HOW BLOCKCHAIN COULD HELP REGULATORS

A Case for Piloting Government Agency Projects

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Good Robot

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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.

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Foreword

Blockchain technologies are profoundly affecting industries ranging from education and culture to the law, finance, and international trade. Innovation, Science, and Economic Development Canada (ISED) is examining the potential of blockchain for government transformation.[1]

The Canadian Food Inspection Agency (CFIA) is a regulatory body "dedicated to safeguarding food, animal and plants, which enhances the health and well-being of Canada's people, environment and economy."[2] It is relatively new as agencies go, emerging in 1997 as a combination of multiple inspection agencies. Today, CFIA faces an environment different from that of 1997: complex global food supply chains, information-hungry consumers, highly mobile and digital workers, rapidly advancing agricultural and food technologies, and the international competitiveness of Canada's food exports.

In collaboration with ISED and CFIA, our researcher Alan Majer authored this analysis of the promise and potential of blockchain applied to the safety and sustainability of Canada's food. He bolsters his research with in-depth interviews with Emma Weston, CEO of AgriDigital, Padraig Brennan of Bord Bia, and leaders at Agri-Traçabilité Québec and BLOCKstrain.

It is an excellent model of the holistic approach that other government agencies could be taking to test blockchain solutions to pressing national problems. Consider America's aging infrastructure. According to the American Society of Civil Engineers, nearly 10 percent of the nation's bridges are structurally deficient, and over 15,000 dams are high hazard.[3] Delays related to poor roadways cost United Parcel Service $105 million a year.[4]

The lead in the water supply of Flint, Michigan, highlighted how infrastructure neglect can culminate in a public health crisis; that 240,000 water mains continue to break across the country each year should make water system modernization a high priority.[5]

These problems may not benefit directly from blockchain, but they beg for the public-private collaboration and holistic approaches used to pilot blockchain projects designed to protect the health and well-being of life on this planet and the sustainability of food, pharmaceutical, and medical supply chains.

⬡ DON TAPSCOTT
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Concept in brief

The world has changed, and food safety has changed with it.

» The world has changed, and food safety has changed with it. The forces that have connected us in a global society have also changed how we produce and consume our food.

» Instead of local agricultural production and consumption, we have complex supply chains, processing technologies, and international trade. Those responsible for food safety face new challenges. They also have an opportunity to lead the development of new techniques for managing agriculture and the food supply.

» Today, Canada enjoys an excellent global reputation.[6] It is a mixed blessing, in that crises are often the drivers of change and innovation. To expand its reputation at home and abroad, Canada can take supply chain leadership in ensuring the quality and safety of its food and all elements of its production.

» The transparency and electronic enablement of food supply chains and the information associated with them have never been so important to the safety, integrity, and value of what Canadians eat and produce.

» Blockchain technologies are new tools for enhancing quality and transparency. As fundamental innovations, blockchains are re-shaping the Internet itself, allowing new distributed collaborative structures, value exchanges, and information sharing that could revolutionize today's supply chains.

» Like many technologies, blockchain is only as good as its implementation: each use requires trustworthy data and multistakeholder participation for us to realize its potential. This prospective examines how blockchain could assist us in managing modern challenges around a core resource—our food—and facilitating Canadian global competitiveness.

Is our food safe? Answering this question is surprisingly difficult.

A changing environment with new risks

Is our food safe? Answering this question is surprisingly difficult. It depends not only what we see right in front of us—a combination of safe ingredients, freedom from contaminants, and transparency in genetic modification and usage of antibiotics and hormone therapies—but also on its safe handling throughout the supply chain from farm to fork. Our ability to access food quality and safety is inextricably tied to the information about the provenance and

handling of that food, as well as the well-being of the plants or animals it came from. Without information about plants, animals, and food handling practices, some of the greatest risks like pathogens or trace contaminants are nearly invisible, or their harm may also accrue over long periods.

"Canada's agfood sector is among the world's largest. Canadian agricultural product exports amounted to $26.1 billion or 5.7 percent of all global agricultural exports and qualified our country as the fifth-largest agricultural exporter in the world."[7] Canada has an excellent global reputation, said President of Nourish Food Marketing, Jo-Ann McArthur. "If you look internationally, Canadian products are trusted. We are seen as having pristine water and natural resources."[8] Canada ranks high in public sector trust, eighth out of 180 countries.[9]

Today there is a gap between Canada's positive global reputation and its ability to deliver sustainable trusted food. Forty-three percent of Canadians profess skepticism about whether Canada's food system is "on the right track."[10] With a handful of exceptions, Canada lacks full farm-to-fork traceability, with limited visibility into the environment and conditions under which animals were raised or plants grown. The reasons are complex:

» Legacy practices have not kept pace with modern requirements. Many processes rely on manual entry or paper-based systems.

» Those who bear the costs of innovation are not always those who benefit from it.

» Increasingly complex global supply chains make it difficult to trace food, plants, and animals.

» Consumers and producers need easy-to-use systems. Consumers want proof, not hard-to-decipher labels; and producers want systems that are easy to implement.[11]

» A disconnection between consumers and producers of food undermines the pursuit of quality.[12]

» Food commoditization has intensified economic pressure and limited the rewards for quality improvements by producers.

» Multiple parties in the supply chain must act collectively to achieve industry or nation-wide benefits.

» Proponents of food safety have failed to show the economic value of, or make the business case for, farm-to-fork traceability systems.

» Compensation schemes that encourage transparency and mitigate harm to producers from food incidents are disincentives for addressing system-wide risks.

» Regulatory approaches have traditionally emphasized mandatory compliance over the communication of benefits.

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President
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There are clear benefits to improving Canada's food, animal, plant handling practices, and embracing greater transparency—direct economic benefits that accrue from food and producer excellence, improved safety, and trust. While these benefits are obvious, the path to realizing them is not.

Today's supply chain realities and fierce global competition set a very high bar.

Today's supply chain realities and fierce global competition set a very high bar. Agricultural and food leadership require more than reputation: global buyers care not only about the quality and provenance of food, but also about the welfare of animals and the sustainability of farming practices. Canada will have to earn its leadership role.

Apple Orchard Apple Trees Red by lumix2004, 2016, used under Pixabay license, accessed 3 June 2019.

Global and integrated supply chains

Global trade and new intermediaries mean today's food is subject to handling by more players, both within and outside our borders.

Global trade and new intermediaries mean today's food is subject to handling by more players, both within and outside our borders. One study concluded that "68.7 percent of national food supplies as a global mean are derived from foreign crops."[13] In an interview with *Food and Health E-ssentials*, Dr. Ron Wacker said, "With the globalized sourcing of food today, the challenges of ensuring food safety have gone international. Today, processed food can easily have ingredients from five to ten different countries, significantly enlarging the scope of risks."[14]

"Concerns related to chemical and biological contamination … are made more challenging due to complex supply chains and inadequate transparency," said Wacker. "Unlike 30 years ago, when a contamination incident was largely contained to a local area, the consequences are significantly greater in a global marketplace, where a single contaminated product can affect thousands of people in multiple countries."[15]

Product can land in Ontario in the morning and be on a plane and in Vancouver by the afternoon, according to Alyssa Daku, chief data and risk officer of CFIA.[16] Today, even a simple pizza may contain up to 35 ingredients sourced from 60 different countries.[17] The complex realities of the global food trade require careful coordination, handling, and information sharing by all supply chain actors to assure safety.

Demand for new and novel products

Even the nature of food is changing: novel products such as synthetic foods, spirulina, and other bacterial food candidates, *genetically modified organisms* (GMOs), and the use of products to control disease or accelerate growth can all amplify risk management challenges. Some issues and risks (declining honey bee health, for example) are inherently complex, requiring multi-disciplinary approaches to address them.[18] Others, like the use of antibiotics in animal feed (and the risks it may create for antibiotic resistance and human health), are not only complex, but politically sensitive too.[19] Fortunately, technology also provides tools to help us overcome some of these challenges. According to Wacker, "new technologies and advanced analytical tools now allow us to test for chemicals and substances that we didn't even think about 10 years ago."[20]

Food fraud

We face threats not only from inadequate food handling practices or unsafe ingredients but also from intentional forms of food fraud, which consultant and analytical scientist John Points estimated to be five to twenty percent of all food-related incidents, "depending on whether [we take] a cynical or a charitable view of documentation and labelling errors."[21] Bad actors may attempt to inject unsafe food at the weakest links in global food supply chains. Today we produce more pepper than the world's supply of peppercorns would allow.[22] "There [are] not enough honey bees in the world to satisfy the claimed sales of honey," said McArthur of Nourish Marketing.[23]

What risk does this represent? Food industry analyst Hirokazu Kawagishi told Japan Today, "The concealment of point of origin and reshipment of items meant for disposal … are widespread practices in the food and wholesale industries."[24] Much of this fraud is economically motivated, but the same criminal mindset that profits from false food may care little about its safety—whether it's horsemeat sold as beef or infant formula laced with melamine.[25]

"The optimistic answer is that awareness and fraud protection processes will have strengthened, and criminals will have switched their attention to another industry that is perceived as a softer touch," Points explained to *New Food Magazine*. "Unfortunately, I think that the food industry will continue to be a tempting target."[26] Full traceability is an important first step to help minimize blind spots, and a critical defensive measure to keep food fraud at bay.

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Vegetables carrots garlic celery by LubosHouska, 2016, used under Pixabay license, accessed 3 June 2019.

Today's food safety, animal health, and plant protection requirements demand traceability and accountability of our food supply, as well as the ability to respond rapidly to threats.

Changing consumer expectations

Today's food safety, animal health, and plant protection requirements demand traceability and accountability of our food supply, as well as the ability to respond rapidly to threats. Traceability practices like "one up, one down," while standard for international trade, no longer suffice in the wake of an outbreak where we need to track down sources of harmful food, animals, or plants in hours, not weeks.

At present, information is unevenly distributed, consumers have far less visibility (26%) into supply chain risks than manufacturers (98%), while other supply chain participants have little visibility at all (11%).[27] Traceability increases the speed and nimbleness of response in an emergency and keeps open access to trade, said Amanda Jane Preece, vice president of the CFIA.[28] We need true end-to-end traceability for it to work. "Anything short of 100 percent traceability still needs a meticulous and resource intensive investigation," stated Preece. "I have to miss only one infected animal to cause an outbreak."[29]

The eventual shift to transparent traceable food is already a foregone conclusion, industry and trading partners require it, and consumers demand it.

The eventual shift to transparent traceable food is already a foregone conclusion, industry and trading partners require it, and consumers demand it. "Before, it was sort of nice to know where your food came from," said McArthur of Nourish Marketing, "Now we're seeing that 'it's my right to know,' and we call it radical transparency."[30] It's a global shift that businesses and governments ignore at their peril, and many players around the globe have focused on farm-to-fork traceability and sustainable practices. Some countries see it as a great catalyst for international growth. "If we want to continue to grow as an industry, and remain viable while we grow, we need to listen to the marketplace," recalled Padraig Brennan, director of Ireland's Bord Bia.[31]

Industry is acting on these new consumer expectations. Companies like Amazon (which recently purchased Whole Foods) view supply

chain opportunities as a competitive weapon, offering detailed information about product sourcing and ingredients.[32] Amazon's Jeff Bezos told *Fast Company*, "There's a subset of customers—I think it's a pretty big subset—that when you're talking about things that go in or on your body, or in or on your children's bodies, they really care about that supply chain."[33] Food supply chains and access to data will ultimately change, for the simple reason that customers demand it.

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Digitalization

We can leverage the same technologies that expanded international trade and supply chain coordination to improve the processes and flow of information that assure food safety and create business value. Focusing on digital service delivery not only helps businesses and consumers to access the information they need more easily, but it also encourages collaboration and process automation. It's about using information to compete and serve the customer. Brian Solis, principal analyst at Altimeter, told *Forbes*, "We will see a renaissance in physical space and a new paradigm for online shopping that merges intelligent technologies, hyper-personalization, and seamless cross-channel engagement."[34]

While these tools benefit information transparency for customers, they also reach back far into the supply chain. Digitalization is affecting the flow of processes and materials in nearly every industry—paper and manual methods are being replaced by smart data collection and networking. A 2016 survey of disruptive supply chain technologies put "digital supply chain" near the top of the list, with 68 percent of respondents citing it as disruptive and important, exceeded only by "big data analytics."[35]

Blockchain promise and potential

At its simplest, a blockchain is a distributed record-keeping system that allows trusted and accurate record keeping among multiple participants. The system works, regardless of whether system participants trust one another, and records are permanent and immutable. This arrangement is unusual because typically "trust" in an electronic system (whether it's a bank or a stock market) requires trust in the institutions that operate it.

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For example, while our bank may have the ability to wire our funds into an account of its own, we trust that it won't do that.[36] In a blockchain, math and cryptography enforce the behavior and rules of the system instead, so that it functions even when the entities and participants running it don't fully trust one another. "Trust is the main benefit of blockchain," said Matt Jackson, research director of the Institute on Governance.[37] Today, $131 billion worth of currency resides in such systems.[38]

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The same features that allow us to trust blockchains for storing units of currency also make them extremely well suited for storing data, code, records, and contracts. Such a system holds enormous potential, not only to create a single version of the truth that is easy to update and share in a distributed manner but also to offer an infrastructure for value exchange and transactions that improve the flow of information, processes, plants, animals, and food. With 60 percent of large companies contemplating the use of blockchain, it's an ecosystem that's expecting rapid growth. According to market researchers, "services and products related to blockchain are set to reach $7.7 billion in 2022."[39]

Yet blockchain is still in its infancy and continues to evolve rapidly. Modern blockchains are beginning to act as global distributed computers, allowing network participants to interact directly with each other, reducing the number of intermediaries which do not add value.[40] "For the first time, we're seeing software automate business itself," former Coinbase employee Olaf Carlson-Wee told *Wired*.[41]

The benefits of digital supply chains

Today, most examples of blockchain-enabled food, plant, and animal supply chains are still in their infancy. They range from small pilots by Provenance (tuna and co-op food) and arc-net (beer and spirits), to more ambitious rollouts by AgriDigital (grains) and BLOCKstrain (cannabis), as well as a handful of supply-chain wide pilots such as the one from Walmart and IBM (pork and mangos).[42]

Research for this report has meant examining a number of agricultural and food supply chain initiatives—including Canada's BIXSco and Ireland's Origin Green program—that don't involve

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Cow red orange curious animal by Karsten Paulick (Kapa65), 2016, used under Pixabay license, accessed 3 June 2019.

blockchain.[43] "We're already delivering what blockchain purports they will deliver," said Deborah Wilson, senior vice president of BIXSco. "We're already tracing and tracking live animals and doing a good job of it."[44]

One of the challenges with early blockchain rollouts is that many of their benefits are indistinguishable from similar initiatives using other types of supply chain digitalization initiatives. In fact, supply chain digitalization is often a prerequisite to more interesting options for blockchain technologies. Still, the advantages of such initiatives (blockchain-based or not) are worth repeating:

One of the challenges with early blockchain rollouts is that many of their benefits are indistinguishable from similar initiatives using other types of supply chain digitalization initiatives.

» *Rapidly isolate food incidents and speed recoveries.* According to Marie-Christine Talbot, general manager of Agri-Traçabilité International, traceability systems can also help re-open markets after a food incident. In 2003, when *bovine spongiform encephalopathy* (BSE) was discovered in Alberta, the Japanese closed its market to Canada; but because of its traceability system, Québec was the first allowed to sell back to Japan.[45]

» *Reduce waste in case of contamination.* Presently, one-up-one-down reporting creates uncertainty in the extent of contamination. Entire shipments can be thrown out as a precaution, and millions wasted.[46] Rapid, accurate detection helps clarify which food is safe and which isn't.

» *Pinpoint responsibilities.* Greater transparency means explicit assignment of responsibilities at each step of Walmart's supply chain. As stated by Brigid McDermott, vice president of Blockchain Business Development and Ecosystem at IBM, "In food safety, [we] don't want anonymity. [We] want transparency of who has responsibility for the food at what given time."[47]

» *Enhance consumer visibility.* Walmart's ability to track crucial data from receipts also enhances consumer visibility, allowing possibilities like sharing customer feedback with supply chain participants.[48]

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» *Streamline efficiency.* Digitization aids interoperability: forcing removal of paper (one of the reasons outbreaks can be so difficult to track down), connecting disparate systems, and facilitating adoption of standards—all of which increase efficiency and save costs.[49] "It's amazing when you start accumulating data the changes in efficiencies you can find and how much more profitable you can become," said Wilson.[50]

» *Reduce risk of nonpayment and transaction costs.* Payment security for farmers is a common source of concern, said Emma Weston, CEO of AgriDigital.[51] "We decided to build out … a commodity management platform that could digitize the supply chain" and remove counterparty risks for sellers.[52]

» *Increase economic opportunities.* Enhanced buyer visibility also *increases* the value of food and agricultural products,

Blockchain offers the opportunity to engineer digital supply chains that more effectively conform to the trust and sharing requirements of participants.

an economic opportunity that is arguably the single most important factor in motivating supply chain participants. Verified sustainable supply chains are key to export growth, said Brennan of Bord Bia, a body responsible for Ireland's innovative Origin Green program.[53] Brennan saw a sustainable supply chain as "something that was really growing in importance with a lot of the key global players."[54]

» *Combat error and fraud.* "Without digitalization, it is very difficult to get to autonomous workflow situations and it's very difficult to remove humans from our supply chains in terms of some of the more banal tasks and the data entry points— which is often where the points of error and fraud are in our supply chains," said Weston of AgriDigital.[55]

While these benefits of supply chain digitization are not directly attributable to blockchain, in practice blockchains solve key problems that help make digitalization feasible. Specifically, it offers the opportunity to engineer digital supply chains that more effectively conform to the trust and sharing requirements of participants.

Honey jars harvest bees frame by PollyDot, 2014, used under Pixabay license, accessed 3 June 2019.

Blockchain helps build supply chain systems that are easier for participants to trust.

The benefits of blockchain-enabled supply chains

"Blockchain solves business problems where trust is part of the solution—you can't do that with a database," said McDermott of IBM.[56] Blockchain helps build supply chain systems that are easier for participants to trust because of:

» *Explicit access, control, and ownership.* Participants must have flexible control over what's shared. Talbot of Agri-Traçabilité said, "Whatever the consortium will decide, we will be able to implement that in the blockchain."[57] Mark

Alexandre Allen-Lefebvre, director of information technology at Agri-Traçabilité, added, "Each participant of the blockchain can have access to the ledger on their own IT software. So this is where it is interesting because they will know at each moment who has access to what. That is important for the transparency of the operation and the confidence we have in that operation."[58]

» *Tamper-proof data.* Immutable data is a key blockchain feature. "Certain information is about trust. Trust of the information being never tampered with or being absconded or being hacked," said Robert Galarza, CEO and director of BLOCKstrain, and that's an area where centralized systems often fail.[59]

» *Provenance via digital identity.* The ability to correlate information related to an animal, plant or food product, to a unique identity on the blockchain makes reliable provenance possible. This can be done in a variety of ways from labels and Internet of Things (IoT) sensors to genetic fingerprints and other unique measurable product attributes.

» *Dynamic contracting.* Smart contracts make it easy to tailor automated supply chain processes to individual needs as items move through the supply chain. "We really like the interoperability of dynamic smart contracting solutions for moving product. … We can create trigger points within the agreements that are dynamic," said Galarza.[60]

» *Single version of the truth.* Conventional interconnected systems (each with varying speed of synchronization), often have ambiguous states, making the current status of a system unknowable. Blockchain contracts are Turing-complete—meaning that they can interact with any other software that is Turing complete—with definitive states for each block of records, making them excellent candidates to communicate a single version of the truth.[61]

Walmart has used blockchain to help solve traceability issues that have stymied it in the past. In the wake of pork and mango food scares, the company implemented a blockchain traceability pilot with remarkable results: in the past it took up to seven days to track the source of contaminated mangos, now it takes 2.2 seconds.[62] Yet these promising results raise larger questions about the role of public regulators. Can private companies use blockchain to achieve tasks and functions that were formerly under the banner of government and public institutions?

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The potential for a global computer that automates business

As useful as the Web has been, it lacks many features: there is no universal authentication scheme; there is no native payment mechanism; files have no unique identifiers or version control; and data, services, and applications are transient, dependent on their

Blueberries berries fruit healthy by Ilona (Couleur), 2018, used under Pixabay license, accessed 3 June 2019.

providers.[63] Software companies can take down or discontinue servicing the tools that users have come to rely on. Juan Benet, creator of InterPlanetary File System, said,

> *That's just not how humans tend to intuitively interact with our tools. We need to move to a world where software tools themselves behave more like physical tools: where once [we] give someone this power—this amazing superpower based on software—they can keep it as long as they want, and they can continue using it as long as they want.[64]*

Blockchain technologies are important in the evolution of the Internet: in offering nearly every key feature the Web does not, they lay the groundwork for a global computer able to automate all commerce and transactions.

Technologies like the InterPlanetary File System offer a content-addressable platform that works without central servers, and Ethereum's Swarm likewise offers a distributed file mechanism designed to support the storage needs of Ethereum's "global computer."[65] These shared resources turn applications into digital tools that behave more like physical tools than as a service that disappears with the service provider.

Technology that affords the creation of object-like software and services that we can own and control, also makes it easier to compose digital systems with behaviors much closer to that of their real-world counterparts. These technologies bridge many of the data, digital asset, and computing silos that the Web hasn't, blurring distinctions between the physical and the digital. In the not-to-distant future, physical and digital worlds may grow to be perfect mirrors of one another.[66]

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The digital representation (or tokenization) of physical assets

Physical and digital systems that mirror one another have surprising consequences. In a centralized Internet-based system, digital entries are "representations" or facsimiles of their physical counterparts, producing what we might call a *simulation*. A farmer's database may hold an official livestock inspection certificate or a bill of sale for one of the farmer's cows, and the farmer can e-mail the cow's documentation to everybody and still retain ownership and custody of the cow. With blockchains, the transfer of such a representation becomes a transfer of ownership of the actual cow.

Consider money as a trusted unit of value. Fiat currency represented bullion—a pound sterling referred to a pound of sterling silver. As trust grew in the banknotes themselves as a medium of value, the distinction between money as a precious metal and its paper representation diminished.[67] Money is equally *real* as bullion or its representation in the medium of paper.[68]

Blockchain ensures digital scarcity: there is one digital registration per cow; not even the cow's owner can make a copy of its registration.

The same is true of any valued physical object and its representation in a digital medium. Establishing a trusted network of the intermediaries needed to move digital money around the world took centuries because financiers needed to solve the *double spend problem*, where a party could spend the same digital dollars in two places at once and enjoy the benefits of doing so before one of the other two parties discovered the deception. Blockchain ensures digital scarcity: there is one digital registration per cow; not even the cow's owner can make a copy of its registration.

Thus, blockchain allows farmers to turn the registration of a cow into a true digital asset.[69] *They can electronically transfer the registration of that cow from one person to another,* as easily as they can send an e-mail. With a smart contract, they can specify exactly which aspects of the cow gets transferred—for example, they can retain ownership but license milking or breeding rights. We could create agency for all living creatures and natural objects, enshrining their rights in smart contracts that exercise influence or authority within a system on their behalves.

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These scarce digital assets create a new digital version of physical supply chains through which real-world transactions flow. Weston of AgriDigital said,

> The most fascinating thing is going to be the emergence of digital assets and how we use those in trade and through our supply chain. That's probably where blockchain comes in … how you create digital assets, a faithful representation of a physical load of grain for example in digital form, but with a whole lot of data richness to that digital asset that we can't have with that physical asset.[70]

The richness of those digital assets, low transaction costs, and the granularity with which they can be controlled and managed, will cement this resulting "global computer" as an essential part of our economy. It's part of a larger shift that is decoupling the flow of bits from the movement of atoms: whether it's storing grain at a farmer's site after it has been sold, purchasing a truckload's worth of barley while it's still growing in the field, or selling a lifetime's worth of milk production from a dairy cow.

Piglet sleep pig sow farm relaxed by Roy Buri (RoyBuri), 2018, used under Pixabay license, accessed 3 June 2019.

Like many other technologies, blockchain is not a panacea.

Challenges to implementing blockchain solutions

Like many other technologies, blockchain is not a panacea. "I don't want to give the impression that blockchain is a silver bullet because it's not," Weston told Farm and Rural Ag Network. "It's a very good tool in our toolkit."[71] Realizing its transformative possibilities is far from automatic and depends on other factors.

Real-world complexity demands thoughtful approaches

Scalable real-world implementations in complex distributed global supply chains are not a simple task. Success is less about the technologies themselves, than an ability to manage transformation and even cultural change. "It is not the tools," said Preece, "I'm quite sure someone can design it. But there's all this other stuff that goes with it … the big piece at the moment is the lack of trust."[72]

Real-world implementations demand a thoughtful approach that navigates both the opportunities and challenges associated with greater transparency.

Digitization initiatives often overlook the softer elements that transformation involves: things like the desire for greater supply chain awareness/visibility, a willingness to embrace the view of the customer, practical/fair approaches to change, and an eagerness to learn and innovate.[73] Real-world implementations demand a thoughtful approach that improves ease of use, lowers transition barriers, communicates business benefits, and navigates both the opportunities and challenges associated with greater transparency. These cultural aspects are as important as the technology itself to a successful digital transformation.

Difficulty in making the business case for adoption

Successful farm-to-fork transparency initiatives often focus on business benefits. Yet many of them didn't start out that way. Many traceability initiatives emerged from food-related incidents—with a priority to minimize risk and improve public safety. Japan has achieved farm-to-fork traceability of the beef supply chain, and similar initiatives in the European Union offer full traceability, from an animal's birth to final sale to the consumer.[74] Once a traceability system is put in place, users can build upon it.

For example, in Ireland, over the last five to ten years, corporations have shown interest in sustainable food supply chains.[75] Brennan of Bord Bia said, "We were fortunate in that there was already a really robust traceability system in place."[76] Bord Bia used that traceability system as a starting point: it was already present on farms and in food manufacturing business. Why not apply its quality assurance capabilities to sustainability?

"If customers are asking us those sorts of questions, why don't we try to utilize the quality assurance infrastructure that we have, and broaden and deepen the scope of what it does," said Brennan.[77] In response, Bord Bia launched a sustainability program, Origin Green, focused on improving (and marketing) Irish food and agricultural products in 2012.

Origin Green worked with the most influential business-to-business buyers to raise awareness throughout the supply chain. Its voluntary program has attracted 50,000 beef farmers and 16,000 dairy farms, representing 90 percent of Ireland's production capacity.[78] That's success! The industry's reliance on exports and its strong ambitions for growth were catalysts. Participants recognized the business benefits that supply chain transparency and greater sustainability could bring; their costs and benefits were aligned.

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Marton Ven, chief marketing officer of the food traceability company TEFOOD, explained why many traceability projects fail:

> *Most of the traceability costs are paid by participants who are in the beginning of the supply chain (typically the farms), while the companies at the end of the chain (retailers) benefit the most from transparent traceability data. To gain the support of companies [that] will provide the most traceability*

information to the system, [we] have to find a way they can benefit from using it.[79]

Similarly, Canada's BIXSco (in collaboration with Cargill) worked with buyers such as Walmart, Loblaw's Cara Foods, and Cactus Club to offer producers upwards of $10 more per head of cattle to join the pilot.[80] They needed to provide supply chain visibility of quality improvements by producers to the customers who desired them.

The easier it is to adapt to a new system or process, the greater the likelihood of success.

The goal of "food quality" itself is an important lens for viewing sustainable practices and traceability. Quality doesn't cost, it pays.[81] That's a message that Irish farm organizations worked hard to communicate. "It wasn't red tape for the sake of red tape, or inspection for the sake of inspection. It was actually wanted from the marketplace point of view—an opportunity for farmers to identify room for improvement for themselves as well," said Brennan. "The more sustainable your farm is, the more efficient it actually is."[82] Measures that reduce greenhouse gas emissions will also tend to make a farm more financially efficient. "Quality is free, but no one is ever going to know it if there isn't some sort of agreed-on system of measurement," wrote Philip Crosby in his book, *Quality Is Free*.[83]

Making implementation easy is also important to realizing benefits. The easier it is to adapt to a new system or process, the greater the likelihood of success. According to Ven,

> *It's idealistic to believe that good technology or blockchain itself will convince supply chain companies to adopt traceability. Due to the low margins in food supply chains, farms, slaughterhouses, food producers, wholesalers are working with extremely optimized manual processes. Convincing them to embed new activities takes a lot of time, determination, and training. Although most of them support information transparency and credibility in general, when they have to use it you need a ready and efficient implementation methodology to show them how to do it efficiently.*[84]

Access to relevant data is critical for traceability systems. Each year, ATQ handles four million events. The organization has made it as easy as possible for producers and stakeholders to send those data, including manual methods. "Fifteen percent is through a human action through customer service," said Talbot in a 2017 presentation.[85]

Access to relevant data is critical for traceability systems.

To minimize manual entry and avoid duplication of records, Agri-Traçabilité has integrated with producers' preferred software systems and exchanged data with insurance organizations that maintain animal data. Said Talbot, "A producer works with herd management software … adapted to take the data we need. For the producer, it makes it easier to collect the data and to send it to us."[86] If Agri-Traçabilité did not use these methods, its manual entry could be as high as 40 percent.[87] Designing user experiences from the participant's point of view is key.

Today there's a push for transparency, but it's mainly coming from those at the far ends of the supply chain: farmers and consumers.

Cereal countryside crop cropland by Pexels, 2016, used under Pexels license, accessed 3 June 2019.

Resistance to transparency

Historically, many supply chain participants have benefited from a *lack* of transparency—maintaining distance between upstream and downstream supply chain participants reinforced the roles of intermediaries. Today there's a push for transparency, but it's mainly coming from those at the far ends of the supply chain: farmers and consumers.[88] That creates important new opportunities. Said Weston of AgriDigital, "There is a wave of inevitability, and for those participants who are ready to embrace levels of transparency, that will be very advantageous for them."[89]

Supply chain intermediaries must rethink their roles. New entrants like Amazon with its $13.7 billion purchase of Whole Foods are disrupting the status quo.[90] Farmigo CEO Benzi Ronen told *Fortune,* "I would be terrified if I were a consumer packaged-goods company right now."[91] *Forbes* contributor John Wasik said, "It's about busting the supply chain in an ancient business."[92]

The result is better food integrity for customers.

The result is better food integrity for customers. Amazon's Bezos stated, "We'll use experts to manufacture those products, but we'll inspect and audit how it's done, and where the raw ingredients are sourced from."[93] Intermediaries need to consider the value they add. Weston said, "If you are an intermediary who adds no other value to the transaction in the supply chain, I think blockchain could be quite threatening to those occupying those roles."[94]

An even greater challenge for any transparency initiative is resistance from those who actively benefit from hiding their activities. Said Ven,

> *The reality is that counterfeiting, dilution, and contamination are food frauds that provide a huge income for those who*

commit them. In many cases, these people are participants of the supply chain, or even representatives of an authority. They will fight traceability implementation as hard as they can. … You have to be aware and fight your way to a fraudless industry.[95]

Implementation difficulties can be a symptom of intentional supply chain gaps. Martin Mayorga, founder and president of coffee company Mayorga Organics, told *The Source*, "What happens in the industry is that segmentation is a great place for reality to hide. … The broker doesn't know what the roaster doesn't know. … It's a mess and it's purposeful."[96]

Another challenge is that some of these participants want to enjoy the benefits of transparency without any of the drawbacks. According to Weston of AgriDigital:

You can't really have partial transparency. … It's not feasible to be transparent only when it suits you. … There is a movement toward a more transparent market overall, and that is going to be a shift for some of the participants. … If you're basically involved in hiding certain aspects of your business from government, then I can see why you would want to continue doing that if that's a benefit to you. But I think, by and large, the taxation and other systems are evolving to … be more comprehensive.[97]

Any transparency process must focus on process improvement rather than punishment and limit the scope of data sharing to intended purposes only.

In areas like agriculture and food, records of activity may affect employment insurance eligibility or taxation.[98] Ratcheting up transparency inevitably brings improper practices to light. Without a safe harbor or some assurances against retribution, actors simply drive bad behaviors deeper underground, and a distorted version of reality is recorded in the system.[99] Any transparency process must focus on process improvement rather than punishment and limit the scope of data sharing to intended purposes only.[100]

» Transparency is a delicate balancing act. While we are moving to greater transparency overall, full transparency is neither necessary nor desirable. Said Weston, "There are certain parts to transparency that perhaps are not needed, for example, complete pricing transparency across the market."[101]

» Supply chain participants need assurance that others will respect their business needs and neither abuse nor misuse their information—especially trade secrets. Recipes, growing conditions, and processing techniques can bestow important competitive advantages. If members of a blockchain agree that such information is mission critical, then participants can store such secrets off-chain in a uniform format and perform functions on them without discovering any detail.[102] Supply chain participants need "really strong assurances that that information stays and is used for what it is intended to be used and nothing else," said Nicole Bouchard-Steeves, associate vice-president of operations at the CFIA.[103]

» That's where blockchain comes in: participants can engineer digital supply chains to achieve the degree of trust and information that they need of each other. Said Weston, "We don't think that a prefect market is necessarily a perfectly transparent market, but it's a market where I can be certain that—the people that I'm dealing with—I can trust within the context of the network that I'm operating in."[104]

Technical risks

Blockchain itself is not without its challenges. For all its growth and safe handling of billions of dollars' worth of value, it is still a bleeding edge technology with a short track record.

Blockchain itself is not without its challenges. For all its growth and safe handling of billions of dollars' worth of value, it is still a bleeding edge technology with a short track record. Public blockchain developers are working hard to improve scalability and interoperability.[105] Despite its immaturity, few still question whether it works; most are looking for suitable areas of application.

Weston said, "We take a pretty similar view to what the banks in Australia are taking now—which is that none of them are looking at blockchain from the perspective of 'we need to experiment to see if this technology works.' Everybody has moved past proof of technology and everybody knows that the technology works."[106]

That's not to understate some of the technology's key challenges nor to minimize the chicken-and-egg challenge to adoption, but to highlight the greatest areas of opportunity. It's a natural fit with supply chains. Weston of AgriDigital said, "That's what a supply chain is, a distributed network. You start to see how a distributed technical protocol could underlie and provide value to so much of what we do commercially within the supply chain."[107]

We are at the earliest stages of commercial application, and so there is a lot to learn. Every technology has unanticipated consequences, the "unknown unknowns," and blockchain's autonomy and irreversibility warrant caution because mistakes are harder to stop or to fix.[108]

Consistency in quality of data

A blockchain is only as good as the data within it— garbage in, garbage out.

A blockchain is only as good as the data within it—garbage in, garbage out. The immutability of the blockchain does little good in complex supply chains (including those with incentives for fraud) unless users can trust the data. Deputy Chief Food Safety Officer for Canada and CFIA Executive Director Aline Dimitri said, "How do we get assurances of the quality of the data that is going in?"[109] We might be able to see that information hasn't been edited or changed, but how do we know whether to trust it in the first place?

Standards, veracity, verification, data collection, and sharing processes are all important. As modern food supply chains grow in complexity and generate more data, achieving data quality becomes increasingly difficult. CFIA already plays a key role in food labeling and certification. If we are to publish data about plants, animals, and food on a blockchain, then we must ensure its reliability and accuracy.

Radish vegetables for sale lettuce by Paul Brennan (paulbr75), 2016, used under Pixabay license, accessed 3 June 2019.

There is a gap between perceptions of Canadian food quality and the traceability available to ensure it; Canada's traceability is "average," below that of many EU countries.

Conclusions and recommendations

There is a gap between perceptions of Canadian food quality and the traceability available to ensure it; Canada's traceability is "average," below that of many EU countries.[110] Its approach is adequate for international trade but not for global leadership. Traceability systems (a few of them blockchain-enabled) may increase or decrease opacity depending on how they are implemented.

Understand the trade-offs

Although most blockchains are decentralized, the design of the systems built on top of them could be distributed and open or highly centralized and tightly controlled.[111] In the quest for greater transparency, regulators must not paint themselves into a corner. "We have to also acknowledge the risk that rather than leveling the playing field … it could build bigger moats," said Jackson of the Institute on Governance.[112]

While not a panacea, blockchain technologies raise important issues and offer new problem-solving tools. Governments must engage with the communities that are digitizing their supply chains. The features that help forge trusted supply chains with immutable data, guaranteed transactions, and automated processes may also be extremely difficult to un-forge as well. Self-enforcing smart contracts "subsist independently of any moral or legal entity," said Primavera De Filippi, a researcher at the National Center for Scientific Research in Paris. "Once they have been created and deployed onto the blockchain, they no longer need (nor heed) their creators."[113]

These technologies create both opportunities and change-management challenges. Supply chains must evolve their capabilities beyond legacy practices and acquire skills that allow them to embrace the potential of modern tools. Agencies need people who know how to use and think critically about diverse data. Said Dimitri of the CFIA,

> We have to remember that, for the longest time, we've had people who are hands on. They are inspectors: they see with their eyes, they touch with their hands. Now we're saying, "No, this information is a proxy," because now this data has become so complex that what we see with our eyes is insufficient. It is only one factor in the decision-making process.[114]

Extend holistic approaches

In response to a changing global environment, CFIA has embarked on a multi-faceted transformation strategy that embraces holistic approaches. CFIA has outlined several priorities to position Canada as a global leader:[115]

» *Adopt outcomes-based regulations that are less prescriptive.* Although regulation allows for mandatory access to information in the name of compliance, a 'regulatory watchdog' approach is not conducive to collaboration and can lead to adversarial relationships where only the minimum gets shared. A joint focus on food quality would take this a step further, creating incentives with clear benefits for voluntary sharing that enhances food value, marketability, and safety.

» *Embrace holistic risk management to focus resources where they're needed most.* "The risk landscape is extremely dynamic for us right now. Globalization, climate change, movement of people—all of these kinds of things have really played into a risk landscape that is changing very rapidly," said Daku of the CFIA.[116] Collaborative approaches allow the CFIA to get a bird's eye view of where and how to manage risks via a comparative risk model that quantitatively assesses the effectiveness of different control measures, allowing CFIA to "be more intentional in how we're allocating those resources."[117]

A joint focus on food quality would enhance food value, marketability, and safety.

» *Maintain consistent approaches to service delivery and inspections.* "The Agency's mandate is broader than many of its international counterparts in which the food safety, animal health, and plant protection mandates are managed in distinct organizations," said Daku.[118] The development and export of training programs for those who deliver services and conduct inspections may help the CFIA to scale the quality and consistency of its operations beyond Canada's borders.

» *Center digital delivery on the client experience.* The more data consumers get, the more they'll want, according to Amazon CEO Jeff Bezos. "One thing I love about customers is that

they are *divinely discontent*. Their expectations are never static—they go up. It's human nature," he wrote. "People have a voracious appetite for a better way, and yesterday's 'wow' quickly becomes today's 'ordinary.'"[119] For example, not every consumer understands GMOs. "You ask them what it stands for and they can't tell you," said McArthur of Nourish Marketing. They still want the information: "A lot of people are saying 'GMOs are fine, but at least tell me.'"[120]

» *View national activities in an international context.* Canada plays an active role in international standards and trade, recognizing that our degree of international alignment has a direct bearing on the competitiveness of our exports.[121] "There is a lot of work goes on in the international sphere to ensure that we are establishing sound and science based international standards," said Barbara Jordan, vice president of the policy and programs branch of the CFIA.[122]

◇ Foster a free flow of information

Transparency is a shared responsibility.

Transparency is a shared responsibility. "Canadians believe it is the responsibility of food manufacturers (75%) and farmers (67%) to share information about how their food is grown/produced," according to the Canadian Centre for Food Integrity.[123] "It gives a much more positive role for governments and the regulators as conveners of the ecosystem rather than watchdogs," said Weston.[124]

» Engage and leverage consumer and producer interest in improving food safety, quality, and the flow of information. Foster an ecosystem that encourages participation and openness of data.

» Start outside with shared immutable records that integrate with other systems, processes, and applications as needed rather than connect internal silos of systems and records. The distributed structure of blockchain technologies is well suited to bridging information silos to foster multistakeholder interactions.

» Balance public-private sector participation, management of supply chain risks and benefits, and ease of integration into existing systems and processes.

Engage and leverage consumer and producer interest in improving food safety, quality, and the flow of information.

» Translate conventional identification tactics and technologies (e.g., CFIA vouching for data or applying certifications) into blockchain equivalents (e.g., via a data-reporting role called an "oracle").[125]

» Use novel technologies or automation to collect accurate data, from sensing data using IoT technologies to novel methods of digital fingerprinting that can uniquely identify and track objects as they flow through a supply chain.

Prioritize initiatives

Transformation often starts with a change catalyst. Unfortunately, in many countries this has taken the form of a major food-related incident. Potential food, plant, and animal risks continue to emerge, and Canada cannot afford a BSE incident, horsemeat scandal, or an unknown risk such as an antibiotic-resistant superbug triggered by livestock feed. As Ireland demonstrated, a government can stimulate voluntary change without a crisis.

While the situation in Ireland differs from that of Canada, it offers a formula for effecting change:

» Strong ministerial endorsement and a public/private strategy process for the sector

» An industry with strong ambitions for export growth

» Recognition of future industry requirements such as sustainability

» Key business-to-business buyers to motivate other supply chain participants

» Multistakeholder rollout and implementation (nearly 20 organizations)

» A strong traceability program in place

» A quasi-state body (Bord Bia) offering greater "elbow room" for innovation[126]

Start small, share lessons learned

Like any transformation initiative, especially one that cuts across multiple organizations, leaders should start small and foster initiatives that build momentum and expand collaborative capabilities. Agency-industry collaboration and service delivery transformation initiatives are natural fits. "The best thing the government can do is to identify places where they can start to pilot projects and build these proofs of concepts," said Jackson. "Go out and do it."[127]

More comprehensive initiatives would handle privacy and competitive concerns and steer blockchain implementations toward interoperable ecosystems of data and services.

Even informal efforts like shadow ledgers are useful to unearth new possibilities. More comprehensive initiatives would handle privacy and competitive concerns and steer blockchain implementations toward interoperable ecosystems of data and services. Participants can lead the pieces most relevant to them:

» *Start with a critical mass of buying power.* Make recruiting, motivating, and engaging other supply chain participants easier.

» *Engage consensus builders.* One of the most difficult implementation challenges is overcoming collective action problems.[128] Engaging organizations with a strategic view of the industry that can aid consensus is key—whether it's an

Leveraging the immutability, transparency, and distributed sharing features of blockchain technologies is the first step in enabling global interoperability and improved competitiveness.

industry round table, a not-for-profit industry association, or a collective marketing organization.

» *Pilot farm-to-fork traceability.* Reinforce the viability and benefits of farm-to-fork traceability in Canada, even if it's in a narrow domain. This can either be implemented in a domain where full traceability doesn't currently exist or by building upon existing programs or certifications (e.g., halal, humane, non-GMO project verified).

» *Put blockchain's potential to the test.* Choose a challenging domain, such as a complement to Canadian beef traceability pilots.[129] Canada requires not only a continuous approach to quality improvement focused on production, manufacturing, and handling practices but also innovation in information handling and collaboration.

» *Align with international standards to promote global interoperability.* Collaborate effectively with relevant stakeholders and foster continuous process improvement in education, surveillance, traceability, certification, risk management, and response.

Leveraging the immutability, transparency, and distributed sharing features of blockchain technologies is the first step in enabling global interoperability and improved competitiveness. National governments are uniquely positioned to foster true digital supply chains that respond to today's demanding food supply requirements via information transparency, streamlined regulations, comprehensive surveillance, trustworthy certification practices, and increased responsiveness.

Apricots apricot fruit fruits by Rita (RitaE), 2016, used under Pixabay license, accessed 3 June 2019.

About the author

Alan Majer is the founder of Good Robot. For the first half of his career, Alan worked as a technology researcher and writer, helping to identify cutting-edge technology and business innovations. Today, Alan also works with technology hands on, exploring the potential of connected sensors and the Internet of Things, new display technologies, machine intelligence, robotics, and interactive interfaces. The result is exciting new opportunities to innovate and transform client experiences, and the ability to combine strategy and research activities with a real-world approach to their implementation. Alan is an active member of the local "maker" scene, frequenting spaces like HackLab.TO and InterAccess. He holds an MBA from McGill University.

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The author has no professional or personal affiliation with or ownership stake in any company or agency discussed in this paper

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.

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56. Reshma Kamath, "Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM," Blockchain Research Institute, Sept. 2017. Brigid McDermott, interviewed by Kamath, 23 June 2017.

57. Marie-Christine Talbot, Mark Alexandre Allen-Lefebvre, and Brian Kowaluk, interviewed via telephone by Alan Majer, 3 May 2018.

58. Marie-Christine Talbot, Mark Alexandre Allen-Lefebvre, and Brian Kowaluk, interviewed via telephone by Alan Majer, 3 May 2018.

59. Robert Galarza, Brice Bielaski, and Rob Klein, interviewed via telephone by Alan Majer, 22 March 2018.

60. Robert Galarza, Brice Bielaski, and Rob Klein, interviewed via telephone by Alan Majer, 22 March 2018.

61. At the risk of simplification, "Turing complete" means these contracts can perform standard computational tasks.

62. Reshma Kamath, "Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM."

63. Hosting and serving duplicate versions of files creates inefficiencies.

64. Juan Benet, "Filecoin: A robust foundation for human knowledge," video at 00:11:43, 00:19:00, Blockstack Berlin 2018, 1-2 March 2018. www.youtube.com/watch?v=6h2WNxEV8q4&feature=youtu.be, accessed 25 June 2018. See also Juan Benet, "Future Proofing IPFS, Blockchains, and other Systems," Stanford University, 27 Jan. 2017. cyber.stanford.edu/sites/default/files/juanbenet.pdf, accessed 14 July 2018.

65. Blockchain-based Filecoin may complement the Ethereum virtual machine.

66. Some refer to this as a "digital twin." See Bernard Marr, "What is Digital Twin Technology—and Why is it so Important?" *Forbes*, Forbes Media, 6 March 2017. www.forbes.com/sites/bernardmarr/2017/03/06/what-is-digital-twin-technology-and-why-is-it-so-important, accessed 25 June 2018.

67. Fiat currency (e.g., paper currency) is a currency declared to be legal tender, but is not backed by any asset or commodity. See Investopedia, "Fiat Money," Investopedia LLC, n.d. www.investopedia.com/terms/f/fiatmoney.asp, accessed 25 June 2018.

68. Of course, even physical paper currency and coins are already an abstract form of value that hinges upon collective beliefs.

69. Like Ethereum's ERC-721 non-fungible token standard.

70. Emma Weston, interviewed via telephone by Alan Majer, 19 April 2018.

71. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications," podcast, *Farm and Rural Ag Network*, 14 Feb. 2018. www.farmruralag.com/future-of-agriculture-farmgate-blockchain-applications-with-emma-weston-of-agridigital, accessed 25 June 2018.

72. Amanda Jane Preece, interviewed via telephone by Alan Majer, 18 May 2018.

73. Charles Galunic, "Sustaining Digitization Hinges on Culture," INSEAD, INSEAD Knowledge, 11 April 2018. knowledge.insead.edu/leadership-organisations/sustaining-digitisation-hinges-on-culture-8851, accessed 25 June 2018.

74. Jim Bracken and Gary Mathews, "Beef Traceability Case Study," GS1 Ireland, Feb 2005. www.gs1si.org/Portals/0/GS1_Dokumentacija/GS1_Resitve/Sledljivost/BeefTraceabilityCaseStudy_Ireland.pdf, accessed 25 June 2018.

75. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

76. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

77. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

78. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

79. Marton Ven interviewed by Steven Male, "Complete transparency in food information through blockchain and TE-FOOD," *StevenMale.com*, 26 Jan. 2018. www.stevenmale.com/blog/te-food-interview, accessed 25 June 2018.

80. Deborah Wilson, Sr. VP, BIXSco, interviewed by Alan Majer, 18 April 2018. For more information on the Canadian Beef Sustainability Acceleration Pilot, see cbsapilot.ca.

81. A concept popularized by Philip B. Crosby, *Quality is Free: The Art of Making Quality Certain* (New York: McGraw-Hill, 1977).

82. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

83. Philip B. Crosby, *Quality Is Free*.

84. Marton Ven interviewed by Steven Male, "Complete transparency in food information through blockchain and TE-FOOD."

85. Marie-Christine Talbot, "Traceability and Trade: Implications/Opportunities," 00:06:15.

86. Marie-Christine Talbot, "Traceability and Trade: Implications/Opportunities," 00:07:00.

87. Marie-Christine Talbot, "Traceability and Trade: Implications/Opportunities," 00:07:30.

88. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

89. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

90. Natalie Gagliordi, "How Amazon's Whole Foods purchase could solve its grocery supply chain puzzle," *ZDNet*, CBS Interactive, 17 June 2017. www.zdnet.com/article/how-amazons-whole-foods-purchase-could-solve-its-grocery-supply-chain-puzzle, accessed 25 June 2018.

91. Beth Kowitt, "Why Amazon's Whole Foods Deal is Terrifying Food Makers," *Fortune*, Meredith Corporation, 22 June 2017. fortune.com/2017/06/22/amazon-buying-whole-foods-disruption, accessed 25 June 2018.

92. Jason Bloomberg, "Amazon's Whole Foods Strategy: It's Not What You Think," *Forbes*, Forbes Media, 23 June 2017. www.forbes.com/sites/jasonbloomberg/2017/06/23/amazons-whole-foods-strategy-its-not-what-you-think, accessed 22 June 2018.

93. Noah Robischon, "Amazon's Grocery Ambitions Are Far Bigger Than Whole Foods," *Fast Company*, Mansueto Ventures, 16 June 2017. www.fastcompany.com/40432297/amazons-grocery-ambitions-are-far-bigger-than-whole-foods, accessed 25 June 2018.

94. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

95. Marton Ven interviewed by Steven Male, "Complete transparency in food information through blockchain and TE-FOOD."

96. Marcus Stern, "Latte Illusion,"*The Source: The human cost hidden in a cup of coffee*, The Weather Channel and Telemundo, The Weather Company LLC, 19 Jan. 2017. features.weather.com/thesource, accessed 14 July 2018.

97. Emma Weston, interviewed via telephone by Alan Majer, 19 April 2018.

98. Nicole Bouchard-Steeves, interviewed via telephone by Alan Majer, 11 May 2018.

99. Nicole Bouchard-Steeves, interviewed via telephone by Alan Majer, 11 May 2018.

100. While enforcement is still key to serving the public interest, it's important to reserve enforcement for those who have no interest in improving and choose to undermine the process instead.

101. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

102. Such techniques as *homomorphic encryption* allow computations on encrypted data, where the data remain secret and secure. See, for example, the Enigma Project originating at MIT: Guy Zyskind, Oz Nathan, and Alex "Sandy" Pentland, "Enigma: Decentralized Computation Platform with Guaranteed Privacy," white paper, 7 June 2015. s3.amazonaws.com/enigmaco-website/uploads/pdf/enigma_full.pdf, accessed 14 July 2018.

103. Nicole Bouchard-Steeves, interviewed via telephone by Alan Majer, 11 May 2018.

104. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

105. Mix, "Ethereum will soon test sharding tech to fix scaling issues, Vitalik Buterin hints," *The Next Web*, The Next Web B.V., 23 Feb. 2018. thenextweb.com/hardfork/2018/02/23/ethereum-vitalik-buterin-sharding, accessed 14 July 2018.

106. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

107. Emma Weston, "Future of Agriculture: Farmgate Blockchain Applications."

108. One example is the DAO, a distributed autonomous organization created on the blockchain. The rules that gave the DAO its autonomy also gave a hacker time to exploit an error in the DAO's code and drain funds from the DAO. These rules also hindered the community's actions to stop the draining and return the drained funds. For more information, see the Blockchain Research Institute's Slock.it case study.

109. Aline Dimitri, interviewed via telephone by Alan Majer, 3 May 2018.

110. Sylvain Charlebois et al., "Comparison of Global Food Traceability Regulations and Requirements," *Comprehensive Reviews in Food Science and Food Safety*, Vol. 23, 29 May 2014. onlinelibrary.wiley.com/doi/10.1111/1541-4337.12101/epdf, accessed 25 June 2018.

111. Some cryptocurrency exchanges are highly centralized (Poloniex), while others offer various levels of openness and decentralization (EtherDelta, 0x, and Kyber).

112. Matt Jackson, interviewed via telephone by Alan Majer, 24 May 2018.

113. Primavera De Filippi, "Ethereum: Freenet or Skynet?" videocast, Berkman Klein Center for Internet and Society, Harvard University, 15 April 2014, updated 21 June 2018. cyber. harvard.edu/events/luncheon/2014/04/difilippi, accessed 14 July 2018.

114. Aline Dimitri, interviewed via telephone by Alan Majer, 3 May 2018.

115. Paraphrased from "My CFIA, Ask CFIA: Responding to Today, Building for the Future," presentation, Canadian Food Inspection Agency, Nov. 2017. fermenbfarm.ca/wp-content/ uploads/2017/12/3-My-Ask-CFIA-E.pdf, accessed 14 July 2018.

116. Alyssa Daku and Brian Kowaluk, interviewed via telephone by Alan Majer, 18 May 2018.

117. Alyssa Daku and Brian Kowaluk, interviewed via telephone by Alan Majer, 18 May 2018.

118. Alyssa Daku, "Integrated Risk Management: Harnessing Technology," Regulatory Speaker Series, Canada School Public Service, LaSalle Academy, Ottawa, Ontario, 1 March 2018. www.csps-efpc.gc.ca/events/rss/index-eng.aspx, accessed 17 July 2018.

119. Jean-Louis Gassée, "Bezos: A CEO Who Can Write," *Monday Note*, Medium, 29 April 2018. mondaynote.com/bezos-a-ceo-who-can-write-2f368ee36599, accessed 25 June 2018.

120. Jo-Ann McArthur, interviewed via telephone by Alan Majer, 18 April 2018.

121. Barbara Jordan, interviewed via telephone by Alan Majer, 3 May 2018.

122. Barbara Jordan, interviewed via telephone by Alan Majer, 3 May 2018.

123. "How the Canadian Beef Sustainability Acceleration Pilot Works," video, Canadian Beef Sustainability Acceleration (Canadian Roundtable for Sustainable Beef, Cargill, Verified Beef Production Plus, Beef Infoxchange System, and Where Food Comes From), n.d. cbsapilot.ca/wp-content/uploads/2017/12/45485_CBSA_Cattle_Qualification_Animation_ V3.mp4, accessed 25 June 2018. See 00:02:15.

124. Emma Weston, interviewed via telephone by Alan Majer, 19 April 2018.

125. Blockchains are deterministic computing systems, unable to access real-world data directly. Instead, a party called an "oracle" must provide real-world data to a smart contract—for example, the latest score in a football game, the outcome of a vote, or the location and status of an object in a supply chain.

126. Padraig Brennan, interviewed via telephone by Alan Majer, 20 April 2018.

127. Matt Jackson, interviewed via telephone by Alan Majer, 24 May 2018.

128. Keith Dowding, "Collective Action Problem," *Encyclopædia Britannica*, Encyclopædia Britannica Inc., 7 March 2013. www.britannica.com/topic/collective-action- problem-1917157, accessed 14 July 2018.

129. This document discusses relevant issues for each type of supply chain participant: Antoine de Riedmatten, Peter Barr, Jack Ringquist, and Vicky Eng, "The food value chain: A challenge for the next century," Deloitte, Deloitte Touche Tohmatsu Ltd., 2013. www2. deloitte.com/content/dam/Deloitte/ie/Documents/ConsumerBusiness/2015-Deloitte- Ireland-Food_Value_Chain.pdf, accessed 14 July 2018.