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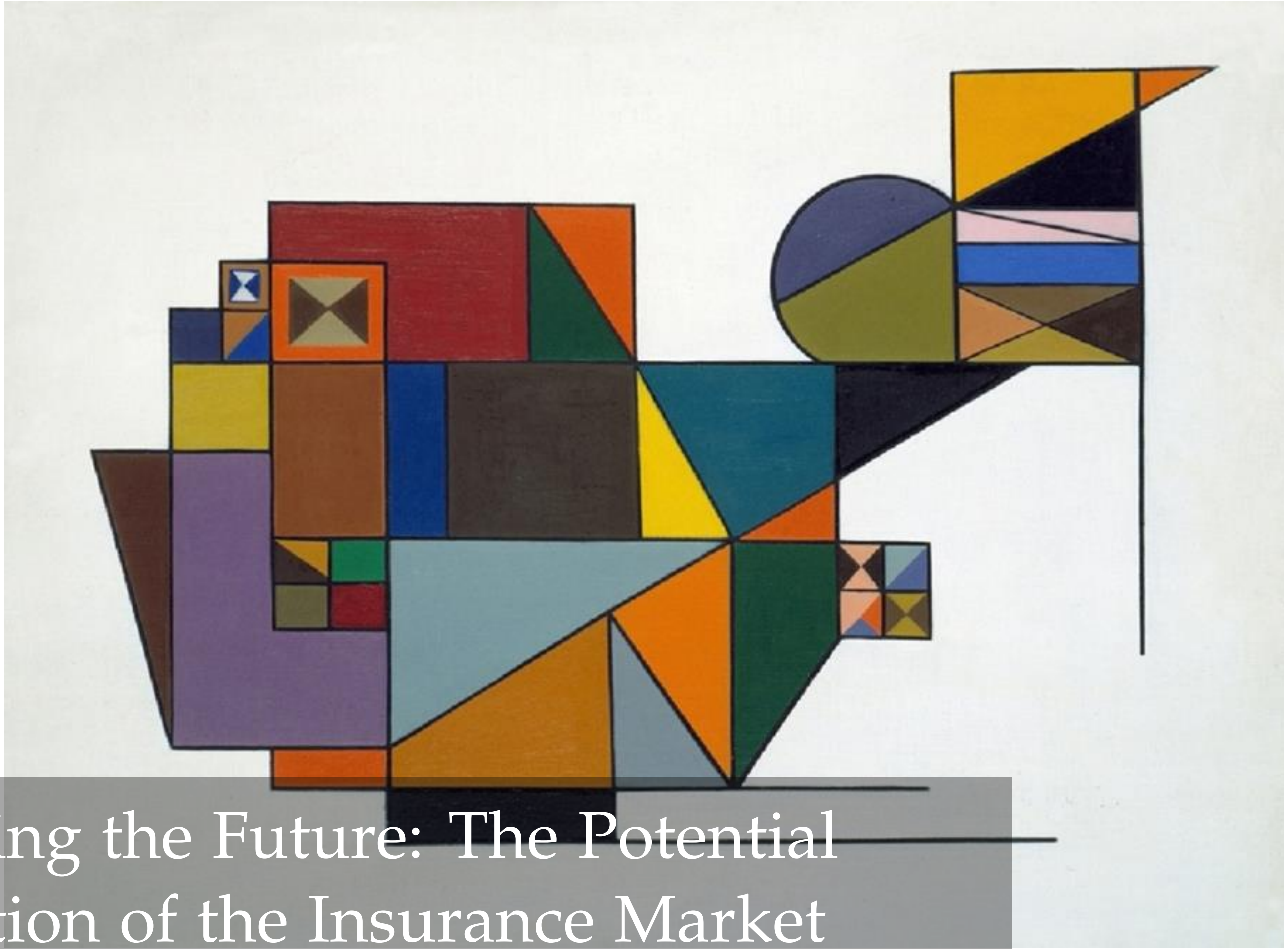

Ensuring the Future: The Potential Evolution of the Insurance Market

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Front Cover: **Atanasio Soldati**, *Sulla Diagonale*, 1949.

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Executive Summary

Financial markets are facing deep changes driven by the rapid advancement of digital innovation. In this ever-changing environment, new potential benefits and challenges arise and the organizations' need to develop more adaptive and agile solutions and business models has become even more crucial. Within this context, the rise of new risks, such as climate change, data security, technological-related risks, and economic volatility, and the issues related to traditional industry approaches, such as high operational costs and slow response times, will lead the insurance industry to rethink their business models and traditional risk management procedures. At the same time, the possibility given by the growth in technology and financial innovation could help tackle these risks, particularly through the integration of DeFi and Open Insurance. Through the implementation of environments that rely on blockchain, smart contracts, Oracles, and other data-sharing protocols, DeFi and Open Insurance will foster automated claims processing, better data gathering, and reduce information asymmetry. The research aims to explore how DeFi, Open Insurance frameworks, as well as their integration, could provide decentralized, automated solutions that address the limitations of conventional insurance approaches exploring future solutions where digital innovation empowers insurers to effectively navigate and mitigate modern risks.

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This document was prepared in collaboration with Nicola Mazzoni, who at the time was working for Iason Consulting.

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Ensuring the Future: The Potential Evolution of the Insurance Market

Valerio Ciminelli Jacopo Figuriello Nicola Mazzoni

Advancements in digital innovation are significantly transforming financial markets, introducing new potential benefits and challenges while reshaping traditional business models. In meanwhile the rise of emerging risks and the limited versatility of traditional industry practices are driving the need for new solutions and products within the insurance sector. This analysis explores the potential positive impacts of integrating technologies and paradigms such as asset tokenization, decentralized finance, and Open Insurance within the insurance industry. The research begins by examining the foundations of insurance, explaining the main drivers that lead the demand and the supply of insurance policies and providing an overview of industry trends and developments (a reader who is already comfortable with the concepts related to insurance markets could consider to go after to the next parts of the analysis or reading the chapter as a "refresher"). Next, a brief overview of Digital Ledger Technologies (DLTs) and asset tokenization is provided to set the stage for an analysis of insurance DeFi environments. The section dedicated to insurance DeFis will proceed in explaining the composition and the functioning of these environments, covering also the potential for the insurance market. After that, the focus will be put on Open Insurance, illustrating the main concepts of this new paradigm. Before concluding, the research will bring an illustrative view of some of the most relevant projects that rely on insurance DeFis and Open Insurance. Conclusions will focus on analyzing the potential benefit that the integration of insurance DeFis and Open Insurance could bring in the industry.

1. Insurance Foundations

1.1 Insurance Market

Looking back at history, we can see that risk coverage has always been part of human economic activities; indeed insurance policies were perhaps one of the first financial products ever developed, grounding its roots more than 3.000 years ago in the Babylonian Age with the first written evidence of pooling risks documented in the Hammurabi Code. Over centuries insurance market have gained in dimension and complexity evolving with the changing needs of societies becoming nowadays an industry managing trillions of dollars in assets. Despite the continuous technological innovation and the creation of countless insurance tools, the main element of the insurance industry remains the essential need it satisfies, the same need that led to its inception in the early ancient merchant communities: the need to protect one's assets (tangibles and intangibles) from the risks arising from the occurrence of uncertain events. This first chapter aims to analyze the key elements of insurance products and their main classifications, as well as to investigate the relationship between the insurance industry and the macroeconomic context to identify potential weaknesses in the sector that could become the targets for innovation introduced by blockchain technology.

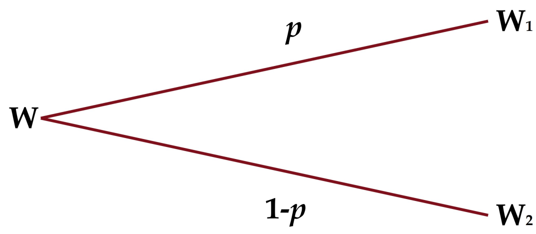


FIGURE 1: Monetary Lottery W.

According to academic literature, the main functions of insurance are:

- **Risk Allocation;**
- **Wealth Protection;**
- **Investment;**
- **Mobilization of Financial Resources;**
- **Improvement of Governance;**
- **Reduction of Public Expenditure.**

To better understand the achievement of the aforementioned functions, it is useful to focus on the components of demand and supply in the global insurance market.

1.1.1 Demand Analysis

Predominant academic literature identifies two main types of components in the demand within the insurance market:

- **Objective Components.** The risk of loss associated with owning an asset, external macroeconomic factors, and the level of premiums.
- **Subjective Components.** The risk aversion of individual economic agents.

The basic model of the demand for insurance coverage hypothesizes the presence of a binary risk scenario. Essentially, a loss of amount L on a particular asset will occur with probability p or, conversely, will not occur with probability $1 - p$. This model is very similar to the classical microeconomic model of consumer choice (also the two goods model), where the goods represent, in our case, two alternative levels of asset values in the absence of insurance coverage:

- W_1**:** where the loss does not occur (with probability p).
- $W_2 = W_0 - L$**:** where the loss occurs with probability (1-p).

The model could be represented by the following monetary lottery W:

$$W = (W_1, W_2; p, 1 - p).$$

The demand for insurance is influenced by a myriad of factors that operate both on individual and aggregate levels:

- **Individual-Level Drivers:**
  1. **Income and Wealth.** Income levels are a primary determinant of insurance demand. As individuals' income increases, they are more likely to purchase insurance because they have more assets that need to be protected and greater financial means to afford higher premiums. Wealthier individuals often pursue broader coverage policies, including health, life, and property insurance, to safeguard their accumulated assets. Higher-income

earners are also more likely to opt for policies with higher coverage and additional benefits. More disposable income allows families to invest in financial planning and risk management tools, including insurance. This is because, after covering the cost of living, they have surplus funds that can be used to purchase insurance coverage. Higher-income earners, due to a higher level of education, often have a greater awareness of financial risks and a stronger desire to protect their wealth and assets. This drives them to purchase insurance as a mean of securing their financial stability and protecting their tangible and intangible assets

2. **Risk Aversion.** Another factor that has been widely debated in academic literature, as a determinant of insurance demand, is risk aversion. An individual's risk aversion directly influences the perceived need to purchase insurance coverage. Those who perceive higher risks, whether due to health concerns, the nature of their occupation, or the safety of their assets, are more likely to seek insurance coverage. To maximize utility, risk-averse individuals are willing to pay a premium to avoid the potential loss of a large amount of wealth. This is the essence of insurance demand: by transferring risk to the insurer, individuals effectively "buy" safeness and preserve their utility against uncertainty. Risk aversion, measured in academic literature through the RRA (Relative Risk Aversion) variable, and its relationship with the demand for insurance products has been one of the most debated topics for decades in the economic field known as "behavioral finance." Risk perception is a crucial determinant of insurance demand. It refers to the subjective process by which an individual economic agent assesses the probability and magnitude of a potential loss due to adverse events. This perception influences his decisions regarding whether to purchase insurance and, if so, what types and amounts of coverage to seek[1]. In the 2021 paper by Jaspersen et al[13], the authors found moderately sized and statistically significant predictive power for the three most discussed primitive preference motives of insurance demand: utility curvature, probability weighting, and loss aversion.
3. **Education Level.** Education level plays a pivotal role in determining individuals' financial decisions, including the demand for insurance coverage. Several academic papers have analyzed the relationship between education level and demand for insurance coverage. The evidence from these papers suggests a positive correlation between an individual's level of education and their participation in the insurance market. Education affects an individual's risk perception, understanding of financial products, and informed decision-making about protection against uncertain events. Guiso and Paiella (2008) [10] highlight that individuals with higher education tend to have a better assessment of the probability of adverse events and are better able to evaluate the benefits of insurance as a risk management tool. This improved risk assessment leads to a more rational decision-making process regarding insurance, where individuals weigh the cost of premiums against the potential financial consequences of unexpected events.

- **Aggregate-Level Drivers.** The demand for insurance is significantly affected by a range of macroeconomic factors, which include broader economic conditions and trends that influence both individuals' and businesses' financial behaviors and approaches to risk management. Financial literature understanding these macroeconomic influences is essential for comprehending how varying economic environments impact insurance markets. Below we will see how the main macroeconomic variables influence the demand for life and non-life insurance. The relationship between the broader economic environment and insurance demand is well-documented in the literature, with key factors including economic growth, inflation, interest rates, financial market development, and government policy playing prominent roles.

1. **Economic Growth.** One of the most widely studied macroeconomic drivers of insurance demand is economic growth, obviously measured by GDP. Beck and Webb (2003) [2] conducted an empirical study across 68 countries and found that economic growth is a major determinant of life insurance demand. The authors used real GDP per capita as an indicator of permanent income, calculated as a predicted value from a regression of the log

[1] For a review of the empirical literature on risk aversion and with a particular focus on insurance demand or consumption see "J. François Outreville Risk Aversion, Risk Behaviour and demand for Insurance: a survey."

of each Country's real GDP per capita on a time trend (40 years observation period). The results of the regression indicate that a 10% increase in real income per capita increases life insurance penetration by 5.7%, confirming the theory that life insurance is a luxury good. As a Country's economy grows, individuals and businesses accumulate wealth, which increases the need to protect their assets and income streams through insurance products. To better understand the correlation between GDP per capita and insurance demand, as well as the correlation with other factors, it is necessary to introduce the variable typically used by academia and industry to quantify demand: the gross premium. The gross premium is the amount the insured pays for an insurance policy that is not the amount the insurance company earns for writing the policy. Gross premiums are typically adjusted upwards to account for commissions, selling expenses like discounts, and other insurer's expenses. In a 2014 paper (Cristea, Marcua, and Cârstina) [3], the authors found, using a multiple linear regression model, a high correlation between GDP per capita and gross premium in both the life and non-life sectors, with a stronger correlation observed in the life sector.

2. **Inflation.** Inflation is another key macroeconomic variable that potentially impacts insurance demand, although its effects can be complex depending on the type of insurance product considered. In a 2002 research paper, Ward and Zurbruegg (2002) [15] state that inflation creates uncertainty in the insurance market, leading to higher premium costs. Insurers raise premiums to compensate for the expected increase in claims costs due to inflation, which can reduce the affordability of insurance and subsequently lower demand. As inflation erodes the cash value of any sums received in the future, the benefits of purchasing life insurance diminish. Further, higher levels of inflation are associated with macro-economic uncertainty and as a result the discounted value of financial assets, including life insurance, will be less.

3. **Interest Rates.** It comes as no surprise that interest rates play a critical role in the functioning of the financial markets and have also a profound influence on the demand for insurance, with particular reference to life insurance products which often include significant savings or investment components. Feyen et al. (2011) [9] argue that life insurance demand is inversely related to interest rates, particularly in developed economies. In a low-interest-rate environment, returns from life insurance policies are relatively more attractive compared to other financial products. As a result, individuals may prefer to purchase life insurance for both its risk coverage and savings benefits. Inversely, when interest rates rise, alternative financial products like bonds or savings accounts offer better returns, making life insurance policies less attractive.

1.1.2 Supply Analysis

Once we have completed the quick overview of the main drivers of demand for insurance products, the focus will now be provided on the supply side, thus turning our attention to insurance companies and their premium determination policies based on what is now a well-established academic theory. Insurance pricing is a critical aspect of the insurance industry, determining how premiums are set for various insurance products. It involves complex calculations that account for risk assessment, administrative costs, profit margins, and market conditions; the pricing of insurance products is so impactful and complex that it is the focus of an entire discipline: actuarial science. The primary objective of the pricing processes for insurance products is to ensure the economic sustainability of insurance companies' supply. Let's now take a closer look at the factors that contribute to determining the premiums of insurance products:

- **Risk Assessment:** The classical theory of insurance risk, in defining models for calculating insurance premiums, emphasizes the underwriting activities of insurance companies. Considering an Insurance Portfolio, actuaries form a stochastic process in time, consisting of two components:
  - Uncertain Number of Claims;
  - Uncertain Amount of a Claims.

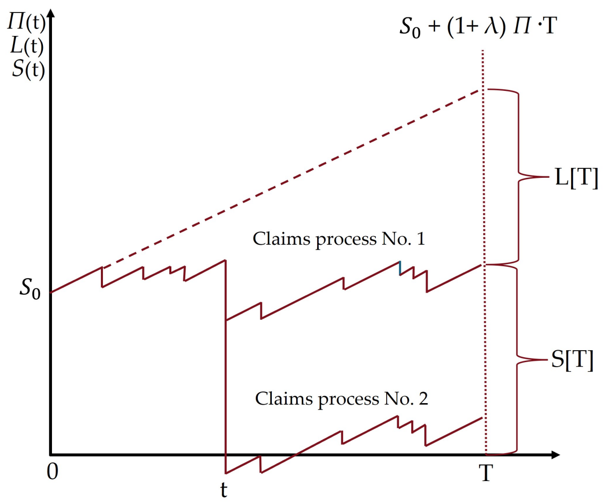


FIGURE 2: *Stochastic Claim Process.*

Here we describe a typical stochastic claim process: At time t_0, the insurer has a surplus, S_0, consisting of equity capital and accumulated reserves. Until the first claim occurs, the only inflow in the process is from premium payments, causing the surplus to grow in line with the amount of the premium over a given period:

$$(1 + \lambda)\pi,$$

where π represents the fair premium income and λ is the surcharge per monetary unit which is a safety loading designed to mitigate the risk of insolvency. At time T and in the absence of any claim, the surplus would be:

$$S(T) = S_0 + (1 + \lambda)\pi \cdot T.$$

When the first claim occurs, the surplus decreases by the amount of loss payment. After that, the surplus process continues with the same slope until another claim is submitted. The vertical distance from the premium income process represents the cumulative value of losses paid L_T as clearly shown in Figure 2. Since this is a stochastic process, the claims process can take on different variables. For example, in Fig.2, we can see that claims process No. 2 is significantly less favorable from the insurer's perspective, with a high claim occurring at time t_c, causing the surplus to drop to negative values for a certain period and resulting in a concrete risk of insolvency for the insurer. It is precisely this concrete risk of insolvency that guides the insurer in the pricing process. In fact, by generalizing the claims process No. 2 described above, the latter can be represented by a loss distribution function f(x). Given an estimated loss distribution, the underwriters typically apply one of the several premium principles developed by academic literature to determine a fair premium $\pi(x)$. Considering the importance of the underwriting and risk assessment process in determining the insurance premium, it would be useful to explore the potential improvements that blockchain could bring to the process.

- **Regulatory Framework.** One of the most critical components of insurance regulation that affects supply is solvency regulation, which ensures that insurance companies maintain sufficient capital to meet their liabilities. The Solvency II Directive in the European Union[2], and similar frameworks like Risk-Based Capital (RBC)[3] requirements in the United States, are intended to maintain the financial stability of insurance companies by mandating a capital buffer proportional to the risk they underwrite. As well documented in an Eling & Schmeiser paper of 2010[7], solvency requirements have a direct effect on the capability of insurers to

[2]For a complete overview see "Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)".
[3]See NAIC's "Risk Based Capital (RBC) for Insurers Model Act", initially adopted in 1993 (latest revision, 2011).

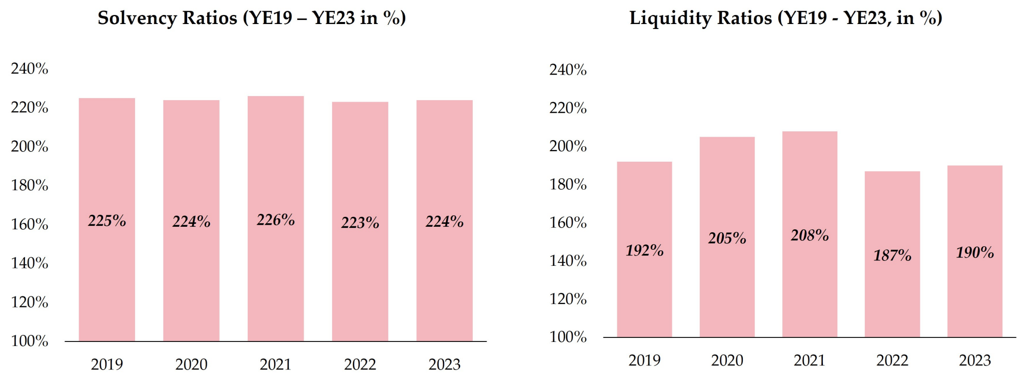


FIGURE 3: Solvency Ratios and Liquidity Ratios.

provide coverage, indeed, tighter capital requirements often lead to a reduction in supply, as insurers are forced to either raise new capital or limit the amount of risk they take on to maintain solvency levels.

- **Financial Markets.** Insurance companies are among the main players, alongside commercial and investment banks, in global financial markets. Their role stems from the need for capital reserves, as described in the previous two points, which drives insurers to constantly seek investment returns, particularly in debt instruments. It is therefore not surprising that there is a correlation between interest rate trends and the amount of insurance product supply. Considering the context of rising interest rates, insurance companies can rely on higher returns from their investments and expand their underwriting activities. Empirical studies have found that life insurance companies are particularly sensitive to changes in interest rates, as their long-term liabilities must be matched with assets generating consistent returns (Koijen & Yogo, 2016)[14].

1.2 Global Insurance Market: Outlook and Trends

Once the discussion of the main determinants of insurance product supply is completed, it is appropriate to conduct a deep dive into the trends of the global insurance market and the key industry developments. This will provide, by the end of the chapter, an initial "glance" at the role that tokenization could play in the insurance sector, also considering the relevant economic context. The key figures and economic indicators for this section are mainly taken from the annual reports of the IAIS (International Association of Insurance Supervisors)[11] and EIOPA (European Insurance and Occupational Pensions Authority). The typical indicators considered by Market Authorities to monitor the health of the insurance industry are Solvency, Liquidity, and Profitability. The solvency ratio is the ratio of eligible own funds (Eligible Own Fund - EOF) to the solvency capital requirement (Solvency Capital Requirement - SCR) and expresses the level of capitalization of insurance companies. The SCR is the capital required for insurance companies to remain solvent with a probability of 99.5% over a one-year time horizon.

$$SolvencyRatio = \frac{EligibleOwnFund}{SolvencyCapitalRequirement}.$$

On the other hand, the ILR, as defined by IAIS, is the ratio of an insurer's liquidity sources and needs over a selected time horizon of assumed liquidity stress:

$$InsuranceLiquidityRatio = \frac{LiquiditySources}{LiquidityNeeds}.$$

The IAIS accurately identifies the various components that contribute to forming the Liquidity Sources, assigning each of them a specific weight to calculate the LCR (e.g. Cash 5%, Sovereign Debt 65%, Corporate Debt 30%).
Based on data collection from a pool of the 60 largest insurance groups worldwide, in its annual

report, the IAIS notes that, during the observation period from 2019 to 2023, the solvency and liquidity of the global insurance market demonstrated considerable resilience to macroeconomic changes, showing a rather stable trend as illustrated in Figure 3.
The primary factors influencing solvency and profitability include increased interest rates in many regions (which can reduce the present value of liabilities, especially for life insurers offering long-term products), higher premium income, reduced dividend payouts by insurers, and an upswing in financial markets resulting in higher investment returns. Despite 2023 being a year of significant macroeconomic uncertainty and geopolitical instability, the insurance market and, in fact, the global economy, demonstrated relative stability, with a positive outlook for the next two years. This growth is expected to be supported by a decline in inflation resulting from monetary policy actions.
Now that we have analyzed the health of the global insurance market, it could be useful to provide a summary, non-exhaustive overview of the upcoming trends that insurance companies should embrace, as well as the risks that need closer monitoring.

- **High Interest Rates and Inflation.** According to IMF World Economic Outlook Update, the global economy is now stabilizing but we are not out of the woods yet, indeed, even if inflation is coming down it remains high in many countries, forcing their Central Banks to keep interest rates elevated. Furthermore, the complex geopolitical context must be considered, as it risks making any economic policy action much less effective; one only needs to think about the tensions that various conflict scenarios around the world can generate in international trade. These developments might mean that inflation is likely to remain a global concern for some time and any interest rate increase has potentially significant impacts on insurers. On one hand, Property and Casualty (P&C) insurers should face higher difficulties due to the potential rise of claims costs and they may need to minimize any shortfalls between premium revenue and claims payouts by raising premiums; on the other hand for Life and Retirement sector, higher interest rates could reduce the need to reinsure or transfer interest rate risks to other parties pushing insurers to potentially underwrite more new business. The "P&C" sector is therefore the most sensitive to rising interest rate dynamics. One additional tool available to insurance companies compared to the past could be leveraging the potential of new technologies in their information systems to obtain reliable data on "loss costs" and promptly guide business decisions aimed at minimizing this negative trend.

- **Credit Risk.** As revealed by a recent round of inspections by the ECB, there is a concrete credit risk associated with the deterioration of exposures secured by Commercial Real Estate, stemming from a collapse in CRE prices that began with the pandemic in 2020, leading to a drop in demand and further exacerbated by higher borrowing costs due to the inflationary context. This has implications for the insurance sector, which often holds substantial exposure (higher for life insurers) to these assets to generate income and manage risk. Furthermore, there is a business impact on the securitization market for real estate assets, which is also under downward pressure. In a 2024 scenario analysis conducted by the Federal Reserve Bank of Chicago[8], it has been estimated that the life insurance sector could face combined losses of about $36.3 billion from direct and indirect exposures to CRE.

- **Climate-Related Risks.** Climate change is contributing to heavy alterations in the Earth's climate system, leading to an increase in the frequency and intensity of catastrophic natural events. According to 2022 EIOPA's dashboard on the insurance protection gap for natural catastrophes, only around a quarter of the total economic losses caused by extreme weather and climate-related events are insured, leading to a substantial insurance protection gap. As the cost and frequency of claims increase, insurers are likely to increase premiums, potentially making insurance more expensive and even unaffordable. In extreme cases, insurers may withdraw from market segments as it becomes uneconomical to offer insurance, resulting in an even larger protection gap, as has happened recently in Florida in the aftermath of Hurricanes Helene and Milton. The increased frequency and severity of natural disasters make it harder for insurers to accurately predict future losses and appropriately price insurance products. Climate risk is a full-fledged source of financial risk, and as such, authorities are calling on insurance players to take an active role in the identification, measurement, mitigation, and coverage of climate risks, also with a view to contributing to the net-zero transition. However, there is often a gap between regulatory mandates and the actual achievement of targets due to market dynamics, which responds to the logic of utility maximization and risk aversion. A key to trying to influence market dynamics could be the introduction of innovative financial instruments by insurance companies that incentivize climate risk prevention, such as policies where the premium is tied to the implementation of risk exposure reduction measures by the insured (e.g., fire prevention systems, flood barriers, alarm systems...). A key challenge in offering these products is collecting high-quality, reliable data on the insured. To this end, insurers could leverage Open Insurance and tokenization to reduce data collection costs and significantly lower information asymmetry. An adequate and cost-effective data collection process could also reduce the risk for insurers related to incorrect policy pricing, possibly through the implementation of scenario analysis to properly calibrate their models and limit underwriting losses.

- **Impact of Digitalization and AI.** The rapid advancement of technologies such as big data, artificial intelligence (AI), machine learning (ML), blockchain, and the Internet of Things (IoT) is set to bring profound changes in how insurance companies operate, engage with customers, and manage risks. Each of these technologies can potentially bring benefits to both insurance companies and policyholders by introducing innovative services or simply making distribution channels more efficient. According to a 2024 EIOPA's Report on the digitalization of the European Insurance Sector[6], more than 52% of insurance companies that participated in the survey already have a dedicated digital transformation strategy in place, that covers areas such as customer service/user experience, digital infrastructure, data interfaces, digital platforms, and ecosystems, Application Program Interfaces (APIs), digital distribution channels, interaction with sales agents or IT security issues. Going into more detail, we can observe that while 50% of European insurance players in the non-life segment are already using artificial intelligence tools, only 15% of respondents reported actual usage of blockchain. Moreover, half of these use cases are still at the proof-of-concept stage. A noteworthy example is that of home insurance policies linked to mortgages. This is a collaborative project between the banking and insurance systems, which ensures access to a DLT database containing information related to mortgage loans. This allows for an automatic insurance offering to customers who take out a mortgage, using smart contracts. We believe, with a certain level of confidence, that the use of Open Insurance processes combined with the implementation of DLT technologies could bring numerous benefits to the insurance industry by reducing operational and agency costs through faster and more efficient processes; furthermore, digitalization could enable providers to automatize their interaction with clients, including at the claims stage, facilitating the accessibility for customers, and speeding the overall claims management processes.

2. Digital Ledger Technology

In recent years, digital assets and asset tokenization have captured the interest of many, especially in the financial sector, for their potential disruptive applications in a wide range of markets. The foundation that has made the spread of Digital Assets possible is the DLT (Digital Ledger Technology). In analyzing the potential benefits that insurance DeFis could bring to the insurance market, it seems necessary to begin by exploring the concepts related to DLTs. DLTs are nothing less than a digital ledger that differs from the classical centralized digital ledger by its core feature of being distributed in identical copies between the nodes that compose the network. One of the main characteristics of DLTs is that the information of the ledgers is constantly and simultaneously updated on each node of the network for every transaction. The following paragraphs will focus on explaining:

- **Consensus Mechanism;**
- **DLTs Architectures;**
- **Smart Contracts;**

- **Tokens;**
- **Asset Tokenization.**

2.1 Consensus Mechanism

One of the core features of DLTs is that every node in the network has stored the same information as the other nodes. When an event changes the information embedded in a node, each other node of the network must be updated in the same way. In a decentralized environment, one of the biggest challenges is to accord participants in the way a decision, such as the update of a node, should be taken and accepted. To prevent chaotic situations and address double-spending issues, DLTs rely on a particular cluster of algorithms that helps the network to agree on the information that must be updated in the nodes (the introduction of consensus mechanisms helps to overcome the so-called, Byzantine Generals Problem[4]. In the DLTs landscape, a lot of different consensus algorithms have been adopted to solve the need to coordinate the network's nodes update, in particular, we can cite as the most notables:

- **The Proof of Work (PoW).** The PoW mechanism relies on a "Mining Process that requires the network components to solve high-level computational problems to validate the information and update the ledgers"[16]. The first participant in the network who correctly solves the hash puzzle receives a reward (e.g. a unit of a cryptocurrency). The other participants can easily prove the solutions proposed and verify if it's correct or not. After the correctness is verified, the new information is updated across the entire network. The PoW ensures network trust and robustness against fraud due to its high computational and energy costs. Despite its high costs and its low scalability PoW represents one of the most famous consensus mechanisms and is the one on which Bitcoin relies on.
- **The Proof of Stake (PoS).** The PoS mechanism does not rely on the computational power of the validators, instead it requires the participants of the network that want to validate transactions to store as a collateral part of their tokens in the network. In case of malevolent behavior, the "stake" will be "slashed", and his tokens will be detained within the network.
- **The Proof of Authority (PoA).** In the PoA mechanism the validators are predefined trusted public entities. This configuration permits a faster and less costly environment in exchange for a reduction of the degree of decentralization of the network
- **The Proof of Capacity (PoC).** The PoC mechanism is based on the storage power of the network participants. The validators must store a pool of hash solutions in a memory space and every time a new block of the chain is created, they must search for the solutions inside their storage. The bigger the memory space they have at their disposal the bigger the probability is of having the solution of the hash in the downloaded pool of solutions.
- **The Proof of Burn (PoB).** The PoB bases its trusted validation mechanism on the requirement of "burning" tokens to become a network validator. This configuration requires that validators destroy a certain number of tokens (that are removed from the network circulation) to participate in the "mining" of new nodes. Typically, the reward for the miners is the mined fresh new coins.
- **Direct Acyclic Graph (DAG).** In DAG environments each transaction must be linked to previous validated transactions to be accepted by the network. Relying on its network for the connection between transactions DAGs do not require miners or validators resulting in an energy-efficient environment but the absence of validators hides an increase in security costs to maintain a trusted network
- **Byzantine Fault Tolerance Models (BFT-Models).** The BFT Models refer to a multitude of architectures that aim to solve the Byzantine Generals' Problem ensuring that the consensus

[4]An informatic problem that describes a scenario where multiple participants (the generals) have to agree on a coordinated decision, but some of the agents should be against the system. The challenge is to find a consensus even when some of the participants act against the system.

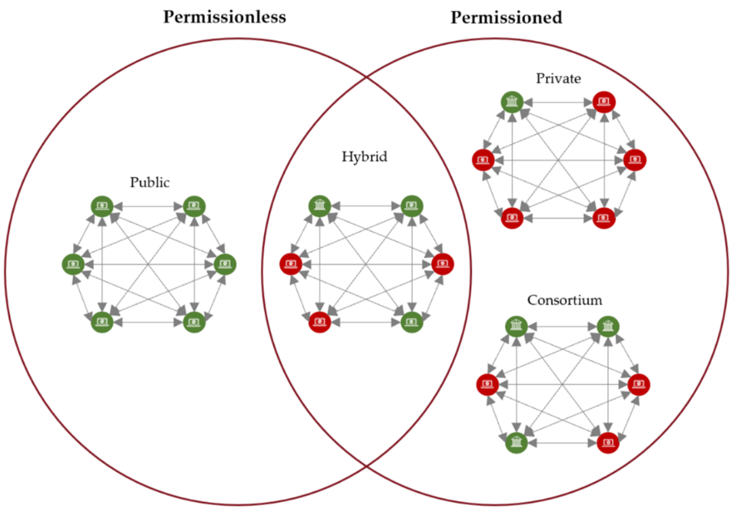


FIGURE 4: DLTs Architecures.

within a network is reached even if a third of the participants act malevolently. The most notable are:

- **Practical Byzantine Fault Tolerance (PBFT).** PBFT environments are based on a voting-round system where at least two-thirds of the network must agree on the validity of a transaction.
- **Delegated Byzantine Fault Tolerance (DBFT).** In the DBFT environment network participants choose a delegation of participants that has to carry the burden of reaching the consensus for the network.

2.2 Architecture

Usually, when analyzing DLTs two main categories based on the network access control profile are taken into consideration:

- **Permissionless (or Public) DLTs.** In this environment, every network participant could work as a validator. This form of DLTs represents "the purest form of decentralized ledgers; without a centralized authority that manages the network, anyone can join it"[16] and relies on consensus mechanisms in order to validate the transactions within the network. The most famous Permissionless DLT is Blockchain, a DLT based on a data block structure where every time new information is validated it is added to the "chain" as a new block of it.
- **Permissioned DLTs.** In these environments, only a restricted pre-defined group of trusted participants could take part in the consensus mechanism. These environments are also divided into:
  - **Permissioned Private DLTs.** In these DLTS "the transaction validator role is in the hand of the Central Authority (typically the Network owner)"[17].
  - **Permissioned Consortium DLTs.** The role of validators in these configurations is in the hands of a small group of participants who act as trusted validators of the network.

Despite the taxonomy explained covering the majority of DLT networks is there the possibility of hybrid configurations that could present a mix of features from both permissionless and permissioned DLTs.

2.3 Smart Contracts

The core of the automatization of the functions embedded into a DLTs is represented by a family of computer protocols that under the satisfaction of an agreement execute some predetermined

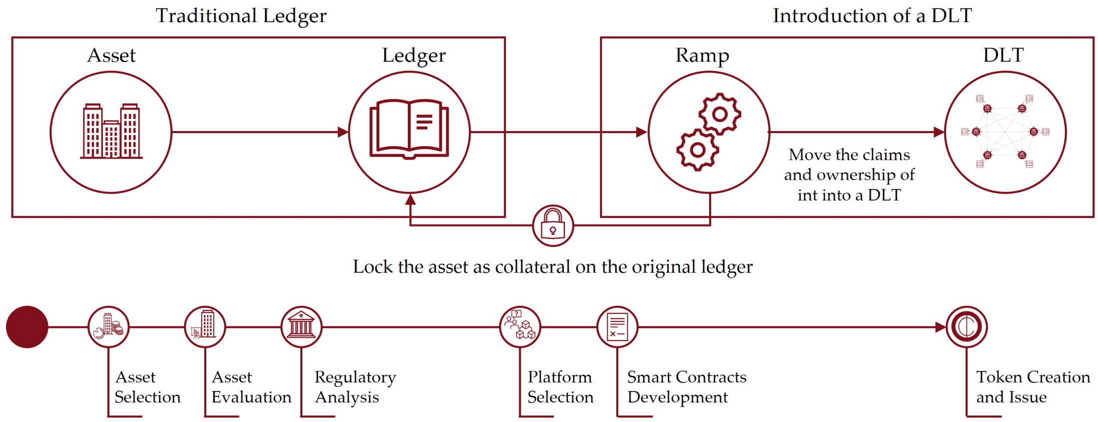


FIGURE 5: Asset Tokenization Process.

function, such as the payment of coupon or the exchange of a token, these protocols are the well-known smart contracts. Smart contracts play a crucial role within a DLT network, acting as its rule vault. In fact, the conditions embedded into smart contracts are the ones that enable the automation of the functions that rule exchanges and interactions within the network participants. To summarize, "a smart contract is a self-executing program that automates the tasks outlined in an agreement or contract; once executed, these transactions are traceable and cannot be reversed. Smart Contracts emerged as a solution to remove intermediaries in trustless third-party transactions"[18].
It is easy to figure out that smart contracts, and their nature of if/then condition protocols, could see their application in many markets, especially in insurance and financial ones where payments and claims are based on the trigger of pre-determined contractualized events.

2.4 Tokens

Tokens are the native digital assets exchanged among DLT network participants that can represent any form of value or claim such as a real-estate property or an IP, through the support of the conditions embedded in the smart contracts that foster their creation, issuing, and management. Tokens are composed of two main layers that determine the features and the rules of the token within the network and the token's characteristics:

- **Core Layer.** This specifies the logic and the rules that the token will be subject within the platform (e.g. the interoperability and Cross-Chain Functions or the token regulatory conditions).
- **Service Layer.** This contains the determining features of the token (e.g. ownership rights, issuance value, etc.).

Tokens could serve a vast variety of purposes and could represent a barely unlimited group of claims depending on both their design and reference platform. Considering so the token taxonomy distinguishing a vast plethora of possible tokens, following a brief view of the most famous ones:

- **Cryptocurrencies.** Decentralized Digital currencies that rely on cryptographic algorithms to ensure the safeness of the transactions and the robustness of their network. Notable examples of cryptocurrencies are Bitcoin and Ethereum.
- **Security Tokens.** Tokens that represent a financial asset, such as equity shares, bonds, or real estate assets.
- **Stablecoins.** Tokens directly pegged to an underlying asset, usually a fiat currency, to which they ensure a par-exchange.
- **NFT (Non-Fungible Tokens).** This typology of tokens incorporates the ownership or the claim on a unique, real-world or digital, asset such as an art masterpiece.

- **Commodity Tokens.** Similarly to security tokens, these tokens are directly linked to the value of a particular commodity such as rare metals (e.g. gold, silver, etc.), oil, or other commodities (e.g. oat, pork belly,etc.).
- **Governance Tokens.** This typology embedded the voting rights that permit the network users to participate in the decision-making process of the decentralized environment.
- **Insurance Tokens.** These tokens "are designed to provide coverage against specific events and are typically used to create a kind of insurance contract into a DeFi Environment. They could also represent Tokenized ownership rights of insurance-related Assets, such as insurance policies or risk pools" [19].

2.5 Asset Tokenization

The process that allows a real-world asset, such as a real-estate asset or an art masterpiece, to be moved on a DLT is called asset tokenization. Technically speaking the process locks the real-world asset on its origin ledger as collateral for the tokens and, through a so-called "ramp", the asset is moved on the DLT. The process will guarantee the existence of the asset off the chain, while its related claims will be moved on the chain. The flow that will allow the tokenization of an asset is divided into six main phases:

- **Asset Selection.** The first step will involve the selection of the type of asset that should be tokenized. As seen before, asset tokenization could involve any real-world asset so choosing one or another typology of assets will affect every other step of the process influencing the valuation methodologies, the regulatory framework, the platform selection, and so on.
- **Asset Evaluation.** Starting from the asset that will be moved on the chain, this step regards first the choice of the evaluation methodologies of the assets then the potential demand analysis and other key evaluation steps such as the potential future revenues. To understand the importance of the right evaluation, it is important to state that discrepancies between the evaluation of the off-the-chain asset and its digitalized claims could lead to potential speculative and disruptive results.
- **Regulatory Analysis.** The scope of this process phase is to ensure that the right regulatory framework within the reference country for the chosen asset is identified. This also regards assessing the ALM (Anti Money Laundering), KYC (Know Your Customer), and data protection regulations that are in force in the reference country.
- **Platform Selection.** The core of the entire environment for the tokenized asset passes through the decisions that will be made regarding the platform and the technology on which it will rely, in particular, during this step, it will be defined if the native platform will be permissioned or permissionless, blockchain-based or not. The right platform and its configuration will directly affect several parts of the token distribution determining the transaction scalability, costs, and typologies (e.g. cross-boarders transactions).
- **Smart Contracts Development.** The rules and logic of the environment will be embedded, as already stated, in the smart contracts, which are going to be in charge of deploying the necessary actions for the token issuance, transaction management, determinate governance, and voting rights. Practically, this phase will define the rules on will govern the platform.
- **Token Creation and Issue.** The token creation and the following issue will end the process. At this stage, mostly all the decisions have been taken but this final part will be as crucial as the others defining the property tokenization model opting for fractional ownership of the asset (and the number of tokens that will be issued) or for the individual ownership of the asset. The last part of the process will be the determination of the offering structure of the tokens, with the decision between an initial public offering (IPO) or a private placement.

Asset tokenization could foster the development of the economic system through several potential benefit effects. First, the fractionality of the ownership that could be reached through asset tokenization could lead the providing liquidity in historically un-liquid markets, such as real-estate markets or art markets. The possibility of dividing the ownership of an undividable asset could bring more retail investors into markets where they were excluded by the high barrier costs, boosting the liquidity of these markets.The market's efficiency could also be supported and boosted by the automatism guaranteed by smart contracts that could enforce faster and frictionless transactions. For instance, "a representative case of these possible improvements is the atomic settlement condition that could be coded into a smart contract that will permit an instantaneous exchange between two tokens once both parties submit their transaction"[19] Also, the lack of a central authority could indeed bring a reduction in transaction costs while the immutability of the ledger records could foster a more transparent environment, and the consensus mechanisms will ensure the safety of the network.

3. Decentralized Finance (DeFi)

The possibility unlocked by the scalability of programmability and the rise of DLTs has made possible the creation of decentralized environments that offer different financial services without the need to rely on financial intermediaries, these "ecosystems" are the DeFis. Decentralized finance environments leverage the power of smart contracts to establish protocols offering various financial services. The DeFi DLTs Network and the automatisms generated by smart contracts make it possible to have financial services offered that directly link the network participants without the need for "middlemen". The technical composition of a DeFi is correctly described by the DeFi Stack Reference Model (DSRM)[1]. The model identifies three main layers:

- **Settlement Layer.** The basement of the DeFi that is made by the native DLT on which the network is built and defines the transaction execution and validation rules ensuring the updating of the nodes and the safety of the environment.
- **Application Layer.** This layer defines the protocols and the services that are offered within the network, including also the native crypto asset that is exchanged within the environment.
- **Interface Layer.** The end-user interfaces.

3.1 Insurance DeFi

For the research purpose, it is important to enlighten the features of the so-called insurance DeFis. These environments rely, as seen before, on the DLTs and the automation of smart contracts to offer a wide plethora of decentralized insurance services. Two main families of insurance DeFi can be recognized in the market:

- **Traditional Insurance-Like DeFi.** Relies on the potential of DLTs to offer traditional insurance products substituting insurance agencies with a decentralized environment
- **DeFi's Risks Coverage Insurance DeFi.** Shields the network participants from risks directly embodied in a decentralized digital network such as hacking events or other technical issues.

Insurance DeFis exploit DLTs and smart contracts to create a liquidity pool, powered by the crypto asset flows of the liquidity provider, that serves as the monetary coverage for the risks that want to be covered by the insurance buyer. Usually, an insurance DeFi environment works as follows:

- **Liquidity Pool.** The liquidity of the environment is fed by users, the liquidity providers, that deposit funds (e.g. crypto assets) into a smart contract. Usually, the liquidity providers will receive a pool token that will represent the share of their participation in the pool. The liquidity pool represents the vault that will be used to cover the payment of the insurance claims to the buyers.
- **Insurance Offer.** The insurance DeFi could cover, as said, specific different risks, that range from smart contract failures to flight delays, to which the pools are linked. The liquidity providers choose which risk they want to cover with their funds and the smart contract associated with the pool will manage the eventual payment only on the designed specific risk

- **Price Evaluation.** The price that will be required to be insured is calculated through the support of smart contracts. The models applied are usually based on:
  - The evaluation of the probability of occurrence of the risk on the duration of the contracts;
  - The liquidity of the pool at the moment where the coverage is required.

  Automated Market Maker Models (AMM) are the most famous price algorithms in the DeFi landscape, including the insurance DeFi. These models calibrate the price of the insurance, and the most famous one is Constant Product AMM. The Constant Product AMM requires that the value of the product of two variables remains constant during time, specifically, the following equation must be always satisfied:

$$x \cdot y = K,$$

  where:
  - **x** represents the total liquidity of the pool;
  - **y** represents the coverage demand, as the total value of contracts in charge in a moment t;
  - **k** represents the constant value.

  If the demand for coverage rises the liquidity available to cover claims decreases, so to maintain the constant relation, the insurance premium increases. On the other hand, if the demand lowers the liquidity of the pool rises and the price for coverage falls as well. These models allow the definition of the prices through the simple mechanisms of offer-demand fostering the transparency of the pricing and avoiding intermediaries' arbitrage. Despite their simplicity, Constant Products AMM defines insurance prices by assessing the true liquidity risk of the environment. On the other hand, these models suffer from impermanent loss risk, which is defined as the loss generated by the significant movements in the liquidity pool deposited asset's prices. In these cases, the withdrawal of the assets could generate a loss in value for the liquidity provider's respect if they have detained their assets outside the pool.

- **Revenues for the Liquidity Providers.** Liquidity providers' revenues usually come through two channels:
  - **Insurance Premiums.** Based on their share of the liquidity pool the providers receive a proportional part of the revenues generated by the insurance's premiums.
  - **Interests.** DeFi environments usually pledge the liquidity pool funds (or a part of it) in other activities, to create passive revenues for the liquidity providers, for instance utilizing practices such as:
    * **Yield Farming.** The funds of the providers are pledged into other DeFi environments to support other financial services that generate passive incomes for the liquidity providers.
    * **Stacking.** The funds of the pool are stacked into a PoS (Proof of Stake) to receive the revenues for participating in the validation process of another DLT environment.

- **Insurance Payments.** If the event covered by the insurance occurs usually smart contracts provide automated payment to the insured. Smart contracts rely on oracles to determine if an event occurs. Oracles are an external party that permits the linkage between smart contracts and real-world data, their function is to permit the smart contracts' algorithms to determine if a claim should be paid or not. For instance, considering a DeFi that covers the risk of train delays, the oracles will link the smart contracts to the train schedule of the train company permitting them to define if a train is on late or not. Usually, we can distinguish between two typologies of oracles:
  - **Inbound Oracles.** Which take real-world data and transmit them to the chain.
  - **Outbound Oracles.** Which take information from the chain and transmit it outside of it.

- **Governance Tokens.** The liquidity pool providers are usually rewarded with governance tokens that enable them to participate in the management of the DeFi environment and to definition of its rules.

The application and development of Insurance DeFi could boost the existing insurance market thanks to some of their typical features, in particular:

- **Costs Reduction.** The development of a decentralized environment allows the reduction of agency and transaction costs typically associated with insurance contracts (and, more broadly, with all financial agreements). Additionally, the use of smart contracts and oracles significantly accelerates the refund process lowering the perceived recovery costs for policyholders. Traditionally, the time required to access these funds can be lengthy, often involving extensive bureaucratic procedures. However, the speed of transactions enabled by DeFi insurance will bring the immaterial costs of fund recovery close to zero.

- **Acces to the Market.** The reduction of costs, in general, will help to open up the market to under-insured or uninsured consumers, boosting both the financial inclusion of the economic system and the market growth.

- **Transparency.** In an insurance DeFi environment the insurance conditions are directly embedded into smart contracts meaning that there cannot be unilateral modification of the policy terms. Smart contracts also remove opacity in the policies pricing system to guarantee a fair price based on the true risk of the platform and/or of the event ensured (depending on the pricing model).

- **Reduction of Systemic Risk.** The total risk of the DeFi is distributed all along the liquidity providers, reducing the risk concentration, which could be sensibly higher in a traditional centralized environment, and making the system more resilient to adverse scenarios.

- **Flexibility and Innovation.** Relying on smart contracts it is possible to define coverage for any kind of scenario and events, boosting the possibility of widening the plethora of insurance events covering new market niches and deploying more tailored services that could attract more users to open an insurance contract. The flexibility guaranteed by smart contracts could also support the creation of new innovative solutions to cover more specific risks with the possibility of creating new markets.

4. Open Insurance

Open Insurance could be defined as accessing and sharing insurance-related data and services between all the actors involved in the process (consumers, insurance, third parties) to build better applications and services. This process could encourage consumers to compare the products in the market and to buy the best for their own interests; at the same time, this could push the growth of new insurance products and services tailored to the needs of the consumers.
Summarizing what we introduce in the above description, we can understand that Open Insurance refers to the exchange of data between consumers and third parties. This will potentially lead to positive effects on the growth of insurance markets, for instance through the development of new products and services or the reduction of information asymmetry'costs. So, the key aspects of Open Insurance are:

- **Data Sharing.** Insurers and other stakeholders share customer data, under their consensus, securely allowing for personalized and innovative insurance products and services.

- **Customer-Centric.** Customers gain more control over their data and can benefit from tailored insurance solutions that better meet their needs.

- **Innovation.** By opening up their data and services, insurance companies can foster innovation, leading to new products and services that can enhance customer experience and efficiency.

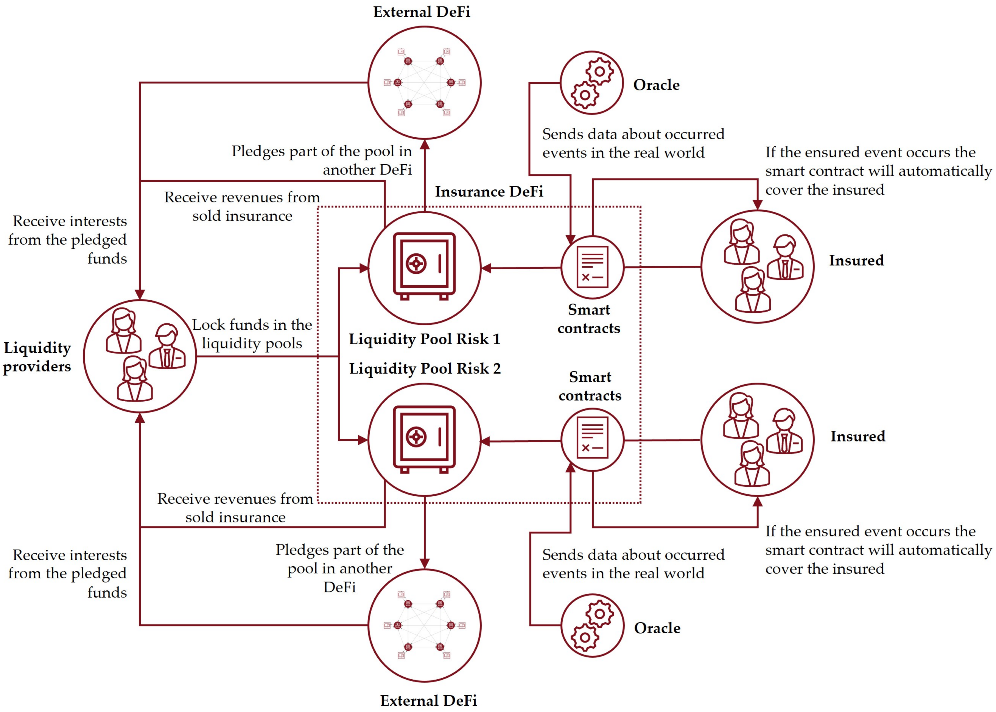


FIGURE 6: *Insurance DeFi Enviroment.*

The services of Open Insurance are now offered mainly using APIs (Application Programming Interface), where insurance and third parties (such as big tech companies or other players) exchange data of their consumers. The first step in the Open Insurance implementation through API is the so called API Layer. This means making all company data and services available via APIs to the ecosystem of partners and company channels. Companies require two additional layers to address the challenges of Open Insurance through API:

- **The Data Management Layer.** That serves as a decoupling mechanism that collects data from the underlying systems and ensures its availability 24/7, regardless of the systems' availability.
- **The Business Logic Layer.** Where companies develop, reuse, and enhance microservices, as well as potential frontend components, which can be combined to generate unique services for partners.

An example of the actual structure of Open Insurance built through API can be represented by the example of car insurance reported in EIOPA's discussion paper on Open Insurance[4]. Assume having an insurance dashboard that could collect:

- Consumer existing insurance policies;
- Product information of the insurance companies/intermediaries who agree to use the dashboard.

The consumer can decide that his data could be visible only to the companies with which the client has a specific contract or can be visible to all the players belonging to the dashboard. In this second way, when the consumer needs to renew his car insurance, he can see and compare all the products offered by the insurance companies and make an informed choice. All the exchange of data between the client, the dashboard, and the insurance companies is performed through APIs. In Figure 7 is portrayed how the process works.
After this brief description of Open Insurance, we can highlight some advantages and disadvantages. Starting with the benefits we have:

- Reduction of the information asymmetry between the insured and the insurer with a potential reduction in the information costs and a consequential decrease of policy prices which could lead to a widening of the potential individuals that could underwrite a policy;

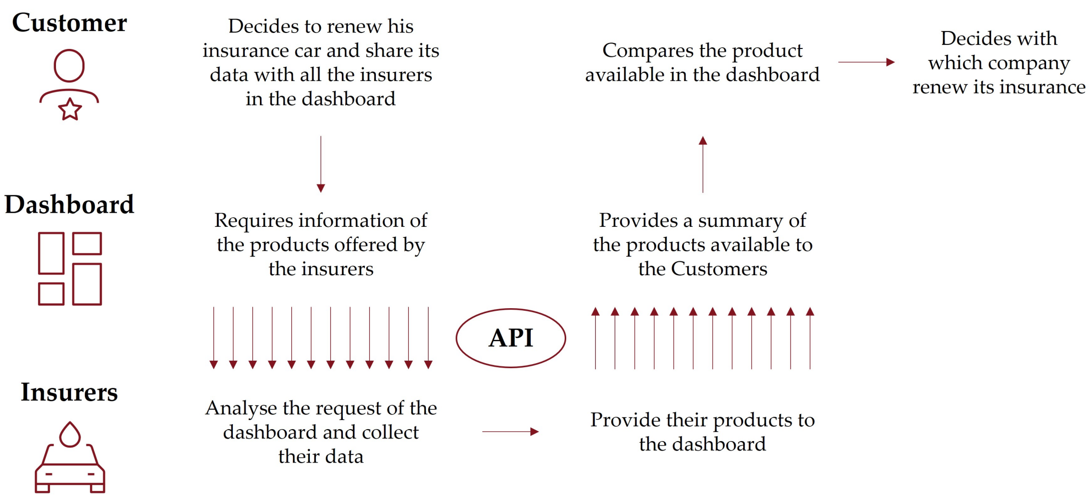


FIGURE 7: Open Insurance.

- More tailored products related to specific events (e.g. travel insurance when the consumer buys a train ticket; the proposal of insurance policy when the consumer reaches a certain age, etc.);
- The comparison between different companies and insurances is simplified. Moreover, also the change of insurance and product could be simplified by the comparison between more products and the choice of the product that better fits the interest of the consumer.
- The availability of new services is more specialized due to the needs and the situations in which they are offered to the customers. Having more data for their analysis, insurance companies can provide a better service due to the situation in which the customer needs of an insurance service.
- Enhanced competition between all the players to provide better products. Indeed, as stated before, the client has simplified opportunities to compare all the insurance's products, so the companies have to attract the interest of the client by proposing products that are better and more tailored to the needs of the customers.
- Development of new business models. Indeed, the insurance industry could implement new ways of studying the new data shared by the customers and new ways to offer their products; at the same time, the customer could receive and evaluate different proposals by simply comparing them in a unique environment.

There are also some risks related to Open Insurance:

- Data security and privacy, indeed all the parties involved in the process could get unauthorized access to data about the consumers.
- Common risks of the digitalization process, such as not being properly advised in all the steps of the subscription of a contract and receiving an incredible amount of offer based on own interests.
- The concentration of data of high quality could prevent the entrance into the market of new players narrowing the offer to the players who are already embedded and widely diffused.

All these risks are characterized and encouraged by the lack of a regulatory framework. This absence of a specific regulatory framework governing sharing data systematics in the insurance sector ensures that all Open Insurance projects are left to private initiative and are therefore implemented with special contracts stipulated by the Subjects involved. This has been highlighted by EIOPA[4] in his work and, despite this absence, the common sentiment is that Open Insurance will continue to expand in the following years. This absence of regulation underlined in Open Insurance is

contraposed to the regulation born in the last years in Open Finance. Open Finance expands on the principles of Open Banking, extending the concept of data sharing and interoperability beyond just banking to encompass a broader range of financial services. This includes not only banking but also investments, pensions, insurance, and other financial products. The main goal of Open Finance is to create a more inclusive, competitive, and innovative financial ecosystem. Open Finance regulation in Europe is largely driven by the principles and frameworks established for Open Banking, particularly through directives such as the Revised Payment Services Directive (PSD2). However, as the concept of Open Finance expands beyond banking, additional regulatory considerations and frameworks are being developed.
The key regulatory framework is constituted by:

- **PSD2 (Revised Payment Services Directive).** Emphasizes strong customer authentication (SCA) and explicit consent, ensuring data privacy and security.
- **GDPR (General Data Protection Regulation).** GDPR's principles of data protection, transparency, and user consent is crucial for Open Finance, ensuring that consumer data is handled securely and ethically.
- **European Data Strategy.** Promotes the development of common data spaces, including finance, where data can be shared and utilized to foster innovation.
- **Digital Finance Strategy.** It supports the development of Open Finance, emphasizing the need for regulatory frameworks that facilitate data sharing across various financial services beyond banking.
- **MiFID II (Markets in Financial Instruments Directive II).** It enhances transparency and investor protection, which are important for the integration of investment services within the Open Finance framework.

The regulatory landscape for Open Finance in Europe is evolving, building on the foundations of PSD2 and GDPR while expanding to encompass a broader range of financial services. The focus is on creating a secure, transparent, and innovative financial ecosystem that benefits consumers and promotes competition. As Open Finance develops, ongoing regulatory adjustments and collaborations among EU institutions will be crucial to address emerging challenges and opportunities. Given that also the regulation on Open Insurance will start to grow according to Article 1(6) of the Regulation establishing the EIOPA (Regulation (EU) No 1094/2010)19 requires the EIOPA to contribute to promoting a sound, effective, and consistent level of regulation and supervision, ensuring the integrity, transparency, efficiency and orderly functioning of financial markets, preventing regulatory arbitrage and promoting equal competition. In addition, Article 9(2) requires the EIOPA to monitor new and existing financial activities. The above is the key motivation underpinning EIOPAÂ´s work on digitalization. As stated before, Open Insurance is a field that is in continuous expansion and a process that can increase the development of this field is its integration in insurance DeFi environments. Indeed, the integration process of these two innovative paradigms could open up to several positive effects that could foster the growth of the insurance market. The analysis on the effects that integrating insurance DeFis and Open Insurance could have on the evolution of the insurance market will be analyzed in the final parts of the paper, while the next section will focus on illustrating some interesting cases of implementation of both insurance DeFi and Open Insurance environments.

5. Market Applications

This section of the analysis aims to illustrate some real-word examples of insurance solutions that rely on the technical frameworks that have been illustrated in the previous paragraph, trying to give a view on what are the potential unlocked by the technological innovation of insurance DeFis and Open Insurance.

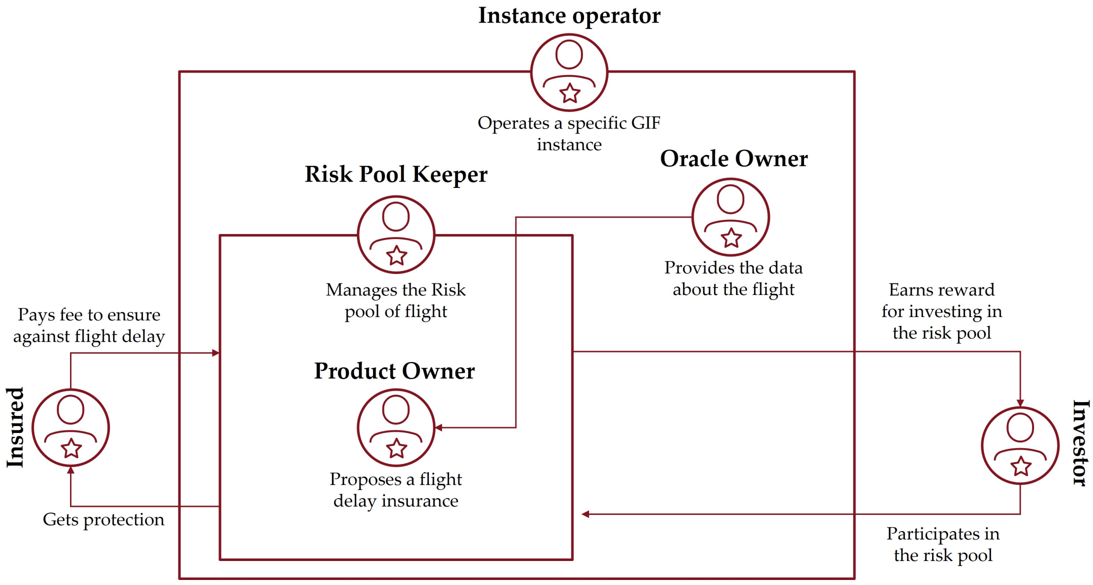


FIGURE 8: Etherisc.

5.1 Etherisc

Etherisc provides a complete suite of solutions to build, manage, and inspect decentralized insurance products. The essential utility token of the Etherisc ecosystem is the DIP token. DIP tokens give users access to the Decentralized Insurance Platform; by staking them, participants provide collateral for risk pools and guarantee future performance, availability, and service level. A risk pool, as previously discussed, is a smart contract that aggregates ("pools") various risks, represented by policy objects, and links them to risk capital. These pools gather collateral from investors contributing to capital rise. Risk investors stake DIP tokens and/or stablecoins into the pool, locking their assets in exchange for a reward. If a loss occurs, payouts are made from the risk pool, putting the stablecoin portion of the pool at risk. Investors have the flexibility to increase their investments in the pool or withdraw funds. However, before withdrawing, any associated risks must either expire or be settled. The Etherisc ecosystem is based on three pillars:

- **Risk Trasfer Market.** Investors will lock a certain amount of DIP tokens. The staked DIP token is a prerequisite to investing the actual risk capital in DIP or stablecoins. It is demanded that parties who profit from the ecosystem also own a share by owning and staking DIP tokens.
- **Regulatory Framework.** Insurance companies are highly regulated worldwide to protect customers as well as investors. The legal framework must be considered for each project, product, and jurisdiction, and the product owner is responsible for the proper implementation.
- **Techincal Framework.** The GIF developed and maintained by Etherisc allows for modeling, deploying, and operating insurance products based on blockchain in a decentralized and transparent way. Using GIFs, interested parties may quickly implement and securely operate their insurance products.

GIF stands for Generic Insurance Framework and consists of a collection of open-source smart contracts that implement essential functions of the lifecycle of insurance products and policies. Thus, GIF enables the modeling of a wide variety of insurance types. It is a basic implementation that can be used to create blockchain-based insurance applications. To be able to design insurance products quickly and easily, processing steps that run similarly in all products have been identified and made available as modules. Thus, only product-specific aspects, such as pricing models, need to be implemented for each product. To operate insurance products, including selling policies, collecting premiums, calculating trigger events, and handling payouts, a complete execution environment is needed in addition to the smart contract collections that define products and policies. GIF provides

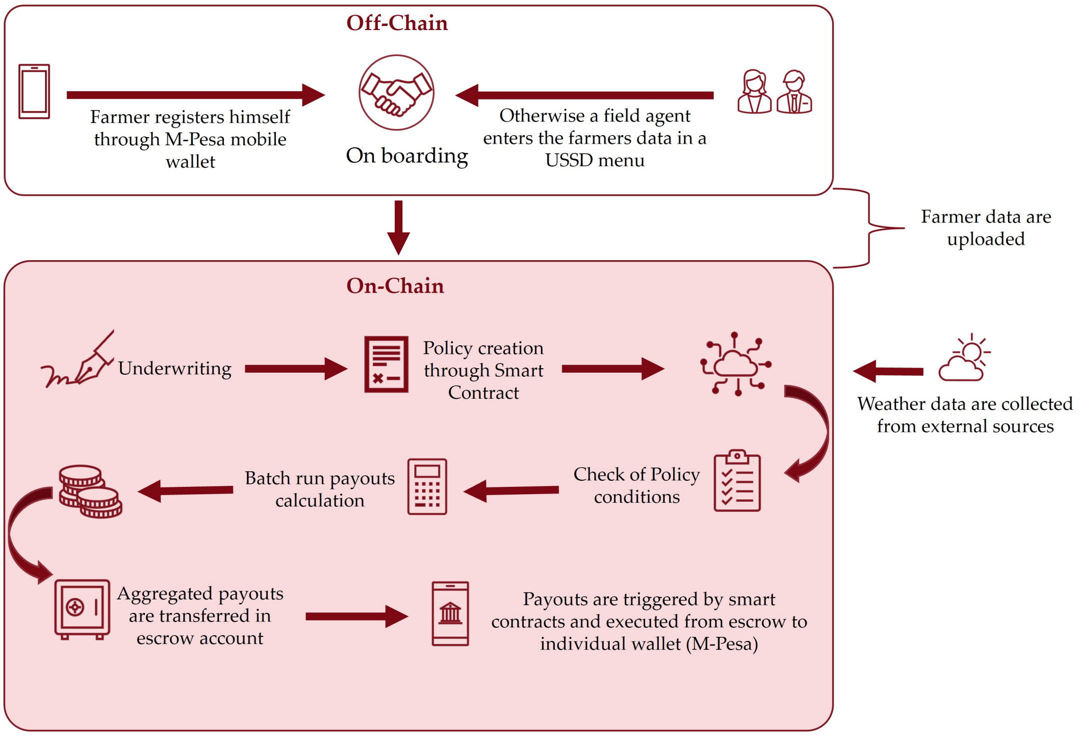


FIGURE 9: Lemonade.

these generic functions for all sub-steps in the lifecycle of an insurance policy, thus enabling an automated workflow that controls the sequence of processing steps. The stakeholder roles in Etherisc are the following:

- **Insured/Customer.** Policyholder who wants to pass his risk to the risk pools. He is a customer of the insurance company.
- **Investor.** Investors have an interest in participating in risk pools to balance/diversify their risk portfolios. They provide collateral for risk pools in exchange for interest payments.
- **Oracel Owner.** Provides oracles that interface between the blockchain smart contracts and external data sources. For example, in the case of flight delay insurance, the oracle informs the smart contract whether the flight landed in time, how much it was delayed, or if it was canceled entirely.
- **Product Owner.** Designs and operates one or more products. This would be an insurance company or an MGA (Managing General Agent) in the traditional insurance industry. Due to the multi-client capability, a product owner can use all oracles located on the respective platform by the oracle owners.
- **Risk Pool Keeper.** Manages one or more risk pools.
- **Instance Operator.** Key role that operates a specific GIF instance.

Any instance of the GIF maintains:

- **Products.** A product is a specific smart contract that implements the functionality of its specific requirements, or it can use the generic functionality of GIF. After the product is technically developed and deployed to the blockchain, it must be registered in the GIF instance. This action is typically integrated into the deployment process.
- **Oracles.** Oracles form a vital part of the GIF, as they link the blockchain-based smart contracts and the index/parameter information necessary to operate real-world insurance products. Products can utilize product-specific oracles, but they can also make use of generic oracles,

which can, in turn, be implemented by many different parties. For example, the FlightDelay rating oracle has one input parameter, the carrier/flight number combination, and one output parameter, an array of integers that represent the historical number of delays for different amounts of delays.

- **Risk Pools.**

The GIF instance is agnostic about the way payments are made. Therefore, Etherisc does not offer specific functionality for this.

5.2 Lemonade

As described in the section dedicated to the main trends in global insurance markets, climate change-related risks represent a significant driver in the future business scenarios of insurance companies. The greatest challenge is to provide adequate coverage for climate risks without undermining the financial stability of insurers. In recent years, several initiatives have emerged in the insurance sector aiming to explore the sustainability of products covering climate risks. For the purposes of this paper, we consider the case study of the Lemonade Crypto Climate Coalition to be of particular interest for two reasons: the first relates to the blockchain technology used by Lemonade in this project, and the second is the high social impact that this initiative aims to achieve. Founded in 2022 by Lemonade Foundation, the non-profit arm of Lemonade Insurance Company, LCCC has the ambitious mission to use exponential technologies like blockchain to create social value in the real world. The pilot project was launched in Kenya to offer protection to smallholder farmers who, despite being the most exposed to extreme weather events such as droughts and floods, do not have access to insurance coverage products in the traditional market. In Sub-Saharan Africa, crop insurance is not very widespread; less than 3% of farmers have access to insurance products, according to the latest ISF report.[12] This happens because, for traditional insurance companies, offering products in the most rural areas is extremely costly and unsustainable: underwriting is very complex, and with low premiums due to limited demand, it is difficult to find agents willing to distribute their products. Additionally, the payout from the claim process is often lower than the costs incurred for the process itself. Last but not least, assessing and processing claims in the traditional insurance business model involve extensive documentation and verification processes which are not always feasible in rural contexts.
By the combination of Blockchain Technology, Data Intelligence, and Insurance expertise, Lemonade is trying to close this insurance protection gap. Using DAO (Decentralized Autonomous Organization) instead of a traditional corporate structure, smart contracts instead of policy documents, Oracles instead of claims adjusters, and providing services at cost instead of looking for a profit, LCCC managed to take a product that is unsustainable to something that is infinitely scalable; once the blockchain infrastructure is built, it can be easily replicated in any other market in the world.
As previously mentioned, key players in the blockchain market such as Avalanche and Etherisc are part of the coalition. The former provides a technically sustainable infrastructure from an environmental standpoint, while the latter offers blockchain-based insurance solutions and the user interface for the project. The enabling paradigm to provide adequate risk coverage to typically "uninsured" populations is, once again, the reduction of costs associated with the claims management process. The key to lowering costs lies in the implementation of smart contracts, programmed to automatically trigger payouts when predefined conditions are met, verified by external data sources provided by Chainlink. This ensures timely support for the farmers enrolled in the program. To overcome the challenges posed by the complexity of blockchain in a context with limited technological and financial literacy, the policy subscription process has been made as simple as possible: the entire onboarding takes no more than 30 seconds and is done directly from the farmer's phone via a text-based interface, as the vast majority of farmers in the region do not own smartphones but feature phones.
Once the farmer purchases insurance directly from his phone[5], at the end of the harvest season, the LCCC collects parametric data on weather and crop yield, which is then transferred to an Oracle on

[5] Purchases are made through M-Pesa mobile/wallet, a mobile banking service, particularly diffused in Sub Saharan Africa, that allows users to store and transfer money through mobile phones.

the Avalanche blockchain. This data triggers smart contracts and eventually sends money directly into the mobile wallet linked to the farmer's phone. At the moment these smart contracts are essentially re-insured by the Lemonade Foundation which basically provides funding for it, this is also because the first year saw a loss ratio of 173%, with payouts exceeding the premiums collected (the average premium is 5$ per farmer); thus, the greatest challenge for the project will be to make the model financially sustainable on its own. In its first year, the program collected premiums of 98,000$, reaching over 6,400 farmers, but with a total payout of 170,000$. These figures demonstrate the significant need for coverage in these communities, which are exposed to a real risk of food insecurity due to the unpredictability of weather events. A possible step toward market integration could be the issuance of a token, allowing retail investors to participate in the risk pool and help provide insurance coverage to small-scale farmers in emerging countries.

5.3 Solace

As noted by EIOPA[4] one of the most widespread applications of Open Insurance, although still in its early stages, in the European insurance market is claim management. The survey reveals that insurance players are preparing to leverage the efficiency improvements that APIs can bring to traditional claim management systems. It is not surprising, as improving claim management processes, in addition to reducing the overall costs of insurance products, would represent a significant enhancement of the user experience for policyholders. In fact, according to recent studies, more than 80% of customers surveyed considered changing their insurer after a negative experience during the claim submission process when the covered event occurred. In this context, APIs can be the enabler of new claim management models, particularly by leveraging applications based on event-driven architectures (EDA). An example is the PubSub+ solution created by Solace. Solace is a Canadian IT company founded in 2001, and a leader in providing event management platforms for clients across various sectors (e.g., capital markets, aerospace, retail, automotive).
Event-driven architecture is a software design pattern that sends messages based on specific events, in IT terms events represent a status change in data such as a field changing in a database, a bank deposit being completed, or a checkout button being clicked in an e-commerce app. There are three main elements in event-driven architecture:

- **The Publisher.** The entity that sends or publishes a message (also called a producer);
- **The Event Broker.** The message distributor from the publisher to the subscriber;
- **The Subscriber.** The message receiver.

In this architecture, the message represents the information that the publisher wants to send. Messages often contain event data, but can also carry queries, commands, and other information; in an event-driven architecture, a message typically has a destination that distinguishes the publisher from the subscriber.
The key advantage of EDAs compared to traditional APIs (also known as REST APIs) is that the subscriber only needs to "subscribe" to the event notification, specifying the endpoint that the publisher can call to send the message once the event has occurred and been confirmed. In contrast, with REST APIs each request is sent by the consumer to the provider, generating multiple potential negative responses until the event occurs. It is easy to understand how an event-driven architecture requires less processing and storage, while also reducing the time and costs associated with the event notification process.
Although the main documented applications of Solace's event management systems so far concern banks and capital markets, particularly in the development of data distribution layers for high-speed trading, we believe that insurance companies could leverage this architecture to significantly improve customer experience during the claim process. Let's take a closer look at how Solace's application works, to outline a potential claim management process for a health insurance company. We previously mentioned the endpoint that the publisher can call to send a message once the event has occurred. In the specific case of Solace PubSub+, these endpoints are, in turn, accessed via so-called topics. From a technical point of view, Solace topics are simply strings composed of one or more levels added as metadata in a message header that let publishers classify messages and let subscribers specify what they want to receive messages about. This publish-subscribe model

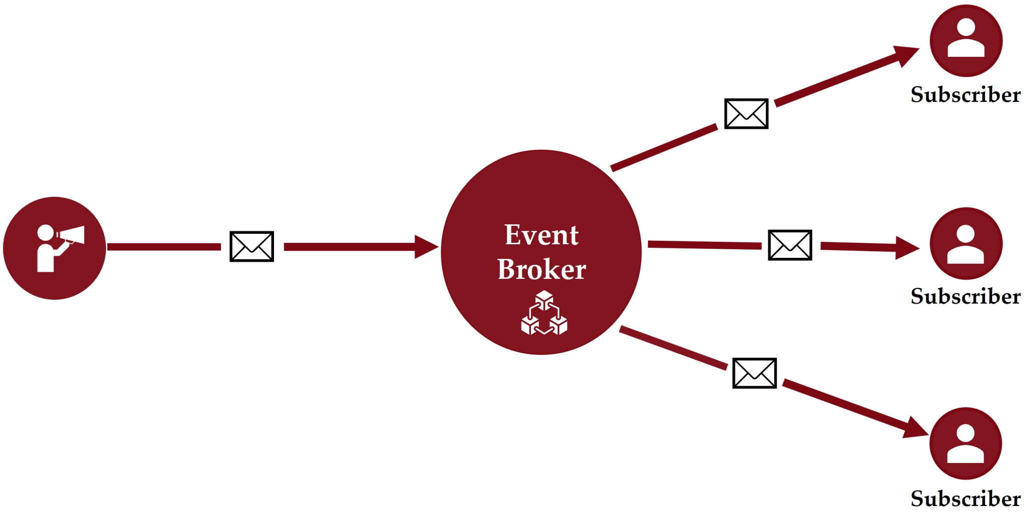


FIGURE 10: EDA's elements.

enables event brokers to use topics as routing information to send event messages everywhere they need to go. On the consumer side, when an application connects to PubSub+ and specifies a topic subscription, the Event Broker maintains it in a list of all subscriptions for all clients. A Solace topic is a string with the format a/b/c/.../n where a/b/c and so on are levels in a hierarchy of information used to describe events; one or more topic levels can be defined using variables that are replaced with properties specific to the event when it occurs. Let's suppose we want to design an event broker that allows the insurer to speed up the claim management process in the specific case of health insurance. In this scenario, one could implement an event-driven messaging system between the hospital's TPA (Third Party Administrator) and the insurance company's underwriting service, leveraging the scalability of Solace PubSub+. In this setup, the hospital would take on the role of publisher, and the insurer would act as the subscriber. In the traditional claim process, the insured retrieves the claim form from the hospital's TPA or the insurer's website, fills it out with all the necessary information, collects the required documentation from the hospital (e.g., medical records, prescriptions...), and then submits the claim to the insurer. With the use of PubSub+, the hospital's TPA, acting as a publisher, can create specific topics to which, potentially, multiple insurers can subscribe, receiving timely information about the occurrence of the insured event almost in real-time. Let's consider a typical insurance coverage that offers reimbursement for illness or injury expenses in the case of hospitalization or surgery. In this case, the Publisher can create a topic with a hierarchical structure to standardize the messaging related to hospitalization events, such as the string shown below:

Claim/[Hospitalisation]/[Policy Number]/[Hospital]/
[Certificate Number]/[Hospital Bill]

The brackets "[ ]" indicate a variable in the topic that is then replaced in the message by data specific to the event.

- **Claim.** Indicates the type of event.
- **Hospitalisation.** Indicates the action that generates the event.
- **Policy Number, Hospital, Certificate Number, Hospital Bill.** Are properties of the specific event.

In this type of application, the insurance company will simply need to define its topic subscription to capture the published events that are relevant to it. The event broker will then route topics without deserializing, decoding, or interpreting the event. When the event occurs, the TPA publishes the message, including in the body all the information required by the insurer to verify the eligibility for claim acceptance, such as receipts and medical records. The event broker, upon receiving the

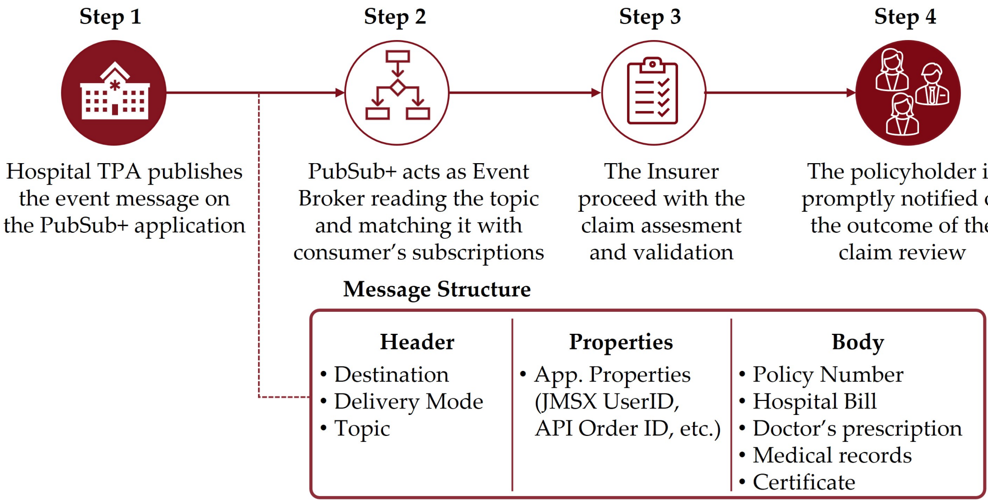


FIGURE 11: *Claim Management Process.*

message, reads the topic and routes it to all subscribers of the event almost in real-time. The message is then received by the insurer's claim service, which proceeds with the document assessment and promptly provides the outcome of the review to the policyholder (see process below). It is reasonable to assume that a further acceleration of the process described here could be achieved through the introduction of blockchain in event-driven architecture. Let's suppose that in Step 3 of the process, blockchain technology is used. Smart contracts can be deployed to minimize claims management expenses, mitigate claims fraud, and automate the verification of claims when the conditions specified in the insurance contract are met.

5.4 InsurAce

As mentioned in paragraph 3.1, in addition to the traditional family of insurance products, DeFi insurance finds another extensive application in covering risks arising from the use of blockchain technology itself. The case of InsurAce deserves further examination in this regard. As platforms offering services on blockchain grow, along with the increasing number of holders of so-called crypto assets, the demand for coverage of the risks to which crypto holders are exposed also rises. Consider that the TVL (Total Value Locked) in DeFi protocols as of October 2024 exceeds 86$ billion, of which only a small percentage is actually insured. InsurAce aims to close this protection gap by offering the possibility to purchase a wide range of mutual protection products for digital assets against various types of risks, below a non-exhaustive list:

- **Smart Contract Vulnerability Cover.** This type of product offers protection against any claimable loss due to malfunction, programming flaws, unauthorized, malicious, criminal attacks or hacks of the designated smart contract.
- **Stablecoin De-Peg Cover.** Refers to the risk that a stablecoin, which is designed to maintain a fixed value (typically pegged to a fiat currency like the US dollar), deviates or "depegs" from its intended value. For example, InsurAce offers a $USDT De-Peg Cover that compensates the policyholders for claimable loss realized in selling $USDT below the US$ 1.00 per $USDT peg between the claimable risk event and the claim deadline.
- **Ethereum Slashing.** coverage on a basket of different DeFi protocols, if they misbehave, a portion of their staked ETH can be slashed (confiscated).
- **Bridge Cover.** This kind of product aims to offer protection against the risk associated with using cross-chain bridges, which allow the transfer of assets and data between different blockchain networks. Claimable risk events protected are loss of tokens in transit to bridge malfunctions, hack or vulnerability exploits and loss of tokens in transit to error in slippage reported by bridge and/or DEX for tokens received at bridge or DEX on destination chain.

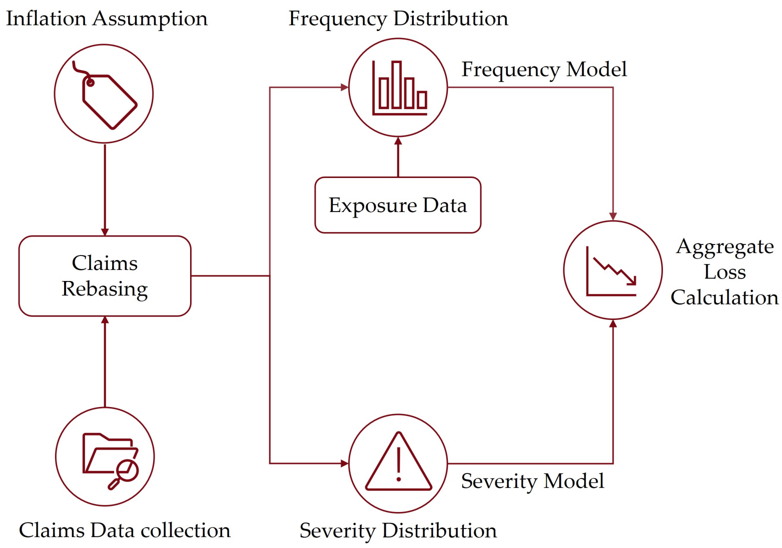


FIGURE 12: InsurAce's Aggregate Loss Model.

InsurAce's approach, based on covering the various risks associated with holding assets on the blockchain, allows it to offer policyholders comprehensive portfolio coverage on a basket of different DeFi protocols, creating a well-diversified risk management tool for investors.
Risk is currently shared in two mutual pools under the InsurAce protocol: cover payment pool and underwriting mining pool (with the latter offering higher returns to investors) which are governed by its members where membership rights are represented by the $INSUR token. More specifically, InsurAce's business model consists of two functional branches: the Cover arm that manages a low risk capital pool which helps maintain the InsurAce protocol's solvency and therefore ability to meet its cover obligations and the Investment arm which manages high risk investment pools which generates returns in order to finance possible claim payouts and attract investment capital; unlocked capital in the Cover capital pool may be transferred to the Investment pool to earn higher yields and subsidize users' costs from cover payments. According to InsurAce's official documentation, the project's key strength from a management perspective is its pricing model for the insurance products offered. InsurAce claims to provide more competitive prices compared to major competitors, who use models based on the staked value in their respective protocols (an inversely proportional relationship between staked value and insurance price), thanks to its use of actuarial pricing models. The price of the different coverages offered by InsurAce consists of two components: the base price, determined using an Aggregate Loss Distribution model, plus a dynamic component calculated based on the supply and demand volume for the insurance coverage. As for the base component of the price, it is the output of a model whose workflow is described in the figure below, based on the estimation of expected loss. The model's input factors include the number and amount of claims, the number and amount of exposures during a specific observation period, as well as assumptions about the level of inflation. These inputs are used to develop and train two distinct models: the frequency model and the severity model. The frequency model estimates the probability of a certain number of losses occurring within a given period, while the severity model generates the distribution of loss amounts and determines deductibles and coverage limits. Once both models are accurately calibrated, they are combined to calculate aggregate loss; the aggregate loss is then integrated with protocol-specific risk factors (such as bridge risk or de-peg risk) in order to calculate the actual base price.

5.5 Nexus Mutual

Nexus Mutual is a decentralized insurance platform that allows members to join and share risks. Members can purchase cover products that protect against different kinds of risk. The Nexus Mutual protocol is built on Ethereum and provides the infrastructure for members to buy cover, underwrite risk, assess claims, and build risk management businesses. The token on Nexus Mutual protocol is

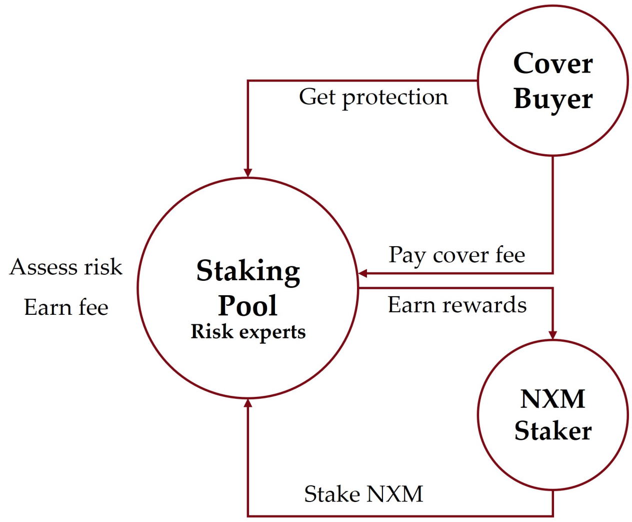


FIGURE 13: Nexus Mutual.

the NXM Token which is a governance and utility token backed by crypto assets held in the capital pool contract. Members can purchase cover products that protect against various types of risk:

- **Protection Against a Range of Loss Events Caused by Smart Contract Hacks/Exploits, Oracle Manipulation or Failure, Severe Liquidation Failures, and Governance Takeovers (Protocol Cover, Bundled Protocol Cover, DeFi Pass Cover, Native Protocol Cover).** These protections guard against smart contracts exploits/hacks, severe oracle failure/manipulation, severe liquidation failure, governance attacks. For example, when you hold Protocol Cover and suffer a loss of funds, you can file a claim and claim assessors will review your claim submission to determine whether your claim is valid. The process works in the following way:
  - If you hold Protocol Cover at the time the loss event occurs, you can submit a claim with supporting evidence, otherwise referred to as proof of loss. You will be able to include written details, links to supporting documentation, and/or upload screenshots or other files in the Incident Details section of the claim submission process. You will choose to either sign a message from the affected address or send a 0-value transaction from the affected address to prove your own and control the affected address.
  - Claim assessors will review, discuss and vote to approve claims where proof of loss shows that you have indeed suffered a loss of funds. If your claim is approved, you will be able to redeem your claim payout after the 24-hour cooldown period passes in the Your Covers menu. You can also check your Dashboard to see the status of any active claims; if your claim is denied, you will be able to file another claim with more supporting evidence.
- **Protection for Underlying Risk Underwritten by a Cover Provider (Quota Share Cover).** On-chain cover providers that can protect their underwriting capital against the underlying risks they offer coverage for. When a covered organization pays out claims for an underlying risk that is included in the Quota Share Cover terms, they can file a claim in the Nexus Mutual user interface. Your organization will need to wait 14 days for the cooldown period to pass. The process works in the following way:
  - Your organization will file a claim using evidence of their payments for the underlying risks covered;
  - Claim assessors will review, discuss, and vote to approve claims where proof of loss shows that your organization has indeed paid out claims for covered underlying risks above the deductible. If the claim is approved, your organization will be able to redeem the payout after the 24-hour cooldown period ends; if the claim is denied, your organization will be able to file another claim with more supporting evidence.

- **Protection Against Underwriting Risk in Traditional Markets Using On-Chain Capital.** This type of protection is expected to go live soon but currently is unavailable.

The Nexus Mutual DAO operates as a discretionary mutual where people are required to join as members before they can interact with the protocol. The process works in the following way:

- **Staking Pool Managers.** Members with risk and pricing expertise that create and manage risk-staking pools;
- **NXM Staker.** Delegates their staked NXM to risk experts that manage staking pools;
- **Cover Buyer.** Members which buy the protection paying a fee. The fee is distributed both to the staking pool managers and to the NXM Staker.

6. Integrating Insurance DeFis and Open Insurance

In the previous sections of the research, we have delved into the potential of both asset tokenization and Open Insurance in developing much more innovative and resilient insurance markets. This final section of the analysis will leverage on a simple model based on choice behaviors under uncertainty in order to assess the potential benefits for the insurance market that could be generated by developing solutions that leverage both asset tokenization and Open Insurance. First, let's assume an economic system where individuals are characterized by risk aversion and hold a capital endowment of K. Within the economic system, there is a probability that an event may occur with a negative effect on the capital endowment K of the individuals, which could be represented by the non-degenerate monetary lottery A (Figure 14) with:

- **K**= Capital Endowment;
- **L**= Loss.

The expected value of this lottery, EV(A) is defined as follows:

$$EV(A) = pK + (1-p)(K-L).$$

In this environment, individuals can buy an insurance policy offered by an agent that guarantees the full coverage of the loss L at the cost C. The payoff generated by the purchase of the insurance could be represented by the monetary lottery B_1 (Figure 15).
The expected value of B_1 could be represented as:

$$EV(B_1) = p(K-C) + (1-p)(K-L-C+L);$$

$$EV(B_1) = p(K-C) + (1-p)(K-C);$$

$$EV(B_1) = K-C.$$

With the policy purchase, the individuals transform A into the degenerate lottery B_1. Now let's assume that in fixing the price C the insurance agent overturns the costs associated with the agency costs and the cost related to the information asymmetry of the contract to insured individuals. That considered, we can determine:

$$C = I + U + A,$$

where:

- **I** represents the risk premium required to be assured of a specific risk;
- **U** represents the price markup for the information asymmetry and the moral hazard risk;
- **A** represents the agency costs (e.g. bureaucracy costs).

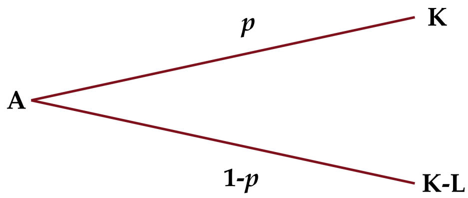
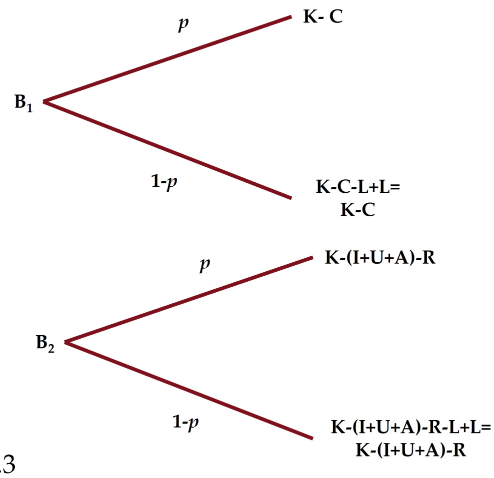


FIGURE 14: Lottery A.



[b]0.3

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FIGURE 17: Lotteries B_1 and B_2.

Other than these, let's assume that the individuals bear a non-material cost R, which represents the claims processing cost for retrieving the insurance payout once the negative event occurs. Considering this, we can redefine the lottery B including the cost decomposition and R (Figure 16) with:

$$EV(B_2) = K - (I + U + A) - R.$$

As assumed before, the economic system is characterized by risk-averse individuals which implies that they prefer a lottery only if its expected value is strictly greater than their certain equivalent. In order to have individuals underwrite the insurance policy the following equation has to be satisfied:

$$u(\overline{K}) < u(K - C - R).$$

With $\overline{K}$ = Certain equivalent of the lottery A
And so, considering that a VNM utility function is monotonously increasing:

$$\overline{K} < K - C - R.$$

At this point we have to introduce a new assumption: in this economic system individuals are characterized by different levels of risk aversion. This implies that at the price at which the insurance is offered C, only the portion of individuals that have $u(\overline{K}) < u(K - C - R)$ will purchase the insurance. Now, as shown earlier in the analysis, insurance DeFis could reduce the recovery cost R to zero, thanks to oracles and smart contracts automatization, while relying on a decentralized environment will prevent the agency costs from increasing the cost of policies. Considering this, the development of an insurance DeFi could reduce the costs for individuals, setting, for simplicity:

- **R**= 0,
- **A**=0.

With a new lottery T (Figure 18).
With: $C_1 = I + A + U + R > CT = I + U$
and so:

$$u(\overline{K}) < u(K - C_1) < u(K - C_T).$$

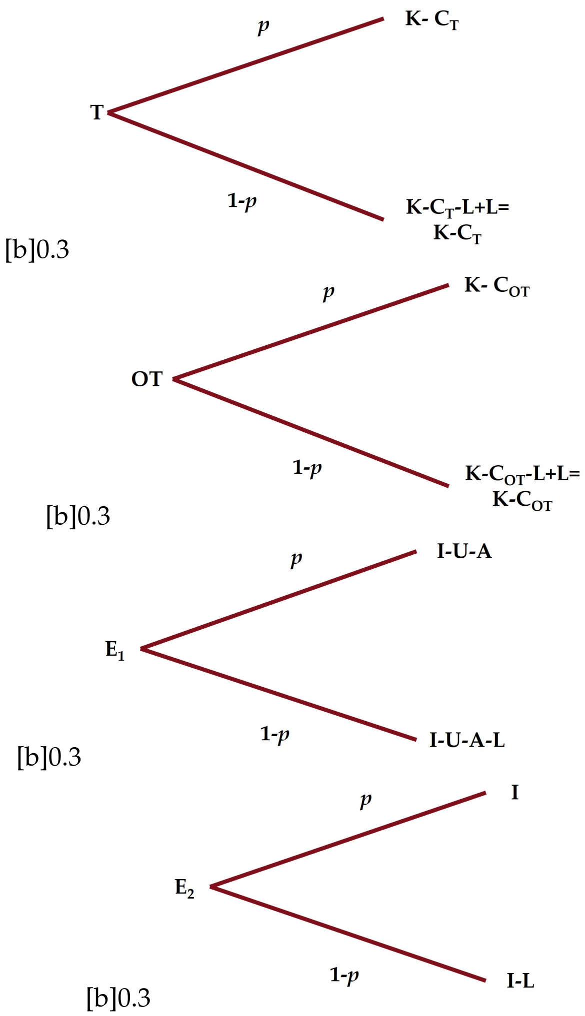

FIGURE 22: Lotteries T, OT, E_1 and E_2.

The integration of the Open Insurance practices into a tokenized environment thanks to the sharing through API of the information of the individual's behaviors could also set to zero the costs related to the information asymmetry. Regarding this, we can define the risk premium modified by the integration of both asset tokenization and Open Insurance as:

$$C_{OT} = I.$$

With the new lottery OT (Figure 19) and:

$$C_1 = I + A + U + R > C_T = I + U > C_{OT} = I.$$

These considerations will lead to the following relation:

$$u(\overline{K}) < u(K - C_1) < u(K - C_T) < u(K - C_{OT}).$$

The reduction of the costs required to ensure capital K against the loss L will bring even the more risk-averse individuals, that were cut off by the market, to underwrite the insurance policy. With a new lottery T (Figure 18) with $C_1 = I + A + U + R > CT = I + U$ and so:

$$u(\overline{K}) < u(K - C_1) < u(K - C_T).$$

The integration of the Open Insurance practices into a tokenized environment thanks to the sharing through API of the information of the individual's behaviors could also set to zero the costs related to the information asymmetry. Regarding this, we can define the risk premium modified by the integration of both asset tokenization and Open Insurance as:

$$C_{OT} = I.$$

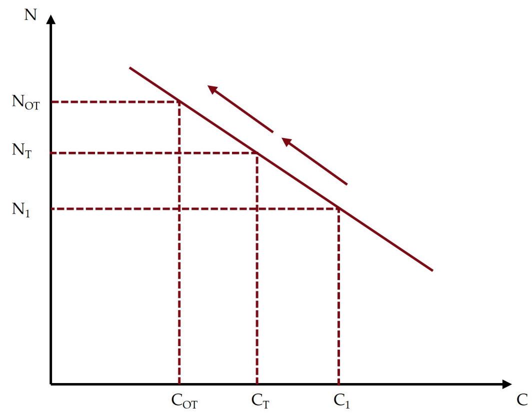

FIGURE 23: Increase of the Number of Insurend.

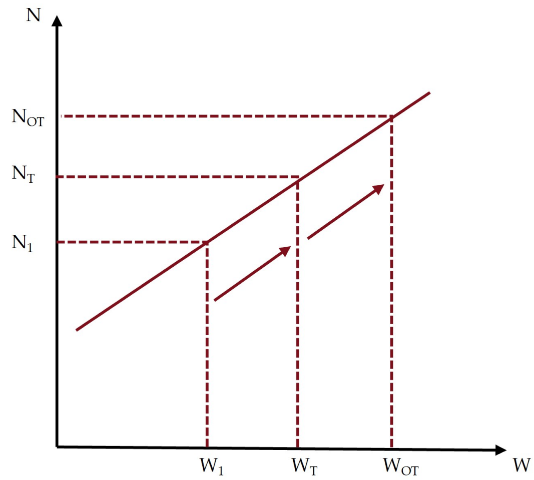

FIGURE 24: Increase in Insurers Profits.

With the new lottery OT (Figure 19) and:

$$C_1 = I + A + U + R > C_T = I + U > C_{OT} = I.$$

These considerations will lead to the following relation:

$$u(\overline{K}) < u(K - C_1) < u(K - C_T) < u(K - C_{OT}).$$

The reduction of the costs required to ensure capital K against the loss L will bring even the more risk-averse individuals, that were cut off by the market, to underwrite the insurance policy.
On the other hand, the insurers face the lottery E_1 (Figure 20).
As already explained, insurers entirely shift the agency costs, and the costs related to information asymmetry onto the consumers. Considering this, the lottery E_1 could be transformed in the lottery E_2 (Figure 21).
Thus, the profit function of insures could be described by the following equation:

$$EV(E_2) = W = N[p(I) + (1 - p)(I - L)].$$

With:

- **N**= number of individuals that underwrite the policy.

Considering that the insurers maximize their profits, and their profit function W is a growing function in N, it can be stated that the growth of individuals willing to underwrite insurance policies given by the introduction of insurance products that rely on both insurance DeFis and Open

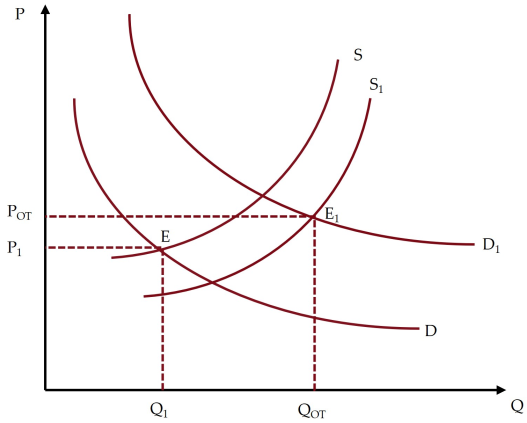

FIGURE 25: Market Equilibrium.

Insurance practices could also boost the total profit of the insurance market.
The reduction of prices, guaranteed by the integration of both insurance DeFi and Open Insurance and the consequent increment of individuals who are willing to be insured, will lead to the growth of the total demand for insurance policies. Consequentially, the effect of technological improvements in these new environments will bring a reduction of the costs that insurers will bear[6] $(C_1 > C_T > C_{OT})$; also, the new technology will potentially lower entry barriers with new players from other sectors that could be encouraged to break into the market. These factors could lead to an increment in the total supply of the market. This will permit it to reach a new higher economic equilibrium with benefits for the entire market. This model is an oversimplification of the real world but could help illustrate the possible effects that the introduction of innovative solutions - such as Open Insurance and insurance DeFis - could bring to the markets.

7. Conclusions

In conclusion, the analysis delved into the main features of insurance DeFis and Open Insurance, trying also to figure out the advantages that the embracement of these two paradigms could bring into the insurance markets. To summarize, we can highlight the following potential benefits of integrating Open Insurance and insurance DeFi:

- **Cost Reduction:** The integration of Open Insurance and DeFi insurance could lead to a cost reduction through:
  - **The Reduction of Manual Processes and Agency Costs.** Asset tokenization, thanks to smart contracts automatization, could eliminate manual processes and reduce the needs of intermediaries. Smart contracts, with Oracles' support, directly execute insurance policies when predefined conditions are met, cutting down agency costs significantly.
  - **Reduction of Information Asymmetry'Costs:** Open Insurance, relying on APIs, enables the access and sharing of customers' data. This access to real-time and historical data could lead to a bigger transparency, reducing the infamous costs of adverse selection and moral hazard. This reduction of the information asymmetry will also lead to more accurate pricing decisions.
  - **Lowering Information-Gathering Costs through Smart Contracts:** The integration of Smart contracts data collection, verification, and claims execution automatisms with Open Insurance procedures will facilitate the data sharing between multiple entities minimizing the need for manual data collection and thus reducing the associated costs.
- **Increase in Transparency.** The integration of Open Insurance and DeFi insurance could lead to an increase in market transparency through:

[6] In the model hypothesis we have considered that the insurer will completely shift its cost on the insurer, but in a more realistic environment there will be some costs that cannot be entirely shifted on the price of a good.

  - **Reduce Information Asymmetry.** As already seen, Oracles connect real-world events to smart contracts, helping the development of automated processes in event verification and policy settlement lowering the information gaps between insurers and policyholders.
  - **A Better Risk Assessment.** The pillar of an Open Insurance environment is the insured's data sharing between organizations fostered by APIs. Thanks to real-time data access and the historicization of data series the market will potentially benefit by a lowering in moral hazard and adverse selection, bringing insurers to offer more tailored policies thanks to a more accurate risk assessment.
  - **Tailor-Made and Transparent Prices.** The deeper data granularity unlocked by oracles and Open Insurance will lead to a better risk assessment allowing to design of customized price brackets much more specific to true individual's or entity's risk exposure.

- **Increase in Financial Inclusion.** The possibility of developing more tailored policies and the reduction of costs, as simplified in the behavioral model, will potentially lead to an increase in the number of insured. The individuals that were excluded by the market will benefit from policies that reflect their real risk and offer a consequent fair price.

- **Fraud Reduction.** The integration of DeFi insurance and data sharing of Open Insurance could improve fraud prevention, thanks to the traceability guaranteed by DLT. Moreover, the possibility of verifying data from multiple sources will make it harder to falsify information or manipulate insurance processes.

- **Market Innovation.** The development of highly innovative environments that rely both on DeFi insurance and open data sharing will lead to the deployment of new insurance solutions and automated policies for extreme market events or for specific risks related to emerging technologies.

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