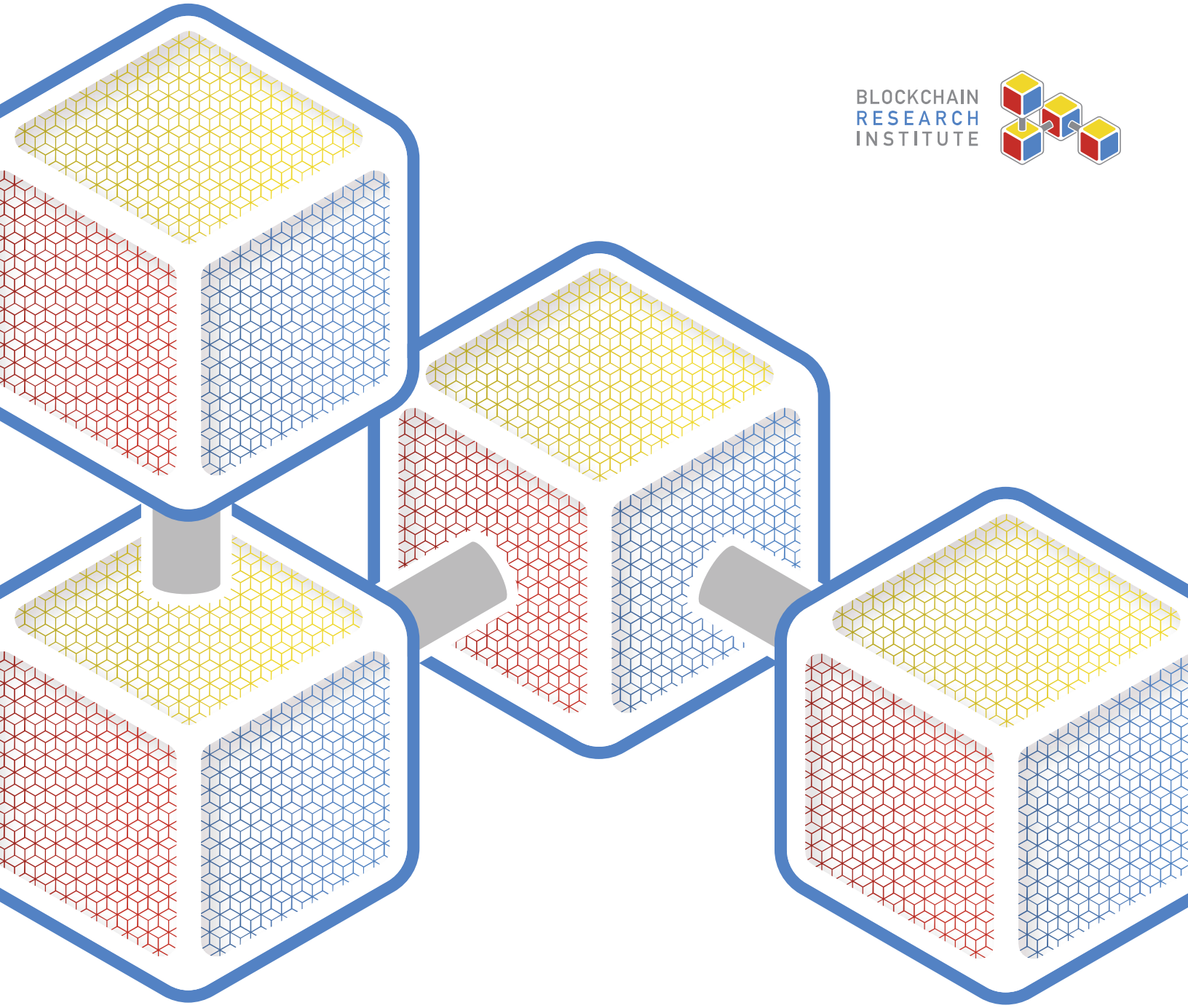

BLOCKCHAIN RESEARCH INSTITUTE

AGRICULTURE ON THE BLOCKCHAIN

Sustainable Solutions for Food, Farmers, and Financing

Henry Kim and Marek Laskowski
York University

December 2017

A BLOCKCHAIN RESEARCH INSTITUTE LIGHTHOUSE CASE STUDY

Realizing the new promise of the digital economy

In 1994, Don Tapscott coined the phrase, "the digital economy," with his book of that title. It discussed how the Web and the Internet of information would bring important changes in business and society. Today the Internet of value creates profound new possibilities.

In 2017, Don and Alex Tapscott launched the Blockchain Research Institute to help realize the new promise of the digital economy. We research the strategic implications of blockchain technology and produce practical insights to contribute global blockchain knowledge and help our members navigate this revolution.

Our findings, conclusions, and recommendations are initially proprietary to our members and ultimately released to the public in support of our mission. To find out more, please visit www.blockchainresearchinstitute.org.

Contents

Foreword

We founded the Blockchain Research Institute to conduct research that would have the greatest global impact on business and society, and few industries have a greater impact than agriculture. A variety of technologies, especially blockchain, has real promise to transform such areas as food safety, fraud reduction, and market access for small farmers. The first area is perhaps the most important since food-borne infectious diseases can have disastrous effects on public health and local economies if unchecked in cross-border trade. This project shows how blockchain can track fresh produce and meat from farm to fork.

In addition to reducing hazards and screening out bad actors, blockchain and Internet of Things (IoT) technology can dramatically improve agriculture. This research features use cases that show how blockchain, soil sensors, satellite monitoring, and drones can increase crop yields, improve quality of crops and soil, and reduce waste throughout the food chain.

For this project, we were pleased to recruit Dr. Henry Kim and Dr. Marek Laskowski, both of whom are blockchain experts at York University. Dr. Kim is one of the world's leading thinkers in the area of supply chain traceability and has written more than sixty scientific articles. Dr. Laskowski is involved in developing agent-based models for public health decision support and devising smartphone-based public health surveillance technologies. Together, they have generated an outstanding report that combines deep thinking with practical applications for forward-looking leaders.

DON TAPSCOTT
Co-Founder and Executive Chairman
Blockchain Research Institute

Case in brief

- This research explores applications of blockchain across the agricultural sector, beyond the typical finance use cases. In considering agriculture itself as a chain, a network that reaches from farm to fork, we analyze blockchain efforts to improve safety, efficiency, and accountability at every stage of the process.
- Provenance tracking or traceability across the various stages of the global food supply chain ensures food safety both for direct consumers as well as for a global community vulnerable to a food-born pandemic.
- Smart contracts and chain of custody records can mitigate instances of food fraud and identify untrustworthy middlemen and business practices that exploit both independent farmers and cooperatives.
- Sustainable agriculture and "local economy" cooperatives—such as AgriLedger with pilot programs in Kenya, Myanmar, and Papua New Guinea—can generate economic activity and retain more value locally, even to the extent that the community operates within its own economy complete with distinct cryptocurrency and tracked exchanges.
- Instantaneous transactions and accountable origin and route tracking of goods such as Provenance's blockchain for the Grass Roots Farmers' Cooperative in Arkansas can transform a sprawling, complicated, and decentralized food market into a local one with high trust and quality.
- Agriculture finance innovations, especially for developing world farmers, include transparent and efficient futures contract payment platforms, smart contract insurance against crop catastrophes, and microfinancing opportunities for under-served communities that can grow from subsistence-level loans into investments in new businesses.

Cock 2522623 by svklimkin (klimkin), 2017, used under CC0 1.0.

The challenges of agriculture worldwide

Food safety failures are magnified, last longer, and cost more because of lack of access to information and traceability.

According to the UN Food and Agriculture Organization, 2.5 billion people in developing economics derived their livelihood from agriculture in 2011; that was over a third of the world's population.[1] Yet, without farming sophistication, business knowledge, financial resources, and leverage against much larger buyers—not to mention corrupt intermediaries and government officials—developing world farmers receive only a tiny share of the ultimate value of their crops. For instance, Kenyan farmers reported receiving only 30 cents per kilogram for their coffee, which retailed for more than 100 times that price.[2]

Blockchain is a revolutionary technology that implements a shared ledger or database to deliver an immutable, single version of the truth among numerous, sometimes adversarial, stakeholders. Blockchain provides transparency to inefficient and corrupt business practices by enabling equitable participation for farmers and other stakeholders on the global food value chain, leading to greater prosperity for developing world agricultural workers.

Where in agriculture can we best fulfill this promise? First, it is in *provenance and traceability* for food safety. Every year, one in ten people fall ill—and 400,000 die—because of contaminated food.[3] Food safety failures are magnified, last longer, and cost more because of lack of access to information and traceability. In the summer of 2017, the US Food and Drug Administration took two months to trace salmonella-tainted papayas consumed in the States back to a Mexican farm where the contamination originated.

Using blockchain, global supply chain participants can gain permissioned access to trusted information regarding food provenance. They could then access data on the blockchain network to trace contaminated products expeditiously, stemming public health outbreaks, and potentially saving lives.[4]

Blockchain can help co-op farmers retain more of their revenues so that they need not exchange long-term sustainability practices for the short-term profit.

A second class of blockchain applications is the support of *farmer cooperatives* at the local level, especially in developing worlds. Cooperatives pool individual farmers' resources, giving the collective more leverage over large buyers and inefficient or corrupt middlemen. As legal stakeholders, co-op members are inherently interested in sustainable agriculture practices that "minimize tilling and water use, encourage healthy soil by planting fields with different crops year after year and integrating croplands with livestock grazing, and avoid pesticide use by nurturing the presence of organisms that control crop-destroying pests."[5] Blockchain can help co-op farmers retain more of their profits, ensuring that they will not have to forsake long-term sustainability practices in exchange for the short-term need to turn a profit. Sustainable agriculture is complementary to local, community-based economics, wherein the goal is to have producers and buyers transact locally and, therefore, retain economic value in the community.

A third class is *agriculture finance*, which comprises financial services for agricultural enterprises. Many applications leverage transparency and smart contract automation features of blockchain to make financing and insuring farmers—especially those in the developing world—more viable.

Finally, a fourth class is *precision agriculture*, which describes very precise and granular data-driven decision-making facilitated by advancements in data collection and analytics technologies. Using blockchain, data from sources like soil sensors, weather satellites, drones, and farm equipment improve decision-making and automation both at the individual farm level and the community level via pooling and analysis of those data.

Three classes of agriculture applications

Food safety

In many use cases, the focus remains on the farm side of the equation, rather than on the entirety of the farm-to-fork chain.

The application of blockchain for provenance tracking is central to the most developed and highly publicized blockchain case studies in agriculture. The Walmart-IBM food ecosystem has received much coverage.[6]

Lesser known is the Chinese e-commerce giant Alibaba's partnership with food suppliers in Australia and New Zealand, as well as Australia Post and PricewaterhouseCoopers on another blockchain pilot for food traceability.[7] Nimble start-ups are also addressing food safety and traceability. For example, a key pilot by Provenance ensures

Loaded Vegetable Stand by Christopher, 2009, used under CC BY 2.0 Generic.

blockchain use for near real-time monitoring and traceability in the seafood chain emanating from Indonesia. The network can detect and address wholesaler fraud within hours, once the offending wholesalers are uniquely identified and confronted, as opposed to days or weeks of investigation, during which the offender can disappear without consequence or hide behind another name and business ID.[8] Other endeavors have so far focused on specific items to trace: Bureau Veritas/Stratumn for tuna, Chai Wine Vault and Wine Blockchain EY for wine, and ZhongAn for poultry.[9] In many cases, the focus remains on the farm side of the equation, rather than on the entirety of the farm-to-fork chain.

The question for decision-makers in the food industry is not if, but how to incorporate blockchain into their food safety systems.

Mitigating the risk of animal-borne disease is central to food safety. According to the World Health Organization, consuming or even contacting infected poultry or livestock presents a vector for introducing zoonotic diseases such as avian influenza into human communities, potentially resulting in a global pandemic. The mobile app Intellichain employs distributed AI agent-based simulation and VR visualization of blockchain data for monitoring and analyzing infectious disease spread. Public health officials could apply Intellichain to data from an agrifood blockchain to monitor spread within both animal and human populations, diagnose the jumps from animal to human populations, and highlight where along the agrifood chain this jump might have taken place—and how.[10]

The question for decision-makers in the food industry is not *if*, but *how* to incorporate blockchain into their food safety systems. There are several issues to consider. The first is that blockchain is not a panacea, though in concert with Internet of Things (IoT), the traceability capability that it provides is revolutionary. According to Mitchell Weinberg, head of INSCATECH, whose agents identify counterfeit and mislabeled food,

> *The problem is the data is only as reliable as the person providing the data. In most supply chains, there is one or more "unreliable" data provider. This means blockchain is likely useless for protecting against food fraud unless every piece of data is scrutinized to be accurate.*[11]

Another issue is that industry players such as grocers and restaurants have notoriously slim profit margins, and investment in food traceability systems incurs costs without necessarily increasing revenues.

Blockchain is far from useless, but its effectiveness is constrained by missing or unscrutinized data. To minimize this constraint, we ought not develop a system for IoT, blockchain, and smart contracts in isolation, but in a sociotechnical context—flagging locations, for example, where regulatory inspection of food is compromised by frequent, local corruption.

Another issue is that industry players such as grocers and restaurants have notoriously slim profit margins, and investment in food traceability systems incurs costs without necessarily increasing revenues. As a result, the profit motive is often not compelling for investing in this type of innovation. Mammoth, powerful grocers like Walmart have the capital and incentive to comply with regulators and inspectors, but even then, such industry players are often motivated

Western Style Grocery Store by Daylen, 2017, used under CC BY 4.0.

to develop systems designed to meet minimal compliance, and no more. The industry could end up with multiple blockchains for food traceability that are minimally useful and unable to communicate with each other. In the event of large-scale food contamination, the available systems might not be up to the task of rapidly identifying the source.

We spoke with Brian Sterling, the former managing director of the Global Food Traceability Center in Washington, DC. According to Mr. Sterling, the key to addressing this issue is to think, "Traceability is free."[12] In Total Quality Management (TQM) and Six Sigma improvement initiatives, "quality is free" expresses the notion that processes are managed so well in a world-class operational system that high quality is a free by-product of the system itself. In a similar vein, his perspective is that a world-class value chain would operate so well that traceability would be a capability inherent in the chain's systems rather than delivered via alternative systems. To date, the traceability blockchains of Walmart, Alibaba, and Provenance appear to be such alternatives to the systems of i2, SAP, Oracle, or custom implementations. Extending Mr. Sterling's perspective, we believe that Walmart's blockchain for food traceability, for instance, will reach an important milestone when and if it is so integrated with the company's own excellent supply chain management system. Then Walmart and its partners can declare, "Traceability is free."[13]

"Quality is free" expresses the notion that processes are managed so well that high quality is a free by-product of the system itself.

A third issue for food industry decision-makers, and certainly for blockchain providers like IBM, is that because food is truly ubiquitous—more than cars, smartphones, or shoes—the global food supply chains look much more like a complex, entangled hodgepodge than other industries' supply chains. For the vision of global blockchain-enabled food safety, the blockchains of Alibaba, Provenance, Walmart, and others ought to interoperate, or at least communicate, with each other. The Tapscotts have conceptualized

a governing structure for chain interoperability.[14] Nuco is taking the first steps toward the Tapscott vision by building an infrastructure network to bridge different blockchains.[15] They are focusing on lower, protocol, or hardware level interoperability.

However, more work is needed. Additional initiatives—such as the use of ontologies for blockchain interoperability from York University's blockchain lab—will be required for different food blockchains to communicate among themselves.[16] To achieve chain interoperability, we must enable them to communicate at a higher, more semantic level through shared vocabulary and industry terms among different chains. Somehow, global supply chain standards like GS1 or data reference models like United Nations Centre for Trade Facilitation and E-Business (UN/CEFACT) International Supply Chain Reference Model (ISCRM) must be implemented in the blockchains so that different food chains can "talk to each other."

To achieve chain interoperability, we must enable them to communicate at a higher, more semantic level through shared vocabulary and industry terms among different chains.

Sustainable agriculture and the local economy

Agricultural entities range in scope from global consortia to local farming communities. Historically, cooperatives have been key pillars in many farming economies. There are some blockchain initiatives harnessing this ethos, specifically for sustainable agriculture to leave a smaller, community-based carbon footprint and to contribute to the local food economy.

Especially in developing worlds, cooperatives of small farmers have emerged to negotiate collectively with notoriously exploitative intermediaries. However, even with cooperatives, there are losses due to inefficient and fraudulent paper handling and the use of informal and verbal agreements. AgriLedger is a philanthropic initiative vying to move farming co-op data and transactions onto the blockchain to mitigate these losses. Participating farmers would access the blockchain using mobile phones, which are pervasive even in developing communities. AgriLedger has developed pilot programs in Kenya, Myanmar, and Papua New Guinea.[17]

Provenance is developing a blockchain for meat product monitoring for the Grass Roots Farmers' Cooperative in Arkansas. This co-op was launched and funded by Heifer International, a nonprofit that establishes sustainable agriculture and commerce in impoverished international and US communities. It employs sustainable practices like micro broods and herds, hormone-free grass feed, use of local suppliers and services, and local delivery to homes and restaurants. This last point is important because it means reliable traceability: "farm to fork" is simple and hence comprehensive data collection, scrutiny, and tracking are possible. Information about meat products will be registered on the blockchain and labeled on the packaging as QR codes. Customers can scan QR codes to learn not only about meat quality, but also how the animal was raised and who was involved in production.[18]

Blockchain holds promise to store much more intensive data about meat, even down to the DNA level.

Blockchain holds promise to store much more intensive data about meat, even down to the DNA level. We spoke with Dr. Ellen Goddard,

Herd of Cows by Jordan Stimpson, 2014, used under CC0 1.0.

professor of agricultural marketing and business at the University of Alberta, Canada. She participates in the Canadian Cattle Genome Project, a multimillion-dollar initiative between scientists and the cattle industry to sequence the genome of Canadian cattle breeds and create a reference library for future breeding decisions.[19] She sees the blockchain as an opportunity to leverage genomics. In her view, food safety is an obvious area of leverage. Consider arc-net, a blockchain start-up for traceability that aims to provide a unique ID for food items where the ID is comprised in part by the item's DNA code.

Dr. Goddard also sees how genomics and blockchain can contribute to sustainable agriculture practices. The tendency to breed dairy cows for optimal milk production has led to a loss of genetic diversity. There are concerted efforts to counter this trend. Moreover, blockchain can contribute by enabling transparent and tamper-proof recording of genetic markers of a cow's biodiversity—that is, the extent to which the cow's lineage is diverse. By accessing this information on the blockchain along with production traits that mark a cow's milk production capabilities and functional traits like fertility, health, and calving ease, dairy farmers can make more sustainable breeding decisions.[20]

The transparency that blockchain affords might help consumers experience global food with local proximity, leading to a greater connection to food, as if it were sourced locally.

We also spoke with Marieke de Ruyter de Wildt, founder of The Fork, an Amsterdam-based software company with a network of blockchain and food supply chain experts. One of its engagements, for instance, is a proof of concept for managing certificate information of South African grapes to farmers, auditors, standard setting organizations, and retailers in Europe. She believes that one of the subtle but potentially powerful uses of blockchain is fostering greater customer intimacy between the consumer and the grower—say, between a Dutch consumer and a South African orchardist. Ms. de Ruyter de Wildt believes that blockchain can help the consumer know more about, for example, South African grapes, the orchards of origin, and the transit conditions for the grapes.[21] This transparency leads to a greater connection to the food, as if it were sourced locally. That is, blockchain might help consumers experience global food with local proximity.

Blockchain might help consumers experience global food with local proximity.

Blockchain can store information beyond what is required strictly for traceability for food safety. For instance, there is little food safety rationale for Grass Roots co-op to make animal welfare or production personnel data available to its customers via the blockchain, but it chose to do so, anyway. Why? Because that additional transparency enables the co-op's health conscious and sustainability-minded customers to recognize more value in their food. Whether it's Grass Roots co-op or The Fork, blockchain enable something interesting: blockchains for food safety are being co-opted to demonstrate sustainability and "local economy" benefit.

Another effort that does exactly this is an early stage initiative called FarmShare, which is billed as a decentralized blockchain-based platform for local economy/community-based economics.[22] Through the FarmShare platform, a local community would be able to set up and operate a virtual farmers' market. It would allow other local economy exchanges to be linked, so that its users could trade, for instance, apples for solar energy with another user on a community micro-grid. FarmShare plans to enable this trade by issuing and using its own native currency, called the farmshare token. As FarmShare is developing on the Ethereum blockchain network, customers and farmers would need first to possess Ethereum cryptocurrency, ether, which they would exchange for farmshare tokens. Customers would pay tokens to farmers and schedule weekly deliveries as well as pay in real-time if they bought in a face-to-face transaction at a physical farmers' market. The tokens would also represent shares in FarmShare, such that if activity and economic value increased in many farmers' markets operated by FarmShare, the tokens would appreciate relative to ether.

The major issue for this application is quite simply who will pay to build these blockchains. Local economy participants usually do not

Corn Field during Daytime by Alejandro Barrón, 2015, used under CC0 1.0.

have deep pockets and lack technical and business sophistication to seek out, develop, and fully realize the business value of a blockchain-based solution, even when ROI is demonstrable. In the AgriLedger and Grass Roots co-op examples, charities stepped in and funded the blockchains. FarmShare was conceived as a for-profit venture. It would not necessarily charge transaction or maintenance fees but would receive ether in exchange for its tokens. The market for ether (around $31 billion as of August 2017) is so liquid that it is easily converted to cash. In addition, by decree, FarmShare would create and hold large amounts of tokens that would appreciate—just as stock shares appreciate as buyers bid up the shares in a stock exchange—as economic activity in the various markets it operated within increased. As a very early stage start-up, FarmShare faces many challenges and is currently on hold, but there might be merit in its business model.[23]

There are also novel blockchain applications on the farmer transaction and payment side.

In sum, local economy participants might be unwilling or unable to fund blockchain solutions. However, others might be willing to invest on their behalf because the economic activity spurred by the blockchain might be of value to charities or governments that do not necessarily have a profit motive. Alternatively, the blockchain provider might be incentivized to invest because they can directly convert an increase in activity as a realizable increase in monetary value.

Agriculture finance

There are also novel blockchain applications on the farmer transaction and payment side. In December 2016, 23 metric tons of wheat were delivered within Australia, and that transaction was recorded on the blockchain.

> The deal was "auto-executed" by a smart contract run by commodity management platform AgriDigital. This smart contract performed a series of tasks, including valuing the delivery, verifying that the buyer had sufficient funds, and securing the funds in the grower's name pending delivery. Once the grower made the physical delivery, the title for the grain was transferred to the buyer as the grower's payment was simultaneously created from the reserved funds.[24]

Blockchain can be used by governments and NGOs to level the playing field for developing world farmers in the global futures market.

Blockchain can be used by governments and NGOs to level the playing field for developing world farmers in the global futures market. Buyers purchase price contracts for West African cocoa or Indian sugar cane before the season. However, if the futures prices of those commodities make those contracts unprofitable, the buyers will sometimes renege on those contracts. Because these farmers are very under-resourced, the buyers renege knowing that there is not much recourse for the farmers. Even if the farmers can scramble and find another buyer, they will have to sell at a reduced price, and if there is a time lag in the scramble, significant spoilage in their crops might have occurred reducing the amount that can be sold, leading to further losses.

Watering Can Man by Qui Nguyen Khac, 2016, used under CC0 1.0.

AgriDigital is also tackling this problem "by enabling real-time transactions for farmers through 'smart contracts' that run on blockchain. Because pre-approved logic can be built into a blockchain—as long as all parties have opted in—payments can be made immediately following the transfer of asset ownership."[25] This discourages reneging as payment is automatically scheduled and if the buyer actively stops payment, there is well-documented evidence trail that can be used against them in litigation.

Etherisc, a start-up using blockchain to provide decentralized insurance, has conceptualized how they can help the plight of farmers in the developing world. Crop insurance is under-utilized in these countries even though the need is great: these farmers typically lack substantial financial reserves and would greatly benefit from insurance against natural events that are catastrophic for their crops. However, there are instances where farmers have been unable to collect against crop insurance they held because they could not navigate the complex, sometimes corrupt claims process, or didn't fully understand terms of their insurance. Often, farmers simply can't afford the premiums. Etherisc uses *parametric insurance*, wherein processing would be done by smart contracts that are triggered when certain events occur (modeled as certain parameter threshold values being reached).

Etherisc would execute a smart contract so that if the rainfall in the region of a farmer is below a threshold specified by insurance it would be paid out to them automatically.

In one use case, a developing world farmer would be insured for one or two dollars a month, a rate that a traditional insurance provider could not viably offer. Etherisc would execute a smart contract so that if the rainfall in the region of a farmer is below a threshold specified by insurance it would be paid out to them automatically. Rainfall information would be sourced from a trusted weather database. There would be little human intervention for claims processing, keeping costs low. More importantly, the farmer would receive timely payment, without having to deal with

potentially corrupt bureaucrats. Etherisc is working to integrate insurance processing with M-Pesa, the cell phone based payments infrastructure used in much of developing Africa.[26]

Another example is the start-up Everex's blockchain use to offer microfinancing to the developing world.[27] Inevitably, much of that money will be lent to farmers. Microfinancing is the notion of offering small, low barrier loans to businesses or individuals who would be otherwise shut out by their region's traditional bank lending practices. The major problem of microfinancing is that loans often go for subsistence, not necessarily for growing businesses. As a result, borrowers might be further burdened with loan repayments. Lenders often charge exorbitant rates (e.g., a large Mexican bank charged as much as 200 percent per annum), effectively transforming a well-intentioned program into a loan sharking scheme. From the lender's perspective, given the borrowers' high-risk profiles and small loan sizes, as well as the possibility of corruption, administrative costs per dollar lent for providing these loans is relatively high. By offering transparency, automating processing using smart contracts, and speeding up money transfers, Everex can significantly lower costs for the lender, which could lead to better terms being offered to borrowers, who then can take on larger loans to drive business growth beyond subsistence.

The major problem of microfinancing is that loans often go for subsistence, not necessarily for growing businesses.

We spoke with Anne Connelly, the founding team member of ixo Foundation, a nonprofit based in South Africa that is optimizing impact to achieve the UN's Sustainable Development Goals.[28] ixo is building a protocol that enables sustainable development organizations to create an impact claim around the work they have achieved. Claims could include such impacts as improving farm production yields, delivering vaccines, or increasing access to education. The claim is then verified by an evaluator or an oracle, creating *proof of impact* through ixo's decentralized impact exchange. This proof enables organizations to access funding like social impact

Harvest Grain Combine by Hendrik van der Heide, 2014, used under CC0 1.0.

bonds and government subsidies, and funders can reduce the evaluation costs associated with their investments.

The data from the verified impact claims is stored in the Global Impact Ledger, an open data commons that funders, organizations, researchers, and governments can use to make more informed decisions about their work and optimize their impact. The ixo Foundation has partnered with UNICEF, with whom it has been running field trials of an application called Amply that tracks preschool attendance on the ixo protocol.[29] It is operating in over 72 schools across South Africa and has recorded 44,000 attendance records, improving access to government subsidies while creating valuable data about access to education.

Blockchain solutions in food safety, sustainable agriculture, and local economy are directly conceived to address issues in agriculture.

The top two of the 17 UN sustainable development goals are "No Poverty" and "Zero Hunger," hence numerous UN projects focus on improving agriculture in the developing world. Ms. Connelly hopes that ixo can improve the effectiveness of such projects and become a shining example of how blockchain can positively affect developing world farmers.

Finance was the first area to which blockchain was applied. Not surprisingly then, some of the examples presented here adapt blockchain designs born of finance to the agriculture space. In contrast, blockchain solutions in food safety, sustainable agriculture, and local economy are directly conceived to address issues in agriculture. There are fast-paced innovations in blockchain for finance, and so the issue for agriculture decision-makers is to determine whether and how applications in that space can translate into agriculture solutions.

Key takeaways

Traceability for food safety is thus far the most adopted application of blockchain for agriculture. As blockchain initiatives in food safety reach widespread acceptance, we make the following recommendations for decision-makers to stay ahead of the curve. The blockchain pioneers we interviewed contributed to these insights.

- **Experiment with, and add blockchain capability to, your organization's food safety programs.** Be sure to include a sociotechnical perspective to provide the right incentives and context to address the weakest link in traceability—false, incomplete, or missing data.
- **Plan to partner with champions and key personnel of your organization's value chain systems** (e.g., implementations from SAP or Oracle). Such partnerships lead to tight coupling between the blockchain and the value chain system and a world-class traceability capability that will be a by-product of your organization operating a world-class value chain.

Meetups are particularly informative because they are not only about blockchain, but also based on use cases. They gather diverse perspectives and help enlist companies to invest time and money in blockchain initiatives.

- **Participate in global standards initiatives like GS1 and UN/CEFACT.** Your organization will need to ensure that your blockchain maps to these standards to bridge with other blockchains and enable global scale food traceability.
- **Get personally and socially involved in learning about blockchain and agriculture.** According to Ms. de Ruyter de Wildt, The Fork's meetups are particularly informative because they are not only about blockchain, but also based on use cases. They gather diverse perspectives from software developers, agriculturalists, brand managers, and government officials. She told us that she has been able to enlist companies to invest time and money in The Fork's initiatives partly because of these meetups.
- **Invest in your own proofs of concepts.** Obviously, the most motivated companies should invest in their own proofs of concepts such as The Fork's managing certificates for South African grapes, ixo's proof of impact exchange, Etherisc's crop insurance smart contracts, AgriLedger's co-op data collection, FarmShare's local economy exchanges, and Everex's microfinancing platform.
- **Contribute time and money to a third party or consortium blockchain initiative.** Ms. de Ruyter de Wildt's corporate collaborators told her they wanted to dip their toes, view first-hand how The Fork consortium would work, and collaborate with partners in their ecosystems, all while mitigating the risk of going at it alone.
- **Perform due diligence before contemplating participating in any initial coin offering (ICO).** Ms. Connelly at ixo told us that UNICEF as a founding partner of ixo will be a "coin holder" if ixo does an ICO, another means of funding and investment with less regulatory oversight and hurdles than initial public offerings. Not only would UNICEF be a key user of ixo's blockchain that measures the impact of development projects, it would also effectively be a key shareholder.
- **Consider buying coins or tokens of third party partners who help build your blockchain.** Coin purchases in combination with direct payments can constitute total remuneration to such partners as ixo, FarmShare, AgriLedger, or Etherisc. Agricultural organizations can amplify their ROI, as they receive direct cost or profit benefit from their blockchains and as their coins appreciate.

Blockchain holds great promise to revolutionize agriculture. We hope that this research will help stakeholders in the global agriculture ecosystem get their journey started.

About the authors

Professor Henry Kim is a leading expert in developing enterprise models based on an AI technology called ontologies. He is often cited by food scientists for his work on an ontology of supply chain traceability. He works at the Schulich School of Business at York University in Toronto as an associate professor of decision technologies. He has authored 60-plus scientific articles; and as co-director of the Blockchain Lab, he is focusing his research on blockchain use, especially for supply chain applications.

Dr. Marek Laskowski is co-director of the Blockchain Lab at York, a certified Ethereum blockchain developer, and a researcher, professor, and entrepreneur studying the potential of blockchain and distributed ledger applications to disrupt the technology and business landscape. He also has experience and interest in modelling and simulation of complex social systems, machine learning, data analytics, and the design of next-generation participatory decision support platforms. For example, he is involved in developing agent-based models for public health decision support and devising smartphone-based public health surveillance technologies.

About the Blockchain Research Institute

Co-founded in 2017 by Don and Alex Tapscott, the Blockchain Research Institute is a knowledge network organized to help realize the new promise of the digital economy. It builds on their yearlong investigation of distributed ledger technology, which culminated in the publication of their critically acclaimed book, *Blockchain Revolution* (Portfolio|Penguin).

Our syndicated research program, which is funded by major corporations and government agencies, aims to fill a large gap in the global understanding of blockchain technology and its strategic implications for business, government, and society.

Our global team of blockchain experts is dedicated to exploring, understanding, documenting, and informing leaders of the market opportunities and implementation challenges of this nascent technology.

Research areas include financial services, manufacturing, retail, energy and resources, technology, media, telecommunications, healthcare, and government as well as the management of organizations, the transformation of the corporation, and the regulation of innovation. We also explore blockchain's potential role in the Internet of Things, robotics and autonomous machines, artificial intelligence, and other emerging technologies.

Our findings are initially proprietary to our members and are ultimately released under a Creative Commons license to help achieve our mission. To find out more, please visit www.blockchainresearchinstitute.org.

Leadership team

Don Tapscott – Co-Founder and Executive Chairman
Alex Tapscott – Co-Founder
Joan Bigham – Managing Director
Kirsten Sandberg – Editor-in-Chief
Jane Ricciardelli – Director of Marketing
Hilary Carter – Director of Research
Jenna Pilgrim – Director of Business Development
Maryantonett Flumian – Director of Client Experience
Luke Bradley – Director of Communications

Notes

1. UN FAO, "FAO Statistical Yearbook 2012: World Food and Agriculture," foreword by Pietro Gennari, Food and Agricultural Organization of the United Nations, www.fao.org, 17 April 2017, p. 11. issuu.com/faosyb/docs/fao_statistical_yearbook_2012_issuu; Carl Haub et al., "World Population Data Sheet 2011: The World at Seven Billion," Population Reference Bureau, July 2011. www.prb.org/pdf11/2011population-data-sheet_eng.pdf, all accessed 5 Dec. 2017.
2. Gro Intelligence, "Kenya's Farmers Demand Coffee Break," *Gro Intelligence Insights*, 26 Feb. 2016. gro-intelligence.com/insights/kenyas-farmers-demand-coffee-break, accessed 29 Nov. 2017.
3. World Health Organization, "WHO Estimates of the Global Burden of Foodborne Diseases," 12 March 2015. www.who.int/foodsafety/publications/foodborne_disease/fergreport/en, accessed 29 Nov. 2017.
4. Michael del Castillo, "Walmart, Kroger & Nestle Team with IBM Blockchain to Fight Food Poisoning," *Coindesk*, 22 Aug. 2017. www.coindesk.com/walmart-kroger-nestle-team-with-ibm-blockchain-to-fight-food-poisoning, accessed 29 Nov. 2017.
5. National Geographic, "Sustainable Agriculture," *National Geographic Reference*, n.d. www.nationalgeographic.com/environment/habitats/sustainable-agriculture, accessed 29 Nov. 2017.
6. Nathaniel Popper and Steve Lohr, "Blockchain: A Better Way to Track Pork Chops, Bonds, Bad Peanut Butter?" *The New York Times*, 4 March 2017. www.nytimes.com/2017/03/04/business/dealbook/blockchain-ibm-bitcoin.html, accessed 29 Nov. 2017.
7. Alicia Noel, "Blockchain is Now Being Used on the Food Supply Chain," *LinkedIn Pulse*, 27 June 2017. www.linkedin.com/pulse/blockchain-now-being-used-food-supply-chain-alicia-noel-%E5%87%A4%E5%85%B0-, accessed 29 Nov. 2017.
8. Provenance, "Provenance: Every Product Has a Story," *Provenance.org*. www.provenance.org, accessed 29 Nov. 2017.
9. Noel, "Blockchain is Now Being Used on the Food Supply Chain," 27 June 2017.
10. Marek Laskowski, "A Blockchain-Enabled Participatory Decision Support Framework," *Social, Cultural, and Behavioral Modeling*, Proceedings of the International Conference on Social Computing, Behavioral-Cultural Modeling and Prediction and Behavior Representation in Modeling and Simulation, Washington, DC, 5-8 July 2017, pp. 329-334. www.springer.com/us/book/9783319602394, accessed 29 Nov. 2017.
11. Noel, "Blockchain is Now Being Used on the Food Supply Chain," 27 June 2017.
12. Martin Gooch and Brian Sterling, "TRACEABILITY IS FREE: Competitive Advantage of Food Traceability to Value Chain Management," VCM International, 12 Aug. 2013. vcm-international.com/wp-content/uploads/2013/08/Traceability-Is-Free.pdf, accessed 29 Nov. 2017.
13. Brian Sterling, interviewed by the authors, 11 July 2017.
14. Don Tapscott and Alex Tapscott, "Realizing the Potential of Blockchain: A Multistakeholder Approach to the Stewardship of Blockchain and Cryptocurrencies," World Economic Forum, June 2017. www3.weforum.org/docs/WEF_Realizing_Potential_Blockchain.pdf, accessed 29 Nov. 2017.
15. Stan Higgins, "Nuco Builds Tokenized Blockchain 'Bridge' for Enterprise Applications," *CoinDesk*, 17 July 2017. www.coindesk.com/nuco-builds-tokenized-blockchain-bridge-enterprise-applications, accessed 29 Nov. 2017.

16. Henry M. Kim and Marek Laskowski, "Towards an Ontology-Driven Blockchain Design for Supply Chain Provenance," Workshop on Information Systems and Technology (WITS), Dublin, Ireland, 2016. yoda.lab.yorku.ca/files/2016/08/wits-2016-hk-ver2.1.pdf, accessed 29 Nov. 2017.

Henry M. Kim and Marek Laskowski, "A Perspective on Blockchain Smart Contracts: Reducing Uncertainty and Complexity in Value Exchange," The Third IEEE Workshop on Workshop on Privacy, Security, Trust and Blockchain Technologies, Vancouver, BC, 31 July-3 Aug. 2017. doi:10.1109/ICCCN.2017.8038512, accessed 29 Nov. 2017.

17. Tim Lea, "b3 Blockchain Interview with the Founders of Agriledger.com - The International Philanthropic Blockchain Application to Protect Third World Farmers," LinkedIn, 10 Aug. 2016. www.linkedin.com/pulse/b3-blockchain-interview-founders-agriledgercom-application-lea, accessed 29 Nov. 2017.

18. Joshua Althauser, "Arkansas Livestock Cooperative Planning Use Blockchain Technology in Meat Products Monitoring," *CoinDesk*, 7 Aug. 2017. cointelegraph.com/news/arkansas-livestock-cooperative-planning-use-blockchain-technology-in-meat-products-monitoring, accessed 29 Nov. 2017.

19. Paul Stothard, Xiaoping Liao, Adriano S. Arantes, et al., "A large and diverse collection of bovine genome sequences from the Canadian Cattle Genome Project," *Gigascience*. 2015; 4(1):49. doi:10.1186/s13742-015-0090-5, accessed 29 Nov. 2017.

20. Ellen Goddard, interviewed by Henry Kim, 17 Aug. 2017.

21. Marieke de Ruyter de Wildt, interviewed by the authors, 17 Oct. 2017.

22. William E. Bodell III, "FarmShare: Blockchain Community-Supported Agriculture," white paper, modified 1 Nov. 2017. docs.google.com/document/d/1jntZtiw0VQQ6ZctVyWsCcg-ZGvv6MCSvlFIIPG5GDSg/edit, accessed 5 Dec. 2017.

23. See matthew-lohry-kded.squarespace.com. As of 5 Dec. 2017, this page indicated that FarmShare is "currently on hold."

24. Julien Hall, "AgriDigital Pioneers Blockchain Use with First Farmer-Buyer Agriculture Settlement," *The Barrel Blog*, 2 Feb. 2017. blogs.platts.com/2017/02/02/agridigital-pioneers-blockchain-agriculture, accessed 29 Nov. 2017.

25. Gro Intelligence, "Blockchain: Beyond Bitcoin to Agriculture," *Gro Intelligence Insights*, 2 Aug. 2017. gro-intelligence.com/insights/blockchain-in-agriculture, accessed 29 Nov. 2017.

26. Bernard Lunn, "IOT Meets DLT and Blockchain meets M-Pesa in Africa," *Daily Fintech*, 24 March 2017. dailyfintech.com/2017/03/24/iot-meets-dlt-and-blockchain-meets-m-pesa-in-africa, accessed 29 Nov. 2017.

27. Everex, "Problems with Microlending and How Blockchain Solves Them," *Everex blog*, 22 Aug. 2017. blog.everex.io/problems-with-microlending-and-how-blockchain-solves-them-1582f98e2a7c, accessed 29 Nov. 2017.

28. Anne Connelly, interviewed by Henry Kim, 22 Oct. 2017.

29. Michael del Castillo, "No Token Response: UNICEF Is Open to Doing Its Own ICO," *CoinDesk*, 13 Oct. 2017. www.coindesk.com/no-token-response-unicef-is-open-to-doing-its-own-ico, accessed 29 Nov. 2017.

blockchainresearchinstitute.org