The Economics of Blockchain-Based Supply Chain Traceability in Developing Countries

Nir Kshetri, University of North Carolina at Greensboro

Shirking, cheating, and other misbehaviors are pervasive in many developing countries, increasing the costs of economic exchanges. Blockchain-based solutions may address these problems and help developing world–based economic actors to engage in exchange relationships.

According to The Netherlands-based market intelligence platform Blockdata, traceability and provenance constituted the most popular blockchain use case among the world's biggest brands in 2020.[1] This use case of blockchain is especially important in developing countries, where most serious environmental, social, and governance issues can be found.[2] Vulnerable smallholder farmers who grow subsistence and cash crops and workers in artisanal and small-scale mines (ASMs) in these countries are often exploited by powerful supply chain actors.

Due to social issues such as human rights violations and environmental injustice, some developing countries have lost the trust of developed world-based multinational enterprises.[3] To take an example, until 2019, the German manufacturer of luxury automobiles BMW sourced its cobalt needs from many countries, including the Democratic Republic of the Congo (DRC). In 2019, BMW announced its plans to avoid the DRC and source cobalt from Morocco and Australia instead, starting in 2020, for the production of electric vehicles. BMW's decision to avoid cobalt from the DRC was based on several factors, including sustainability.[4] Due to

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EDITOR **NIR KSHETRI**
University of North Carolina at Greensboro;
nbkshetr@uncg.edu

the weak rules of law, ineffective and corrupt law enforcement, and inefficient judiciary systems, many actors shirk, cheat, and engage in opportunistic behavior with impunity in countries such as the DRC.

Blockchain-based solutions have the potential to address these types of problems and help developing world-based economic actors engage in exchange relationships. Sustainability-related indicators can be measured with emerging technologies such as artificial intelligence (AI) and machine vision, using data from Internet of Things devices, remote sensing satellites, and other sources. Blockchain can help establish the authenticity of measurement data. Blockchain-based smart contracts, which execute automatically when certain conditions are met, can address some of the deficiencies of existing problems associated with contract laws and their enforcement in these countries. All of these features can increase efficiency and help developing world-based economic actors to build and gain the trust of the counterparties in economic transactions.

In light of these considerations, in this article, we look at how blockchain can help developing world-based economic actors engage in exchange relationships. We illustrate this by considering several blockchain-based traceability solutions implemented in developing countries.

BLOCKCHAIN-BASED SOLUTIONS' EFFECTS ON THE COSTS OF EXCHANGE

Among the key factors that influence the costs of exchange are 1) the costs of measuring and 2) the costs of enforcement.[5] Regarding 1), measuring the dimensions and attributes of the goods and services being exchanged or the performance of agents is not an easy task.[5] Blockchain-based traceability systems can provide new methods for accurate measurements to describe precisely what the parties engaged in a transaction are exchanging and what performance characteristics can be expected.

Regarding 2), in a society characterized by perfect contract enforcement, a neutral third party impartially evaluates disputes and awards compensation to the party affected by a violation. In such a situation, opportunism, shirking, and cheating are not attractive options. However, the real world is far from ideal. The high costs of measurement often make it difficult to determine if a contract has been violated and, if so, who violated it. Many developing economies have a weak rule of law and lack well-developed court systems and state's coercive power to enforce judgments. It is difficult to employ complex contracting as a formal governance tool.

Several blockchain solutions have been launched that have the potential to address measurement and enforcement issues. In Table 1, we look at the effects of blockchain-based traceability systems on the costs of measuring and enforcement.

MEASURING

In the previous BMW example, the company's decision not to source cobalt from the DRC was due to the difficulty in determining whether the mining companies' practices were sustainable. Nongovernmental organizations and activists are promoting corporate social responsibility by naming and shaming companies that are responsible, knowingly or unknowingly, for human rights violations and child abuse.

Some blockchain-based traceability solutions have been launched to

TABLE 1. The effects of blockchain-based traceability systems on measuring and enforcement.

Effect	Explanation	Examples
Facilitating measurements	Measure the attributes of goods and services/performance of agents that otherwise cannot be measured	Circulor's system captures data related to cobalt's origin, attributes, and supply chain participants' actions
Lowering costs of measurement	By automating, costs of measuring can be reduced	In the solutions of Circulor, Bext360, and BlocRice, costs to small commodity producers are lower than the alternatives
Increasing accuracy of measurement	In many cases, compared to humans, machines can provide more accurate and objective measurements of the attributes of goods and services or the performance of agents	Bextmachines use machine vision and AI to analyze coffee cherries and coffee parchment
Strengthening contract enforcement with transparency and documentary evidence	A higher degree of authenticity can be achieved in documentary evidence, such as contract documents, which can make contract enforcement more effective and less costly	eMin tool to benefit migrant workers in the seafood industry Parties in BlocRice's contract include organic farmers and rice exporters in Cambodia and buyers in The Netherlands.

address measurement challenges in the context of sustainability practices in developing countries. With such solutions, it is possible to measure the attributes of goods and services or the performance of agents that otherwise cannot be measured and establish the authenticity of measurement data.

The U.K.-based traceability-as-a-service provider Circulor operates a blockchain platform to monitor cobalt from the DRC used in electric vehicle batteries.[6] Circulor combines blockchain with AI to perform due diligence, detect data anomalies, and identify actions that may need additional investigation. The data captured include the cobalt's origin, attributes (for example, weight and size), the chain of custody, and information to establish supply chain participants' compliance with globally recognized guidelines.[7]

In July 2020, Volvo Cars' venture capital investment arm Volvo Cars Tech Fund teamed up with other investors to further develop Circulor's traceability system.[8] The new funding was intended to train and improve Circulor's machine learning models to distinguish between children and adults working in the mines with a high level of accuracy, using the data obtained from aerial imagery of mining.[9]

Also, some blockchain-based solutions are more affordable than alternative technologies used in establishing and demonstrating supply chain traceability. Table 2 presents three such solutions. For instance, the International Tin Industry Association Tin Supply Chain Initiative's (ITSCI's) bagging and tagging system is an established traceability program, which was started in response to the Dodd–Frank Wall Street Reform and Consumer Protection Act, which requires U.S. companies to vet their supply chains.[10] Countries that are covered under this legislation include South Sudan, Uganda, Rwanda, Burundi, Tanzania, Malawi, Zambia, Angola, Congo, the Central African Republic, and the DRC. The ITSCI does not use blockchain. Complaining about the high costs of the ITSCI at a 2019 mining forum in Kigali, Rwanda, the chief executive officer of Rwanda Mines, Petroleum and Gas Board, demanded that "the cost of traceability and due diligence must be reduced to make it affordable and fair."[11] An ASM producing 0.5 ton per month is required to pay US$780–1,080/year to use ITSCI traceability. Circulor has said that its system will change the business models of ASMs by shifting traceability costs from miners to end users.[12] Its mobile app is free for small companies, whereas companies further up the supply chain pay and use more complicated interfaces.[13]

Some blockchain-based traceability systems automate measurements. Such systems replace labor-intensive activities, such as physical inspection and paper work, which can reduce the costs of measuring. In the coffee industry, such audit tasks are performed by intermediaries such as certification agencies, which are estimated to cost as high as US$0.91 per pound of coffee.[14] For instance, in the agriculture sector, a key role of middlemen is to reduce the measurement cost problem.[15] Middlemen are more likely to visit the farm during cultivation and harvest compared to urban wholesalers and bigger traders.[16]

An example of a company providing a blockchain-based traceability system that has eliminated labor-intensive audit tasks is Denver, Colorado, based startup Bext360. Its kiosks in Uganda and Ethiopia evaluate coffee beans using a Coinstar-like device known as a *bextmachine*, which employs smart image recognition technology machine vision, AI, and blockchain to grade and track coffee beans. Bext360's systems store data related to the time, date, and location of transactions and the amount paid. The systems also record indicators related to sustainable sourcing and satellite images to determine if producers are polluting water.[17]

As another example, in 2018, the charitable organization Oxfam launched the Blockchain for Livelihoods From Organic Cambodian Rice (BlocRice) project in Cambodia. It uses blockchain to improve Cambodian small-scale rice farmers' bargaining and negotiating power by storing relevant data on a blockchain system. BlocRice is arguably a lower cost social certification mechanism compared to alternatives such as FairTrade.[18]

Blockchain systems would allow for accurate and objective measurement of the attributes of the goods and services being exchanged or the performance of agents. This aspect is important because smallholder farmers often get paid low wages due to the subjective quality assessment by powerful value chain actors, such as middlemen and industrial buyers.[19] In the bextmachine example, machine vision and AI, rather than human beings, measure the quality of coffee. Bextmachines take a 3D scan of each bean's outer fruit to analyze coffee cherries and coffee parchment.[20] Farmers who supply bigger and riper cherries are paid more.

TABLE 2. Some blockchain solutions to trace/track commodities.

Blockchain solution	Implemented in	Commodities traced/tracked	Cost performance in relation to available alternatives
Circulor's platform	The DRC	Cobalt	ASMs do not pay for traceability
Bext360	Ethiopia and Uganda	Coffee	Because of automated processes, costs are lower than those of certification agencies
BlocRice	Cambodia	Rice	Lower costs compared to FairTrade

The bextmachines link the output to cryptotokens, which represent the coffee's value. New tokens are automatically created when the product passes through the supply chain. The values of tokens increase at each successive stage of the supply chain.[14]

ENFORCEMENT

Blockchain-based solutions can also help address human rights issues, such as slave labor and the exploitation of migrant workers. For instance, the marine fishing industry exhibits a high propensity to use "slave" or underpaid labor due to its huge size and the lack of enforcement mechanisms. Most of the workers in the Thai fishing industry are migrants from Cambodia and Myanmar. These workers are paid about 25% lower than the Thai minimum wage. They often sign a contract in their home country, but that changes when they arrive in Thailand.[21]

The blockchain solutions provider Diginex has been working with the International Organization for Migration and the antislavery organization the Mekong Club to ensure ethical recruitment of migrant workers by increasing the transparency of workers' contracts.[22] Its blockchain-based mobile app eMin stores copies of employment contracts for workers in the aquaculture sector.[21] Workers can access their contracts on the Ethereum blockchain, which can be used as a basis for claiming the rights and benefits offered when they were recruited.[21]

Likewise, in BlocRice, key parties involved in the contracts include agricultural cooperatives, organic farmers, and rice exporters in Cambodia and buyers based in The Netherlands. The term of the contract is that the exporter will pay farmers the market price plus a premium.[23] Such a condition would guarantee a market for the rice and reduce some uncertainties for farmers.[23] Each farmer receives a digital identity, which can be used to log onto a website to see details such as shipment weights and prices. The information is available in both Cambodian and English.[24]

ENABLERS AND INHIBITORS OF BLOCKCHAIN DEPLOYMENT IN DEVELOPING COUNTRIES

Many factors have facilitated the implementation of blockchain-based traceability systems in the developing world. Because of the increasing competition in the area of enterprise blockchain, there are several quick and easy options to develop blockchain projects in supply chains. For instance, enterprise blockchain solutions based on Hyperledger Fabric, which are used in Circulor's traceability system, are offered by a number of technology companies, such as IBM, Amazon Web Services, SAP, Oracle, and Microsoft. For instance, SAP provides Hyperledger Fabric on its cloud platform, and Microsoft offers this solution on Azure.[25] Companies do not need to worry about infrastructure, storage, and networking costs. A ready-made blockchain platform also has sharing, encryption, a consensus algorithm, and a peer-to-peer network.[25]

Such systems are becoming affordable, and their ease of use is improving. Using Circulor's system, for instance, small mining companies do not see an increase in their workload. The mobile app is easy to use.[26] Once the miners open the app, there are three buttons on the front page. A step-by-step process is presented by clicking "Start." The process begins with facial recognition. The next process involves the scanning of a tag to enter the details of minerals such as cobalt.[26]

Blockchain's future potential is even greater. For instance, blockchain-based smart contracts in combination with automated payments would be the game changer in the agriculture sector. Such systems can make it possible for small-scale farmers to be automatically paid when the produce is delivered.

Many challenges remain, however. First, a large proportion of populations living in rural areas in least developed countries (LDCs), which are low-income countries that perform poorly in human assets and face high economic vulnerability, lacks connectivity (Figure 1). The penetration rates of mobile devices such as smartphones are low

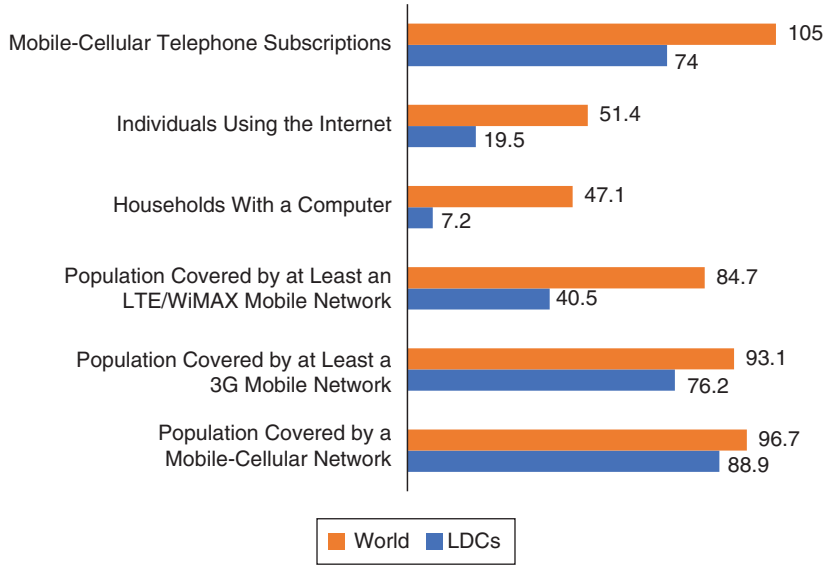

FIGURE 1. A comparison of connectivity indicators in LDCs and the world (in percentage of the population). Data for computer use and Internet use are for 2019. Others are for 2020. (Data source: International Telecommunications Union.)

in these countries. For instance, in 2019, only 10–20% of the farmers had smart phones in Cambodia.[13] These factors increase the costs of establishing and operating traceability systems. Some farmers are illiterate and thus cannot take advantage of blockchain-based traceability systems.

The implementation of smart contracts also requires high-quality data, such as those related to the weather. In the absence of such data, blockchain-based solutions such as BlocRice provide only a small improvement over the current alternatives. The availability of risk-sharing and risk-transfer mechanisms such as farm insurance is critical to improve the livelihood and development of farmers. In addition, the regulatory frameworks to support blockchain-based innovations such as smart contracts are lacking.

Blockchain-based solutions have been designed to measure sustainable practices, which would help reward responsible and ethical behaviors and penalize unethical and irresponsible ones. Such solutions can help economic actors in developing countries to engage in exchanges as well as reduce the costs of and maximize the benefits from an exchange relationship. Since a key role of middlemen in these countries is to reduce the measurement cost problem, automated measurements of blockchain-based traceability systems can eliminate intermediaries. This would allow economic actors with limited resources, such as smallholder farms and ASMs, to increase their incomes.

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NIR KSHETRI is a professor at the Bryan School of Business and Economics, the University of North Carolina at Greensboro, Greensboro, NC, 27412, USA, and the "Computing's Economics" column editor for *Computer*. Contact him at nbkshetr@uncg.edu.

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