Flood risk insurance: the Blockchain approach to a Bayesian adaptive design of the contract.

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Abstract

Informatics tools underlying cryptocurrencies markets, the so-called Blockchain, is raising up a lot of interest for applications in a wide range of fields. The key function of its use is to collect reliable information that could be used for a dynamic updating of contracts, that is one of the main opportunity given by smart contracting, with an adequate support of law's context in which such contracts are merged, that is one of the main issue to be developed for the full functioning of this kind of innovative business model. Blockchain and the connected smart contracting, seem very interesting even for insurance business, in particular for the bayesian adaptive approach which is a classic issue of actuarial science, based on the updating of premium evaluation using the collection of new information of risks phenomena. The new opportunity of collecting offered by the so-called big data even for classic insurance risks as for example, health, driving, climate and seismic events, together with the validating role of Blockchain approach, seem to be the perfect scenario for a massive use of smart contracting in insurance business. In this paper we describe the scheme of a flood risk insurance, the bayesian adaptive design of the contract, using Blockchain to validate both new data of risk phenomenon and the effect of mitigation of the faced risk due to infrastructural works.

Keywords: Blockchain, smart contracts, flood insurance, bayesian inference.

Introduction

The insurance sector, among many others, has an increasing interest for the application of blockchain technology, introduced by the milestone paper by the inventor Nakamoto [1], to its business, as shown by many documents of main insurance groups (let see [2], [3]) and consultancy firms ([4],[5],[6],[7]) and we have arrived to the creation, in 2016, of the B3i, the first blockchain-centered insurance consortium (as described in [8]). The key point for the use of blockchain for insurance business is the feasibility of smart contracts in this sector and the answer seems to be positive almost for the so-called instantaneous insurance, i.e. contracts with short duration which imply an automatism in issuing and in paying the eventual benefit settled in the contract as, for example, the flight delay insurance proposed by AXA, called Fizzy, completely developed on a blockchain platform.

In Gatteschi et al. ([9],[10]), there is a complete resume of the potential advantages of blockchain in many processes characteristics of insurance business, for instance the increase of speed of claim processing, data entry for identity verification, collecting reliable data for fraud prevention, use of mobile devices for instantaneous insurance (as the case mentioned before). One of the potential application field which still has to be investigated is peer-to-peer insurance or reinsurance (let see, [11], [12]), though it must be said that, at present, they are not real peer-to-peer models, as they have a traditional insurance model or risk carrier behind them, supporting the heavy part of the insurance business. In this context, smart contracts could represent an important innovation and a prototype solution based on the Ethereum blockchain has already been implemented [13]. It should be underlined, however, that the adoption of peer-to-peer insurance models by the wider public is not imminent yet since a large part of customers still considers necessary the interaction with intermediaries [14].
Our paper is focused on the analysis of the potential use of blockchain technology for smart contracts which consider a multiperiodic insurance coverage, exploiting the automatism allowed by blockchain technology for updating the contractual conditions, based on new reliable information collected while time passes. Up to our knowledge this is a new issue in the literature and our aim is to underline opportunities and criticisms of this kind of contracts.
This periodic updating of the contract is a well-known approach in actuarial science, e.g. the so-called credibility theory, which is based on a bayesian adaptive scheme.
Among the possible fields for applying a bayesian adaptive scheme in a multiperiodic insurance coverage, we choose one of large current interest, that is the risk connected to extreme climate events and, in particular, we analyze the flood risk. To pursue this kind of research we need a multidisciplinary approach, since the macro-fields which are involved are the actuarial science for the quantitative analysis, an engineering expertise for evaluating the flood risk in a certain area, the legal point of view in order to give a proper law support for smart contracts in a multiperiodic scenario and, finally, the informatics expertise to explain the process provided by blockchain technology.
Considering the current instruments for an economic mitigation of extreme risks due to climate events, traditional reinsurance, cat-bonds and resilience bonds, we propose an approach similar to one implicit in resilience bonds scheme, that is not only a coverage of eventual damages, but also the opportunity of financing infrastructures for mitigating the risk. Our propose is based on the calculation of the insurance premium at issue date and at every updating time, based on information collected at each time in a classic bayesian adaptive scheme, such that the premium level may automatically change time by time. Furthermore, at each renewal time, part of the eventual surplus of the premium payed respect to the payments occurred for damages has to be (automatically, settled in contractual conditions) used for financing mitigative infrastructures. Blockchain technology has the role of certifying reliable new information and also the state of mitigative infrastructures, which can vary according to the use of the surplus as mentioned before.

This paper has the following structure. In the first paragraph the engineering point of view of measuring and mitigating flood risk is presented. In the second we present an overview of the legal aspects of smart contracts in a multiperiodic scenario. In the third paragraph it is presented the bayesian adaptive design of the contract according to an actuarial approach. Then we propose some conclusions and mainly some comments of possible developing lines of this multidisciplinary research.

1. 1. Assessment of flood risk of critical infrastructural systems

1.1 Flood and critical infrastructure

Since the early 1970s extreme events associate to natural disaster have been growing both in frequency and intensity. Specifically during the last 15 has been recorded an increase of 2% a year [15] . The same increased trend was also reflected on the number of disaster flood events more than 600 from the year 2007 [16] . What happens in the year 2013 in the Central Europe was particularly impactful: 16.5 billion in economic losses (large-scale damage across Germany, the Czech Republic, Hungary and Poland) for 4.1 billion in insurance paid claims. The year 2013 has negative record of the increase of flood damages of approximately 50% respect the period 20032012 [3] and to show for first time three consecutive losses exceeding 100 billion in a 10 years period time [15, 18]. These figures represents an evidence how the increase of the population in urban areas [15] and the consequential increase of their complexities of both social and technological dimensions define a bottleneck within flood risk management. In fact the rapid growth of human concentration and urbanized areas has increased the exposure to the existing flood recurrence time making more difficult the realization of proper mitigation measures such as the availability of the land to be settled as potential flood risk zone. Among different assets that increased their risk to flood due to an increased exposure Critical Infrastructures (CI) need a specific emphasis. Critical infrastructures represent body of systems, networks and assets that are essential for the functioning of a society, publics health and/or safety and economy of a nation. CI are thus engineering and technological networks, such as energy/water supply, transport services, water supply, oil and gas supply, banking and finance, and ICT (information and communication technology) systems. All these systems are important (and thus critical) to maintain essential functions of society, and their failures can heavily seriously affect the population, economy, and national security [19, 20]. Such CI systems, facing with the increase of the complexity of urban systems must strengthen their interactions among people, activities, and properties. In fact this represents an increase of the vulnerability without the possibility to build new infrastructures in risk areas mainly due to lack of land [20, 21]. In other words the complexity of infrastructures and urban systems lessens the activities of components in a crisis period. This is the reason that addressed the attention of policy-makers, economist, urban planners, engineers, insurance companies and scientist to find innovative Risk Management frameworks to more sustainable and more resilient cope with climate changes effect and natural hazards [22]. A new approach has thus been gradually developed, based on the concept of urban resilience, nowadays implemented within the Sendai Framework for Disaster Risk Reduction [23].

1.2 The concept of Infrastructural Resilience

Due the complexity and independency of infrastructure in urban areas there is an higher risk to have cascading effects in fact generating secondary effects in areas much more far from the real flooded area [21, 24]. It is a key aspect to minimize the secondary problems that flooding of networks may have [25]. In order to move towards these directions a novel risk reduction approach based on a strategic development of urban and infrastructural systems has been proposed within the last Sendai Protocol developed in the 2015 based on the resilience concept [26]. Based on the United Nations Office for Disaster Risk Reduction (UNISDR) within the term resilience was introduced a time reference respect the disaster event (i.e. ex-ante, during, ex-post) and the concept of essential functionality of the communities, infrastructures or any other type of systems under the effect of an hazard [27]. In this way resilience it can be seen as as the capability to withstand a shock or stress, resisting and adapting, in order to restore the initial functionality [1]. This is also involving the definition of absorption/resistance, adaptation, recovery capacities to (re) create or maintain a balance functionality of the system [15]. In this definition there is the proactive capacity to learn and thus anticipate the effect of a catastrophe [15]. Resilience has direct connection with ecological dimension as proposed by Holling [27]. The definition can be thus generalized as capacity of a system to absorb disturbances and to recover after a major disruption and to restart an activity on the territory [15]. Different methods have been proposed to assess resilience and role of the infrastructural resilience within it. For example in the work of Serre et al. [15] is proposed for urban/engineering networks are able to propagate flood risk the overall urban resilience is identified into 3 main capacities namely: Resistance capacity, Absorption capacity and Recovery capacity. Similarly like in the concept proposed by Bruneau et al. [28] with the introduction of the 4Rs (i.e. Robustness, Redundancy; Resourcefulness; and Rapidity) approach. It is thus evident how conceptual and (semi) quantitative model approaches based on the selection of a set of proper indicators must be developed for assessing the effectiveness of specific mitigation and/or adaptation strategies within an overall Risk Reduction framework.

1.3 Flood Risk definition

As mentioned urban population increase and the consequential rise of the increase complexity of the CI represent factors that amplify the level of local vulnerability [29, 30]. In fact there is a direct connection of the natural hazard losses to the number of people and complex infrastructure living in areas prone to hazards. Thus the assessment of the Risk losses is not a trivial task since both the engineering dimension as well as the social impact should be evaluated.

Generally the Risk to natural disaster including flood is defined within the probability perspective in terms of occurrence time of a certain hazards, factored by the severity of its consequences [31] , according to the following formula:

Risk =Probability x Consequence (1)

Thus Risk represents a key instrument and criteria leading to flood zone management policy, land and infrastructural development planning [32]. It is thus evident the important role of the engineering dimension to assess the potential cost/benefit in terms of decreased flood risk level once a specific CI (or other engineering system) is strengthened and/or newly built. Risk formula presents also other expended description on where the probabilistic dimension of the Hazard is then related to the Exposure and Vulnerability. Both aspects are related to the intrinsic propensity of a certain asset to be at Risk. Thus, the engineering aspect to understand the effects of an hazard of a certain magnitude is essential. This general formula is reported below:

Risk = Hazard x Exposure x Vulnerability (2)

Within the proposed Risk assessment there the need to use GIS-based system on which hazard (e.g. flood), vulnerability and assets maps are combined trough the use a weighing process and normalization. This task has to be replicated for each climate-related impact [33]].

In this way the flood risk assessment is translated in terms of potential loss and damages costs. This is most of time impossible to be done for each infrastructure and/or asset at risk due to data scarcity. In these way insurance companies databases are often using proxies to overcome this bottleneck. As reported by Kaspersen and Halsnes [34] Danish Insurance Company define a damage function and unit damage costs based on flood levels for different buildings during extreme precipitation. In this case health costs (based on number of people exposed to mixed rain-sewage water) and expected costs for different rain patterns considering extremes climate event are calculated in monetary values as losses for each asset and damage costs. Since quantitative and probabilistic approaches are not always possible to be used and converted into a monetary dimension (mostly in connection to the social dimension, the effectiveness of Risk Reduction scenarios through a Multicriteria Assessment (MCA) towards urban adaptation planning [35]. Normally with adaptation strategies are beneficial for the overall resilience of certain system and thus its risk reduction. According to [36] for physical systems can be identified in 2 types of measures namely hard and soft. The first referred to (semi)permanent installation within the area of the potential flood, the second ones are those relate to natural process for example like are tackling flood in terms of erosion decrease and or increase of roughness in the flooded areas [15, 37].

1.4 Holistic resilience approach for Risk reduction: a new paradigm for adaptation and mitigation strategies

Within the presented perspective there is a need to move towards an holistic risk reduction to areas prone to natural disaster not only including the engineering infrastructural system but also the social and territorial dimensions in terms of human, environmental, financial and political system which could increase or decrease the overall resilience. Consequently there is need to assess how potential CI infrastructure improvements including hard and/or soft measures together with financial and insurance mechanisms can optimize the overall territorial resilience. In this context there is a need to develop quantitative or semi quantitative approaches that could evaluate the optimization in a sort of cost/benefit analysis among the capacities characterizing the resilience of an urban system and/or community. In this respect over the last decade particularly attention was devoted to the selection of specific on risk assessment with an emphasis on the measure of vulnerability areas and community at risks [38]. In fact on this extend the select of specific vulnerability indicator for food risk can have a real effect on the formula used to define the local risk. Nowadays most of the common indicators are addressed to characterized vulnerability in terms of susceptibility, fragility sometime even embedding specific resilient aspect such as adaptability [15]. The aspect to move towards a new paradigm of the disaster risk reduction emphasis the multidisciplinary of the resilience thus including ncluding the social, economic, institutional, infrastructure/engineering and community structure and all the connected information [15, 39]. Thanks to the indicators methodology, it is now possible to explore social, urban, technical phenomena and to determine which area is more or less resilient by a comparative work [39] normally within a Multi Criteria Analysis (MCA) approach. The technical dimension and thus the engineering perspective within this approach highlight the importance of taking into account the assessment of the critical infrastructure vulnerability, and more specifically urban networks facing with natural disaster such flood risk. The study of Serre et al. [15] proposes an assessment on the impacts of potential disruption of urban networks based on the evaluation of the capacities that characterized the level of resilience of a urban environment from a technical perspective. In this the methodology is able to identify resilience characteristics at the urbane scale and to plan for enhancing strategies. The contribution of the use of MCA model identified factors that would lead to increase urban resilience, highlighting the importance of urban networks and critical infrastructure. As reported in the work of Feofilovs et al. [40] the approach Mayunga [41] provide also a consistent holistic method resulting in an index score for the measure of communitys disaster resilience taking into account both the different phase of a disaster (i.e. mitigation, preparedness, response, and recovery) and the potential dimensions of resources (so called capitals including the infrastructural) that can be mobilized (i.e. social, human, economic, physical, environmental) or affected by an occurred hazard.

1.5 The need of multidiscipline interface: the implementation of the block chain

Several examples of urban disasters show the challenges still actual in urban flood management, especially in an uncertain context, driven by as strategic and innovative approaches to build urban resilience strategies. It is thus clear how within risk assessments, hazards need to be identified, together with estimations of their probability, and quantification of the impacts these hazards will have on vulnerable areas. This enables adaptive management strategies to be developed. This becomes even more a crucial aspect towards sustainable development plans and strategies according to the framework of the so called Sustainable Energy and Climate Action Plans (SECAPs) for Municipality. Within it Risk, Vulnerability assessments represent aspect that must assessed, evaluated and improved [33]. Within the definition of measures addressed to enhance the infrastructural resilience for the engineering dimension must be emphasized how preparation, resistance and adaptation capacities to flood Risk are spatial and time dependent. All these aspect suggest how there is a need of a new and innovative technology toward the direction of an integrated Risk Management toward strengthening resilience to flood at urban level In this direction is going the latest development advances in computing power within the processing of Big Data that can anyway create a criticalities once there is a need of analysis and processing of several dataset such as environmental, flooding, geological, weather, satellite obervations, topography/cadastral location, corporate, specific insurance, social economic, Risk/Hazard [42] specifically addressed for the flood risk evaluation. In this direction is going the use of Big-Data and the latest development of computing power that can anyway create criticalities once there is a need of analysis and processing of several dataset such as environmental, flooding, geological, weather, satellite obervations, topography/cadastral location, corporate, specific insurance, social economic, Risk/Hazard [42] specifically addressed for the flood risk evaluation. Rumson [42] underlines the need to better assess risk flood thanks to improved ability of programming device to store, process and analyse aggregated and disaggregated data, combining database and real-time streaming data [43]. In this way is highlighted the need of an holistic approach on data collection, analysis and processing with different types of analytical tools involving Geographical Information Systems (GIS), probabilistic modelling and definition of the damage curve thus in connection of engineering aspects relied to the vulnerability of physical assets exposed to Risk (e.g. any type of networked critical infrastructure as key instrument proposed. This interconnection and multidisciplinary aspect can thus support the development of proper insurance-based mechanisms as an option of adaptation able to increase local resilience to flood Within this view blockchain technology represent a good platform to mitigate risk and vulnerability towards the collection and analysis of different data source (i.e. Big data related to GIS systems, Environmental variables, Exposure data, Social media data, etc..) a real time risk assessment and thus a better definition of a risk-based pricing of insurance policies facing with potential losses. The article of Hokey Min [44] emphasis how within a blockchain platform Big Data and any other types of distributed database can be more efficiently share and more fast confirmed and validated. Within the same article the author explains the potential of blockchain to categorize and assess vulnerability and risk associated to a certain occurrence probability, and how consequently develop contingency plan for risk mitigation.

2. An overview of the legal aspects for multi-period smart contracts

To highlight the scientific and applicative gap of a specific smart insurance contract against natural hazard, the first methodological approach, specifically the legal one, leads to an overview of the state of the art of the thematic areas of implementation of smart contracts themselves. The most important implementation of the Bitcoin protocol is without any doubt Ethereum, with its cryptocurrency Ether (second to bitcoin by capitalization and by currency/dollars exchange). This platform allows the use of the so-called Smart Contracts.[45] These "smart contracts" are the development of the research carried out by Nick Szabo, who in the nineties was a reference author in the data encryption landscape. In 1997 he published two papers [46] in which he theorized a system of transfer of rights in execution of a mathematical algorithm, inspired by the sales system of vending machines.[47] The following year he released the third paper in which he formalized the concepts outlined in previous works. In his scheme a specific property right is included in a title intended to circulate, together with related information.
The transfer is put into a mathematical-cryptographic security and the ownership title is placed in a logical chain of previous similar securities as a guarantee of the continuity of operations.[48] Thanks to the invention of the Blockchain, in 2014, the twenty year old Vitalik Buterin, outlined the characteristics of what then became the main platform for the development and performance of smart contracts: Ethereum. The purpose of this platform is to provide a Blockchain tech-tool with a built-in programming language, which can be used to build "contracts" and to encode functions, so that these contracts are self-executed in accordance with the pre-set rules: all this simply by writing the logic of their operation in a few lines of code.[49]
There is no universally accepted definition of Smart Contract, due to its recent appearance on the scene and its technological complexity. A simple definition is that of an agreement whose performance is automatic, so an algorithm for computer transactions, which comply with the terms of the contract. [50] Perhaps a more correct definition, even thinking about the applicative scope of the paper was provided by the Italian IVASS (Italian Institute for Insurance Supervision), according to which smart contracts are contracts that are written in a specific language that can be understood, translated and executed by a computer, whose clauses can produce actions without external intervention based on information received in input and processed according to predefined rules.[51]
In accordance with the fact that the characteristics of any good or data can be digitized and represented by a code, each of these informations can be stored and secured in a distributed register, not only from a static but also a dynamic point of view .The operations and the agreements between the nodes of the network can be tracked and their execution can be automatically performed by the Blockchain itself without the intervention of intermediaries. All this has become possible thanks to the Smart Contracts which, as IT protocols, formalize the elements of an agreement and automatically execute the terms of the agreement

(terms that are therefore predefined) when the conditions foreseen by the agreement are fulfilled (even the conditions are therefore predefined and codified). In a nutshell, to provide a significative statement in order to understand the operation of smart contracts a smart contract is a piece of code which is stored on an Blockchain, triggered by Blockchain transactions, and which reads and writes data in that Blockchains database [52] The development and evolution of Smart Contracts have been sudden, their application is expanding day by day. In addition to Ethereum, other open source projects were born to create increasingly sophisticated Smart Contracts (like Counterparty and Mastercoin). To date, they have been created to automatically execute derivatives, futures, swaps and options. They have also been used to build platforms for the sale of goods on the internet, among unknown people, without the help of central authorities. [53]
As regards and more closely related to the development of the paper, the most analysed state of the art, to obtain a link to the current regulatory substrate referred to in the blockchain, was clearly that of the insurance dynamics. In the insurance sector, forms of insurance have developed that use Smart Contracts. The first example is InsureETH, an UK startup, in the field of airline reimbursements/compensations. Another case is that of the pilot project of the American International Group (AIG) together with IBM and Chartered Bank who worked together for a multinational insurance coverage, preparing a Blockchain insurance Smart Contract.
It is worth adding that recently AXA insurance [54] in order to refunds following delay or cancellation of the flight, has developed an extremely interesting smart contract. The insurance called Fizzy, appears revolutionary because, as described in the AXA portal, it excludes any kind of negligence, tipycal instead of the traditional insurance dynamics. The smart insurance, regardless of any external event or subjective / objective liability, automatically compensates in case of flight delay. [55]
And therefore, summarizing the two research questions, it is possible to determine that, firstly, the smart contracts have had a rapid development and evolution, and secondly, in the insurance sector, the blockchain technology is used and relegated to the automation of the mechanism of compensation. This huge implementation gap leaves the way for the use of blockchain data storage technology and modification of the contractual structure. In practice, it's time to move from a purely refund insurance blockchain to a big data management one.[56] In order to the title section, what would be the difference of a standard smart insurance contract, therefore with instant effect, compared to a multi-period contract? One of the main differences was highlighted at the end of the section just ended. and it is quite clear that the main difference is about multiperiod. And, in this case it is appropriate to clarify this aspect, because multiperiod is not necessarily synonymous with a long term as the smart standard contract is not synonymous with short term.
The desired multiperiod implementation within the smart insurance contract is subject to the fact that, periodically, through the storage of data from external certified sources, using the blockchain technology, the contractual structure can

change, such as the insurance premium, the sum of compensation or the determination of the percentage of risk.[57]
And therefore, even if in a perspective about natural disasters, the scanned periods may be related to prolonged periods, the determination of multi-mode concerns the scanning of temporal phases in which it is possible to change and modify essential elements of the contract without the latter termination or requiring a new agreement between the parties. The second difference concerns the method of using the blockchain technology. Picking up one of the smart contracts mentioned above in the insurance field, the blockchain is simply used in two steps: 1) validation of the insured event, such as the hours of flight delay, and 2) the payment of the sum of money.[58] In other words, in the very few applicative experiences that took place in the last few years, insurances first of all made use of blockchain technology as an instrument to verify the insured event. The information, using as an example the AXA contract, deriving from the airline are stored within the blockchain data flow and any event of delay beyond the allowed limit "unblocks" and acts as a check and authorization for the second step.
The one-dimensional perspective of the contract in relation to the uniqueness of the period, understood as a contractual phase, emerges clearly. The data entered and the "transformation" of these through blockchain technology into legal effects, such as compensation, are contained in a single phase, without any possibility, that extends or changes the contractual structure. Therefore, in a one-dimensional perspective, the will of the parties, the economic agreements, regardless of information, external events, blockchain technology acts exclusively as a verifying agent of the insured event, relegated to a kind, using a parallel with civil law, of contract for future effects.[59]
On the other hand, the contract that, hopefully, should be implemented, involves a completely different dimension, that of periodic data scanning, aimed not at the termination of the contract, but at its evolution, change and adaptation.
In the perspective of a multi-phase contract, the relevant data, in accordance with the insurance dynamics against natural hazards, for example, rainfall, the height of the rivers, the damage previously incurred, not only serve to create a network of useful information to counteract the harmful phenomenon of risk, but also serves to store information using blockchain technology. The implementation, in addition to the aforementioned characteristics of a smart insurance standard contract, involves the perpetuation of the contract, step by step, following the flow of data and the physiological modification of the initial parameters to which the parties have expressed their consent.
It is essential to delineate, first, the minimal and necessary features of a multi-phase contract mentioned above, and secondly, to highlight if there are examples, even partials that can be joined from a regulatory point of view to the latter. What are the minimum and essential characteristics imputable to such a contract?
Onerous, and therefore, taking up the standard scheme of an insurance contract, the agreement is based on the bilateral provision by which the insured

party pays, at agreed intervals, a sum called insurance premium, to the company, which, in the case which the event occurs compensates the damaged party.[60] Aleatory, in the sense that the insured event, even if determined, described and outlined, is uncertain in its occurrence.[61] IT, in the sense that the stipulation of the contract occurs through an online platform through blockchain technology. In particular, the methods of signature are constituted by the expression of consent through the use of a digital signature device. Blockchain Technology. Real time data flow, in the sense of an IT contract structure able to receive data and information related to the insured asset and related environment able to modify time by time the initial parameters set out in the stipulation of the contract. [62]
Automatic renegotiation, automatic consensus, in the sense that the contract, considering the flow of data, capable of physiologically modifying the initial parameters of the contract, is legitimated, in relation to the flow, to change economic conditions even when the new conditions result "in peius" for the so-called weak party, the insured subject.[63]
An analysis of the contracts disseminated with the individual characteristics mentioned above can be carried out by determining some cases that are widespread within the Italian regulatory system.
As far as the cost of the contract is concerned, this is meant as the one in which a subject receives an advantage in exchange for a non-gratuitous disbursement, defined as performance. There is a close relationship between advantage and performance, a causal link. A typical example in the Italian civil code panorama is represented by the sale, regardless of whether it concerns movable or immovable assets, in which a subject pays a sum to another party and the latter, as a counter-claim, sells the asset de quo. [59]
The dynamics inherent in the concept of "aleatory", on the other hand, pertains to the uncertainty of the occurrence of a determined event. Remaining in the specific theme of research and paper, clearly the insurance contract is the perfect example. IT technology is inherent in the numerous chaos of digital contracts. In particular, a digital contract is an agreement entered into on an online platform through which legal effects desired by both parties emerge. one of the best known digital contracts is certainly the one related to e-commerce platforms, through which the buyer, in exchange for a payment, in most cases by credit card or similar means, purchases one or more assets on a website, which can act as a vendor tout court (Nike store, Ticketone) or as a mere intermediary (Amazon, Ebay).
The technical definition of blockchain is "decentralized ledger and cryptographically secure transaction" [64]. More generally, it is a technology that makes it possible to exchange not only information on the internet, but, for the first time, properties as well. Not therefore the simple payment or exchange of goods and services, but, thanks to this innovation, any other form of collaboration between men can take advantage of the possibilities offered by the network. So, when we talk about blockchain, we refer to an international safe register, shared by all the subjects acting within a specific computer network, based on peer-to-peer technology.

The chain has the peculiarity of recording and archiving all the transactions that are carried out within that network, not requiring the presence of third parties, so-called trusted. The name blockchain originates from the nature of the structure: each node of the network has a specific function in ascertaining the information entered, which is transmitted to the next node in a chain formed by blocks, the blockchain indeed. All transactions carried out to date and verified directly by the system are recorded in it. In fact, transactions are only possible if they are approved by 50% + 1 of the nodes.[65] The European association of credit institutions has, in one of its reports, expressed a positive opinion about the reliability of the system. The main characteristic of the whole IT structure can be synthesized with a single term: decentralization. In fact, there is no central repository in the blockchain but a peer-to-peer between users, by entering transactions in blocks.[66]
In a standard blockchain architecture, transactions are created from active components inserted in the network: the active user is called node and transfers Bitcoin to another node inserted in the network. The blocks of the network are created, in a chain, by other participants in the architecture that are defined miners. Miners to create blocks must solve complex algorithms and, if they succeed, they are rewarded with some Bitcoins. The newly created transaction is distributed and validated following a rigid one verification protocol to avoid, among others, the problem of "double spending problem ". In practice, the validity of one transaction is confirmed with the consent of the nodes of the network on the basis of parameters set for the operation of the network itself; the nodes that validate they are rewarded with Bitcoins. When the validity of the transaction is verified, the miners put it in a block and the transaction is executed (performed) in full respect of privacy.[49]
The flow of data, in the sense of the mere consecution of information entered in an IT platform, can be understood thinking of what is set out above regarding the smart insurance contract on air delay. the peculiarity of this contract is the discrepancy between the initial condition, and therefore the uncertainty inherent in the event, and the event itself. In practice, following the random logic of the insurance contract, the peculiarity consists in the input of data in real time and the consequent immediate simultaneous supply of the sum established in favour of the insured subject. The change of facts, the occurrence itself, modifying the conditions and using IT produces legal effects.[50] In the determination of a new possible contract the flow of data, albeit with different purpose, that is exclusively that relating to the change of the editorial, risk and insurance premium parameters, and therefore excluding the provision of any sum, it would have exactly the same functioning.
The last single feature inherent to the possible implementation of the contract de quo, concerns the forecast and contextual acceptance of the parties, of the modification in fieri of the economic conditions. This profile is closely linked to the data flow above. In particular, a data entry could be envisaged as per the insured asset, as well as the surrounding environment, capable of modifying the economic conditions, and therefore the insurance premium.[67] A contract to refer to and to use as a potential analogy tool certainly concerns the so-called

variable interest rate mortgage. A variable rate mortgage is a type of mortgage whose interest rates vary based on the performance of certain parameters indicated in the contract.
The reference parameters to which the interest rates are linked are usually the Euribor (EURo Inter Bank Offered Rate, ie the average interest rate of the financial transactions in Euro between the main European banks) the IRS (Interest Rate Swap) - EuroIRS or the Official ECB Reference Rate. The Euribor (Euro Interbank Offered Rate) is the interest rate used as an indexing parameter for variable-rate mortgage loans. The Euribor has replaced the national indexes since January 1, 1999. It is calculated daily as a simple average of the quotations recorded by a group of banks representing the European and world credit panorama selected by the European Banking Federation.
The reference rate for variable-rate mortgages is published daily at 11 am by a group of banks representing the European credit landscape. There are currently 20 institutions that contribute to taking over the Euribor.[68]
Summarizing the main section, regardless of the will of the parties that have signed the contract, the data coming from a third party, an external and independent entity, the economic characteristics may undergo changes. and so, if the Euribor, with the flow of data, is capable of modifying, inaudita altera parte, with the increase or decrease of the interest rate, the economic conditions, imposing on the parties, as above, with a view to an insurance smart contract against natural hazard, the flow of data entered into the digital blockchain platform is capable of modifying the parameters, such as risk and insurance premium, regardless of the parties will.[69]
For the purposes of drafting the paper, it is worth highlighting that almost all the features, some of which are inherent ex se, such as compensation and the "alea", others for subsequent implementation, such as IT, the flow of data and blockchain, are adaptable to our contract implementation project. As regards the dynamics of the renewal of the consensus to change the initial parameters, it seems appropriate to briefly outline a double scenario. Prima facie, the dynamics of the variable rate inherent to the loans, by structure and contractual framework do not seem to coincide with the insurance dynamics, and therefore, and this is the trait d'union with the section of engineering mitigation risk, [70] it appears extremely prudent to operate a contract in which a high premium insurance is envisaged, above the real initial risk. In particular, when the initial conditions change into peius, the prize in any case continues to be suitable from the point of view of the insurance company for the continuation of the activity, and when, with defined time scans, reconnecting to the theme of the multiperiod, the risk conditions reduce the difference between the bonus paid and the premium that, ideally, would have been corrected from a mathematical point of view, could be used to create risk mitigation structures.[71]

3. The actuarial model: a bayesian adaptive design of the contract

In this paragraph the bayesian adaptive design of the multiperiodic contract is described according to an actuarial scheme. Let $H(0)$ be the set of data representing information collected at time 0 starting from time $-m$ and let

$W(0) = f(H(-m, 0) \equiv f(H(0)$

the premium which has to be paid for one unit of time until the first updating time. Among such data we have the damages due to the insured risk and other information relative to flood risk, mitigative infrastructures and so on.

Let $m_1, m_2, ...$ be the sequence of updating times settled in the contract. At the generic time m_i, with $i = 1, 2, ...$, exploiting the collected information starting from$-m$, that is $H(-m, m_i)$, the new premium becomes

$W(i) = f(H(-m, m_i) \equiv f(H(i)$

and has to be payed until updating time m_{i+1}.
Let assume that the collected information $H(0)$ is the historical series of the damages $x(i)$, with $i = -m, -m+1, ...0$, in each time unit starting from $-m$ to issue date 0

$H(-m, 0) = x(-m), x(-m+1), ...x(-1), x(0)$

and let assume $H_r(0)$, for $r = 1, 2, ...$, the estimate of the $r-th$ moments of this random variable. If we assume a premium principle based on a variance style charge, we are interested only in $H_1(0)$, $H_2(0)$ and so the premium for a time unit starting from issue date, $W(0)$, could be expressed as

$W(0) = f(K_1(0), K_2(0))$.

Starting from issue date the contract provides the payments of the premium $W(0)$ for each unit of time, until the contract will have a first update, at time m_1, based on the arrival of new information, that is $H(1, m_1) = x(1), x(2), ..., x(m_1)$. At time m_1, using all the information registered in the interval $(-m, m_1)$ we have new estimates of $H_1(m_1)$, $H_2(m_1)$ and consequently the premium becomes

$W(m_1) = f(K_1(m_1), K_2(m_1))$

which has to be payed for each time unit from $m_1 + 1$ to next updating time m_2.
Let $n_i = m_i - m_{i-1}$ with $i = 1, 2, ...$ be the number of time units between m_i and m_{i-1}, so the total premium payed in such interval is $n_i W(i)$. The difference between such total premium and the total claim in the same time interval $C(i)$

$n_i W(i) - C(i) = U(i)$

is a profit or a loss for the insurance company.
The contract could provide that in case of profit, i.e. $U(i)$ is positive, part of the surplus obtained by the company will be shared with the insured, that is, used for infrastructural investment for risk mitigation. The evaluation of mitigative infrastructures costs and their impact in term of risk reduction, has to be assessed by an engineering analysis as described in paragraph 1.
The effect of this infrastructural investment on this numerical model could be introduced by a not decreasing sequence of thresholds $L(i)$, with $i = 1, 2, ...$, in the interval $m_{i-1}i$,m_i, which have an impact on the damages in the same time: the higher is $L(i)$, the lower we expect the total damage $C(i)$.
The assessment of the relationship between surplus and threshold increase has

to be implemented using engineering issues. It seems reasonable to consider a delay between the arise of the surplus and the effect on threshold, due to the time necessary to accomplish the infrastructures.

The role of blockchain technology is the certification of the collected information and the automatism with which the contractual terms (i.e. the premium level and the sharing of the surplus) should change at each updating time. Such automatism is the core of the concept of smart contracting, that is an update of the contract without a new bargain between the two counterparties. The legal aspects such that smart contracting is really admissible for this kind of insurance contract, has been analyzed in paragraph 2.

4. Comments and further lines of research

This paper has presented an insurance contract facing flood risk in a multiperiodic scenario, based on an adaptive bayesian scheme, pointing out the opportunities and the criticisms by the point of view of the disciplines which are involved: actuarial, engineering, law. We disregard to detail the informatics aspects linked to the blockchain technology, leaving this issue to the specialist informatics literature. We underline that a classical actuarial approach, the bayesian adaptation due to the collection of new reliable information on the considered risk, could be inserted in a smart contract approach, with the support of blockchain technology.
Since the risk is the flood one, we remark that an automatic updating scheme of the contract could concern also the infrastructures which have the role of risk mitigation and that also such component of the contract could be linked to the certification of blockchain approach.
Develops of this research could be imagined in various directions. The engineering and the actuarial approach have to dialogue in order to make their own analyzes usable and useful one for the other and the legal overview has to clarify all the aspects such that the automatism provided by smart contracts in multiperiodic scenarios can be effectively conceivable in real cases.

5. References

1. Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System; 2008, Available online: https://bitcoin.org/bitcoin.pdf (accessed on 19 February 2018).
2. Higgins, S. Insurance Giant Allianz France Exploring Blockchain Potential. Available online: http://www.coindesk.com/allianz-france-exploring-use-cases-with-blockchain-startup/ (accessed on 30 June 2016).
3. Insurance Times Newsdesk. AXA leads 55m investment in blockchain. Available online: http://www.insurancetimes.co.uk/axa-leads-55m-investment-in-blockchain/1417270.article (accessed on 29 June 2016).
4. Ramada, M. For insurers blockchain is the new black. Available online: http://blog.willis.com/2016/12/for- insurers-blockchain-is-the-new-black/ (accessed on 29 December 2017).
5. Shelkovnikov, A. Blockchain Applications in Insurance; Deloitte Report; Deloitte LLP: London, UK, 2016; pp. 12.

6. Lorenz, J.-T.; Mnstermann, B.; Higginson, M.; Olesen, P.B.; Bohlken, N.; Ricciardi, V. Blockchain in Insurance-Opportunity or Threat?; McKinsey Company Report; McKinsey Company: New York, NY, USA, 2016; pp. 19.
7. McKinsey Company. Blockchain Technology in the Insurance Sector. In Proceedings of the Quarterly Meeting of the Federal Advisory Committee on Insurance (FACI), McKinsey Company: New York, NY, USA, 2017.
8. Higgins, S. European Insurance Firms Launch New Blockchain Consortium. Available online: http://www.coindesk.com/europe-insurance-blockchain-consortium/ (accessed on 29 December 2017).
9. Lamberti, F.; Gatteschi, V.; Demartini, C.; Pranteda, C.; Santamaria, V. Blockchain or not blockchain, that is the question of the insurance and other sectors. IT Prof. 2017, doi:10.1109/MITP.2017.265110355.
10. Lamberti, F.; Gatteschi, V.; Demartini, C.; Pranteda, C.; Santamaria, Blockchain and Smart Contracts for Insurance: Blockchain and smart contracts for insurance: Is the technology mature enough? In: FUTURE INTERNET, vol. 10 n. 2, 2018, pp. 1-16. - ISSN 1999-5903.
11. de Broglie, L.; Mury, E.; Corbeaux, L. insPeer.
Available online: http://www.inspeer.me/ (accessed on 29 December 2017).
12. Kunde, T.; Herfurth, S.; Meyer-Plath, J. Friendsurance: The P2P Insurance Concept. Available online: http://www.friendsurance.com/ (accessed on 29 December 2017).
13. Davis, J. Peer to Peer Insurance on an Ethereum Blockchain. Available online: http://www.dynamisapp.com/whitepaper.pdf (accessed on 29 December 2017).
14. Ernst Young. Voice of the CustomerTime for Insurers to Rethink Their Relationships: Ernst Young Report; Ernst Young: London, UK, 2012; pp. 136.
15. D. Serre, C.Heinzlef. Assessing and mapping urban resilience to floods with respect to cascading effects through critical infrastructure networks. International Journal of Disaster Risk Reduction 30 (2018) 235243.
16. C. Zevenbergen, A. Cashman, N. Evelpidou, E. Pasche, S. Garvin, R. Ashley, Urban. Flood Management, CRC Press, 2010.
17. G. Pescaroli, M. Nones, Cascading Events, Technology and the Floods Directive: future challenges. E3S Web of Conferences, 7, 7003, 2016. 18. Swiss Re, Natural catastrophes and man-made disasters in 2013, 2014.
19. J.-P. Galland, Critique de la notion d'infrastructure critique. (Criticism of critical infrastructure concept), Flux (81) (2010) 618.
20. D. Serre, DS3 model testing: assessing critical infrastructure network flood resilience at the neighbourhood scale, in: A. Fekete, F. Fiedrich (Eds.), Urban Disaster Resilience and Security, Springer International Publishing, Cham, 2018, pp. 207220.
21. G. Pescaroli, I. Kelman, How critical infrastructure orients international relief in cascading disasters, J. Contingencies Crisis Manag. 25 (2) (2017) 5667.
22. B. Quenault, La rsurgence/convergence du triptyque catastrophe-rsilienceadaptation pour (re)penser la fabrique urbaine face aux risques climatiques. (The resurgence / convergence of the triptych "disaster-resilience-adaptation" to (re) think

the "urban factory" in the face of climate risks.) Dveloppement durable et territoires, 5, 3.
23. UNISDR (The United Nations International Strategy for Disaster Reduction), Sendai Framework for Disaster Risk Reduction 2015 - 2030, p. 36, 2015.
24. S. Lhomme, D. Serre, Y. Diab, R. Laganier, Analyzing resilience of urban networks: a preliminary step towards more flood resilient cities, Nat. Hazards Earth Syst. Sci. 13
25. S. Lhomme, D. Serre, Y. Diab, R. Laganier, Analyzing resilience of urban networks: a preliminary step towards more flood resilient cities, Nat. Hazards Earth Syst. Sci. 13.
26. S. Lhomme, D. Serre, Y. Diab, R. Laganier, Analyzing resilience of urban networks: a preliminary step towards more flood resilient cities, Nat. Hazards Earth Syst. Sci. 13.
27. C.S. Holling, Resilience and stability of ecological systems, Annu. Rev. Ecol. Syst. 4 (1) (1973) 123. 28. D. Bruneau, M., Chang, S., Eguchi, R., Lee, G., ORourke, T., Reinhorn, A., Shinozuka, M., Tierney, K.,Wallace,W., von Winterfelt, A framework to quantitatively assess and enhance the seismic resilience of communities, EERI Spectra J., vol. 19, no. 4, pp. 733752, 2003.
29. R.S. Roberts, Economic Strategies for Coastal Disaster Risk-Reduction: A Case Study of Exmouth (Ph.D.), Murdoch University, Western Australia, 2012.
30. W.J.W. Botzen, J.C.J.M. van den Bergh, Insurance against climate change and flooding in the Netherlands: present, future, and comparison with other countries, Risk Anal. 28 (2008) 413426.
31. A. G. Rumson, S. H. Hallett, T.R. Brewer. Coastal risk adaptation: the potential role of accessible geospatial Big Data. Marine Policy 83 (2017) 100110.
32. T. Filatova, A. Veen, Microeconomic Motives of Land Use Change in Coastal Zone Area: Agent Based Modelling Approach, 2006.
33. Bertoldi P. (editor), Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA), EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018.
34. Kaspersen, P.S. and Halsns K. (2017), Integrated climate change risk assessment: a practical application for urban flooding during extreme precipitation. Climate services 6, pp.55-64.
35. EEA (2016), Urban adaptation to climate change in Europe 2016. Transforming cities in a changing climate. European Environmental Agency report, No 12/2016, pp.140.
36. A. G. Rumson, S. H. Hallett, T.R. Brewer. Coastal risk adaptation: the potential role of accessible geospatial Big Data. Marine Policy 83 (2017) 100110.
37. UNISDR, Global Assessment Report on Disaster Risk Reduction Revealing Risk, Redefining Development, Geneva, 2011.
38. S.L. Cutter, L. Barnes, M. Berry, C. Burton, E. Evans, E. Tate, J. Webb, A place-based model for understanding community resilience to natural disasters, Glob. Environ. Change 18 (4) (2008) 598606.
39. A. Mller, J. Reiter, U. Weiland, Assessment of urban vulnerability towards floods using an indicator-based approach a case study for Santiago de Chile,

Nat. Hazards Earth Syst. Sci. 11 (8) (2011) 21072123.
40. Maksims Feofilovs, F. Romagnoli. Measuring community disaster resilience in the Latvian context: an apply case using a composite indicator approach. Energy Proceedia, 2016.
41. J. Mayunga, Measuring the measure— A multi-dimensional scale model to measure community disaster resilience in the US Gulf Coast region, no. May, pp. 1 247, 2009.
42. A.G. Rumson, Stephen H. Hallett. Innovations in the use of data facilitating insurance as a resilience mechanism for coastal flood risk. Science of the Total Environment 661 (2019) 598612.
43. Jagadish, H.V., 2015. Big Data and Science: Myths and Reality. Big Data Res. 2, 4952.
44. H. Min. Blockchain technology for enhancing supply chain resilience. Business Horizons (2019) 62, 3545.
45. M. A. Khan and K. Salah, IoT security: Review, blockchain solutions, and open challenges, Futur. Gener. Comput. Syst., vol. 82, pp. 395411, 2018.
46. N. Szabo, The Idea of Smart Contracts, http://szabo.best.vwh.net/idea.html, 1997.
47. N. Szabo, Read related articles on Internet economics and Security, http://firstmonday.org/ojs/index.php/fm/article/view/548/469, pp. 124, 1997.
48. M. L.?; D. C. P. Perugini, Introduzione agli Smart Contracts, http://ssrn.com/abstract=2729545, 2015.
49. V. Buterin, A Next-Generation Smart Contract and Decentralized Application Platform,
https://github.com/ethereum/wiki/wiki/White-Paper, 2014.
50. A. Grasso, Smart Contracts: Adoption Value for Enterprises and General Use Case, 2018.
51. IVASS, Relazione sullattivit svolta dallIstituto nellanno 201, 2016.
52. G. Greenspan, Beware of the Impossible Smart Contract,
http://www.theblockchain.com/2016/04/12/beware-of-the-impossible-smart-contract, 2016.
53. P. Wright, A. -De Filippi, Decentralized Blockchain technology and the rise of Lex Cryptographia, https://ssrn.com/abstract=2580664, 2015. 54. AXA Is Using Ethereum s Blockchain for a New Flight Insurance Product This website uses cookies, 2019.
55. AXA - Comunicato Stampa, AXA fa decollare in Italia Fizzy, la prima assicurazione viaggio al mondo basata su tecnologia blockchain che rivoluziona lesperienza cliente, 2018.
56. W. Viriyasitavat and D. Hoonsopon, Blockchain characteristics and consensus in modern business processes, J. Ind. Inf. Integr., no. June, pp. 01, 2018.
57. W. E. Forum, Rischi dei cambiamenti climatici?: il ruolo delle assicurazioni, 2013.
58. D. Macrinici, C. Cartofeanu, and S. Gao, Smart contract applications within blockchain technology: A systematic mapping study, Telemat. Informatics, vol. 35, no. 8, pp. 23372354, 2018.
59. Campobasso-Diritto commerciale. 3.pdf.

60. Aa. Vv., L Assicurazione dei Rischi Calamit Naturali, 7th R.I.B. Conv., no. November, 2000.
61. D. Porrini and R. Schwarze, Insurance models and European climate change policies: An assessment, Eur. J. Law Econ., vol. 38, no. 1, pp. 728, 2014.
62. I. Makhdoom, M. Abolhasan, H. Abbas, and W. Ni, Blockchains adoption in IoT: The challenges, and a way forward, J. Netw. Comput. Appl., vol. 125, no. October 2018, pp. 251279, 2019.
63. M. Andoni et al., Blockchain technology in the energy sector: A systematic review of challenges and opportunities, Renew. Sustain. Energy Rev., vol. 100, no. February 2018, pp. 143174, 2019.
64. H. Vranken, Sustainability of bitcoin and blockchains, Curr. Opin. Environ. Sustain., vol. 28, pp. 19, 2017.
65. H. Min, Blockchain technology for enhancing supply chain resilience, Bus. Horiz., vol. 62, no. 1, pp. 3545, 2018.
66. Banche , la sfida pi grande la blockchain.
https://www.startupbusiness.it/banche-la-sfida-della-blockchain/86184/, 2019.
67. K. Sayegh, Blockchain Application in Insurance and Reinsurance, no. October 2018, 2019.
68. Banca dItalia Tassi di interesse Analisi E Approfondimenti, 2019.
69. A. Jobst, What is Securitization?, Finance Development , IMF. p. Vol 45, 3, 2008.
70. M. Breckner, F. Englmaier, T. Stowasser, and U. Sunde, Resilience to natural disasters Insurance penetration, institutions, and disaster types, Econ. Lett., vol. 148, pp. 106110, 2016.
71. J. McAneney, D. McAneney, R. Musulin, G. Walker, and R. Crompton, Government-sponsored natural disaster insurance pools: A view from down-under, International Journal of Disaster Risk Reduction, vol. 15. 2016.