

Blockchain in Agricultural Development: Overcoming Challenges for the Smallholder

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ABSTRACT

The blockchain is an open ledger of accounts and transactions which is transforming the way an endless array of sectors--from public administration to education to banking--hold themselves accountable. The blockchain has also been making waves in the international aid and development sectors for its versatile usages in ‘filling the gaps’ between the State and those who live beyond its reach (the undocumented, unbanked, uninsured, etc.); this report focuses on the current uses and visible advantages of using the blockchain in agricultural development, arguing that the new technology is indeed a positive development in the sector, while also pointing out three main weaknesses: first, that it is at times a victim of institutional mistrust; secondly, that it could potentially benefit large shareholders more than small shareholders; and thirdly, that its direct socio-economic impacts are both qualitatively and quantitatively difficult to measure. Unless large institutions and governments make the initial capital investments into implementing the blockchain for the benefit of smallholders, it will continue to be a technology reserved for large producers in middle- and high-income countries.

1. The Blockchain in International Development

1.1. Blockchain Basics

Beyond the functioning of the well-known bitcoin, there is a disruptive technology whose aim is to allow credit transactions without the intermediation of any central authority. According to the creator of bitcoin, the blockchain is a "peer to peer network using proof-of-work to record a public history of transactions" which are categorized, encrypted, and linked to their precedent blocks, creating a "blockchain"[1]. The consensus among the participants is necessary to validate each block of the transaction chain, creating trust among the traders without the need for a concrete third-party observer. This approach enables transparency, auditability, and resilience, while reducing uncertainty among the participants involved. In fact, according to experts, the blockchain system is completely secure, since the transactions cannot be changed once the network has verified them. The potential applications of this technology open a wide range of possibilities to implement new forms of contracting and to increase cooperative efficacy, meaning the willingness of people to contribute to public goods but also the mechanism to convert this willingness into effective provision[2]. As a demonstration of its versatility, the blockchain technology has been successfully used in several sectors, such as financial services, insurance, shipping, or logistics.

1.2. Advantages to Utilizing Blockchain in International Development Projects

The blockchain could potentially play a fundamental role in different aspects of the international development area. Due to its strong potential within developing economies, it has been receiving increasing attention in recent years --in several regions, such as Africa, the Caribbean, the Middle East and Latin America, countries are considering using the technology-- particularly due to its open, democratic, and trustworthy system, which demonstrates a clear departure from the systems of several local institutions which happen to be dysfunctional, weak, or inefficient. These qualities of the blockchain, particularly its resilience, could also be helpful to guarantee the coherence of public records, thus countering corruption[3].

1.3. Common Usages of Blockchain in International Development

[1] Masters, Lorelie S., Sergio F. Oehninger, and Patrick M. McDermott. "Blockchain: Tapping Its Potential and Insuring Against Its Risks." *Business Law Today*, 2017: 1.

[2] Nair, Malavika, and Daniel Sutter. "The Blockchain and Increasing Cooperative Efficacy." *The Independent Review*, 22, no. 4, 2018: 529-530.

[3] Rupino P. et al., "Blockchain for development: a guiding framework", *Information Technology for Development*, 2021: 418.

The global financial system excludes a significant portion of the population, while blockchain services could enable such excluded individuals to gain necessary access to financial services and overcome discrimination. For instance, due to the implementation of cryptocurrency as an investment tool, Nigeria is now the third largest economy in the world in terms of trading volume[4]. A further area of application could be donor fund tracking; the improvement of flow and transparency of funds and services could be useful to track donations, at the benefit of underserved people. The startup Disberse, operating in three different countries, has already launched three programs aimed at drastically reducing the risk of misappropriation or mismanagement of funds moving from donor to beneficiary[5].

At the time of the European refugee emergency – especially in view of potential further arrivals in the aftermath of the Afghanistan crisis – the issue of displaced people's identities could represent an urgent concern. The blockchain could be a successful response: by creating a blockchain emergency ID, such as Bitnation, "the world's first decentralised voluntary nation"[6], the refugees could have a permanent identity documentation which does not require any government recognition, but could be verified through their close relationships, such as friends or family[7]. Other potential opportunities of implementation of the blockchain system for development could be environment, healthcare, social inclusion, but also public administration, trade, supply chains or security.

2. Blockchain Applications in Food Systems

2.1 Ensuring Traceability in Food Systems

Due to the immutable nature of the blockchain ledger, consumers are able to trace the origins of their food with no risk of interference by a third party, enhancing trust and efficiency[8]; the path from "farm to fork" is easier than ever to follow with the scan of a QR code or the click of a button, especially in organic food production where fraud is a frequent concern, as global supply chains continue to grow and become more transnational. Furthermore, the blockchain has been

[4] *Ibidem*.
[5] "Home", Disberse.
[6] Bitnation Pangea: Governance 2.0. Accessible at: https://tse.bitnation.co.
[7] Thomason J., "Opinion: 7 ways to use blockchain for international development", Devex, 2017.
[8] "Blockchain food traceability can revolutionize the industry", Openlink.

implemented in the fair trade sector, in order to ensure consumers of fair working conditions throughout the food supply chain[9].

Practical examples of implementation of the blockchain for traceability include Verstegen spices, located in Rotterdam, who use the blockchain to map out the path of nutmeg produced in Indonesia, including information on the cooperative which produced the nutmeg, the processing site, and the route taken in order to arrive to its final destination[10]. Large retailers have also been catching onto the 'practical' advantages of blockchain in the food supply chain; for example, Walmart, in collaboration with IBM, using traditional tracking methods, managed to track mangoes from a farm in Mexico to a Walmart store in the US in a span of 6 days, 18 hours, and 26 minutes, compared to just 2 seconds using the blockchain[11]. On the other side of the Atlantic, Carrefour (also in collaboration with IBM) has been gradually rolling out blockchain and QR code technology in various products to increase transparency throughout the supply chain, even including GPS coordinates of where the product was originally farmed[12].

2.2 Streamlining Fund Transfers for Rural Shareholders

The blockchain, originally born out of a post-economic crisis 'cypherpunk movement' and intended to remove any regulatory authorities from global transactions, offers the possibility to completely change the way in which shareholders access financial services. According to The International Fund for Agricultural Development, even the most basic of such services, such as access to a bank account, may reach only 10 percent of rural communities who are largely dependent on agriculture and may be considered to be 'unprofitable' by commercial banks (or may simply be located too far from a bank for a bank account to be practical)[13]. The Blockchain is a potential solution to such bureaucratic and geographical obstacles, as identification is carried out through biometric data--most often via mobile phones--while cryptocurrency acts as a bridge between two different currencies, reducing conversion costs, wiring fees (calculated to be on average around 11% of the transaction when initiated through banks)[14], and, most practically, time spent traveling to the

[9] van Hilten, M., et al, "Blockchain for Organic Food Traceability: Case Studies on Drivers and Challenges", Frontiers in Blockchain, September 30, 2020.
[10] Back to the Origin, Verstegen Fair Food.
[11] Hackett, R., "Why Big Business is Racing to Build Blockchains", *Fortune,* August 22, 2017.
[12] "Carrefour applies blockchain technology to Carrefour quality line salmon", Carrefour, January 29, 2020.
[13] "Financial Inclusion for the World's Poor", IFAD.
[14] Klebanov, S., "A Look at Blockchain in Cross-Border Payments", *Payments Journal,* February 5, 2021.

nearest financial institution[15]. In using the blockchain for financial services, the funds are transferred through the ledger into a mobile money account, an initiative which, in the case of Kenya, is estimated to have lifted 2% of the entire Kenyan population out of poverty[16]. Thus, the blockchain is already being utilized as a banking solution for rural populations who are largely dependent on agriculture.

Similarly, lack of insurance renders volatility in agricultural incomes commonplace in developing and emerging economies; for example, agricultural wages in India are twenty-one times more volatile than agricultural wages in the United States, due to US-based farmers' access to crop, income, and social insurance (and Indian farmers' lack thereof)[17]. Blockchain technology may supply insurance to rural smallholders who did not previously possess it, but it may also, for example, immediately release payouts triggered by recorded local weather events, thus reducing the risk of insurance fraud or discrepancies between payouts and on-farm loss[18].

For practical examples, MyPlanet.green, a "conservation tool that empowers everyone to contribute to global conservation projects"[19] operating mainly in Tanzania, utilizes the blockchain to release payments from donors every time a successful milestone has been reached and is registered on the ledger by local monitors[20]. Furthermore, Agriledger, a social enterprise headquartered in London, uses the blockchain for many different purposes in agriculture, one of them being offering fund transfers and crop insurance to small and rural producers[21].

2.3 Smart Agriculture

Smart agriculture comprehends technologies such as ICT (Information and Communications Technology), IoT (Internet of Things), and UAVs (Unmanned Aerial Vehicles), all of which require a security system which protects sensitive data from manipulation[22], loss, or cyber attacks[23]. The Blockchain, by distributing data to stakeholders' computers, decentralizes the sensitive data and

[15] Hoggarth, D., "Blockchain, a plus for smallholder farmers?", IFAD, November 5, 2018.
[16] Suri, T. and Jack, W., "The long-run poverty and gender impacts of mobile money", *Science* Vol. 354, no. 6317, December 8, 2016: 1292.
[17] Banerjee, A. and Duflo, E., *Poor Economics,* London: Penguin Books, 2012: 136.
[18] Xiong, H., et al, "Blockchain Technology for Agriculture: Applications and Rationale", Frontiers in Blockchain, February 21, 2020.
[19] "About", MyPlanet.green.
[20] "Home", MyPlanet.green.
[21] "Home", Agriledger.
[22] See, for example, when the Canadian government distorted official environmental data in 2014.
[23] Lin, Y., et al, "Blockchain: The Evolutionary Next Step for ICT E-Agriculture", *Environments* Vol. 4 no. 50, July 18, 2017: 4.

renders it less vulnerable to data loss or cyber attacks, thereby helping to develop and ensure the security of mobile apps that optimize smart farming. On the other hand, connecting the ledger to local environmental conditions, for example, would eliminate the risk of data manipulation[24]. A practical application of the blockchain in smart agriculture is visible in Taiwan, where farmland irrigation associations use the blockchain to gather and publish their own data in order to interact more openly with the public[25]. In summary, the potential applications of blockchain in food systems are countless, as, broadly speaking, it may act both as a guarantee of transparency and as a bridge between essential services and peoples who are isolated from official institutions.

3. Challenges and Limitations to Blockchain Implementation in International Development and Food Systems

3.1 Trust and (Governmental) Mistrust: Finding a Balance

The blockchain's potential to change the governance of vertically integrated food supply chains collides in our society with several dynamics within the ethical sphere, the economic sphere, and in the so-called 'fiduciary balance'. Remembering that blockchain technology was primarily created as a response to the trust crisis that swept the world in the wake of the 2007-2008 financial crisis[26], the fiduciary balance – with particular reference to a fairly widespread governmental mistrust – represents the starting point of the following analysis, a study which pivots on challenges and limitations to blockchain implementation, both in food systems and in international development.

Proceeding step by step, as previously stated, the current agri-food supply chain systems are lacking in transparency and are highly inefficient: this fact helps to explain why an increasing number of stakeholders endorse the blockchain technology, whereby, in terms of trust, it has the potential to impact transaction costs in the supply chain by reducing opportunism and information asymmetries. This is also due to the fact that every single transaction can be monitored by the participating entities, who are the only protagonists, as the system does not require third parties. We can affirm that the aim of using blockchain technology in the food supply chain is to fulfil the desire for a traceable, transparent and interoperable system to be able to generate truly fair

[24] Xiong, H., et al., 2020.
[25] Ibidem.
[26] Bitcoin and other blockchain-based systems were presented as a "trustless" alternative to existing financial institutions and even governments.

products. We have entered, in the words of Potma, in the age of the so-called "distributed trust"[27], which focuses on providing transparency, connectivity and accountability, and which can only accelerate with the blockchain. More generally, if transparency between trading partners can be established, trust can be created, which reduces the suspicion of opportunistic behavior and increases the probability of effective communication and information sharing[28]. An additional key trust attribute is that blockchain is 'consensus safe', as transactions can only be executed when the majority of participants approve them[29].

Broadly speaking, in terms of trust, it can be said that, while the traditional and hierarchical agri-food supply chain networks are based on cornerstones such as information asymmetry and unilateral, written consensus, the new blockchain-based networks are founded on pivotal elements like: peer-to-peer organization, transparency of transactions, mass consensus and smart contracts. The latter are the epitome of the fact that the blockchain technology can provide independent coordination mechanisms, since these contracts can be autonomously executed, without the need for a centrally coordinating authority, through coding and through consensus-driven validation.

At this point, in the presence of the described points in favour of this system, the question arises: where does governmental mistrust come from? At first sight, the skepticism that seems to affect many of today's governments – regardless of their political order – has its roots in potential risks such as: the utilization of the blockchain system in the context of international terrorism, and a very high probability of tax avoidance since the mechanism does not require participants to authenticate transactions and the replacement of the national currency[30]. However, alongside these important factors, there are some other interesting elements to bring to the table.

A worthwhile input is provided by De Filippi et al[31]. The authors underline that, in spite of the fact that blockchain technology is often described as a 'trustless' technology because it eliminates the need for a trusted authority and replaces it with a system of publicly verifiable proofs, this

[27] Potma, M., "Blockchain to Restore Trust in Food Supply Chains? A case study in the cacao sector of Costa Rica", *Digital Society Innovation Project* (1), May 2020: 1-2.
[28] Hanf, J., Dautzenberg, K., "A theoretical framework of chain management", *Journal on Chain and Network Science*, Vol. 6, n. 2, December 2006: 79–94.
[29] Kramer, P. et alii, "Blockchain and Its Impact on Agri-Food Supply Chain Network Management", MDPI Open Access Journals (Sustainability), Vol. 13, n. 4, February 2021: 11-12.
[30] Staples, M. et alii, "Risks and opportunities for systems using Blockchain and smart contracts", CSIRO (61), January 2017: 1.
[31] De Filippi, P. *et alii*, "Blockchain as a confidence machine: The problem of trust & challenges of governance", *Technology in Society*, Vol. 62, n. 1, June 2020: 1-14.

characterization is problematic because it does not account for the multiple layers of trust inherent in blockchain governance and the complex power dynamics that exist.

As a whole, the viewpoint of the authors is relevant because it tries to move away from the definition of blockchain technology as a "trustless" system or "trust machine", to focus instead on what blockchain technology actually brings to the table. It argues that blockchain technology should instead be regarded as a "confidence machine" in the sense that it increases the confidence in the operation of a particular system, and only indirectly (as a corollary to that) reduces the need for trust in that system. While trust is often associated with a feeling of uncertainty, confidence is generally associated with a feeling of predictability: therein lies part of the explanation of governmental mistrust[32].

Moreover, on closer inspection, the absence of a trusted authority in charge of managing and coordinating interactions over a blockchain-based network does not make it a "trustless technology". In fact, while trust is less relevant when it comes to the standard operations of a blockchain-based system, it is nonetheless necessary to trust the actors securing and maintaining the underlying blockchain network, in order to guarantee a sufficient level of confidence in any of the blockchain-based applications operating on top of that network. It is certainly not a detail: lack of trust in any of the constitutive parts of a system might bring people to distrust the system as a whole.

Another issue arises from the assumption that the blockchain itself is not a quality sensor: any quality information communicated via a blockchain originates from sources and procedures of which the trustworthiness should be established separately, not to mention that we shift our trust in institutions to trust in technologies, technologies most of us don't even understand[33]. In this context, technology is meant to substitute the bureaucratic security of institutions or the social bonds of local communities, and this is considered a major selling point of blockchain technology; it is considered doubtful, however, that technology could ever replace human systems for trust and reciprocity. The bottom line is that, in order to make a system trustworthy, there is a need for trustworthy people and for the inclusion of community organization, instead of putting all our trust in software.

[32] Ibidem

[33] Potma, M., "Blockchain to Restore Trust in Food Supply Chains? A case study in the cacao sector of Costa Rica", Digital Society Innovation Project (1), May 2020: 3.

In light of the points previously raised, it can be said that there are reasons to think that blockchain technology is not the final solution to all of our bureaucratic problems, nor a panacea for restoring trust; consequently, the governmental disbelief – and the skepticism of many people – can be understandable, while waiting for a balance that (presumably) will come. Moreover, referring merely to the agri-food industry, we need to consider that it seems to be clear that the blockchain technology in this field is predominantly in the phase of piloting, gaining more insights into its potential future application.

3.2 Blockchain and Food Sovereignty: What Benefits for the Smallest Shareholders?

The approximately one billion people on the planet who live in extreme poverty (less than $2 USD a day) and who are trapped in a vicious cycle of low levels of human development caused by an absence of state transparency and infrastructure[34] would theoretically stand to benefit the most from implementation of the blockchain in food quality assurance, land registries, financial services, et cetera; however, broadly speaking, low and lower-middle income countries--both for reasons related to lack of state trust in blockchain and for lack of financial and human capacity--do not possess the basic technological infrastructure necessary to implement blockchain technologies[35]. As a concrete example, connecting remote peoples to essential services through the blockchain is conducted through mobile phones; the question is, then, if one cannot even afford a pair of shoes, let alone a mobile phone, what advantage could the blockchain possibly bring?

Such a criticism, on the whole, may be related to the food safety-versus-food sovereignty debate; while the prior is related to maximizing production and efficiency through technology and ensuring that "all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"[36], the latter, rather, is "the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture

[34] Rosling, H., et al, *Factfulness: Ten Reasons We're Wrong about the World -- and Why Things Are Better than You Think,* London: Sceptre, 2018: 34.
[35] "Harnessing Blockchain for Sustainable Development: Prospects and Challenges", United Nations Conference on Trade and Development, June 25, 2021: 34.
[36] "Food Security Policy Brief", The Food and Agricultural Organization of the United Nations, June 2006: 1.

systems"[37]. In the realm of food systems, blockchain surely has the potential to further the former objective, especially by increasing the supply chain efficiency of large producers; proponents of the 'food sovereignty' paradigm, however, may argue that further technologization of agricultural smallholders--who constitute approximately 90% of the world's 570 million farms[38]--may result in expansion, globalization, and subsequent hyper-specialization of crops (and thus, greater susceptibility to shocks), rather than leading the producers to have greater autonomy and control over their own crops, livestock, and income. Thus, the effective benefits of blockchain application for small and low-income farmers have yet to be determined.

3.3 Difficulty in Evaluating Blockchain's Financial Outcomes.

In addition to challenging traditional business models and the role of Central and commercial banks, blockchain technology, in general, is transforming the all-round financial landscape, marking, according to some experts, a point of no return. How measurable are financial outcomes?

At a micro level, without an independent audit of financial statements, we need to be aware that financial statements reflect management assertions, including estimates, many of which cannot be easily summarized or calculated in blockchain. This is the reason why it would be desirable that in the immediate future, blockchain technology could not entirely replace financial reporting and financial statement auditing, whereby audited financial statements are a cornerstone of business and play a key role in debt and equity financing, participation in capital markets, regulatory compliance and the effective and efficient functioning of capital markets[39].

At a macro level, despite the promising economic results of mobile money seen in Kenya[40] or of cryptocurrency in Nigeria[41], the overall ability of the Blockchain to bring a substantial economic benefit to rural areas and local farmers remains unclear. The blockchain is undoubtedly profitable for high-value products, such as precious stones, which are easy to physically tag and follow throughout the supply chain; however, food items, as they are cut, repackaged, and processed, often lose value throughout the supply chain, and the technological infrastructure necessary for

[37] "Food Sovereignty Systems: Feeding the World, Regenerating Ecosystems, Rebuilding Local Economies, and Cooling the Planet – all at the same time", Alliance for Food Sovereignty in Africa, 2014: 6.
[38] "Smallholder family farms", The Food and Agricultural Organization of the United Nations, 2021.
[39] Bible, W. et al , "Blockchain Technology and Its Potential Impact on the Audit and Assurance Profession", Chartered Professional Accountants Canada Project, January 2017: 15.
[40] Suri, T. and Jack, W., 2016: 1292.
[41] Rupino P. et al., 2021: 218.

blockchain tagging is often restrictively expensive for smallholders[42]. Thus, due to potential incorrect input of data and an unclear idea of the cost-benefit tradeoff of implementing the blockchain, the immediate economic benefits for small-scale producers remain unclear.

4. Conclusions

Given the increasingly popular features of the blockchain, this report has aimed at investigating how this technology can be used in international development, specifically in the ambit of food systems, illustrating several practical cases of implementation in support of the benefits that the blockchain could provide to the food market. It is possible to rely on all those who have already tested the implementation of the blockchain in food systems, including those explored in this paper, to investigate the potential benefits that the system brings to the food market, including but not limited to: improving food traceability, ensuring food safety, guaranteeing fair working conditions and pay, preventing price coercion, monitoring food processing, eliminating misleading labels, and providing equal access to financial services.

This paper has stressed how the immutable, decentralized and transparent nature of the blockchain technology may have remarkable impacts on food systems in terms of food traceability, financial accessibility, and data security and transparency. All of these aspects are extremely relevant as they represent solutions and improvements to many of the issues that food systems face nowadays. Indeed, first of all, using this technology to provide detailed information regarding all the steps of the food supply chain will enhance trust among consumers who are increasingly interested in knowing, for instance, how their food was processed, whether it was sustainably produced, and whether it is safe and healthy. Furthermore, sharing all information regarding the production of food is essential to verify that fair and humane working conditions are guaranteed along the food supply chain. In this regard, the blockchain is a system that aims at protecting all the workers involved in the food market, including individual fishermen and farmers of developing countries, ensuring that all shareholders are recognized, rewarded and are able to access financial services. Finally, another strength of the blockchain is that all the sensitive information contained within it is highly secured by the decentralized nature of the system, which protects data from potential manipulation, cyber attacks and loss.

[42] Hoggarth, D., 2018.

This secure, transparent and decentralized technology of data collection and processing constitutes the basis for a system fully based on trust and accountability. Nevertheless, as previously mentioned, the notion of trust in the blockchain technology still raises doubts from institutions and individuals. In this respect, what is important to consider, however, is that the world is still witnessing only the outset of the application of blockchain technology in international development and in food systems. The hope is that with time, and with more producers trying to resort to blockchain to improve their food supply chains, trust and understanding in the system will increase. Indeed, only if and when more institutions begin to accept the blockchain, will the system be able to be consolidated, improved, and refined.

One challenge that surely needs to be addressed promptly in order to further improve this system is granting access to the blockchain technologies to all those producers that are more at risk of not being recognized or of being mistreated by the dynamics of the food market: that is, the smallholder farmers, fishermen, and livestock raisers of low- and low-middle-income countries. Indeed, it is essential to guarantee even to small shareholders the possibility to possess both the skills and technological devices necessary to render the blockchain effective in low-income contexts, so that even the poorest individual producers can enjoy the protection guaranteed by the safe storage and collection of information regarding the food supply chain. To do so, investments from governments and relevant institutions--with the interest of the small shareholder in mind--must be encouraged, as these initial investments of financial capital will bring about greater levels of sustainable human development along the food production system through technology education and greater connection to other stakeholders. Thus, only by granting the possibility to implement the blockchain to everyone will the system be able to function at its full potential.

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