Agriculture Supply Chain Improvement using Blockchain

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Abstract— Blockchain is an emerging digital technology allowing ubiquitous financial transactions among distributed untrusted parties, without the need of intermediaries such as banks. This article examines the impact of blockchain technology in agriculture and food supply chain, presents existing ongoing projects and initiatives, and discusses overall implications, challenges and potential. Our findings indicate that blockchain is a promising technology towards a transparent supply chain of food, with many ongoing initiatives in various food products and food-related issues, but many barriers and challenges still exist, which hinder its wider popularity among farmers and systems. These challenges involve technical aspects, education, policies and regulatory frameworks.

Keywords: Blockchain Technology; Agriculture; Food Supply Chain; Blockchain; Supply Chain

I. Introduction

A decade has passed since the release of the whitepaper "Bitcoin: A Peer-to-Peer Electronic Cash System" by the pseudonymous author (Nakamoto, 2008). This work set basis for the development of Bitcoin, the first cryptocurrency that allowed reliable financial transactions without the need of a trusted central authority, such as banks and financial institutions (Tschorsch & Scheuermann, 2016). Bitcoin solved the double-spending problem (i.e. the flaw associated to digital tokens because, as computer files, can easily be duplicated or falsified), with the invention of the blockchain technology. A blockchain is a digital transaction ledger, maintained by a network of multiple computing machines that are not relying on a trusted third party. Individual transaction data files (blocks) are managed through specific software platforms that allow the data to be transmitted, processed, stored, and represented in human readable form. In its original bitcoin configuration, each block contains a header with a time-stamp, transaction data and a link to the previous block. A hash gets generated for every block, based on its contents, and then becomes referred in the heading of the subsequent block (see Figure 1). Hence, any manipulation of a given block would result in a mismatch in the hashes of all successive blocks.

Every transaction is disseminated through the network of machines running the blockchain protocol, and needs to be validated by all computer nodes. The key feature of a blockchain is its ability to keep a consistent view and agreement among the participants (i.e. consensus) (Bano, 2017), even if some of them might not be honest (Castro & Liskov, 1999). The problem of consensus has been extensively studied by researchers in the past, however its use in the domain of blockchain has given new stimuli and motivation, leading to novel proposals for design of blockchain systems. The most well-known, used in Bitcoin, is called Proof of Work (PoW) and it requires computer nodes, called miners in this case, to solve difficult computational tasks before validating transactions and be able to add them to the blockchain (Bentov, Gabizon, & Mizrahi, 2016). The first miner to solve the puzzle bundles the block to the chain, which is then validated by the rest, and gets rewarded with newly minted coins plus a small transaction fee Common criticism of the PoW include that miners compete continuously in computer power, which leads to increased hardware and energy costs, with the subsequent risks of centralization and high environmental footprint (Becker, et al., 2013). An alternative consensus approach gaining momentum is called Proof of Stake (PoS), and it is about giving the decision-making power to entities who possess coins within the system, putting them "on stake" during transaction approval (Bentov, Gabizon, & Mizrahi, 2016). Consequently, PoS achieves the same effect of mining (distributed consensus) without the need of expending large amounts of computing power and energy (BitFury Group, 2015). Hundreds of alternative digital tokens have appeared in the wake of this development, aiming to address some particular weaknesses of the dominant cryptocurrencies, or target some particular domain, such as health, gambling, insurance, agriculture and many others (Coinmarketcap, 2017). Blockchain is also being investigated (and in some cases adopted) by the conventional banking system, and nearly 15% of financial institutions are currently using this technology for their transactions (IBM, 2017). Since 2014 it has increasingly been realized that blockchain can be used for much more than cryptocurrency and financial transactions, so that several new applications are being explored (Tayeb & Lago, 2018): handling and storing administrative records, digital authentication and signature systems, verifying and tracking ownership of intellectual property rights and patent systems, enabling smart contracts, tracking patient health records, greater transparency in charities, frictionless real-estate transfers, electronic voting, distribution of locally produced goods and, in general, for tracking products as they pass through a supply chain from the manufacturer and distributor, to the final buyer. Such changes are already revolutionizing many aspects of business, government and society in general, but they might also pose new challenges and threads that need to be anticipated.

II. Blockchain in Agriculture and Food Supply Chain

While the blockchain technology gains success and proves its functionality in many cryptocurrencies, various organizations and other entities aim at harnessing its transparency and fault tolerance in order to solve problems in scenarios where numerous untrusted actors get involved in the distribution of some resource (Manski, 2017), (Sharma, 2017). Two important, highly relevant areas are agriculture and food supply chain. Agriculture and food supply chains are well interlinked, since the products of agriculture almost always are used as inputs in some multi-actor distributed supply chain, where the consumer is usually the final client (Maslova, 2017). As a successful example, in December 2016, the company AgriDigital executed the world's first settlement of the sale of 23.46 tons of grain on a blockchain

(ICT4Ag, 2017). Since then, over 1,300 users and more than 1.6 million tons of 4 grain has been transacted over the cloud-based system, involving $360 million in grower payments. The success of AgriDigital served as an inspiration for the potential use of this technology in the agricultural supply chain. AgriDigital is now aiming to build trusted and efficient agricultural supply chains by means of blockchain technology (AgriDigital, 2017). The food chain worldwide is highly multi-actor based and distributed, with numerous different actors involved, such as farmers, shipping companies, distributors, and groceries. This system is currently inefficient and unreliable. For example, when people buy goods locally, they are not aware of the origins of these goods, or the environmental footprint of production. Various initiatives have been identified, where blockchain technology could be used to solve real-life practical problems at the agricultural supply chain. These initiatives can be divided into four main categories below: a) food security, b) food safety, c) food integrity, and d) support of small farmers.

A. Food Security

The Food and Agriculture Organization (FAO) defines food security as the situation when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Achieving this objective has proven to be extremely challenging under humanitarian crises related to environmental disasters, violent political and ethnic conflicts, etc. Blockchain is regarded as an opportunity for the transparent delivery of international aid, for disintermediating the process of delivery, for making records and assets verifiable and accessible and, ultimately, to respond more rapidly and efficiently in the wake of humanitarian emergencies (AID Tech, 2017). Examples include digital food coupons having been distributed to Palestinian refugees in the Jordan's Azraq camp via an Ethereum-based blockchain (Ethereum, 2015), where the coupons could be redeemed via biometric data (Built to Adapt, 2018). At the moment, the project is helping 100,000 refugees.

B. Food Safety

Food safety is the condition of processing, managing and storing food in hygienic ways, in order to prevent illnesses from occurring to human population. CDC claims that contamination because of food causes 48M Americans to become ill and 3,000 to die every 5 year (CDC, 2018). In 2016, Oceana performed a research on seafood fraud, showing that 20% of seafood is labelled incorrectly (Oceana, 2013). Leet et al. commented that food supply chains are characterized by reduced trust, long shipment distances, high complexity, and large processing times (Lee, Mendelson, Rammohan, & Srivastava, 2017). Blockchain could provide an efficient solution in the urgent need for an improved traceability of food

C. Food Integrity

Food integrity is about reliable exchange of food in the supply chain. Each actor should deliver complete details about the origin of the goods. This issue is of great concern in China, where the extremely fast growth has created serious transparency problems (Tian, 2017), (Tse, Zhang, Yang, Cheng, & Mu, 2017). Food safety and integrity can be enhanced through higher traceability. By means of blockchain, food companies can mitigate food fraud by quickly identifying and linking outbreaks back to their specific sources (Levitt, 2016). Recent research has predicted that the food traceability market will be worth $14 billion by 2019 (MarketsandMarkets Research, 2016). There are numerous examples of companies, start-ups and initiatives aiming to improve food supply chain integrity through the blockchain technology. The most important projects are listed below.

D. Small Farmers

Support Small co-operatives of farmers constitute a strong method in order to raise competitiveness in developing countries, helping individual farmers to win a bigger share of the value of the crops they are cultivating (Chinaka, 2016), (FarmShare, 2017). AgriLedger uses distributed crypto-ledger to increase trust among small co-operatives in Africa (AgriLedger, 2017). FarmShare aims to create new forms of ownership of property, cooperation of communities and self-sufficient local economies (FarmShare, 2017). OlivaCoin is a B2B platform for trade of olive oil, supporting the olive oil market, in order to reduce overall financial costs, increase transparency and gain easier access to global markets (OlivaCoin, 2016). Finally, some startups support small farmers by offering tools that increase the traceability of goods, such as Provenance, Arc-Net, Bart.Digital and Bext360. As a recent example, the Soil Association Certification (Soil Association Certification, 2018) has teamed up with Provenance to pilot technology which tracks the journey of organic food. We note here that even medium-size farmers could benefit from blockchain and the aforementioned initiatives, as they form a clearly different category than the large corporations (FarmShare, 2017). Cooperatives, on the other hand, might be formed by either small- or medium-size farmers, and can become quite large entities. Still, they are an ideal ground for blockchain, as the transparency of information involved could help to more 8 easily solve disputes and conflicts among the farmers in a fairer way for everyone (Chinaka, 2016), (AgriDigital, 2017).

III. Potential Benefits

Blockchain technology offers many benefits, as it can provide a secure, distributed way to perform transactions among different untrusted parties. This is a key element in agriculture and food supply chains, where numerous actors are involved from the raw production to the supermarket shelf (Lin, et al., 2017). To improve traceability in value chains, a decentralized ledger helps to connect inputs, suppliers, producers, buyers, regulators that are far apart, who are under different programs, different rules (policies) and/or using different applications (Lee, Mendelson, Rammohan, & Srivastava, 2017). Blockchain has the potential to monitor social and environmental responsibility, improve provenance information, facilitate mobile payments, credits and financing, decrease transaction fees, and facilitate real-time management of supply chain transactions in a secure and trustworthy way (Lee, Mendelson, Rammohan, & Srivastava,

2017). In particular, blockchain seems very suitable to be used in the developing world, as we saw in the previous section (see Section 2.4) in relation to small farmers' support. Other 10 scenarios could involve finance and insurance of rural farmers (Chinaka, 2016), as well as facilitation of transactions in developing countries. Although small farmers produce more than 80% of goods in developing countries, in most cases they do not have support of services such as finance and insurance (Chinaka, 2016). Concerning the developed world, existing problems such as unfair pricing and the influence of big companies have historically limited the environmental/economic sustainability of smaller farms. Blockchain could help in a fairer pricing through the whole value chain. Finally, the potential transparency provided by blockchains could facilitate the development of trading systems that are based on reputation. Reputation, as we have witnessed from various other trading systems where it has been used (e.g. eBay, Alibaba) improves the behavior of participating parties and increases their reliability, responsibility and commitment (Khaqqi, Sikorski, Hadinoto, & Kraft, 2018), (Sharma, 2017).

IV. Challenges and Open Issues

There are various barriers and challenges for the wider adoption of blockchain technology (Table 2). A case study in the Netherlands revealed that SME lack the required size, scale or know-how needed, in order to invest in blockchain by themselves (Ge, et al., 2017). Furthermore, convincing business cases are still inexistent, due to large number of uncertainties involved. In respect to education, there is a general lack of awareness about the blockchain, and training platforms are inexistent (ICT4Ag, 2017). Before adopting blockchain, farmers need to effectively understanding it. As farmers globally tend to dedicate their efforts in farming, they usually do not have expertise in cutting edge technologies. Moreover, an important barrier is regulation. The current experience of existing cryptocurrencies indicates they are vulnerable to speculators and their price has large fluctuations almost daily. Hence, without some form of regulation, cryptocurrencies are not trustful to be used yet in food supply chains as a complete solution. A lack of (common) understanding among policy makers and technical experts still exists on how blockchain technology and transactions based on some currency should be used (ICT4Ag, 2017). Furthermore, there are many design decisions that affect the existing blockchains or the ones under development (e.g. (AgriDigital, 2017), (AgriLedger, 2017), (FarmShare, 2017), 11 (Ripe.io, 2017), (OriginTrail, 2018)). For example, shall they be permissioned (i.e. participants are trusted), permission-less, open (i.e. everyone can join) or closed systems etc. Existing blockchain protocols face serious scalability obstacles (Eyal, Gencer, Sirer, & Van Renesse, 2016), since the current processing of transactions is limited by parameters such as the size and interval of the transaction block. Although blockchain offers advanced security, there are high risks related to loss of funds, just because the account owner might have lost accidentally the private keys needed to access and manage the account. Finally, there seems to be a gap among the developed and developing world, in respect to digital competence and access to the blockchain technology. Many of the bibliographic sources come from developed countries with a well-organized and wealthy primary sector (i.e. the USA, Australia, the Netherlands, etc.). This digital divide was also observed in the use of big data in agriculture (Kamilaris,Kartakoullis,&Prenafeta-Boldú,2017).

12 Opportunities and potential benefits Challenges and barriers Traceability in value chains Small SME cannot adopt this technology Support for small farmers Lack of expertise by small SME Finance and insurance of rural farmers High uncertainties Facilitation of financial transactions in developing countries Limited education and training platforms Fairer pricing through the whole value chain No regulations in place. Be used as a platform in emission reduction efforts Lack of understanding among policy makers and technical experts Open technical questions and scalability issues Digital divide among developed and developing world.

V. Conclusion

This article demonstrates that blockchain technology is used by many projects and initiatives, aiming to establish a proven and trusted environment to build a transparent and more sustainable food supply chain, integrating key stakeholders into the supply chain. There are still many issues and challenges that need to be solved, not only at technical level. Blockchain needs to become simpler. Various startups have been working in developing software to make blockchain technology easier for farmers to use, such as 1000 EcoFarms (1000EcoFarms, 2017), which has aggregated all the important blockchain processes relevant to food, farming and agriculture, using FoodCoin as the proposed ecosystem (FoodCoin, 2017). To reduce barriers of use, governments should invest more in research and innovation, as well as in education and training, in order to produce and demonstrate evidence for the potential benefits of this technology. Gupta (Gupta, 2017) discusses the possible transition of governments towards the use of the blockchain, noting the fact that governments and 13 their relevant departments should observe and understand the particular “pain points”, addressing them accordingly. From a policy perspective, various actions can be taken, such as encouraging the growth of blockchain-minded ecosystems in agri-food chains, supporting the technology as part of the general goals of optimizing the competitiveness and ensuring the sustainability of the agrifood supply chain, as well as designing a clear regulatory framework for blockchain implementations. Summing up, blockchain is a promising technology towards a transparent supply chain of food, but many barriers and challenges still exist, which hinder its wider popularity among farmers and food supply systems. The near future will show if and how these challenges could be addressed by governmental and private efforts, in order to establish blockchain technology as a secure, reliable and transparent way to ensure food safety and integrity.

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