Blockchainizing Food Law: Promises and Perils of Incorporating Distributed Ledger Technologies to Food Safety, Traceability, and Sustainability Governance

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ABSTRACT

Blockchain refers to distributed ledger technologies that can store, maintain, and update data collaboratively along a network of computing nodes. With the help of cryptography, peer-to-peer networks, and consensus mechanisms, data input to the blockchain is simultaneously and permanently recorded and updated in all the nodes of the network, ensuring a high level of consistency and authenticity of such data. Given such technological advantages, blockchain's potential to revolutionize the global food supply chain seems salient: transforming paper-based documents into a blockchain-enabled identity to generate a high level of transparency and data integrity, enabling smaller farmers to bypass middlemen in crops trading and cash transfers and providing an efficient and cost-effective way to manage the production system. In 2017, IBM announced a collaboration with a few major food producers and retailers, including, *inter alia*, Dole, Nestlé, Tyson Foods, Kroger, Unilever, and Walmart, to leverage disruptive technologies such as blockchain to enhance quality control, food safety, management, and traceability. Similarly, the United Nations World Food Program launched the "Building Block" program in 2017, which uses iris-scanning technologies and blockchains to help Syrian refugees verify their identities and directly receive aid without intermediaries.

Despite such promising development, blockchain is not a silver bullet to solve all food governance issues. Rather, there may be some new challenges that need to be adequately addressed. As argued by this Article, "blockchainizing" governance of food safety, traceability, and sustainability may pose another layer of regulatory questions about technical capacity and infrastructure gap, scalability and implementation costs, global standardization politics, cybersecurity and data protection, and technologically inherent limits of blockchain. In addition, policy challenges to both developed and developing countries (albeit in different ways) in terms of operational expertise and technical infrastructure, scalability and implementation costs, and power asymmetry in international standard-setting cannot be ignored. More generally, this Article argues that such regulatory questions may call for a reconceptualization of the forms and substances of conventional food law and

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policy as well as data protection law, anti-trust law, and trade law. In this light, this Article calls for a more technologically informed policy-making process before rushing into the hype of blockchainizing food law.

I. INTRODUCTION

As the production, distribution, and consumption of food has become globalized against the backdrop of trade liberalization, market integration, and technological development in recent decades, the question of how to best ensure the safety and sustainability of agri-food products across state borders poses significant challenges to regulators worldwide.[1] While food governance calls for a global, holistic, system-based approach,[2] the agri-food industry is one of the largest and most fragmented sectors in the world.[3] As a result, while more and more newly adopted food laws incorporate a global supply chain approach,[4] exercising effective and efficient control of the entire supply chain remains a difficult and costly task.

Indeed, the emergence of multinational agri-food corporations, the advancement of food science and transportation technology, and the advent of the World Trade Organization (WTO) and its liberalization efforts have made possible the global sourcing of food ingredients.[5] As a result, the global food supply chain has grown extensive and fragmented, creating room for foodborne risks, economic adulteration, and management inefficiencies.[6] Along the complex global supply chain, a misstep or regulatory failure at one node can spill over to others, with serious public health and economic consequences. Therefore, ensuring reasonable levels of transparency (sharing of correct information), safety and quality control, traceability, and

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[1] *See generally* Ching-Fu Lin, *Global Food Safety: Exploring Key Elements for an International Regulatory Strategy*, 51 VA. J. INT'L L. 637 (2011).

[2] *See generally* Laurie J. Beyranevand & Emily M. Broad Leib, *Making the Case for a National Food Strategy in the United States*, 72 FOOD & DRUG L.J. 225 (2017); Stephanie Tai, *Food Systems Law from Farm to Fork and Beyond*, 45 SETON HALL L. REV. 109 (2015); Ching-Fu Lin, *SPS-Plus and Bilateral Treaty Network: A 'Global' Solution to the Global Food Safety Problem?* 29 WIS. INT'L L.J. 694 (2012).

[3] For example, the agri-food sector in Southeast Asia is significantly fragmented with the majority of the players as small and medium-sized corporations. *See, e.g.*, ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD), ECONOMIC OUTLOOK FOR SOUTHEAST ASIA, CHINA AND INDIA 2017: ADDRESSING ENERGY CHALLENGES 118–19 (2017); Ching-Fu Lin, *The Emergence of ASEAN Regional Food Safety Governance: Structure, Substance, and Context*, 74 FOOD & DRUG L.J. 80, 82 (2019).

[4] A supply chain approach, for instance, has been adopted by the United States' Food Safety Modernization Act, China's Food Safety Law, and the European Union's General Food Law. For more discussion, see Mengyi Wang & Ching-Fu Lin, *Towards a Bottom-up SPS Cooperation: An Analysis of Regulatory Convergence in Food Safety Regimes*, 8 TRADE L. & DEV. 117, 123–26 (2016).

[5] *See* Lin, *supra* note 1, at 661–63.

[6] *See, e.g.*, *Global Health Observatory Data Repository*, WORLD HEALTH ORG. http://apps.who.int/gho/data/node.home [https://perma.cc/AV88-NXVV]; WORLD HEALTH ORG., WHO ESTIMATES OF THE GLOBAL BURDEN OF FOODBORNE DISEASES: FOODBORNE DISEASE BURDEN EPIDEMIOLOGY REFERENCE GROUP 2007–2015 (2015) [hereinafter WHO ESTIMATES]; *FDA Strategy for the Safety of Imported Food*, U.S. FOOD & DRUG ADMIN. (Feb., 2019), https://www.fda.gov/food/importing-food-products-united-states/fda-strategy-safety-imported-food [https://perma.cc/EA86-Y9BP]; *see generally* SubbaRao M. Gavaravarapu et al., *A Case for Refining the WHO Global Strategy on Food Safety: Perspectives from India*, 1 THE LANCET: GLOBAL HEALTH 254 (2013); Mieke Uyttendaele et al., *Food Safety, A Global Challenge*, 13 INT'L. J. ENVTL. RES. PUB. HEALTH 67 (2016); Fred Fung et al., *Food Safety in the 21st Century*, 41 BIOMEDICAL J. 88 (2018).

sustainability is a crucial task for multiple stakeholders globally, which necessitates collective, well-informed governance actions and institutional designs.[7]

Myriad governance initiatives have been adopted by various public, private, and hybrid actors at the national, regional, and multilateral levels, incorporating command-and-control, as well as market-oriented approaches.[8] What has largely been absent in the regulatory landscape, however, is the active use of technology as a means to deliver good governance.[9] In the sphere of agri-food law and policy, distributed ledger technologies (DLTs, or colloquially known as "blockchain") seem to be one of the most promising solutions (or "technical fixes") in addressing imminent governance challenges along the global food supply chain.

As will be analyzed in-depth in Part III, blockchain refers to decentralized databases that can store, maintain, and update data collaboratively along a network of computing nodes.[10] With the help of cryptography, peer-to-peer networks, and consensus mechanisms, data input to the blockchain is simultaneously and permanently recorded and updated in all the nodes of the network, ensuring a high level of consistency and authenticity of such data.[11] For instance, IBM recently announced a collaboration with a few major food producers and retailers, such as Nestlé, Kroger, Unilever, and Walmart, to leverage blockchain technologies to enhance quality control, food safety, management, and traceability.[12] Walmart has further required its upstream suppliers of leafy greens to employ the cloud- and

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[7] The adoption of the Food Safety Modernization Act (FSMA) in the United States marked a move towards such a multi-stakeholder, global supply chain and public-private collaboration institutional designs. *See, e.g.,* Caroline Smith DeWaal, *The Legal Basis for Food Safety Regulation in the USA and EU*, *in* FOODBORNE INFECTIONS AND INTOXICATIONS 511, 521–22 (J. Glenn Morris, Jr. & Morris Potter eds., 2013); *see generally* Michaela Tarr Oldfield, *Enactment of the Food Safety Modernization Act: The US FDA Within the Context of Interacting Public-Private Governance Processes*, 6 EUR. J. RISK REG. 488 (2015).

[8] *See, e.g.*, Beyranevand & Leib, *supra* note 2, at 235–39; Sam Halabi & Ching-Fu Lin, *Assessing the Relative Influence and Efficacy of Public and Private Food Safety Regulation Regimes: Comparing Codex and Global GAP Standards*, 72 FOOD & DRUG L.J. 262, 266–70 (2017); Neal D. Fortin, *HACCP and Other Regulatory Approaches to Prevention of Foodborne Diseases*, *in* FOODBORNE INFECTIONS AND INTOXICATIONS 497 (J. Glenn Morris, Jr. & Morris Potter eds., 2013); Ching-Fu Lin, *Mega-Regional Transformation of Global Food Safety Governance: Normative Roots and Ramifications*, *in* GOVERNING SCIENCE AND TECHNOLOGY UNDER THE INTERNATIONAL ECONOMIC ORDER: REGULATORY DIVERGENCE AND CONVERGENCE IN THE AGE OF MEGAREGIONALS (Shin-yi Peng et al. eds., 2018); Ching-Fu Lin, *The Emergence of ASEAN Regional Food Safety Governance: Structure, Substance, and Context*, 74 FOOD & DRUG L.J. 80, 82–86 (2019); and Mengyi Wang & Ching-Fu Lin, *Ploughing Away Capacity Constraints in Global Agri-Food Trade*, *in* BUILDING LEGAL CAPACITY FOR A MORE INCLUSIVE GLOBALIZATION: BARRIERS TO AND BEST PRACTICES FOR INTEGRATING DEVELOPING COUNTRIES INTO GLOBAL ECONOMIC REGULATION (Joost Pauwelyn & Mengyi Wang eds., 2019).

[9] It should be noted that there is a limited but growing use of Global Trade Item Numbers (GTINs) to strengthen product traceability in the agri-food industry. GTIN records information about a lot of products in the form of numbers and a barcode. The GTIN system was endorsed by the Traceability Task Force—a multi-stakeholder group jointly created by the Produce Marketing Association (PMA) and the Canadian Produce Marketing Association (CPMA) in 2002—in its best practices guidelines. *See, e.g.,* TIMOTHY D. LYTTON, OUTBREAK: FOOD BORNE ILLNESS AND THE STRUGGLE FOR FOOD SAFETY 191–93 (2019); FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO), PRIVATE STANDARDS IN THE UNITED STATES AND EUROPEAN UNION MARKETS FOR FRUIT AND VEGETABLES: IMPLICATIONS FOR DEVELOPING COUNTRIES 24–25 (2007).

[10] *See infra* Part III.B.

[11] *Id.*

[12] *Id.*

blockchain-based "IBM Food Trust" platform by September 2019.[13] Similarly, the United Nations' (UN) World Food Program (WFP) launched the "Building Block" program in 2017. Using iris-scanning technologies and blockchains, this program helped Syrian refugees verify their identities and directly deduct what they spend from the amount of aid they receive from the WFP.[14] Such initiatives have the potential to help retailers and consumers pinpoint sources of contamination at times of outbreak or provide production details and quality certifications (e.g., product origin, farm history, processing and shipping information, and fair trade or safety/sustainability standards).[15] Blockchains can also be combined with smart contract systems and other AI techniques to increase efficiency, simplify transactions, ensure compliance and security, and promote trade facilitation across borders.

While the far-reaching ramifications of blockchain technologies in the financial arena (such as fintech and cryptocurrency issues) have been discussed in media, literature, and politics in recent years, the opportunities and challenges posed by blockchain to food safety, traceability, and sustainable development have been less analyzed.[16] The benefits of applying blockchain technologies in the global food supply chain seem salient: transforming paper-based documents into a blockchain-enabled identity to generate a high level of transparency and data integrity, enabling smaller farmers to bypass middlemen in crops trading and cash transfers and providing an efficient and cost-effective way to manage the production system.

Blockchain, however, is not a silver bullet to solve all food governance issues; the use of the technology may create a new layer of challenges and arguably leave some key problems unaddressed. As will be further unpacked by this Article, applying blockchain technologies to the governance of food safety, traceability, and sustainability triggers new regulatory questions of a technical capacity gap, standardization politics, cybersecurity and data protection, and technologically inherent limits of blockchain. In addition, "blockchainizing" the food supply chain may pose legal and policy challenges to both developed and developing (especially underdeveloped) countries in different ways—especially in terms of operational expertise and technical infrastructure, scalability and implementation costs, and power asymmetry in international standard-setting—which may, in turn, undermine the overall legitimacy and accountability of such techno-regulatory mechanisms.

This Article, therefore, aims to explore the potential of blockchain technologies in revolutionizing the global food supply chain in terms of food safety, traceability, and sustainable development. More specifically, this Article will examine concrete cases in which blockchains have been applied to transform how we conventionally think about food safety, certification, and traceability. Premised upon these cases, this Article argues that blockchain technologies can indeed revolutionize the food supply chain by solving the information asymmetry problem and by increasing efficiency, transparency, and trust among all market players, as demonstrated by the recent pilots. If the recent pilot programs can be practically materialized and scaled up to real-world

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[13] *Id.*

[14] *Id.*

[15] *See* Sylvain Charlebois, *How Blockchain Technology Could Transform the Food Industry*, THE CONVERSATION (Dec. 20, 2017)*;see also infra* Part III.A.

[16] For some relatively recent works discussing the use of blockchain in regulation and the agri-food sector, *see infra* Part III.A.

governance mechanisms, the participants in the global supply chain will be able to get connected and upload their data to the cloud-based system, which further generates a transparent, traceable, immutable, and shared record of production details; quality specifications and origin facts; sustainability and fair trade certifications; and storage, import/export, and logistics information.

Such transformation and benefits, however, do not come without costs or challenges. Blockchainizing governance of food safety, traceability, and sustainability poses another layer of regulatory questions about technical capacity and infrastructure gap, scalability and implementation costs, global standardization politics, cybersecurity and data protection, and technologically inherent limits of blockchain. Regulatory questions, as such, may call for a reconceptualization of the forms and substances of conventional food law and policy (as well as data protection law, anti-trust law, and trade law). In this light, this Article will also endeavor to locate possible barriers and challenges to blockchainizing food law at national and international levels and offer recommendations for leveraging such technology in an effective, efficient, and responsible manner.

Part II of this Article sets the scene of contemporary governance issues in the global agri-food supply chain—namely food safety, authenticity, traceability and transparency, and security and sustainability—and points to information insufficiency, inaccuracy, and asymmetry as some of the most crucial root causes. Part III gives an in-depth discussion on the technical aspects and regulatory benefits of blockchain technologies and looks at three promising pilot programs as examples. Part IV will examine the potentials and challenges of bringing blockchain technologies into the governance endeavors by assessing the benefits of blockchainizing food law and policy, such as a high level of consistency, security, and authenticity of information and unparalleled power of traceability. At the same time, Part IV cautions the adverse regulatory byproducts that need to be carefully addressed when regulators and businesses try to scale up the existing pilot projects. Part V concludes by calling for a more technologically informed policy-making process before rushing into the hype of blockchainizing food law.

II. REGULATORY CHALLENGES IN THE GLOBAL AGRI-FOOD SUPPLY CHAIN

The globalization of food production, distribution, and consumption has—together with trade liberalization, market integration, and technological development in recent decades—generated considerable benefits.[17] At the same time, it has posed significant challenges to the industry, as well as to governments and consumers around the world.[18] Among other issues, food safety, authenticity, traceability, and sustainability are of crucial importance and have serious public health, economic, and social ramifications.[19] Food safety, security, and sustainability are further intertwined in

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[17] *See generally* FOOD AND DRUG REGULATION IN AN ERA OF GLOBALIZED MARKETS xxvii-xxx (Sam F. Halabi ed., 2015).

[18] *See* Alexia Brunet Marks, *The Risks We Are Willing to Eat: Food Imports and Safety*, 52 HARV. J. ON LEGIS. 125, 129–35 (2015); Yasmine Motarjemi et al., *Future Challenges in Global Harmonization of Food Safety Legislation*, 12 FOOD CONTROL 339, 340–41 (2001).

[19] *See* Lin, *supra* note 1, at 641–64; *see also* ALBERTO ALEMANNO, TRADE IN FOOD: REGULATORY AND JUDICIAL APPROACHES IN THE EU AND THE WTO 73–223 (2007).

today's multi-level and multi-layered food systems that interact with global environmental change, labor issues, transnational regulatory landscape, scientific development, and other cross-sector interconnectivities.[20] This section provides a quick overview of these issues from a global governance perspective, which will hopefully serve as a premise for subsequent discussions on whether and to what extent disruptive technologies, such as blockchain, can help to address these regulatory challenges.[21]

A. Food Safety and Authenticity

Food safety issues have become globalized, crossing state borders to pose governance challenges to economic development and public health, according to the World Health Organization (WHO).[22] There are more than 3.2 billion cases of foodborne diseases in children above five years of age reported annually in Southeast Asia, and 5 billion reported cases worldwide.[23] Because food products can be made in one place with raw materials from multiple regions, processed in another continent, exported into the global supply chain, and delivered to the shelf or the dinner table in distant locations, food safety incidents that occur in a specific node along the supply chain can pose substantial risks globally.

In the United States, for example, documented food safety incidents result in more than 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths annually (based on statistics rather than actual reports).[24] In addition, the U.S. Food and Drug Administration (FDA) in the United States has been criticized for its failure to combat "food fraud" in various products such as seafood, fruit juice, and olive oil.[25] To be sure, not all forms of food fraud may directly affect food safety. While some types of economically motivated adulteration (EMA), such as padding, diluting, or substituting certain ingredients of food products, may not threaten food safety, other types of food fraud usually pose serious health risks to consumers.[26] Internationally, cross-border food safety crises are no less problematic: Chinese dumplings tainted with harmful

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[20] *See* Tai, *supra* note 2, at 112–16.

[21] While this Article endeavors to offer a sufficient account of the regulatory challenges on food safety, authenticity, traceability, and sustainability, it cannot and does not intend to exhaust all the problems or examine all the details of these inquiries. This Part simply serves to provide a basic background for the subsequent analysis on using blockchain as a regulatory tool to address the above issues.

[22] *See* WHO ESTIMATES, *supra* note 6, at 76.

[23] WORLD HEALTH ORG., REGIONAL FOOD SAFETY STRATEGY 2–3 (2014), https://apps.searo.who.int/PDS_DOCS/B5070.pdf [https://perma.cc/4P7J-USH8].

[24] *Estimates of Foodborne Illness in the United States—Burden of Foodborne Illness: Overview*, CENTERS FOR DISEASE CONTROL AND PREVENTION, https://www.cdc.gov/foodsafety/foodborne-germs.html [https://perma.cc/5DZY-TW85]; *see generally* Elaine Scallan et al., *Foodborne Illness Acquired in the United States—Unspecified Agents*, 17 EMERGING INFECTIOUS DISEASE 7 (2011). Further, Timothy D. Lytton discusses the methodologies adopted by researchers to estimate the number of forborne illness cases and economic costs. *See* LYTTON, *supra* note 9, at 243–45.

[25] Lyndsey Layton, *FDA Pressured to Combat Rising "Food Fraud,"* WASH. POST, Mar. 30, 2010.

[26] *See generally* MICHAEL T. ROBERTS & WHITNEY TURK, WHITE PAPER: THE PURSUIT OF FOOD AUTHENTICITY: RECOMMENDED LEGAL AND POLICY STRATEGIES TO ERADICATE ECONOMICALLY MOTIVATED ADULTERATION (FOOD FRAUD) 5, 21 (2016), https://law.ucla.edu/centers/social-policy/resnick-center-for-food-law-and-policy/publications/food-fraud-white-paper [https://perma.cc/DVA3-BD39].

pesticides made 700 people sick in Japan in 2008;[27] bovine spongiform encephalopathy (BSE, commonly known as "mad cow disease") resulted in 180,000 cattle cases in twenty countries and affected human consumption worldwide;[28] and melamine-laced dairy products from China led to over 50,000 cases of infant hospitalization and affected forty-six countries.

Coupled with the increase in food trade, the continuing consolidation of agricultural and food companies into large transnational food corporations and the remarkable growth of these resulting companies are essential driving forces behind the sweeping changes in the global food system.[29] With the force of international food trade that ties together companies of different sizes and capabilities in jurisdictions with diverse degrees of oversight, the likelihood, scale, and severity of outbreaks of foodborne diseases and contamination from unsafe foods all have increased exponentially.[30] Food science advances and the modernization of various production methods have also contributed to the ever-growing complexity of the agri-food market globally.[31] Considering the rapid scientific and technological developments in the agri-food sector, eminent scholars have also argued that the establishment of the government's national food strategy "should have the ability to respond to changes in science and technology, as well as new and unexpected challenges that emerge."[32] As a result, information asymmetry abounds along the prolonged supply chain,[33] from farm to fork, further leading to market failures (e.g., consumers do not know the production processes, safety, and quality information behind food products, and suppliers are incentivized to cheat or go easy on safety measures), which, in turn, breed rampant food safety problems worldwide.[34]

In addition to food safety, a related problem concerns the authenticity of food products—food fraud or economic adulteration. As rightly pointed out by the European Union's Directorate-General for Health and Food Safety in its most recent 2018 annual report on the EU Food Fraud Network:[35]

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[27] *See* Andrew Cockburn, *Gyoza Scare Offers Insight into Japan's Culture of Eating*, JAPAN TODAY (April 13, 2008, 06:57 AM), https://japantoday.com/category/features/opinions/gyoza-scare-offers-insight-into-japans-culture-of-eating [https://perma.cc/8TBT-MQFQ].

[28] *Prion Diseases*, WORLD HEALTH ORG., https://www.who.int/zoonoses/diseases/prion_diseases/en/ [https://perma.cc/RY4F-UT3J].

[29] *See* David Antony Detomasi, *The Multinational Corporation and Global Governance: Modelling Global Public Policy Networks*, 71 J. BUS. ETHICS 321 (2007), for a general discussion of globalization and the increasing influence of multinational corporations.

[30] *See* WHO ESTIMATES, *supra* note 6, at 98.

[31] *See* Lin, *supra* note 1, at 641–64.

[32] Beyranevand & Broad Leib, *supra* note 2, at 258.

[33] *See* Lin, *supra* note 1, at 467–79; *see also* Gillian K. Hadfield et al., *Information-Based Principles for Rethinking Consumer Protection Policy*, 21 J. CONSUMER POL'Y 140, 143 (1998); Michael J. Trebilcock, *Rethinking Consumer Protection Policy*, *in* INTERNATIONAL PERSPECTIVES ON CONSUMERS' ACCESS TO JUSTICE 68, 68–98 (Charles E.F. Rickett & Thomas G.W. Telfer eds., 2003).

[34] *See* Brunet Marks, *supra* note 18, at 125–35.

[35] The EU Food Fraud Network was established in 2013 in the wake of the horsemeat scandal to serve as a platform to liaise and exchange information between Members State contact points and to facilitate regulatory work on food fraud cases among EU Member States and some other European countries. *See* EUROPEAN COMMISSION, THE EU FOOD FRAUD NETWORK AND THE SYSTEM FOR ADMINISTRATIVE ASSISTANCE–FOOD FRAUD, ANNUAL REPORT 2018 5 (DG SANTE, April 12, 2019) [hereinafter EU FOOD FRAUD NETWORK 2018 REPORT], https://ec.europa.eu/food/sites/food/files/safety/docs/food-

> The complex nature of our globalized food supply chains and the economic motivation to provide cheaper food products have contributed to the prevalence of food fraud. The cost for the global food industry has been estimated at around EUR 30 billion every year, thereby hindering the proper functioning of the internal market. Fraudulent practices in the food sector may also lead to public health risks.[36]

Indeed, food fraud is usually economically driven and emerges when there is a significant price gap between the authentic and substitution products, which incentivizes suppliers to corrupt and adulterate.[37] The increasing globalization and complexity of the agri-food supply chain practically reduces transparency and widens information asymmetry in the marketplace, reducing the risk of being caught, preventing consumers from ascertaining product differentials, and so exacerbating the economic drivers for food fraud.[38] Notable examples include the melamine-tainted infant formula scandal in China in 2008, problems with horsemeat in beef products across Europe in 2013, and the sale of adulterated olive oil in Taiwan in 2013. Given the strong economic incentives for fraud and the weak capability of ensuring transparency (for authenticity verification) in the market, it is unsurprising that even in the European Union, one of the most developed jurisdictions, the number of reported food fraud cases jumped to 234 in 2018, marking a 31% increase compared to reported cases in 2017.[39]

Rampant food fraud—be it dilution, substitution, or mislabeling—can result in economic loss, public distrust, and public health risks, which further weaken the government as well as the industry's credibility and accountability as an effective gatekeeper of food safety and fair trade. While the Food Safety Modernization Act of 2011 (FSMA) incorporates certain rules that aim to cope with intentional adulteration, food fraud (in particular, the European Medical Association) does not seem to be properly addressed under the law and FDA has not devoted adequate resources to alleviate the issue.[40]

At the global level, it becomes more challenging to detect food fraud along the complex and extended supply chain in which a huge number of suppliers, processors, distributors, importers, and retailers are involved. The sheer number of actors taking part in the global supply chain without rigorous cross-border law enforcement means

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fraud_network_activity_report_2018.pdf [https://perma.cc/2PWE-WUD6].

[36] *Id.* at 4.

[37] *See generally* RENÉE JOHNSON, CONG. RESEARCH SERV., R43358, FOOD FRAUD AND "ECONOMICALLY MOTIVATED ADULTERATION" OF FOOD AND FOOD INGREDIENTS (Jan. 10, 2014), http://foodfraud.msu.edu/wp-content/uploads/2014/01/CRS-Food-Fraud-and-EMA-2014-R43358.pdf, [https://perma.cc/8P4Z-Q9T8].

[38] For more discussion, see Karen Everstine et al., *Economically Motivated Adulteration (EMA) of Food: Common Characteristics of EMA Incidents*, 76 J. FOOD PROTECTION 723 (2013).

[39] *See* EU FOOD FRAUD NETWORK 2018 REPORT, *supra* note 35, at 7.

[40] *See* John Spink, *Review: Final Rules for FSMA 'Third-Party Certification,' 'Foreign Supplier Verification,' and 'Produce Rule' Regarding Food Fraud and EMA*, MICHIGAN STATE UNIVERSITY FOOD FRAUD INITIATIVE (Jan. 28, 2016) https://spartanideas.msu.edu/2016/01/28/review-final-rules-for-fsma-third-party-certification-foreign-supplier-verification-and-produce-rule-regarding-food-fraud-and-ema/ [https://perma.cc/EDQ7-3SDE]; *see also* ROBERTS & TURK, *supra* note 26, at 21.

that some can easily remain anonymous or are simply invisible.[41] Commercial practices mean that food products and commodities are often reprocessed, reloaded, and repackaged in different jurisdictions by different factories, increasing the information asymmetry gap and, consequently, the incentives for fraud.[42] Due to the problems of information asymmetry along the global food supply chain, importers and local marketers (except for those that enjoy market power and technical expertise to require third-party auditing and certification) have limited choices other than relying on the regulatory systems of origin countries.[43]

B. Traceability and Transparency

Traceability generally refers to the "ability to identify and trace the history, distribution, location and application of products, parts, and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labor (including health and safety), the environment and anti-corruption," as per the definition provided by the United Nations Global Compact.[44] To be sure, traceability and transparency are not always strictly connected, as the interaction between the two notions is multifold and complex.[45] Yet considering the conceptual, politically and socially constructed nature of transparency, and the practical orientation of traceability, this Article focuses on their mutually reinforcing relationship. In the context of food law, traceability can be understood as "the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution," according to EU General Food Law. [46]

Reading from these texts, we know that traceability is a complete process of knowing each link along the food supply chain and the ability to pinpoint the relationship between different links and activities therein. More specifically, traceability can mean business-to-business documentation of the *path* of distribution along the supply chain, or that of the specific *condition* (such as microbiological tests, pesticide residues, or quality certifications) of a product at each stage of distribution.[47] The former is a minimal implementation of traceability, while the latter is more robust

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[41] *See* KAIROS FUTURE, BLOCKCHAIN USE CASES FOR FOOD TRACEABILITY AND CONTROL: A STUDY TO IDENTIFY THE POTENTIAL BENEFITS FROM USING BLOCKCHAIN TECHNOLOGY FOR FOOD TRACEABILITY AND CONTROL 16 (2017).

[42] *See id.* at 18.

[43] *See* Brunet Marks, *supra* note 18, at 132–38.

[44] UNITED NATIONS GLOBAL COMPACT OFFICE, A GUIDE TO TRACEABILITY: A PRACTICAL APPROACH TO ADVANCE SUSTAINABILITY IN GLOBAL SUPPLY CHAINS 6 (2014).

[45] *See, e.g.*, Nel Wognum et al., *Systems for Sustainability and Transparency of Food Supply Chains—Current Status and Challenges*, 25 ADVANCED ENGINEERING INFORMATICS 65, 68 (2011), http://isiarticles.com/bundles/Article/pre/pdf/80646.pdf [https://perma.cc/QSW8-TJAJ]; R.R. Pant et al., *A Framework for Traceability and Transparency in the Dairy Supply Chain Networks*, 189 PROCEDIA–SOC. BEHAVIORAL SCI. 385, 385–88 (2015); *Understanding Transparency and Traceability in the Supply Chain*. SOCIÉTÉ GÉNÉRALE DE SURVEILLANCE (SGS) (Aug. 2, 2018), https://www.sgs.com/en/news/2018/08/understanding-transparency-and-traceability-in-the-supply-chain, [https://perma.cc/A8F8-FHKX].

[46] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 (laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety), OJ L 31, 1.2.2002, p. 1–24, art. 3.15.

[47] *See generally* Teresa Pizzuti & Giovanni Mirabelli, *The Global Track and Trace System for Food: General Framework and Functioning Principles*, 159 J. FOOD ENGINEERING 16 (2015).

traceability and requires more technological support. Regardless of the kinds and degrees of traceability possibly required in the supply chain, it has generally remained a costly and demanding endeavor for both the government and industry.[48]

Recent food safety and fraud incidents, as noted above, have spurred public outcry and consumer demand for the right to know.[49] Traceability is a key element in ensuring food safety because it empowers regulators and companies to facilitate and expedite outbreak response, increases the legal risks of getting caught, and strengthens deterrence effects on potential violators. There have also been serious calls for better governance actions to ensure sufficient traceability to facilitate outbreak response and corruption deterrence.[50] Nevertheless, the globalization and complication of agri-food supply chains, as well as the characteristics mentioned above (such as weak cross-border law enforcement; information asymmetry in the market; the sheer number of supply chain players with all sizes and abilities; and common commercial practices to reprocess, reload, and repackage) have made traceability a daunting task.[51]

For one, a considerable share of the agri-food industry, especially in less developed jurisdictions, is characterized by labor-intensive manual work and handwritten paperwork,[52] which are prone to mistakes and are vulnerable to fraud. Global food supply chains are not transparent "due to inconsistent or even unavailable data, high proportion of manual (paper) work, lack of interoperability, and limited information on the product's lifecycle or transport history."[53] Indeed, paper-based record keeping tends to be less transparent (not readily sharable among supply chain participants), and handwriting is more error-prone and more likely to facilitate fraud. Practically, proper record-keeping and data integrity mean an overhaul of the system that needs the active use of technology to alleviate problems such as human errors in data recording, inconsistent information, and the lack of data standardization and interoperability among systems.[54]

For another, from a supply chain perspective, the world's "[f]ood systems and agricultural practices . . . are diverse and range from modern, large-scale distribution system channels to traditional food chains," rendering the linkages among all players legally and technically difficult.[55] In addition, most transactions along the agri-food

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[48] *See* LYTTON, *supra* note 9, at 193–94.

[49] For a more recent review and a historical account, see LYTTON, *supra* note 9, at 24–64.

[50] *See* FOOD & AGRIC. ORG. OF THE U.N., FOOD TRACEABILITY GUIDANCE 2 (2017), http://www.fao.org/3/a-i7665e.pdf [http://perma.cc/WV46-QWQH].

[51] In addition, record keeping costs to firms have also been a big obstacle to the implementation of traceability. *See* Carla Mejia et. al., *Traceability (Product Tracing) in Food Systems: An IFT Report Submitted to the FDA, Volume 2: Cost Considerations and Implications*, 9 COMPREHENSIVE REV. FOOD SCI. & FOOD SAFETY 159 (2010).

[52] *See* Michael Lierow et al., *Blockchain: The Backbone of Digital Supply Chains*, OLIVER WYMAN (2017), https://www.oliverwyman.com/our-expertise/insights/2017/jun/blockchain-the-backbone-of-digital-supply-chains.html [http://perma.cc/SQ7G-35UK].

[53] *Id.*

[54] *See* Tina G. Karippacheril et al., *Global Markets, Global Challenges: Improving Food Safety and Traceability While Empowering Smallholders Through ICT*, *in* ICT IN AGRICULTURE (UPDATED EDITION): CONNECTING SMALLHOLDERS TO KNOWLEDGE, NETWORKS, AND INSTITUTIONS 283, 298–302 (World Bank ed., 2017).

[55] Mischa Tripoli & Josef Schmidhuber, *Emerging Opportunities for the Application of Blockchain in the Agri-food Industry*, *in* FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS & INTERNATIONAL CENTRE FOR TRADE AND SUSTAINABLE DEVELOPMENT 6 (2018).

supply chain are processed by multiple intermediaries, without a clear, consistent, and efficient set of procedural standards or rigorous implementation. Indeed, the contemporary agri-food systems are defined by their "inherently cross-level and cross-scale" complexity.[56] It is, therefore, arduous today for companies—especially those who are small or medium enterprises (SMEs) with less market power and technical expertise—to trace each link in the supply chain of a specific agri-food product back to its origin.[57]

C. *Food Security and Sustainability*

Because it holds different meanings to different people in different contexts,[58] food security has been defined and redefined by international organizations and conferences on many occasions.[59] Among the 200 definitions that can be found in worldwide publications, the most influential redefinition seems to be that of the World Food Summit of 1996: "Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[60] There are at least three key elements that form the operational concept of food security in public policy—food stability (an individual's ability to obtain food over time), food access (affordability and distribution of food), and food availability (general supply of food).

The flexible and broad notion of food security incorporates various measures of supply stability, disruption resilience, and equal access, which are closely tied to supply and demand information as well as diverse risk factors (such as climate change, economic instability, wars, and trade measures). For example, one of the biggest disruptions to the stability of the global food market was an incident in which the prices of a few food commodities spiked in 2007 and 2008, seriously impacting global food availability, stability, and access.[61] The adverse consequences of food insecurity were particularly manifest for "developing countries and net food importers, countries that are dependent on the international food market to ensure their domestic food supply."[62]

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[56] Polly Ericksen et al., *The Value of a Food System Approach*, *in* FOOD SECURITY AND GLOBAL ENVIRONMENTAL CHANGE 31 (John Ingram et al. eds., 2010).

[57] *Id.* at 1; *see also* FUTURE, *supra* note 41, at 21.

[58] *See generally* Mark Gibson, *Food Security—A Commentary: What Is It and Why Is It So Complicated?*, 1 FOODS 18 (2012); Francis Snyder, *Toward an International Law for Adequate Food*, *in* FOOD SECURITY AND FOOD SAFETY 79 (Ahmed Mahiou & Francis Snyder eds., 2006); Kerstin Mechlem, *Food Security and the Right to Food in the Discourse of the United Nations* 10 EURO. L.J. 631 (2004); FOOD SECURITY: INDICATORS, MEASUREMENT AND THE IMPACT OF TRADE OPENNESS (Basudeb Guha-Khasnobis et al. eds., 2007); GIOVANNI GRUNI, THE EU, WORLD TRADE LAW AND THE RIGHT TO FOOD: RETHINKING FREE TRADE AGREEMENTS WITH DEVELOPING COUNTRIES (2018).

[59] *See* FOOD & AGRIC. ORG. OF THE U.N., CHAPTER 2—FOOD SECURITY: CONCEPTS AND MEASUREMENT, TRADE REFORMS AND FOOD SECURITY (2003), http://www.fao.org/3/y4671e/y4671e06.htm#TopOfPage [http:/perma.cc/GF7F-8SPY].

[60] FOOD & AGRIC. ORG. OF THE U.N., ROME DECLARATION ON WORLD FOOD SECURITY AND WORLD FOOD SUMMIT PLAN OF ACTION,WORLD FOOD SUMMIT (Nov. 13–17, 1996), http://www.fao.org/3/w3613e/w3613e00.htm [http://perma.cc/SY8M-LMC3].

[61] *See generally* Giovanni Gruni, *Going from One Extreme to the Other: Food Security and Export Restrictions in the EU–CARIFORUM Economic Partnership Agreement*, 19 EURO. L.J. 864 (2013).

[62] *Id.* at 865.

Determining legal, policy, or technical solutions to ensure productivity and efficiency in the global agri-food supply chain, reducing operational and transaction costs and increasing economic gains for suppliers (especially small and medium entities), and lowering food prices for consumers, are of great relevance and importance. Toward such a purpose, market transparency—which can facilitate "greater access to more accurate market information," strengthen the global food system, and reduce the incidence and impact of price surges that are a major threat to food security"—is a key element in the promotion of food security and sustainability around the world.[63] This is where blockchain technologies may come in to revolutionize the food supply chain and empower market players along the agri-food supply chain by increasing transparency, efficiency, and trust among all players. At the same time, applying blockchain technologies to the governance of food safety, traceability, and sustainability, as analyzed below, may pose another layer of regulatory questions about technical capacity and infrastructure gap, scalability and implementation costs, global standardization politics, cybersecurity and data protection, and technologically inherent limits of blockchain. Whether blockchain promises to be a grand "technical fix" calls for a closer examination.

III. BLOCKCHAIN AS A GRAND "TECHNICAL FIX"—ASSESSING EXISTING PILOT PROJECTS

Given the growing consumer demand for transparency from corporations,[64] as well as the need for efficient supply chain management on a business-to-business level,[65] agri-food producers, processors, distributors, and retailers are driven to seek innovative solutions. Due to its unique characteristics, blockchain technology promises to offer transparency, traceability, and security along the food supply chain. Some businesses have addressed traceability challenges by leveraging blockchain technology along the supply chain to ensure product information and data reliability, as well as the consumer's right to know.[66] Notably, there is growing cross-sector collaboration between agri-food and technology companies, which places blockchain at the center of the "technical fix" to regulatory challenges of food safety, traceability, and sustainability. As a result, the total value of blockchain applications in agri-food markets globally is predicted to grow from $41.9 million in 2018 to $195.3 million in 2019, and further jump to $1.4 billion by 2022.[67]

This section examines three prominent examples that shed light on the incremental regulatory shift to "blockchainizing" food law, driven largely by private actors in the agri-food and tech industries. Furthermore, the practical strengths and weaknesses of

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[63] Tripoli & Schmidhuber, *supra* note 55, at 18–19.

[64] *See* FOOD & AGRIC. ORG. OF THE U.N., *supra* note 50, at 1.

[65] *See generally* Ching-Fu Lin, *The Emergence and Influence of Transnational Private Regulation of Food Safety*, *in* FOOD AND DRUG REGULATION IN AN ERA OF GLOBALIZED MARKETS (Sam Halabi ed., 2015).

[66] *See* Margaret D. Fowler, *Linking the Benefit to the Corporation: Blockchain as a Solution for Certification in an Age of "Do-Good" Business,* 20 VAND. J. ENT. & TECH. L. 881, 913–15 (2018).

[67] Pearly Neo & Tingmin Koe, *Trace What Matters: Is Blockchain the Solution to Food Safety, Quality and Brand Reputation?,* FOOD NAVIGATOR-ASIA (Mar 21, 2019), https://www.foodnavigator-asia.com/Article/2019/03/20/Trace-what-matters-Is-Blockchain-the-solution-to-food-safety-quality-and-brand-reputation [http://perma.cc/4EB3-MMAY].

using blockchain to ensure food safety, traceability, and sustainability will be reviewed. Last, but not least, the government's role (or the absence thereof) will be assessed, given the promises and perils of blockchain as it relates to food law, in the context of resorting to technology as a regulatory tool.[68]

A. *Blockchain as a Potential "Technical Fix"*

Blockchain has been called for in various contexts to serve as a "technical fix" of regulatory problems.[69] Regulatory technologies as such may be used to "define and incorporate legal or contractual provisions into code, and to enforce them irrespectively of whether or not there subsists an underlying legal rule."[70] Yet, one should familiarize the technical elements and nature of blockchain as well as the technology's advantages in addressing governance challenges in the global agri-food supply chain. Defined broadly, blockchains (or DLTs) are decentralized databases that are collaboratively stored, maintained, and updated by a distributed network of computing nodes.[71] A combination of technologies—including peer-to-peer networks, cryptographic methods (with public or private key), and consensus mechanisms—comprise this novel type of database, which is shared among parties who do not otherwise trust each other.[72] Data inserted into the blockchain is simultaneously permanently recorded and updated in each node of the network, and the use of cryptography allows for a mathematical consensus to ensure the consistency and authenticity of such data across the network.[73] Each new transaction is stored as an additional "block" and is cryptographically tied to the "chain" of existing blocks, creating a so-called blockchain.[74] Blockchain information is generally "immutable" because cryptographic methods and networked nodes ensure that only information that is consistent with all earlier versions (based on consensus) can be recorded onto the blockchain, while information that conflicts with existing copies of the database would not be accepted.[75] Similarly, information (e.g., transactions) that has been permanently recorded on the blockchain cannot be easily deleted or altered (see additional discussion below).[76]

As a distributed and decentralized system, "[b]lockchain is not controlled by a central authority, person, company, or government," but, rather, by all network nodes (minders, or participants) based on a predefined algorithm, which keeps "complete

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[68] On technology as a regulatory tool, see ROGER BROWNSWORD & KAREN YEUNG, *Regulating Technologies, in* REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES 3, 7–13 (2008).

[69] *See generally* Primavera De Filippi & Samer Hassan, *Blockchain Technology as a Regulatory Technology: From Code is Law to Law is Code*, 21 FIRST MONDAY 3 (2016).

[70] *Id.* at 9.

[71] PRIMAVERA DE FILIPPI & AARON WRIGHT, BLOCKCHAIN AND THE LAW: THE RULE OF CODE 13 (2018).

[72] *Id.*

[73] Karen Yeung, *Regulation by Blockchain: The Emerging Battle for Supremacy between the Code* of *Law and Code* as *Law*, 82 MODERN L. REV. 207, 210–11 (2019).

[74] U.K. GOV'T CHIEF SCI. ADVISER, DISTRIBUTED LEDGER TECHNOLOGY: BEYOND BLOCK CHAIN 5 (2016) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf [https://perma.cc/B2PB-87SS].

[75] Yeung, *supra* note 73, at 211.

[76] *Id.*

information about transactions (and ownership) from the genesis block to the most recently completed block."[77] All of the participants in the network have their own digital signature, which is attached to each of the transactions added to the blockchain with specific timestamps and details.[78] The history of all of the transactions is, therefore, recorded in the blockchain with great security and accuracy, creating a secure ledger for those who have cryptographic keys (public or private) to access and manage the shared ledger.[79]

There are many typologies of blockchains based on different benchmarks. The most relevant for the purpose of this Article is the difference between public (not permissioned) and private (permissioned) blockchains. In a public blockchain, such as the one employed by Bitcoin, all participants in the network can contribute data without being censored or controlled by a single power, and all records are transparent and accessible to them.[80] Public blockchains enjoy a high level of data security, as it is only when all existing ledgers are simultaneously hacked that the data on the blockchain can be tampered with, according to the consensus mechanism.[81] A private blockchain, on the other hand, is owned by one or more entities, and new data are written to the network and verified via a limited consensus procedure by entities with controlling authority over the ledger.[82] Therefore, when we emphasize the critical advantages of the technology as a "distributed, shared, encrypted-database that serves as an irreversible and incorruptible public repository of information,"[83] we are referring to the public type (or not permissioned) of blockchains.

Altogether, a distributed and shared platform, data security and immutability, and transparency and traceability give blockchain technologies the potential to generally ensure accurate and secure records of transactions in the database, generating "trust" for participants in a given market (e.g., supply chain, stock exchange, real estate, or insurance). In this sense, blockchain has the power to "radically disrupt existing political and economic orders by dispensing with the need for conventional third-party intermediaries . . . enabling peer-to-peer transactions via the blockchain without the operational inefficiencies . . . ."[84] The potential of blockchain is not limited to Bitcoin or the financial sector, although it is regarded as one of the most disrupted issue areas.

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[77] Pavel Ciaian, Senior Researcher, Eur. Comm'n Joint Research Ctr., Presentation at the JRC-AGRI Market Transparency Workshop: Blockchain Technology and Market Transparency (May 30–31, 2018), https://ec.europa.eu/info/sites/info/files/law/consultation/mt-workshop-blockchain-technology-and-mt_ciaian_en.pdf [https://perma.cc/VX8J-4SSS].

[78] *See* Tracie Scott et al., *Evaluating Feasibility of Blockchain Application for DSCSA Compliance*, SMU DATA SCI. REV., 2018, at 9–10. Blockchain technologies have "operational resilience" where data is accurate, secure, and accessible, resulting in a situation where "I know who you are. I know who owns this asset. We have a shared record of trusted, validated transactions; no reconciliation required." *Id*.

[79] *Id.; see also* Philipp Paech, *The Governance of Blockchain Financial Networks*, 80 MOD. L. REV. 1073, 1080–82 (2017).

[80] U.K. GOV'T CHIEF SCI. ADVISER, *supra* note 74, at 17; *see also* Primavera De Filippi & Benjamin Loveluck, *The Invisible Politics of Bitcoin: Governance Crisis of a Decentralised Infrastructure*, 5 INTERNET POL'Y REV. 1, 15–19 (2016).

[81] *Id.*

[82] *Id.*

[83] Aaron Wright & Primavera De Filippi, *Decentralized Blockchain Technology and the Rise of Lex Cryptographia*, SSRN (Mar. 10, 2015), https://ssrn.com/abstract=2580664 [https://perma.cc/4LBV-PYDP].

[84] Yeung, *supra* note 73, at 212.

Rather, the technology can be applied in a general manner as a regulatory tool in a myriad of contexts,[85] especially those that value information accuracy, data security, record-keeping, and traceability.

In the area of food law and policy, the above-mentioned governance challenges largely touch upon "information." Specifically, information asymmetry in the supply chain is key to many safety and fraud issues, verifying and sharing information is key to traceability and outbreak response, and sustainability and food security partly depend on accurate information regarding the demand for, and supply of, food. Blockchain technologies can ensure the validity and reliability of the information on the network without relying on a central intermediary and can keep such information cryptographically "tamperproof," as inconsistent or adulterated data are automatically discarded by the network.[86] As such, blockchains can be applied to strengthen digital record-keeping and traceability in the food business, verify transactions and certifications, and increase inventory and management efficiency.[87] A report jointly published by the Food and Agriculture Organization of the United Nations (FAO) and the International Centre for Trade and Sustainable Development (ICTSD) further stresses that "the potential for DLTs to increase efficiency, transparency[,] and trust throughout agricultural supply chains and empower all market players is real. The technology has the potential to simplify and integrate agricultural supply chains, enhance food safety, reduce risk in trade finance and promote inclusive trade . . . ."[88] Although several governance approaches have been adopted by governments worldwide, blockchain holds great potential and has emerged as a promising regulatory tool (more ambitiously, a "technical fix") for the agri-food industry to strengthen various aspects of supply chain management and deliver strong governance performance.

B. Examples of Blockchainizing Food Supply Chain Management

i. Provenance Seafood Traceability Blockchain

The first example of blockchainizing food supply chain governance is Provenance, a UK start-up company that incorporates blockchain into its methodology to monitor processes, track products, digitize certifications, and ensure compliance with social and sustainable standards.[89] More specifically, Provenance constructs "a shared and secure platform" based on blockchain technology, which allows for secure transaction

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[85] *See generally* Michèle Finck, *Blockchains: Regulating the Unknown*, 19 GERMAN L.J. 665 (2018).

[86] Margaret D. Fowler, *Linking the Benefit to the Corporation: Blockchain as a Solution for Certification in an Age of "Do-Good" Business,* 20 VAND. J. ENT. & TECH. L. 881, 898–900 (2018).

[87] *See id*; *see also* Juan F. Galvez et al., *Future Challenges on the Use of Blockchain for Food Traceability Analysis*, 107 TRENDS ANALYTICAL CHEMISTRY 222, 222–32 (2018); FUTURE, *supra* note 41, at 24–25.

[88] Tripoli & Schmidhuber, *supra* note 55, at 2.

[89] *See Blockchain: The Solution for Transparency in Product Supply Chains*, PROVENANCE (Nov. 21, 2015), https://www.provenance.org/whitepaper [https://perma.cc/5ZPS-HYJB] [hereinafter *Provenance White Paper*]; *see also* PROVENANCE, HOW PROVENANCE USES BLOCKCHAIN TO DIGITISE CERTIFICATION (July 25, 2017), https://www.provenance.org/news/technology/blockchain-certification [https://perma.cc/X5U4-CAD6].

audits, supply chain management, and information certainty.[90] As for traceability, Provenance uses blockchain to "enable[] every physical product to come with a digital 'passport' that proves authenticity . . . and origin . . . creating an auditable record of the journey behind."[91] The strengthened traceability and supply chain transparency further help companies in the fishery industry detect and prevent slavery or labor abuse, in line with other social and environmental standards.[92] The company has been working with retailers on a trial of the "from shore to plate" system,[93] requiring local suppliers in source areas (Indonesia) to key in data about their daily catch to a public blockchain with a blockchain ID via text message.[94] Provenance claims that with the successful implementation of this system, the entire history of a seafood product can be recorded online—from catching and processing, to certification, to packaging and distributing, to marketing and selling—and accessed by consumers with a smartphone app.[95]

However, as argued by one commentator, Provenance offers only a partial solution,[96] since the majority of agri-food sustainability issues (e.g., insufficient governance, weak institutions, inferior working conditions, market opacity, and lack of information sharing) happen "at the level of production and first intermediaries/processors," according to the United Nations Environmental Program (UNEP).[97] That is, while blockchain technology can ensure a high level of transparency, traceability, and immutability (security/unchangeable nature), the data initially input by local producers (the first players along the supply chain) remain vulnerable to human mistakes and economic adulteration.[98] Provenance aims to address illegal fishing and fraudulent certification problems by registering each catch and each sale of fish on the blockchain. Yet, the action of registering itself cannot be readily verified by technology without human auditors.

ii. IBM Food Trust Platform

Another example that demonstrates an infrastructure model for blockchainizing agri-food supply chain management is the cloud- and blockchain-based IBM Food

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[90] *Provenance White Paper*, *supra* note 89.

[91] *Id.*

[92] *See* Tom Levitt, *Blockchain Technology Trialed to Tackle Slavery in the Fishing Industry*, THE GUARDIAN (Sept. 7, 2016, 2:30 AM), https://www.theguardian.com/sustainable-business/2016/sep/07/blockchain-fish-slavery-free-seafood-sustainable-technology [https://perma.cc/G8QJ-RAUH].

[93] For a detailed report on this blockchain pilot system for tracing yellowfin and skipjack tuna fish in Indonesia, see *From Shore to Plate: Tracking Tuna on the Blockchain*, PROVENANCE (July 15, 2016), https://www.provenance.org/tracking-tuna-on-the-blockchain [https://perma.cc/VWW7-R3C6].

[94] *See* Luke Parker, *Provenance Tackles Slavery in the Fish Trade, with Blockchain Technology*, BRAVE NEW COIN (Sept. 15, 2016, 5:18 PM), https://bravenewcoin.com/insights/provenance-tackles-slavery-in-the-fish-trade-with-blockchain-technology [https://perma.cc/YF8T-H9PA].

[95] *Id.; see also* Scott et al., *supra* note 78, at 14–16.

[96] Fowler, *supra* note 66, at 915.

[97] Nancy Vallejo et al., *The Role of Supply Chains in Addressing the Global Seafood Crisis*, UNITED NATIONS ENVIRONMENT PROGRAMME 7 (2009), https://unep.ch/etb/publications/Fish%20Supply%20Chains/UNEP%20fish%20supply%20chains%20report.pdf [https://perma.cc/4V27-WAQN].

[98] See LYTTON, *supra* note 9, at 193, 227 for an in-depth discussion on the dependence of "technical fixes" for traceability on human data input.

Trust platform service.[99] Following a pilot project between Walmart and IBM that uses blockchain technology to track produce in the United States and pork in China,[100] IBM forged a collaboration with a few other major food producers and retailers, including, *inter alia*, Dole, Nestlé, Tyson Foods, Kroger, and Unilever in 2017, to leverage blockchain technology to address transparency and traceability challenges along the cross-border food supply chain.[101] Walmart required its upstream suppliers of leafy greens to use the IBM Food Trust platform by September 2019.[102] Under this IBM-Walmart cross-sector collaboration, each food item is digitally connected to the data (which can be either merely about the *path* of movement or detailed records of specific *conditions* of that item, as discussed in Part II.B) entered into the blockchain system at every step of the process, which makes possible the tracing of a package of mangos in just two seconds, whereas traditionally "it took six days, 18 hours and 26 minutes" from shop to farm.[103] In this case, when an outbreak happens, both the consumer and the retailer can easily retrieve crucial information (such as inspection records) about relevant suppliers, processers, and distributors and swiftly identify what went wrong and where.[104] The government may also incorporate such supply chain management information into a public-private partnership "food cloud" to facilitate evidence-based facility inspection, border control, and outbreak responses.[105] A prominent scholar of food law and policy, therefore, cites the Walmart-IBM collaboration and points out the value of using blockchain technology to deliver a more evidence-based food safety governance system with the support of private oversight.[106]

In response to this successful implementation, IBM has expanded its scope of collaboration to work with other players along the agri-food supply chain, such as JD.com, China's second-largest e-commerce company. Since mid-2017, JD.com has worked together with "national departments, fresh and consumer goods brands . . . to build anti-counterfeiting and traceability platforms to . . . protect the rights of brands and consumers" based on this blockchain system.[107] This recent development

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[99] *See* Tripoli & Schmidhuber, *supra* note 55, at 2–9.

[100] *See* Robert Hackett, *Walmart and 9 Food Giants Team Up on IBM Blockchain Plans*, FORBES (Aug. 22, 2017, 8:00 AM), http://fortune.com/2017/08/22/walmart-blockchain-ibm-food-nestle-unilever-tyson-%20dole/ [https://perma.cc/R226-PNTC].

[101] Roger Aitken, *IBM Forges Blockchain Collaboration with Nestlé & Walmart In Global Food Safety*, FORBES (Aug. 22, 2017, 9:15 AM), https://www.forbes.com/sites/rogeraitken/2017/08/22/ibm-forges-blockchain-collaboration-with-nestlewalmart-for-global-food-safety/#1467d4c73d36 [https://perma.cc/SU67-7BFA].

[102] *Food Traceability Initiative: Fresh Leafy Greens*, WALMART (Sept. 24, 2018), https://corporate.walmart.com/media-library/document/blockchain-supplier-letter-september-2018/_proxyDocument?id=00000166-088d-dc77-a7ff-4dff689f0001 [https://perma.cc/UF9J-N7HB].

[103] Sanne Wass, *Food Companies Unite to Advance Blockchain for Supply Chain Traceability*, GLOBAL TRADE REVIEW (Aug. 22, 2017), https://www.gtreview.com/news/fintech/food-companies-unite-to-advance-blockchain-for-supply-chain-traceability/[https://perma.cc/5XU4-WC9Q].

[104] *See* Galvez et al., *supra* note 87, at 223–25. More specifically, this platform uses IBM and Linux Hyperledger Project architecture to digitally track information that "includes storage temperatures, expiration date, shipping details, origination farm details, batch number and much more relevant data when the food is being delivered worldwide." *Id.* at 229.

[105] *Id.* at 229.

[106] LYTTON, *supra* note 6, at 225–28.

[107] Riccardo Berti & Mariagrazia Semprebon, *Food Traceability in China*, 13 EUR. FOOD & FEED L. REV. 522, 530 (2018).

demonstrates how the cross-sectoral "Blockchain Food Safety Alliance"[108] between IBM, JD.com, Walmart, and Tsinghua University in Beijing endeavors to find a technical fix to the traceability challenge in China. IBM has moved to work with Microsoft and the International Article Numbering Association to set international standards for blockchain applications in global supply chains. The Chinese government has yet to intervene and issue standards on this subject matter.[109]

Nevertheless, it should be noted that while the IBM Food Trust Platform is open to agri-food companies, they usually maintain the implementation of blockchain systems in a centralized manner among industry stakeholders (i.e., Walmart itself and its suppliers). Walmart, for instance, while not in a position to easily alter the data stored in the blockchain without being noticed (the system is modifiable or eliminable, yet blockchain makes it more difficult), could "simply, shut down the entire system."[110] As observed by another commentator, "Walmart's system does not solve the information asymmetry between the trades and the consumers; it only solves the information asymmetry between Walmart and its suppliers."[111]

iii. WFP Food Security Initiative

Similarly, the UN WFP launched the "Building Block" pilot program in 2017.[112] Relying on iris-scanning technologies and blockchains, this program helped refugees verify their identities and directly deduct what they spend from the amount of aid they receive from the WFP.[113] In Jordan's Azraq camp, more than 100,000 refugees can pay for their food by utilizing a private (permissioned) Ethereum-based blockchain platform "to make cash-based transfers faster, cheaper and more secure"[114] Using biometric registration data from the UN High Commissioner for Refugees (UNHCR) and authentication technologies, refugees can enjoy peer-to-peer financial assistance to purchase food from local supermarkets in the camp instead of cash, vouchers, or e-cards intermediated by local authorities.[115] Refugees can have more control over their identities and money under such an emergency circumstance. At the same time, the WFP can establish a full record of every transaction that occurs on the retailer's end and reduce transaction costs due to market inefficiency, corruption, and logistics. The 2018 annual report of the Regional Refugee and Resilience Plan (3RP, a collaboration between the UNHCR, Member States, and non-governmental organizations in response to the impact of the Syria Crisis in Turkey, Lebanon, Jordan, Egypt, and Iraq)

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[108] *See* Roger Aitken, *IBM & Walmart Launching Blockchain Food Safety Alliance in China with Fortune 500's JD.com*, FORBES (Dec. 14, 2017, 12:04 PM), https://www.forbes.com/sites/rogeraitken/2017/12/14/ibm-walmart-launching-blockchain-food-safety-alliance-in-china-with-fortune-500s-jd-com/#14e5ace07d9c [https://perma.cc/3NZ2-P5XZ].

[109] Berti & Semprebon, *supra* note 107, at 529–31.

[110] *Id.* at 530.

[111] *Id.* at 531.

[112] *See Blockchain Against Hunger: Harnessing Technology in Support of Syrian Refugees*, UNITED NATIONS WORLD FOOD PROGRAMME (May 30, 2017), https://www.wfp.org/news/blockchain-against-hunger-harnessing-technology-support-syrian-refugees [https://perma.cc/F9UD-GBS5].

[113] *Id.*

[114] *Id.*

[115] *Id.*

cites the success of the Building Blocks pilot project and how blockchain technology has enabled the WFP to assist in a more efficient and economical manner.[116]

Such initiatives have the potential to be generalized to help retailers and consumers pinpoint sources of contamination at times of outbreaks or provide production details and quality certifications (e.g., product origin, farm history, processing and shipping information, and fair trade or safety/sustainability standards). Blockchains can also be combined with smart contract systems or other AI techniques to increase efficiency, simplify transactions, ensure compliance and security, and promote trade facilitation across borders.

IV. BLOCKCHAINIZING FOOD LAW? A CLOSER EXAMINATION OF THE "CODE AS LAW" PROMISE AND ITS LIMITS

Blockchain holds the potential to serve as an effective and efficient governance tool in the global agri-food sector. As demonstrated above, there have been successful cases in which blockchain seems to have provided sufficient solutions to the regulatory problems of food safety, traceability, authenticity, and sustainability, at least in part. In this vein, the promises of blockchainizing food law rest upon the "code as law" ideas in the scholarship of law and regulation, especially in the context of cyberspace.[117] Before we have a closer examination of the promise of "code as law," however, a caveat should be noted: The cases discussed in this Article are still at an early stage of development and application as industry pilots rather than comprehensive application across the board.

Applying blockchain technologies as a regulatory tool to address problems of food safety, traceability, authenticity, and sustainability is premised upon the "code as law" approach, one of the many modalities of regulation including command and control rules, social norms, industry standards, market and architecture, and computer codes.[118] Indeed, technology can be "regulatory" and compliance-driven through different mechanisms to make "regulation [a] sustained and focused attempt to alter the behavior of others according to defined standards or purposes to produce a broadly identified outcome or outcomes, which may involve mechanisms of standard-setting, information-gathering[,] and behavior-modification."[119] Just as information and telecommunication technology can force compliance by building in automatic braking

[116] *See 2018 Annual Report, 3RP—Regional Refugee & Resilience Plan in Response to the Syria Crisis*, 3RP (2019), https://data2.unhcr.org/en/documents/download/68557 (last visited February 29, 2020) [https://perma.cc/YHD4-B7FG].

[117] *See generally* LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE (1999). Lawrence Lessig was the first legal scholar to articulate these ideas in the areas of law and regulation in the cyberspace and beyond.

[118] *See generally* Julia Black, *Critical Reflections on Regulation*, 27 AUSTL. J. LEGAL PHIL. 1 (2002).

[119] *Id.* at 26.

at stop signs for self-driving cars,[120] blockchain can *de facto* shape what is permissive, possible, prohibited, or impossible.[121]

Indeed, blockchain's key features mean that food processes and production information can be recorded in a database that ensures traceability, immutability, and transparency. Agri-food information stored on the blockchain is basically tamperproof, which increases the rate of detection and reduces the incentive to adulterate food or engage in fraud. Data traceability allows for better regulatory control, as competent authorities can trace and identify every registered action from farm to fork (e.g., livestock input, use of fertilizer or pesticide, irrigation, veterinary practices, processing, transportation, storage, etc.),[122] as well as stronger deterrence against food safety violations and fraudulent conduct.[123] The technology's peer-to-peer distributed structure also allows for greater economic and financial inclusion—under certain circumstances, small and medium players can participate without facing formidable financial, technical, and trust-related barriers that prevent them from taking advantage of the market.[124] Further, the disintermediation of data storage and "trustless trust" may lower uncertainty between buyers and sellers,[125] reduce transaction costs, and promote sustainable management and development.[126] Information asymmetry can also be alleviated through blockchain systems to foster greater consumer trust. Such trust toward the food supply chain can also be enjoyed by producers and retailers, as there is greater information transparency and credibility in the ecosystem. Some commentators even argue that blockchain holds the potential to "provide[] the agri-food market a trustworthy framework to store every passage of the production and distribution chain."[127]

Despite blockchain's "code as law" promise, there are formidable challenges that may prevent successful implementation of such a technical fix on the ground. As

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[120] *See* Lyria Bennet Moses & Monika Zalnieriute, *Law and Technology in the Dimension of Time*, *in* TIME, LAW AND CHANGE: AN INTERDISCIPLINARY STUDY (Sofia Ranchordás & Yaniv Roznai eds., forthcoming 2020) (manuscript at 8), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3461408 [https://perma.cc/EHU7-J8EW].

[121] Similar approaches (albeit in different conceptual lenses) include "compliance by design," "compliance through design," "design-based regulation," "RegTech," and "privacy by design." *See id*; *see also* Michael M. Piri, *The Changing Landscapes of FinTech and RegTech: Why the United States Should Create a Federal Regulatory Sandbox*, 2 BUS. & FIN. L. REV. 233, 237–240 (2018) (discussing RegTech); Dirk A. Zetzche et al., *From FinTech to TechFin: The Regulatory Challenges of Data-Driven Finance*, 14 N.Y.U. J. L. & BUS. 393, 399–405 (2018) (same).

[122] *See* Tripoli & Schmidhuber, *supra* note 55, at 7.

[123] Blockchain's immutability potential can ensure that "a digital file, register, certificate of ethical production, photo or video, etc. is still the same as it was when it was first registered in the blockchain," as the technology makes agri-food processing and production data "impossible, or at least very hard, to manipulate." FUTURE, *supra* note 41, at 25–26.

[124] However, as argued below, blockchain might price some SMEs out of the market, as have other advances in food safety, which will likely become a difficult tradeoff.

[125] *See generally* Kevin Werbach, *Trust, But Verify: Why the Blockchain Needs the Law*, 33 BERKELEY TECH. L.J. 487, 498, 549 (2018).

[126] While the scholarly and practical discourse on how disintermediation may lower uncertainty exceeds the scope of this Article, it is worth noting that some intermediaries are designed to lower uncertainty and work well too. For a thorough discussion on the advantages and disadvantages of different forms of intermediation, see Timothy D. Lytton, *The Taming of the Stew: Regulatory Intermediaries in Food Safety Governance*, 670 ANNALS AM. ACAD. OF POL. & SOC. SCI. 78 (2017).

[127] Berti & Semprebon, *supra* note 107, at 529.

analyzed below, while it remains to be seen what problems such pilot projects have encountered as well as what models are likely to be more successful than others and why, a number of challenges such as scaling up, data protection and cybersecurity risks, standardization politics, technical capacity gap, and inherent technological limits are already salient.[128]

A. Capacity Gap Problem: Operational Knowledge and Technical Expertise

First, while blockchain technologies are relatively accessible to business actors due to the high penetration rate of the Internet,[129] stable Internet service is neither available nor affordable in many corners of the developing world,[130] where the primary industry is food and agriculture. It is noted that the future diffusion of blockchain technologies in developing countries may be limited due to the lack of adequate infrastructural support. In particular, network infrastructures for public-key applications pose a formidable obstacle.[131]

There are also significant barriers to implementation due to deficits of operational knowledge and technical expertise among individual actors, especially for small companies in the food industry that follow conventional practice. It is true that for end-market players, taking advantage of blockchain primarily involves an application on a smartphone, but upstream suppliers will need "digital skills" to access data and navigate applications. Therefore, inadequate operational knowledge and technical expertise will be an obstacle to adoption, especially for small and medium players.[132] Effective use of blockchain in the global agri-food supply chain requires operational knowledge about other technologies, such as network management, smart sensors, biosensors, and the Internet of Things (IoTs).

Many businesses in different parts of the agri-food sector have yet to "digitize" supply chain management and record-keeping, not to mention obtaining technical expertise about all of the relevant technologies to link physical food products to various blockchain data. As it is crucial for all participants at all stages to get on the blockchain for the system to ensure comprehensive transparency and traceability,[133] the uneven capacity of different entities (at different nodes of the global supply chain, in different countries, of different sizes, and with different technical backgrounds) underscores just how diverse and fragmented the agri-food industry is. This capacity problem will only become graver as the scope of application expands, especially when

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[128] The actual success on the ground depends on the nature of different subsectors with many different kinds of people working in different types of firms. The role of regulatory culture and economic incentives in supporting consistent data collection and entry routines along the supply chain are also relevant factors.

[129] *See* Ching-Fu Lin & Han-Wei Liu, *Disruptive Technologies and Sustainable Development: Implications for Southeast Asia*, *in* PROGRAMME ON INCLUSIVE ECONOMIC TRANSFORMATION 7–8 (2018).

[130] INT'L TELECOMM. UNION (ITU), ICT FACTS AND FIGURES 2017 (July 2017), https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf [https://perma.cc/SCY6-FTDT].

[131] *See* RAUL ZAMBRANO, INT'L DEV. RESEARCH CTR., BLOCKCHAIN: UNPACKING THE DISRUPTIVE POTENTIAL OF BLOCKCHAIN TECHNOLOGY FOR HUMAN DEVELOPMENT 9, 12 (2017).

[132] Tripoli & Schmidhuber, *supra* note 55, at 22.

[133] *See* Janette Barnard, *The Missing Link in the Food Chain: Blockchain*, DECISIONNEXT (2016), https://resources.decisionnext.com/hubfs/PDFs/missing-link-food-chain-blockchain.pdf [https://perma.cc/K8S3].

"little has so far been done to push this still immature technology."[134] Capacity building and technical assistance at different levels will be of crucial importance.[135] Leaving this capacity challenge unaddressed may lead to greater marginalization among small and medium companies in the agri-food industry.

B. Implementation Burdens and Standardization Costs

Second, the implementation and standardization costs for blockchainizing food law are rather unpredictable and will constitute formidable legal and policy barriers. As we are still at an early and immature phase in terms of applying the blockchain to the global agri-food supply chain, the overall cost of implementing relevant technologies remains difficult to estimate.[136] Further, technically speaking, "the evolution of DLTs has led to the development of both public and private DLTs, which use different consensus algorithms to validate data entries. Current development efforts are implementing a wide range of different consensus mechanisms and types of DLTs."[137] Existing systems are like silos based on different blockchain technologies, data, and organizations, and companies usually have limited incentive to work together or share confidential information with potential competitors. The participation of new (types of) players, from the tech sector to the broad field of business, will further complicate the dynamics and the structures of interactions. There may be issues regarding conflicts and repetition between different private standards, as well as divergences in existing legal frameworks governing such disruptive innovations, which will, in turn, lead to market barriers or other trade frictions.[138]

From an information management perspective, the promise of blockchain as a technology solution for a governance framework, in particular, traceability mechanisms, "requires a well-organized and standardized supply chain between all (internal and external) actors."[139] Practically speaking, the types of blockchain technologies and data structures must be clearly and consistently defined first before automating processes kickstart.[140] At the cross-border level, discussion of whether and how to harmonize rules and standards about the interoperability of blockchain systems across relevant sectors will likely surface and will call for public-private governance dialogues. Some have argued that the agri-food industry should work together with the technology industry to develop best practices and standards for the application of

[134] Galvez et al., *supra* note 87, at 223.

[135] *See generally* Mengyi Wang & Ching-Fu Lin, *supra* note 8.

[136] *See generally* Tsotetsi Makong & Thokozani Ngwira, *Trade Related Capacity Building Measures in African LDCs and the Paradox of the Efficiency-Effectiveness Dichotomy*, *in* BUILDING LEGAL CAPACITY FOR A MORE INCLUSIVE GLOBALIZATION: BARRIERS TO AND BEST PRACTICES FOR INTEGRATING DEVELOPING COUNTRIES INTO GLOBAL ECONOMIC REGULATION 225, 229–32.

[137] Tripoli & Schmidhuber, *supra* note 55, at 21.

[138] *See generally* CORPORATE POWER IN GLOBAL AGRIFOOD GOVERNANCE (Jennifer Clapp & Doric Fuchs eds., 2009); Lin, *supra* note 65; Denise Prévost, *Private Sector Food-Safety Standards and the SPS Agreement: Challenges and Possibilities*, 33 S. AFR. Y.B. INT'L L. 1 (2008).

[139] Kay Behnke & M.F.W.H.A. Janssen, *Boundary Conditions for Traceability in Food Supply Chains Using Blockchain Technology*, INT'L J. INFO. MGMT. (forthcoming 2019) (manuscript at 9), https://doi.org/10.1016/j.ijinfomgt.2019.05.025 [https://perma.cc/YL4S-BAGC]. "Data governance cannot be defined by partners of one Blockchain initiative alone, but requires agreement on sector if not even on industry level. Otherwise, suppliers will have to comply to different interface standards which makes Blockchain technology from an economical point of view inefficient." *Id.*

[140] *Id.*

blockchain to the agri-food sector on a global scale.[141] In this regard, the growing use of and reference to the GS1 standards as industry best practices for identifying products, locations, processes, and assets as well as for structuring data and digital infrastructure regarding the global movement of goods may serve as common bases.[142]

C. *Cybersecurity and Data Protection*

Third, many commentators have pointed out the risks to cybersecurity and data protection that are generally applicable to blockchain technologies, and the agri-food sector is not immune from these. As shown by the recent discussion on cyber-attacks and threats to cryptocurrencies,[143] insufficient cybersecurity or weak data protection can lead to huge losses to blockchain users. Indeed, cybersecurity risks must be addressed to ensure data integrity, promote user trust, prevent breaches of private information, and avoid economic losses.

Certainly, market transactions include some types of confidential information that need to be protected, such as personal data and business know-how. There are also other types of information that should be made available for public knowledge to foster consumer confidence and market reliability. A related and more nuanced question, therefore, concerns the proper balance between what types of data should be publicized and what types are best kept private as business secrets. This question "depend[s] on the rules of the DLT that are based on, the purpose of the platform, as well as the preferences of the users."[144] Such choices further call for different plans at different levels to ensure cybersecurity. Currently, what constitutes best practices and methodologies is contingent upon the future development of blockchain technologies, which are still evolving.

D. *Inherent Limits of Blockchain*

There are a number of inherent limits related to the technological nature of blockchain (and how it works). While ensuring food safety, authenticity, and traceability through blockchain seems promising, the integrity of the system when applied to the agri-food sector (vis-à-vis the case of cryptocurrency) should not be taken for granted. Any data, once input onto the blockchain, are generally immutable, as noted above. However, there does not exist a verification mechanism to ensure that the process of "inputting" the data itself is free from mistakes, adulteration, or manipulation.[145] For example, if a company or an employee tampers with the

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[141] Michael J. Casey & Pindar Wong, *Global Supply Chains Are About to Get Better, Thanks to Blockchain*, HARV. BUS. REV. (Mar. 13, 2017), https://hbr.org/2017/03/global-supply-chains-are-about-to-get-better-thanks-to-blockchain [https://perma.cc/3CG3-7GJ3].

[142] *See* GS1 AISBL, *Bridging Blockchains: Interoperability Is Essential to the Future of Data Sharing* (2018), https://www.gs1.org/sites/default/files/bridging_blockchains_-_interoperability_is_essential_to_the_future_of_da.pdf [https://perma.cc/QL24-72TT].

[143] *See, e.g.*, Luke Fitzpatrick, *A Hacker's Take on Blockchain Security*, FORBES (Feb. 4, 2019), https://www.forbes.com/sites/lukefitzpatrick/2019/02/04/a-hackers-take-on-blockchain-security/#2246f27e4334 [https://perma.cc/JH7T-NEGA]; Arthur Herman, *Why Blockchain Is No Silver Bullet for Cyber Threats*, FORBES (Oct. 2, 2018), https://www.forbes.com/sites/arthurherman/2018/10/02/why-blockchain-is-no-silver-bullet-for-cyber-threats/#7e47d757343c [https://perma.cc/XMD7-ZXKD].

[144] Tripoli & Schmidhuber, *supra* note 55, at 21.

[145] *See* Galvez et al., *supra* note 87, at 230.

production details in the first place or manipulates a sensor, such adulterated information will also be "immutable" on the blockchain without being detected.

For private blockchains, such as the Walmart application, the company that holds authority and control over the entire system can alter raw information (which may be noticed by members of the private blockchain) or simply shut down the system.[146] This concept is noted as the "garbage in, garbage out" problem that applies to some DLT systems, as the use of blockchain technology *per se* does not stop fraudulent data being entered.[147] Therefore, how to ensure accountability in such cases to avoid so-called "second layer information asymmetry"[148] is of crucial importance when we delegate the trust business to machines[149] (or, as argued by Andreas Antonopoulos, a "shift from trusting people to trusting math"[150]). Would there still be a need to place auditors on blockchains, and if so, how? Identifying the optimal institutional design to minimize human error (and corruption) in linking physical product details with blockchain digital information constitutes a significant governance challenge.

Last but not least, existing blockchain systems seem to be able to operate only at a relatively low capacity. Indeed, blockchain faces a serious "scalability problem."[151] For instance, systems such as Bitcoin and Ethereum can process around ten transactions per second, while conventional systems such as Visa or Mastercard can, on average, process around 5,000 to 8,000 transactions per second.[152] This perhaps explains why the current blockchain systems in the agri-food sector are rather limited to a single product category or raw material. Further, just like other blockchain-based systems, energy and physical space consumption remains a crucial issue for effective and efficient implementation.[153] The move towards "cloud-based" blockchain systems may serve as a solution that reduces the use of energy and physical space, yet it requires considerable time and investment to go forward. How much information can be input, stored, processed, and shared on blockchain systems at a reasonable cost will largely determine its place in the agri-food sector. The capacity and scalability problem would need to be addressed for the broader application of blockchain technologies.

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[146] Berti & Semprebon, *supra* note 107, at 530.

[147] *See* MICHÈLE FINCK, BLOCKCHAIN REGULATION AND GOVERNANCE IN EUROPE 163 (2018).

[148] *See generally* Ching-Fu Lin, *Challenges to Third-Party Food Safety Audits and Certification*, HARV. L. BILL OF HEALTH (Dec. 5, 2013), https://blog.petrieflom.law.harvard.edu/2013/12/05/challenges-to-third-party-food-safety-audits-and-certification-2/ [https://perma.cc/QBU9-DZZU].

[149] *See The Promise of Blockchain*: *The Trust Machine*, THE ECONOMIST (Oct. 31, 2015).

[150] Andreas Antonopoulos, *Bitcoin Security Model: Trust by Computation*, O'REILLY RADAR (Feb. 20, 2014), http://radar.oreilly.com/2014/02/bitcoin-security-model-trust-by-computation.html [https://perma.cc/X8BR-2YAQ].

[151] Kenny Li, *The Blockchain Scalability Problem & the Race for Visa-Like Transaction Speed*, HACKERNOON (Jan. 31, 2019), https://hackernoon.com/the-blockchain-scalability-problem-the-race-for-visa-like-transaction-speed-5cce48f9d44 [https://perma.cc/6DRF-7BDX].

[152] Ciaian, *supra* note 77.

[153] *See* Davit Babayan, *Bitcoin's Energy Consumption Equalled That of Hungary in 2018*, NEWS BTC (Mar. 14, 2019), https://www.newsbtc.com/2019/03/14/bitcoins-energy-consumption-equalled-that-of-hungary-in-2018/ [https://perma.cc/J74U-EXHB]. *But see* Steven Huckle, *Bitcoin's High Energy Consumption Is a Concern—But It May Be a Price Worth Paying*, THE CONVERSATION (Nov. 7, 2018), http://theconversation.com/bitcoins-high-energy-consumption-is-a-concern-but-it-may-be-a-price-worth-paying-106282 [https://perma.cc/JVD9-YS8B].

V. CONCLUSION

As the global agri-food supply chain has been rapidly changing and expanding, there seems to be a need to innovate governance tools by leveraging disruptive technologies. The most recent statements from the FDA Commissioner and Deputy Commissioner (who piloted blockchain at Walmart before serving at FDA) also underlined "emerging track and trace technologies that can assist response efforts to allow FDA to intervene in time to alert consumers, implement recalls, and avoid human illnesses . . . includ[ing] blockchain technology."[154] In the area of drug regulation, FDA has successfully launched a pilot program that leverages blockchain technology to execute the agency's duty under the Drug Supply Chain Security Act (DSCSA) to establish a track-and-trace system for medicines by 2023.[155] In the food sector, FDA held a public meeting with a broad range of stakeholders on a new approach—"A New Era of Smarter Food Safety" on October 21, 2019 as part of the agency's ongoing efforts to implement FSMA.[156] This multi-stakeholder deliberation process may help identify legal barriers to the use of this technology (such as concerns over data protection, standardization, and technological limits) and how food law and regulation should be changed in the future. At this moment, FDA aims to adopt this modern approach to addressing issues such as "trac[ing] sources of contaminated foods and using new predictive analytics tools like artificial intelligence to assess risks and prioritize the agency's work and resources" towards a "more digital, traceable, and safer system to help protect consumers from contaminated food."[157] With the support of the President's 2020 budget that brings in resources to modernize FDA's food safety governance efforts, it is possible that blockchain can play an important role in the transparency and traceability mechanisms of the nation's food law.[158] Governments might also embrace such an approach to regulatory technology in other jurisdictions through technical assistance, mutual learning, and trans-governmental cooperation that ease some of the obstacles identified above.

Although there has been support for the application of blockchain to the global supply chain to deliver enhanced transparency, traceability, safety, and authenticity,

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[154] *Statement from FDA Commissioner Scott Gottlieb, M.D., and Deputy Commissioner Frank Yiannas on New Steps to Strengthen FDA's Food Safety Program for 2020 and Beyond*, U.S. FOOD & DRUG ADMIN. (Mar. 19, 2019), https://www.fda.gov/news-events/press-announcements/statement-fda-commissioner-scott-gottlieb-md-and-deputy-commissioner-frank-yiannas-new-steps [https://perma.cc/9XB8-SXP6]; *see also Statement from Acting FDA Commissioner Ned Sharpless, M.D., and Deputy Commissioner Frank Yiannas on Steps to Usher the U.S. into a New Era of Smarter Food Safety*, U.S. FOOD & DRUG ADMIN. (Apr. 30, 2019), https://www.fda.gov/news-events/press-announcements/statement-acting-fda-commissioner-ned-sharpless-md-and-deputy-commissioner-frank-yiannas-steps-usher [https://perma.cc/4W8P-FM8F].

[155] *See FDA Takes New Steps to Adopt More Modern Technologies for Improving the Security of the Drug Supply Chain through Innovations that Improve Tracking and Tracing of Medicines*, U.S. FOOD & DRUG ADMIN. (Feb 7, 2019), https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm630942.htm [https://perma.cc/5XQW-Z8GU].

[156] A New Era of Smarter Food Safety, 84 Fed. Reg. 49,111 (Sep. 18, 2019).

[157] *FDA Announces Public Meeting to Discuss the New Era of Smarter Food Safety*, U.S. FOOD & DRUG ADMIN. (Sep. 17, 2019), https://www.fda.gov/food/cfsan-constituent-updates/fda-announces-public-meeting-discuss-new-era-smarter-food-safety?sfns=mo [https://perma.cc/6C6A-7V5K].

[158] While sufficient resources are of significant importance to the FDA's food safety regulation, it should be noted that budgetary allocation is not always tied to effective outcomes, which also depend on many other factors.

to comply with regulatory requirements, and to gain consumer trust,[159] the technology does not come without shortcomings. Blockchains can introduce data transparency, traceability, and immutability to help address information-oriented issues in the traditional, manual, and labor-intensive sectors. Yet, as argued above, there are also problems regarding operational knowledge and technical expertise, implementation and standardization costs, cybersecurity and data protection, and the inherent limits of the technology—which may adversely impact the effectiveness and the efficiency of this new governance tool.

How do we fix the challenges posed by this "technical fix" when we shift toward the new trust machine and blockchainizing food law? Preliminary thoughts include the following. At a certain level, to scale up the existing pilot programs and implement blockchain technologies to make the global agri-food supply chain "smarter," diverse participants must work on a minimal level of digitalization in order to take advantage of blockchain technologies. Governments may also need to provide infrastructural or research and development (R&D) support to reduce implementation costs (particularly in areas with fewer resources) and scalability problems. It is crucial that such infrastructural support and R&D investment address priority areas identified through a public-private, multi-stakeholder decision-making process. The "code as law" promise of blockchainizing food law inevitably relies on an adequate level of data integrity and digital infrastructure in the industry, which allows computer codes to discipline interactions and shape behaviors in cyberspace in a potentially more influential manner than traditional law and regulation.[160] In the long (and perhaps more futuristic) term, as argued by Yochai Benkler, there may be further development of ways in which networked information infrastructure facilitates broad communication and diverse cooperative mechanisms in the agri-food sector and beyond.[161] In this sense, the role that blockchain technologies can play in the regulatory system extend well beyond computer codes and may include other hybrid forms of rules to operate as autonomous normative systems. In the agri-food sector and beyond, law enforcement practices will continue to change alongside rapid technological advancement, and the use of technologies—such as blockchain—as well as the data and digital infrastructure they generate will become an integral part of law enforcement.

In the cross-border context, harmonization and interoperability of standards set by both public and private institutions are of significant importance. Harmonization is likely one of the most daunting tasks (especially in the North-South and South-South context) given the extremely diverse social, economic, political, and culinary underpinnings of different jurisdictions. Institutional and industry culture may also play a role in promoting reliable use of technology to strengthen food safety oversight and consumer trust.[162] Collaborative actions may need to be taken by international organizations and/or other stakeholders, paying due attention to the distributional

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[159] *See, e.g.*, Casey & Wong, *supra* note 141.

[160] *See generally* LESSIG, *supra* note 117.

[161] *See* YOCHAI BENKLER, THE WEALTH OF NETWORKS: HOW SOCIAL PRODUCTION TRANSFORMS MARKET AND FREEDOM 130, 133, 138–40, 271–72, 385 (2006).

[162] *See generally* TIMOTHY D. LYTTON, KOSHER: PRIVATE REGULATION IN THE AGE OF INDUSTRIAL FOOD (2013); FRANK YIANNAS, FOOD SAFETY CULTURE: CREATING A BEHAVIOR-BASED FOOD SAFETY MANAGEMENT SYSTEM (2008).

justice and sustainable development dimensions to ensure that most market players benefit from the productivity gains. At the same time, there are some inherent limits to the technology as a technical fix, and these call for additional governance methods as gatekeepers to ensure accountability. All in all, cooperation and dialogue between public and private institutions at various levels and sectors in the agri-food industry will help to create a better regulatory environment for blockchainizing food law.