Blockchain and Smart Contracts: Disruptive Technologies for the Insurance Market

Full Paper

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Abstract

Blockchain technologies paired with smart contracts exhibit the potential to transform the global insurance industry. The recent evolution of smart contracts and their fast adoption allow to rethink processes and to challenge traditional structures. Therefore, a special focus is on the analysis of the underlying technology and recent improvements. Further, we provide an overview of how the insurance sector may be affected by blockchain technology. We emphasize current challenges and limitations through analyzing two promising use cases in this area. We find that realizing the full potential of the blockchain technology requires overcoming several challenges including scalability, the incorporation of external information, flexibility, and permissioning schemes.

Keywords (Required)

Blockchain, smart contracts, consensus protocols, insurance industry.

Introduction

The interest in blockchain technologies and their adoption increased noticeably since the introduction of the cryptocurrency Bitcoin in 2008 (Nakamoto 2008). This was the first approach of implementing a blockchain to solve the double-spending problem in the context of digital currency. Hence, the blockchain is implemented and realized as an unalterable data record for transactions (Shrier et al. 2016a). Marc Andreessen, a leading developer of the Mosaic Browser and currently a venture capitalist in Silicon Valley, refers to blockchain as the most important invention since the advent of the Internet (Andreessen 2014). In their works, Swan and Pilkington predict the rise of the "economics of information" as a main driver for innovation and technological change (Swan 2015a; Pilkington 2015).

In general, blockchain provides an open and decentralized platform technology that allows the creation of a transparent, secure and robust data record. It is designed to be a flexible, transparent and efficient decentralized database (Lipsey et al. 2005). Thus, it may be employed to replace centralized systems[1] that organize and administrate information (Davidson et al. 2016). It is worth noting that the main purpose of the first introduced blockchain has been to obtain a system that is publicly governed by participants in

[1] To provide an example, the money supply of a country by its central bank, as well as, the administration of personal identities are all stored in a centralized database.

their network without depending on any credible parties. The clients within the network utilize a so-called consensus protocol to protect and preserve the information records.

The blockchain technology platform Ethereum[2] offers besides its transaction processing capability, turing complete programmability for the integration of smart contracts (Wood 2014). Thereby, the implementation of terms of an agreement between various parties can be enabled based on predefined, i.e., programmed, rules. These rules can be realized in self-executing code and are triggered automatically (Luu et al. 2016). Such attributes have been developed to provide a practical realization of the vision of smart contracts, first introduced by Nick Szabo in 1997 (Szabo 1997). This allows completely new ways of rethinking current processes and to challenge current structures. As a consequence, there are a lot of different fields of application for this technology such as finance, insurance, smart energy systems, as well as, the music industry (Walport 2016). In addition, it can play a crucial role for governments and for recent developments of the Internet of Things due to its decentralized and permission definable architecture (Swan 2015b).

This paper highlights the most recent developments in the field of blockchain technologies and shows the latest improvements of smart contracts by considering the Ethereum network. To narrow down the scope of this work, we exclusively focus on the insurance industry and present two current use cases and show their impact on the industry. We show the potential of the blockchain technology including how it may fundamentally alter the worldwide insurance sector (Crawford et al. 2016).

The remainder of this paper is structured as follows: The first section focuses on application fields of blockchain and smart contracts within the insurance sector. We outline the current state of the art and the potential for innovations. We also provide a detailed overview about the technical characteristics of distinct realizations of blockchain technologies. The second section presents two use cases of blockchain showing promising future opportunities, as well as, current limitations. We conclude the paper with a brief summary.

Blockchain in the insurance industry

Historically, the insurance industry has been slow to adopt new technologies (Crawford et al. 2016). Nevertheless, the emerging initiatives and innovation strategies address key challenges of this industry and focus on improvements in more individual pricing schemes, increasing profitability and retaining clients (Mainelli et al. 2015). Smart contracts that are based on the blockchain technology streamline several processes that are currently spread across numerous systems and databases. Here, blockchain functions act as a shared database and serve as a protected, unique source of trusted information. Smart contracts are implemented on top of this technology platform to automatize authentication and computation processes or similar tasks which may exhibit a high incidence of errors or abuse (Deloitte 2016). Hence, this process may strongly change the insurance industry as insurance policies can often be translated directly to computer code, due to their if-then statements.

Major insurance companies started to put effort into evaluating possible ways of adopting blockchain to support and enhance their core businesses (Crawford et al. 2016). This includes an extended analysis of which type of blockchain systems can be used. Further, different consensus protocols have emerged to overcome the Byzantine General's problem, where a group of people is required to agree upon common information. Overall, the blockchain technology has generated promising opportunities for disruption due to the following reasons (Deloitte 2016):

- Decrease need for trust and financial exposure in already existing agreements and provide legal clarity
- Facilitate deployment and maintenance of internal or inter-organizational infrastructure
- Enhance uptime and overall security
- Reduce costs of running services, error-proneness and the organization's reputational risk

[2] Ethereum was developed as a second-generation blockchain technology to provide a decentralized platform that allows the usage of smart contracts. In addition, this network has seen a constant growing acceptance and already backs nearly one hundred thousand contracts (Luu et al. 2016).

- Improve transparency and auditability by granting instant access for executives, clients and regulators at any time
- Allow new kind of business and operational models as smart contracts enable an inexpensive alternative to guarantee that transactions are accurately performed

The prevention of fraud continues to be a top priority for the insurance industry as mentioned, for example, in the last UK Government Chief Scientific Adviser report (Walport 2016). The underlying goal is to apply blockchain technology to streamline the payment and claims handling process to reduce the risk of fraudulent claims. Further, consumer insurance policies are often distributed by brokers that use third-party software platforms. They are regularly implemented in entirely independent and different code schemes due to an individual realization of the insurer's pricing model. As a consequence, several intermediaries might become dispensable by a shift to blockchain (Mainelli et al. 2015).

Functionality and Application of Blockchain and Smart Contracts

In this section we first present the details of the blockchain technology before introducing smart contracts and their working modes.

Blockchain Technology

In general, a blockchain is a decentralized and trustful database that contains all records of events or transactions that have been executed and shared between participating parties (Shrier et al. 2016a). In addition, the blockchain incorporates a full, unaltered and verifiable history of every single transaction providing a high level of transparency (Wood 2014). To guarantee security for the information on the blockchain, every transaction must be approved by the network. Here, no external authentication measures are necessary. Instead, different consensus mechanisms can be utilized to achieve a consistent state at participating parties. This can be paired with a crypto-economic incentive to perform the verification process of a transaction (Luu et al. 2015).

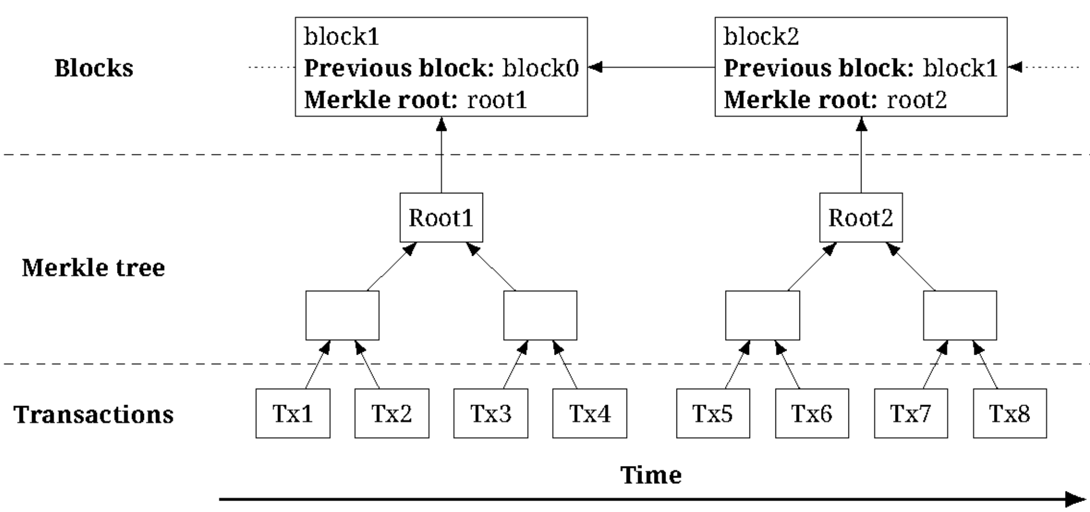

Figure 1: Generic Structure of a blockchain transaction (Adopted from Garzik 2015)

Figure 1 presents the blockchain's generic structure. Both illustrated blocks include four ordered transactions on which the computed Merkle roots rely. Each transaction is linked to the previous one to maintain an ordered structure. As a consequence, transactions can be traced back in time. In general, a blockchain can possess different characteristics in terms of accessibility. A classification of these features is presented in the following table as suggested by (Garzik 2015).

Blockchain type	Characteristics
Public	No restrictions for reading or submitting transactions for inclusion
Private	Direct access to data, submitting transactions is limited to a predefined list of entities
Permission-less	No restrictions on identities of transaction processors
Permissioned	Solely predefined list of subjects with known identities can process transactions

Table 1. Designs and characteristics of Blockchain (Garzik 2015)

Recent development efforts by the industry sector focus on private and permissioned blockchains to leverage the advantages of its database architecture (Pilkington 2015). This combination possesses a better performance compared to public blockchains at the expense of a more centralized design. On the contrary, a public blockchain such as Ethereum is decentralized to guarantee transparent data records and to ensure participants' equality (Wood 2014). Note that a permissioned design with known identities makes a consensus model unnecessary but decreases the degree of data transparency. Instead, network nodes can be encouraged to act in an honest manner by imposing regulations and prosecute fraudulent activities (Crawford et al. 2016). Even if such permissioned structures are often less decentralized, private blockchains managed by nodes from a consortium are still significantly more decentralized than current databases that make use of a master-access structure (Buterin 2015).

To overcome threats of participants with an incentive to maliciously influence transactions, consensus protocols are crucial (Lamport et al. 1982). These protocols achieve a consistent and universal picture of the system state[3]. Contemporarily, the Proof-of-Work (PoW), Proof-of-Stake (PoS) and Byzantine Fault-Tolerant (BFT) protocols are the most widely applied consensus protocols and possess completely different scalability characteristics (Davidson et al. 2016). In brief, a blockchain based on PoW provides favorable node scalability paired with a deficient performance which makes it highly cost intensive due to considerable energy consumption. Whereas PoS exhibits significantly lower costs, less censorship and also a high scalability at the expense of the Nothing at Stake trust Problem (Buterin 2016). The PoS consensus protocol processes significantly more transactions per second compared to other protocols. In contrast, a blockchain that uses BFT exhibits a good performance and restricted scalability (Croman et al. 2016). Here, every node must know all of its peer nodes that are engaged in the network to achieve consensus (Vukolić 2016). As a consequence, a trusted and centralized administration is needed to emit identities and cryptographic authorization to nodes, which makes this algorithm suitable for permissioned blockchains.

It is to expect that blockchain solutions will be heavily cost efficient compared to centralized approaches as they are supported by three downward sloping exponential cost curves (Davidson et al. 2016), i.e.,

1. Moore's law asserting that the price to process digital information halves every 18 months
2. Kryder's Law claiming that the price to store digital information halves every 12 months
3. Nielsen's Law stating that the price of transporting digital information halves every 24 months

Smart Contracts

A smart contract can be defined as an event and state-driven program that may run on a blockchain platform to administer assets that are included in the blockchain (Luu et al. 2016). Further, the scripting attributes of blockchains can be utilized to create cryptographic contracts that execute predefined agreement obligations by using self-enforced scripting languages (Szabo 1997). This type of contracts

[3] Brewer's CAP Theorem asserts for distributed systems that it is not possible to preserve availability, consistency and partition tolerance across all nodes.

needs an unbiased mediator to take decisions and actions on the agreement. Consequently, blockchains are perfectly suitable to run smart contracts as they provide incentives for the mediator to decide honestly by using game theoretical motives. The verification process of such contracts is the same as used for blockchain technology.

One of the leading platforms for smart contracts is undoubtedly Ethereum, which Vitalik Buterin describes as a generalized technology scheme that can be used as a base for state machine concepts (Buterin 2014). It uses its own cryptocurrency "ether" and provides a scripting language for the generation process of contracts.

A main challenge for smart contracts is to achieve sustainability and to prevent malicious usage. In Ethereum this is resolved by requiring a "fee" (ether) that is consumed by the nodes to compensate for contract execution. The amount of "ether" for a contract execution depends on its complexity. In addition, Smart contracts need external data input for the evaluation process. Oracles, i.e., trusted third parties, deliver validated external data to a smart contract that can be logically evaluated to make a decision. To guarantee that the information has not been manipulated, signature concepts such as "three out of five" are installed.

Privacy concerns paired with the vast amount of necessary data required for smart contracts also lead to new structured approaches for the development of blockchain designs. For example, one approach suggests creating parallel working blockchains which permit the transfer of assets and data between them (Pilkington et al. 2015). The concept of using various blockchains resulted in a scheme consisting of the following blockchains: "Identity chains", "transaction chains", and "content chains" (Mainelli et al. 2015). First, the identity chains are responsible to grant authorization for participants to a transaction chain. This structure allows having a public and permission-less identity chain and private transaction chains that allow access after verification was successful. Second, transaction chains keep track of the executed transactions and store solely the corresponding hashes for optimized performance. Third, content chains are decentralized storages that secure the data and guarantee accessibility. In brief, this scheme provides a dynamic and flexible framework for several use cases.

In summary, the blockchain technology offers noteworthy improvements for a variety of applications. This includes increased speed and real-time updates, improved accuracy, lower execution risk, reduced number of insurance intermediaries; lower costs, as well as, new business models (Deloitte 2016). Decentralized smart contracts ensure that participants, usually unknown to each other, can safely perform transactions between them. This is achieved while solving the problem of requiring accredited intermediaries which often provokes significant costs (Mainelli et al. 2016).

Fields of applications: Two current use cases

As already discussed, the insurance industry has the potential to be disrupted by the application of blockchain technology (Mainelli and Manson, 2016). This section presents two use cases that demonstrate the potentials within this area. We also provide an overview of the current challenges and limitations of the underlying blockchain technology.

Use case 1: Smart Contracts Based on Trusted Data Feeds – Natural Disaster Swaps

In 2013 the worldwide market for wholesale insurance and reinsurance summed up to a Gross Written Premium of more than 520 billion USD (Hearn et al. 2014). Insurance against natural catastrophes plays an important role in this sector. Such catastrophes may cause instantaneous large costs for insurers. As a consequence, reinsurance companies may face large claims demanding instant payout. Therefore, they apply various approaches such as prefunding and risk-sharing by selling, e.g., "cat bonds" to financial investors (Dahlen et al. 2012). Cat swaps can easily be expressed as smart contracts due a simple evaluation of the contractually agreed conditions. Thus, the blockchain technology is perfectly suitable as it may achieve substantial improvements of the contract management process.

A promising proof of concept for such natural catastrophe swaps was recently piloted by Allianz Risk Transfer and Nephila Capital to facilitate and improve their contract management process (Allianz Risk Transfer AG 2016). According the online sources we infer that a private and permissioned blockchain is used (Symbiont.io Inc. 2016) and a consensus is achieved by applying the improved BFT-SMaRt protocol as the parties already know each other and a trustful relationship exists among them (Bessani et al. 2014). The underlying blockchain technology paired with smart contracts is especially well suited for such an application as their negotiated agreements can easily be translated in executable code. Hence, the process can be automated while providing an unalterable transactional record facilitating auditing.

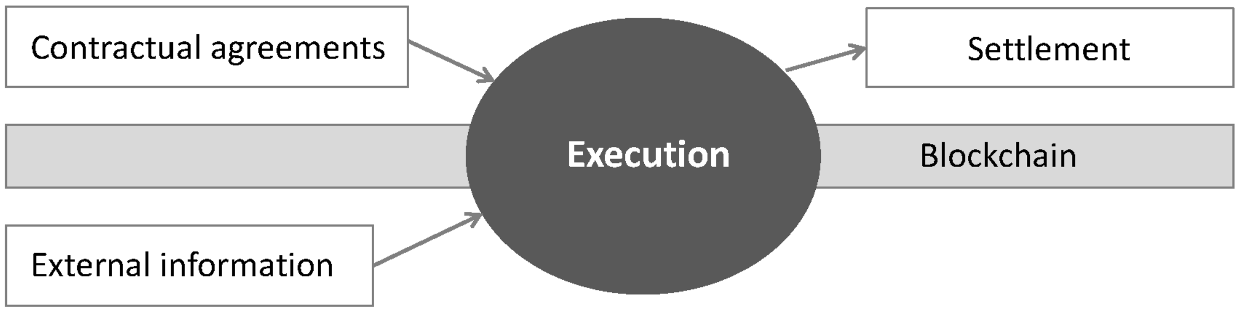

Figure 2: Basic principle of a smart contract (Adopted from Alonso et al. 2015)

In more detail, the process consisting of four main tasks is presented subsequently and its mode of operation is illustrated in Figure 2 (Alonso et al. 2015; Allianz Risk Transfer AG 2016).

1. **Contractual agreements**: Contract terms are translated to executable code that can be evaluated automatically and independently. Several of such validated smart contracts can coexist within a privately shared infrastructure.
2. **Information supply**: A third-party serves as external and trustful data source to provide necessary and secure input information to the smart contracts.
3. **Execution of smart contract**: The receipt of information triggers the execution of the corresponding smart contract to validate whether the predefined conditions are met.
4. **Settlement**: In case that the criteria are met, the value transfer process is automatically initiated as imposed by the contract terms and payouts are determined between the participants. Also off-chain asset settlements can be performed by tracking account modifications on the blockchain to guarantee a creditworthy system.

The presented scenario only shows two involved parties and a third participant serving as provider of unaltered external information. Nevertheless, the example is easily expanded to more parties. Summarizing, the blockchain technology allows improving auditability, reliability and execution time of the contract management process of both cat swaps and bonds. Particularly, this is achieved because of fewer manual processing as well as less verification and authentication through intermediaries (Allianz Risk Transfer AG 2016).

Use Case 2: Instant Insurance – insurETH

Promising fields of applications can be found in areas which allow applying binary rule schemes to provide fast evaluations and instantaneously generate low cost insurance. Especially, in the private sector an increasing demand for just-in-time insurance can be observed. This makes, e.g., instant and simple flight insurance an auspicious use case (Desyllas et al. 2013). The claim process for delayed or canceled flights is commonly known as cumbersome. For example between June 2014 and May 2015 only less than 38 percent of the flight passengers with delayed or canceled flight from or to the United Kingdom did make a claim. (Detlefs et al. 2016).

In contrast to the first introduced use case, the flight insurance concept "insurETH" is built on the prominent Ethereum platform consisting of a public and permission-less blockchain (Wood 2014). Implementation details are highlighted in a greater extent subsequently similar to Figure 2:

1. **Contractual agreements**: The main smart contract with its corresponding criteria is efficiently implemented in Ethereum since the conditions for a flight insurance can easily be measured. Further, the permission-less design allows that everyone can sign an own flight insurance policy. Hence, a deposit is made based on the desired insurance sum and an agreement is automatically established. So, every upcoming flight of a given passenger can be insured with nearly no effort.
2. **Information supply**: Again, an oracle provides trustworthy flight information that is delivered to the smart contract to trigger the execution of the underlying code.
3. **Execution of smart contract**: An event is triggered each time new information is received and, in turn, the smart contract is executed to validate whether the predefined conditions are met.
4. **Settlement**: When the agreed conditions are met, i.e., flight delay or cancellation, the smart contract automatically takes measures of a refund and initiates the payout process in ether.

Consequently, it would be achievable with ease that every passenger facing such delays may easily claim a refund. Such an approach facilitates the process completely as its does not rely on human intervention since triggers binary and initial conditions are limited. In addition, this approach also provides an investment platform which allows to rethink current insurance concepts. In general, both use cases have shown a high disruptive potential. On the one hand, they permit to reduce costs significantly with less manual intervention. On the other hand, they enhance transparency and reliability for customers.

Potential, Challenges, and Limitations

In the following, we focus on the potential, challenges, and limitations of blockchain technology within the insurance sector. We emphasize important drivers that may increase its usability and application. Particularly, insurers can apply blockchain technology paired with smart contracts in their daily activities such as identity authentication and validation, payment operations, as well as, their documentation and data management (Shrier et al. 2016b). Hence, more personalized insurance products can be offered at lower prices by simultaneously increasing transparency, automating processes and introducing the exchange of individual customer's data (Mainelli et al. 2015). Further, new markets can be accessed in regions that lack good data maintenance and exhibit high grades of corruption as blockchain technology provides a more reliable and inalterable alternative to current registries (Shrier et al. 2016a). This leads to the development of new concepts that face increasing attention and already achieved promising results such as in the peer-to-peer and just-in-time insurance.

As a consequence, the latest improvements of the underlying technology for blockchain and smart contracts allow rethinking the so far existing concept of centralized insurance models. Thus, peer-to-peer models to insure risk may arise as the overhead problem of collecting premiums and processing payouts can be resolved using the concepts of blockchain and smart contract. Especially, the fast growing sharing community (PWC, 2014) demands different types of insurance and requires a higher degree of flexibility. For example, using car sharing, cars are available on an instant basis and insurance policies may be hired per trip for which smart contracts guarantee a suitable integration of these new concepts.

As an increase in instant and autonomous insurance occurs, new structures for insurance companies become necessary. Therefore, Decentralized Autonomous Organizations are a promising alternative which can be generated by combining blockchain technology and smart contracts (Luu et al. 2016; Swan 2015b). The underlying business model and rules are stated in the code of this organization, for which reason it becomes a smart contract itself (Swan 2015a). This approach ensures that the rules are followed and it offers different ways of involvement for its policyholders (e.g. selling shares such that policyholders are the owners of the organization). Such autonomous machinery will create enormous markets as it has the potential to generate inclusion and disrupt markets of more than two billion people that are still financially unprivileged in the world (Demirgüç-Kunt et al. 2015). The blockchain approach might become a core technology to enable the development of an instant and more economical as well as decentralized system (Mainelli et al. 2015).

In addition, another promising field for this technology is the so-called "New Deal on Data" as privacy aspects of private information becomes a global concern (Pentland 2009). Recently the current European Consumer Commissioner Meglena Kuneva noted that "Personal data is the new oil of the Internet and the new currency of the digital world" (Kuneva 2009). The presented technology allows to empower this "New

Deal on Data" by ensuring a higher degree of individual's authority and control of personal data and at the same time providing the data readily for public good (Pentland 2009; Mainelli et al. 2015). The use of data aggregation brings huge benefits for the public but the protection of everybody's privacy must be guaranteed at the same time as it is crucial for the success as a society (Shrier et al. 2016a). Technologies such as blockchain and smart contracts may increase the consumer's confidence and diminish identity and claim fraud (Mainelli et al. 2016).

An important challenge is improving the currently applied consensus mechanisms (Lamport et al. 1982; Garay et al. 2015). The decision making whether to use a Proof-of-Work, a Proof-of-Stake or a Byzantine Fault protocol is accompanied by a trade-off between scalability and the desired degree of decentralization, security and performance as well as energy consumption and costs (Vukolić 2016). One promising approach for resource intensive blockchain application is to implement computationally costly components of consensus protocols in hardware to achieve enhanced performance as demonstrated by recent works (Poke et al. 2015). Also, current developments in the era of PoS may achieve significant improvements and may become the most important consensus protocol in future (Buterin 2016). Smart contracts depend heavily on the quality of external resources provided by oracles. As a consequence, it must be ensured that oracles provide trustful data. They must also be protected in case that their information resources disappear or previously independent sources merge.

To be successful, new emerging technologies must attract sufficient users and generate a behavioral change among them (Matthing et al. 2006). Even if change is consistently occurring, a refusal to change can often be found within society (Oreg 2003). Potential clients must become accustomed to the fact that the blockchain technology offers great advantages in terms of a completely secure and trustful record of historical transactions. Consequently, people must also be incentivized to accept and use this technology (Shrier et al. 2016b). Hence, the present barriers to adoption such as the infrastructure or the time needed for the first set up must be reduced and simplified.

The presented benefits are in contrast to technological limitations of the blockchain platform and smart contracts. First, the already mentioned security concerns, consensus protocols and resulting trade-offs must be addressed. Second, the insurance sector must protect and cover policyholders due to regulations which have to be translated for these new emerging technologies. New use cases such as peer-to-peer insurance build upon blockchain technology and do not rely directly on any central authority as transactions are performed in the Internet without geographic limitations (Pilkington 2015). Thus, regulatory governance is one of the most challenging hurdles for a broad implementation of this technology in the insurance sector (Walport 2016). Also, questions concerning the legal validity, how to rule in case of conflicts or how to integrate different legislations have to be considered in a greater extent when the technology is further embraced.

Conclusion

The blockchain technology and smart contracts are in an early stage of a Schumpeterian "creative destruction" phase. These technologies undergo an evolutionary development of market and industrial dynamics (Dopfer et al. 2015). Thereby, they are described as "technium" by (Arthur 2009) and may shape an advanced techno-economic paradigm (Perez, 2009). This diffusion trajectory of the blockchain technology will unfold as sequential applications are discovered and adopted given numerous use cases which may have a significant economic impact (Davidson et al. 2016).

Summarizing, these technologies offer extraordinary potential in all areas where a trustful record of every transaction is needed. To realize their full potential, these technologies still must overcome several challenges such as scalability, incorporation of external information, underlying real assets, flexibility, privacy as well as permissioning schemes.

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