catastrophe insurance policy in the Netherlands as referred into the EIOPA's Report (EIOPA, 2021) [12].

In the 2.2 we define the essential element to contain uncertainty and risk in the NHs.

In 3 we will present our PPP approach to assess the risk-return profiles of insurance and reinsurance private and public companies through advanced modeling techniques and implementing a new Early Warning System.

2.1. The Italian De-Risking State and Its New Public-Private Insurance Program

Climate change and NHs can rapidly and severely hit the financial stability of economies. Due to scarce information and awareness on their impact on the economies and lack of financial literacy, the effective demand for insurance may be scarce and public and private finance may end up being extremely exposed. Thus financial "protection gaps", happening whenever those who may be directly or indirectly injured by the NHs cannot rapidly recover from a disaster due to absence of insurance coverage and other financial protection, can be very far to be closed through a genuine demand for insurance protection. This can justify the choice of the Italian de-risking government to adopt a compulsory coverage as that introduced by the last Italian Budget Law (2024) [11].

Starting from 31 December 2024, the Italian Budget Law introduces the obligation to stipulate insurance contracts to cover damages to their tangible fixed assets as lands and buildings, plants and machinery, industrial and commercial equipment caused by natural disasters and catastrophic events that occurred on the national territory, for companies registered in Italy and abroad but operating in Italy through an establishment, excluding agricultural companies.

This is a novelty in the Italian insurance panorama (within which the perimeter of compulsory insurance coverage was limited to a few activities, the main one being that relating to the circulation of vehicles) whose purpose would appear to be that of replacing the public system with the private one, relieving the public sector from the burden of paying compensation in case of calamitous and catastrophic events, and inducing the private system to seek conditions of mutuality that allow the restoration of economic and productive conditions more rapidly than State intervention.

Any failure to stipulate insurance coverage will determine the exclusion, for the uninsured party, from the assignment of contributions, subsidies, financial benefits to be drawn from public resources, also with reference to those provided for in the event of calamitous and/or catastrophic events (paragraph 102 of the Italian Budget Law 2024) [11].

With reference to the hazards to be covered, pending the detailed indications that the Ministers of Economy and Finance and of Enterprise and Made in Italy, in agreement with the Institute for Insurance Supervision, IVASS, the current list (i.e. earthquakes, floods, landslides, inundations and overflows) is merely exemplary.

Similarly to civil liability arising from the circulation of vehicles and vessels, insurance companies will not be able to avoid the obligation to contract, under penalty of applying an administrative pecuniary sanction ranging between Euro 100,000 and 500,000 to be paid by them.

Given the nature of the insurance commitment that they will have to assume, paragraph 103 of article 1 of the Budget Law 2024 [11] allows insurance companies not only to directly underwrite the risk, having the financial capacity to do so, but also to act in co-insurance or by establishing consortia with other insurance companies; the latter must however be registered and approved by IVASS which will evaluate their stability.

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Acting as a public re-insurer, then, SACE, an Italian insurance-financial group directly controlled by the Ministry of Economy and Finance, will ensure that the obligations undertaken by the insurance companies are fulfilled by acting as reinsurer, indemnifying the insurance and reinsurance companies of the private market up to 50% of the compensation paid by the latter, for an amount not exceeding 5000 million Euro for the year 2024 and, for each of the years 2025 and 2026, not exceeding the greater amount between 5000 million Euro and the free resources at December 31 of the immediately preceding year, not used for the payment of compensation in the reference year.

To further ensure the overall solvency of the system, it is expected that the obligations assumed by SACE will be guaranteed by the State on first demand and without the possibility of recourse. The State guarantee is explicit, unconditional and irrevocable (paragraph 109 of article 1 of the Budget Law 2024) [11].

The eventual expansion of the scope of insured risks will also have an effect on the verification of the solvency conditions of companies by IVASS: it cannot be excluded that, in order to meet the obligations to contract imposed by the provisions mentioned above, companies will seek greater diversification of the risks present in their portfolio and, possibly, alternative forms of reinsurance, with respect to which greater flexibility is hoped for by the Insurance Supervisory Authority, regarding their admissibility. It will also be interesting to see how the pricing of coverage and its tax treatment will be declined, since different areas of our country correspond to a more or less marked exposure to calamitous and/or catastrophic events (which should lead to a different declination of the premium to be paid) and that private intervention replaces public intervention in the management of compensation (and, as such, should have a preferential tax treatment, strictly speaking).

With specific reference to the real estate sector, the legislator also intended to extend the range of subjects obliged to perform the insurance obligations in question. In this regard, in fact, on February 27, 2024, Italian Law 17/2024 [13] was published in the Official Journal, converting Legislative Decree no. 212 of 29 December 2023, according to which, all those who have benefited from the tax benefits under the so-called " superbonus " (see art. 119, paragraph 8-ter, Italian Legislative Decree 34/2020) [14], in relation to expenses for interventions started after 30 December 2023, are also obliged to obtain insurance to cover damage caused to the related properties - including, therefore, even residential properties - by natural disasters and catastrophic events, all within one year of the conclusion of the works subjected to the benefits of the "superbonus". The beneficiaries of the "superbonus", therefore, could find themselves in a delicate position: while, on the one hand, they are entitled to the enjoyment of specific tax breaks, on the other they will now be required to take out additional insurance policies, representing a further financial burden for them.

On the 4th of July 2024 SACE (SACE, 2024) [15], in partnership with Facile.it, launched Smart Climate Risk Protection a catastrophic damage policy for micro-enterprises. That is, SACE, an Italian insurance-financial group, directly controlled by the Ministry of Economy and Finance, and Facile.it, a national reference price comparison site for the insurance sector, announced a partnership in favor of Italian micro-enterprises and SMEs for the dissemination of the new Smart Climate Risk Protection policy specifically for catastrophic damage.

The partnership between SACE and Facile.it marks an important point in the world of insurance and, for the first time, two leading companies join to allow micro-enterprises to obtain maximum benefits with the best technology available on the market. The aim of the agreement is to make Climate Risk Protection smart, accessible in a simple and fast way, with a direct link to MySACE.it, also through the Facile.it platform.

With this initiative, SACE extends its commitment to serving micro-enterprises, providing them with tailor-made products and digital promotion channels, while Facile.it confirms its desire to become a point of reference in savings not only for end consumers, but also for the B2B sector.

The compulsory regime chosen by de-risking Italian government can be mitigated by big data and technologies, useful to better adapt the insurance products or services to customers' needs, but even to prevent NHs and their consequences. Reflecting actual risk a policyholder is exposed, risk-based pricing as premiums and deductibles can produce safer behavior helping climate change

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adaptation and mitigation of the risks. This then reflects on a reduction in risk, less money to afford losses and decreasing premiums. For example, a Lloyd's catastrophe insurance policy in the Netherlands, allowed purchasing coverage for flood damage, earthquake and terrorism risks. As far as flood risk, policyholders received premium discounts if they take measure to "floodproof" their home. They found flood risk information on the insurer's website on which they could enter their zip code to extract information about flood probabilities, potential water levels, quality of flood protections and the risk-based insurance premium. Four different measures allow each a 5% premium discount: 1) installing electrical equipment, 2) the central heating installation above the ground floor level, 3) having flood shields available, 4) having a water-proof floor on the ground floor level, such as tiles.

It was the European Insurance and Occupational Pensions Authority (EIOPA), a European Union financial regulatory institution, that introduced the concept of **"**Impact Underwriting**"** that is "the development of new insurance products and the engagement with public authorities, without disregard for actuarial risk-based principles of risk selection and pricing" (EIOPA, 2019, 2021) [12,16]. A contest of changing climate, expectedly growing climate-related losses and increasing premiums, justifies the intervention of public re-insurances and PPIPs to contain the "protection gap". The unaffordability for the policyholder on one hand and a crowding of the private insurances and re-insurances out of the market due to their incapability to remain profitable were, in fact, other sources of long-term financial instability to economies. Moreover, NHs and extreme severe catastrophic events underlie the necessity for the whole insurance sector to privilege non-life underwriting. Through non-life underwriting the insurance sector not only is able to transfer and pool the risk but even to contribute, through insurance-based solutions, to climate mitigation and adaptation. To this aim the EIOPA (2019) [16] used the categorization of financial climate change risks introduced by the Bank of England (Carney, 2015) [4], for example, to measure how increasing underwriting, counterparty default risk or market risk for (re)insurers, affect the value of the assets and liabilities. The example cited above of the Lloyd's catastrophe insurance policy in the Netherlands offers us the occasion to stress the importance of our PPP contribution as a kind of flood risk assessment based on a zip-code identification is certainly based on an extremely simplified territorial schematization and a static evaluation of the areas that could eventually been involved by the inundation. Even the use of big data, nowadays very important, is based on extremely simplified hypothesis founded on phenomenology of damage. But the climate change effect, on the contrary, may produce dynamic extreme tail events that very simplified and static systems of evaluation are not able to detect. The next section is essentially devoted to highlight these aspects.

2.2. Uncertainties and Risk in NHs

The assessment of the risk of the loss of human lives and material assets (structures and infrastructures) due to catastrophic events is a crucial aspect of civil engineering and emergency management. This risk is closely related with the spatio-temporal probability of a catastrophic event to happen and its potential to strike an engineering work with finite vulnerability with destructive energy. The probability of a catastrophic event is related to the system's ability to counteract it, depending on the mechanical and geometric characteristics of the natural and built system in question. That is, this probability is based on Mechanical Characteristics (including the properties of soil deposits, materials and structures that influence resistance to catastrophic events, such as earthquakes, floods, landslide, etc.), Geometric Characteristics of Engineering System (soil deposits, structure and infrastructure involved), Historical Data of past catastrophic events (to understand the frequency and magnitude of future events) and Predictive Mathematical Models (to predict the behavior of natural and built systems under stress).

Therefore, the calculation of the probability of occurrence is more accurate the more precise the definition of the models capable of following the underlying physical phenomenon and the physical quantities involved is. Hence, the definition of the probability of occurrence is closely tied to the uncertainties inherent in the definition of behavioral models and the related physical quantities. The following will focus on the techniques available in the engineering field for handling uncertainties (Ferrero et al. 2004 [17]; Baecher and Cristian 2003 [18]; Hudson 2013 [19]).

If we solely isolate the cases caused by landslides and earthquakes among NHs, the engineering system to be monitored consist of soil deposits, structures, and infrastructure that interact with the soil deposit and atmospheric components (wind, rainfall, etc.)

The nature of uncertainties in such a system is widely discussed in engineering, and the sources of uncertainty can be classified as (Einstein and Baecher 1983) [20]:

(a) inherent to the spatial and temporal variability of the soil deposit;
(b) due to measurement errors of the monitoring systems (systematic and random);
(c) consequent to assumptions and simplifications introduced in the choice of the model;
(d) related to the difficulty in defining natural and anthropogenic mechanical actions,
(e) relative to omissions due to schematizations and simplifications of different nature or deficiencies in the knowledge phase.

Each source of uncertainty must be adequately considered and addressed in engineering, distinguishing between epistemic uncertainty, which is due to a lack of knowledge, and aleatory uncertainty, which is related to intrinsic variability.

Epistemic uncertainty can be overcome as it is linked to a lack of knowledge that can be refined through in-depth investigations. As discussed earlier (section 2.1), the information available today to define the probability of catastrophic events are based on static studies (essentially relying on historical data analysis that cannot adequately account for the dynamic nature of NHs and the changes induced to the effects of climate change) conducted under highly simplified assumptions regarding the modeling of physical phenomena underlying catastrophic events, and on cartographic bases at a regional scale (most studies are based on cartography with geometric schematizations at a 1:25000 scale). In fact, one of the main sources of epistemic and aleatory uncertainty in risk assessment for landslides and earthquakes lies in the quality of the data and the scale to which they refer. For example, in modeling landslide phenomena and earthquake effects, an analysis scale with insufficient level of detail, such as the one too frequently used in nowadays evaluations, induces not only epistemic errors with serious repercussions on the geological and geotechnical model used, but also errors with high aleatory uncertainties due to greater data dispersion resulting from an excessively broad scale of analysis. Thus, having a detailed analysis of the geotechnical model through a combination of conventional monitoring systems and innovative instruments, along with continuous data acquisition, results in a significant reduction of both epistemic uncertainty (allowing previously unavailable information to be obtained) and aleatory uncertainty (availability of a large quantity of high-quality data) (Dubois and Guynnet, 2011) [21]. For each level of uncertainty (the level of information between complete absence of information and total knowledge), there is an optimal model to be used. A low level of information only permits deterministic analyses, while as the level of information increases, it is possible to achieve a more accurate frequency distribution of a given variable and thus a statistical treatment of it. However, statistical analyses with inaccurate and/or scarce data (such as those currently in use) can lead to unreliable and often misleading results, impacting risk assessment. Our PPP therefore works in the direction of producing information for accurate calculation of the probability of occurrence of catastrophic events and managing the related uncertainties to reduce risk and improve the resilience of infrastructures. In the next section, it is shown how the application of innovation and advanced techniques can be used for managing uncertainties, enabling engineers to develop more reliable and safe solutions, helping to protect human lives and material assets, with direct implications for insurance and re-insurance industries.

3. A PPP Contributing to Overcome Epistemic and Aleatory Uncertainty in Risk Management

As previously mentioned, in the Eurozone, numerous areas are affected by landslide and earthquake risks involving people, buildings, structures, and infrastructures. Landslides and earthquakes impact vast areas, characterized by very complex mechanisms, where the cost of repairing infrastructure, relocating communities, and restoring cultural sites might be unsustainable for the communities. The exposed structures require significant effort for their surveillance and protection, and this is of extremely interest both for insurance and reinsurance companies and for the de-risking State. This effort can be effectively supported by our PPP with the development of advanced models to simulate the effects of natural catastrophes and the development of innovative investigation and monitoring systems. To this aim, since 2012, Netti et al. (2012) [22], Damiano et al. (2012) [23], Olivares et al. (2019) [24], and de Cristofaro et al. (2021) [25] have proposed multidisciplinary approaches to define Decision Support Systems (DSS) and complex models for natural soil deposits to be implemented in landslide and earthquake Early Warning Systems (EWSs) (for details on the development of the proposed DSS and constitutive models, please refer to the cited technical scientific literature).

These papers aim to better identify the physical phenomena underlying rainfall-induced landslides and earthquake-induced liquefaction, providing assessment tools (DSS) that significantly impact the epistemic component of uncertainty. Moreover, since 2019, the research is also supported by KTM of the University of Campania "Luigi Vanvitelli," that implemented technological innovation and advanced expertise in defining monitoring systems both for the study of the effects of landslides and earthquakes and for Structural Healt Monitoring and Reinforcement (Di Gennaro et al. 2022 [26]; Di Gennaro 2024 [27]). This research activity led to the realization of the New Smart Hybrid Transducer (NSHT), the registration of industrial property patents (EP-3948167-A1, 2022 [28]) and the creation of the academic spin-off "STRAIN" (Smart Transducer and Reinforcement for the Development of Artificial Intelligence) for civil engineering applications. The proposed system has enabled the realization of distributed strain and temperature NSHT transducers (Figure 1) based on optical fiber sensing technology. This NSHT transducer can be interrogated from remotely with different techniques (Brillouin scattering and Rayleigh backscattering). In static acquisition, the monitoring system including the NSHT, is capable of continuously monitoring strains and temperatures along distances from 1 km to 50 km with a spatial resolution of up to 20 cm and spatial sampling of 5 cm. In dynamic acquisition, it can monitor sections from 20 m to 100 m with a sampling frequency of 20 to 50 Hz and sub-centimeter spatial resolution and sampling.

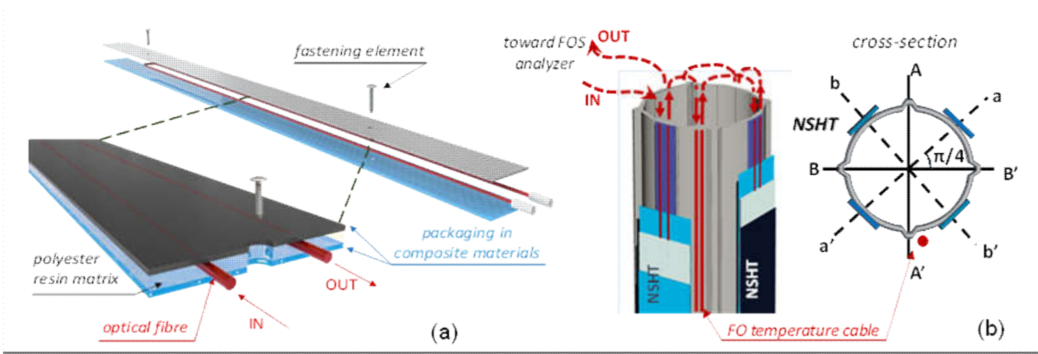

Figure 1. The NSHT transducer (a) and the smart extenso-inclinometer realized by equipping an inclinometer tube with four NSHT (b).

The NSHT has been implemented within Structural Health Monitoring and Reinforcement (SHMR) of masonry buildings of historical and cultural interest (Figure 2), constituting a monitored reinforce with a system that verifies the effectiveness of the reinforcement itself. Additionally, it has been implemented in the case of deep clay shales landslides as a smart inclinometer, with the system installed in Cilento (in the Southern Italy). This monitoring system is capable of providing practically continuous information (one acquisition per minute) on underground strain profiles of deposits (Figure 3), allowing the identification of both newly formed sliding surfaces and the reactivation of inactive landslides. In the dynamic field, it has been used for the testing of wind turbine blades. Applications on pile foundations and bridge piers are ongoing, and it is being used for testing foundation and elevation structures. For further research we suggest that our NSHT might be used even to constantly monitor the strain of underground along very long distances (up to 50km) (e.g. the monitoring of the effects of bradyseism such as that recently seen in Campi Flegrei, in the Southern Italy).

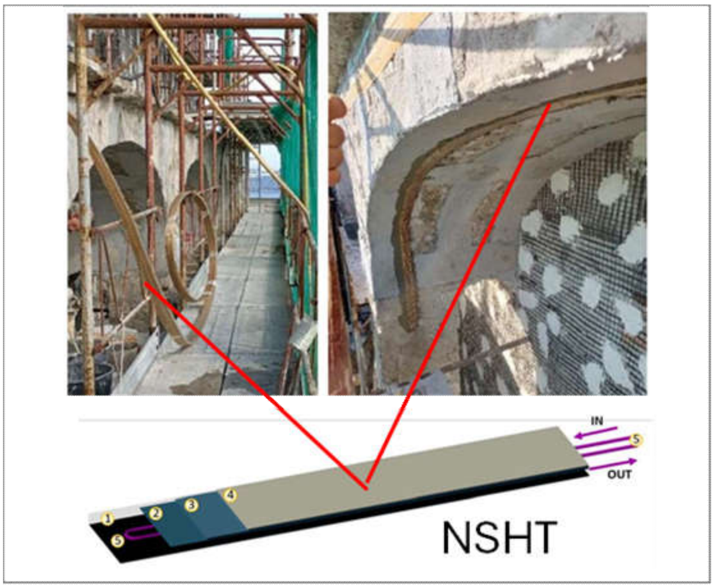

Figure 2. Application of NSHT transducer as Structural Health Monitoring and Reinforcement (SHMR).

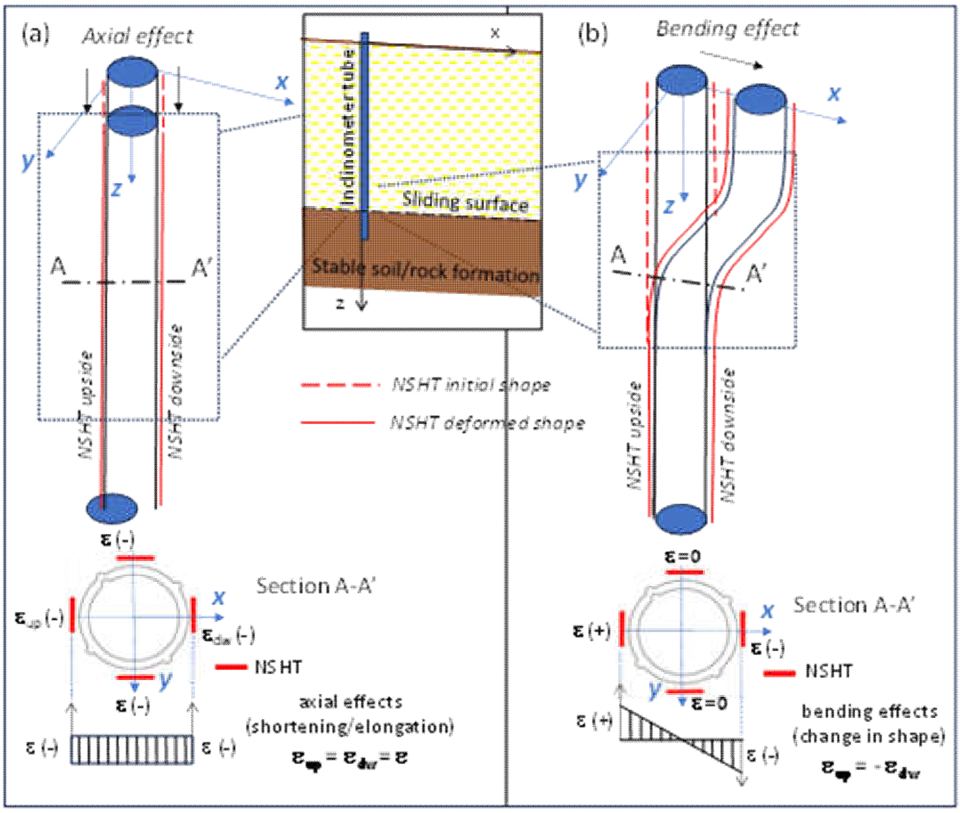

Figure 3. Schematic representation of inclinometer tube in a slope undergoing: a) axial force and b) bending moment in a sliding deposit.

The complex and innovative monitoring system based on the use of NSHT transducer in optical fiber sensor can be remotely managed to continuously acquire data of great quality, accuracy and precision. These are essential elements both for the reduction of epistemic and aleatory uncertainty as they enable to correctly define the system involved in NHs through the collection of a huge amount of data which consent the construction of a more accurate frequency distribution of a given variable and thus a statistical treatment of it.

4. Conclusions

If governments mint public infrastructures into investable assets, they can generate steady returns for global investors and asset managers who look after pensions and insurances schemes. Public-Private Partnerships with big finance would then enable the economies to unlock trillions relaxing their strict fiscal budget constraints. This is extremely urgent in the Eurozone where, due to decades of austerity, economies are experiencing underinvestment and crumbling infrastructures in an era of extremely severe overlapping emergencies and very aggressive global competition. To start this new age of financially sustainable infrastructures, governments are asked to assume a de-risking role in the probability distribution of financial returns. A better knowledge of Natural Hazards is then a fundamental input for the insurance and re-insurance schemes of the implied Public-Private-Insurance-Programmes. To this aim the paper describes the extremely advanced results of our multi-stakeholder partnership among the Department of Economics, Management and Institutions (DEMI) of the University of Naples "Federico II" and a Knowledge Transfer Management (KTM), the Department of Engineering (DI) and the Academic Spin-Off "STRAIN", of the University of Campania "Luigi Vanvitelli" in contributing to the evaluation and mitigation of Natural Hazards such as floods, landslides and earthquakes since 2012.

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References

1. Tobin J., 1958, Liquidity Preference as Behavior Towards Risk, Review of Economic Studies 25: 65-86. https://doi.org/10.2307/2296205.
2. Vickers D., 1987, Money Capital in the Theory of the Firm. A Preliminary Analysis, Cambridge University Press, 1987. https://doi.org/10.1017/CBO9780511528385.
3. Ross S. A., 1976, "The arbitrage theory of capital asset pricing", Journal of Economic Theory 12: 341-60 1976 https://doi.org/10.1016/0022-0531(76)90046-6.
4. Carney M., 2015, Breaking the Tragedy of the Horizon – Climate Change and Financial Stability, Speech given at Lloyd's of London https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.
5. Gabor D. & B. Braun, 2023, "Green Macrofinancial Regimes," SocArXiv 4pkv8, Center for Open Science. https://doi.org/10.31219/osf.io/4pkv8
6. Kornai J.,2012. "What 'Economics of Shortage' and 'The Socialist System' have to say to the (Hungarian) readers today — An Introductory Study to the First Two Volumes of the Life's Work Series." Acta Oeconomica, vol. 62, no. 3, 2012, pp. 365–84. JSTOR, http://www.jstor.org/stable/23526166.
7. G7Italia, 2024, High-Level Framework for Public-Private Insurance Programmes. G7 Finance Ministers and Central Bank Governors' Meeting- Stresa, Italy, May 23-25th 2024. https://www.g7italy.it/wp-content/uploads/Annex-II-Full-Document-High-Level-Framework-for-PPIPs-against-Natural-Hazards.pdf
8. OECD 2023a, Recommendation of the Council on Building Financial Resilience to Disaster Risks. OECD/LEGAL/0436
9. OECD 2023b, "Leveraging technology in insurance to enhance risk assessment and policyholder risk reduction", OECD Business and Finance Policy Papers, No. 38, OECD Publishing, Paris, https://doi.org/10.1787/2f5c18ac-en.

10. IAIS (2023) A call to action: the role of insurance supervisors in addressing natural catastrophe protection gaps. International Association of Insurance Supervisors c/o Bank for International Settlements. http://www.iaisweb.org.
11. Italian Budget Law, 2024, L. n. 213 -30 December 2023.
12. EIOPA (2021), Report on non-life underwriting and pricing in light of climate change, EIOPA-BoS-21/259.
13. Italian Law 17/2024. https://www.gazzettaufficiale.it/eli/id/2024/02/27/24G00030/sg
14. Italian-Legislative-Decree34/2020 https://www.gazzettaufficiale.it/atto/serie_generale/caricaArticolo?art.versione=1&art.idGruppo=8&art.flagTipoArticolo=0&art.codiceRedazionale=20A04100&art.idArticolo=119&art.idSottoArticolo=1&art.idSottoArticolo1=10&art.dataPubblicazioneGazzetta=2020-07-29&art.progressivo=0
15. SACE, 2024, https://www.sace.it/media/comunicati-e-news/dettaglio-comunicato/sace--in-partnership-con-facile.it--lancia--protezione-rischio-clima-smart.--la-polizza-danni-catastrofali-per-le-microimprese
16. EIOPA (2019), Opinion on Sustainability within Solvency II, EIOPA-BoS-19/241, Frankfurt am Main, 30 September 2019.
17. Ferrero A. M., Migliazza M. R., Pirulli M., 2014, Problematiche e prospettive nell'analisi del rischio di frana in ammassi rocciosi fratturati, Keynote lecture. XXV CNG Baveno, 4-6 giugno – AGI – Roma – ISBN 978-88-97517-03-0.
18. Baecher G. B., Christian J.T., 2003. Reliability and statistics in geotechnical engineering. New York: John Wiley and Sons, Inc., 618 pp.
19. Hudson J. A., 2013. An overview of underground rock engineering risk. InProc. of ISRM International Symposium Eurock 2013 on: Rock Mechanics for Resources, Energy and Environment. Kwasniewski&Lydzba (eds), CRC Press, Wroclaw, Poland, 57-68.
20. Einstein H. H., Baecher G. B., 1983. Probabilistic and statistical methods in engineering geology. Rock Mechanics and Engineering Geology 16 (1): 39-72. https://doi.org/10.1007/BF01030217
21. Duboi D., Guyonnet D., 2011. Risk-informed decision making in the presence of epistemic uncertainty. Int. J. Gen. Syst. 40 (2): 145-167. https://doi.org/10.1080/03081079.2010.506179.
22. Netti N., E. Damiano, R. Greco, L. Olivares, V. Savastano, P. Mercogliano. 2012. Natural Hazard Risk Management: a Multidisciplinary Approach to Define a Decision Support System for Shallow Rainfall-Induced Landslides, The Open Hydrology Journal, 2012, 6: 97-111. http://doi.org/10.2174/1874378101206010097.
23. Damiano E., P. Mercogliano, N. Netti, and L. Olivares, A "simulation chain" to define a Multidisciplinary Decision Support System for landslide risk management in pyroclastic soils. Nat. Hazards Earth Syst. Sci., 12, 989–1008, 2012 www.nat-hazards-earth-syst-sci.net/12/989/2012/. https://doi.org/10.5194/nhess-12-989-2012
24. Olivares L., Netti N., Damiano E., de Cristofaro M. (2019), Geotechnical Properties of Two Pyroclastic Deposits Involved in Catastrophic Flowslides for Implementation in Early Warning Systems Geosciences 2019, 9(1), 24; https://doi.org/10.3390/geosciences9010024
25. de Cristofaro M., Olivares L., Orense R. P., Asadi M. S., Netti N., 2021, Liquefaction of Volcanic Soils: Undrained Behavior under Monotonic and Cyclic Loading, https://doi.org/10.1061/(ASCE)GT.1943-5606.0002715
26. Di Gennaro, L; Damiano, E; de Cristofaro, M; Netti, N; Olivares, L; Zona, R; Iavazzo, L; Coscetta, A; Mirabile, M; Giarrusso, G A; D'Ettore, A; Minutolo, V. (2022). An innovative geotechnical and structural monitoring system based on the use of NSHT / - In: Smart Materials and Structures. ISSN 0964-1726. 31:6(2022), p. 065022. https://doi.org/10.1088/1361-665X/ac5fc6
27. Di Gennaro L., 2024. Analysis and applications of innovative instruments for the monitoring of built environment. Ph.D thesis in Environment Design and Innovation. University of Campania Luigi Vanvitelli.
28. EP-3948167-A1, 2022. Transducer, "Università degli Studi della Campania "Luigi Vanvitelli", Lucio Olivares, Martina de Cristofaro, Agnese Coscetta, Angelo D'ettore, Vincenzo Minutolo, 2019-03-28, 2020-03-30, 2022-02-09, https://patents.google.com/patent/EP3948167A1/en.