DISTRIBUTED LEDGER TECHNOLOGIES FOR DEVELOPING ASIA

Benno Ferrarini, Julie Maupin, and Marthe Hinojales

NO. 533

December 2017

ADB ECONOMICS WORKING PAPER SERIES

ASIAN DEVELOPMENT BANK

ADB Economics Working Paper Series

Distributed Ledger Technologies for Developing Asia

Benno Ferrarini, Julie Maupin,
and Marthe Hinojales

No. 533 | December 2017

Benno Ferrarini (bferrarini@adb.org) is a senior economist at the Economic Research and Regional Cooperation Department (ERCD), Asian Development Bank (ADB). Julie Maupin (maupin@mpil.de) is a senior researcher at the Max-Planck Institute for Comparative Public Law and International Law in Heidelberg, Germany. She is also a senior fellow at the UCL Centre for Blockchain Technologies (London) and the Centre for International Governance Innovation (Waterloo), and is an advisor to the IOTA Foundation (Berlin). Marthe Hinojales (mhinojales@adb.org) is an economics officer at the ERCD, ADB.

ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org

ISSN 2313-6537 (Print), 2313-6545 (electronic)
Publication Stock No. WPS179184-2
DOI: http://dx.doi.org/10.22617/WPS179184-2

Notes:
In this publication, "$" refers to US dollars.
Corrigenda to ADB publications may be found at http://www.adb.org/publications/corrigenda.

CONTENTS

ABSTRACT

This paper takes a first pass at assessing areas of implementation for distributed ledger (or blockchain) technology in the context of development finance. It identifies five use cases, including digital identity, trade finance, project aid monitoring, smart energy, and supply chain management. A discussion of the main benefits, risks and implementation challenges suggests that experimentation with distributed ledger technology can produce immediate significant benefits in some areas, while others require further research and investment, as well as additional technical, infrastructural, or regulatory development. Development lenders can play a role in helping unleash these technologies' positive developmental impact throughout the Asian region.

Keywords: blockchain, developing Asia, distributed ledger technology, financial technology

JEL codes: G21, M13, O33

I. INTRODUCTION

Commercial banks and other financial institutions are adopting blockchain and distributed ledger technologies (DLTs) at a breathtaking speed and huge sums are being invested in research and development. More recently, national governments, international development banks, and aid agencies have started collaborating with technology firms to find out how to best leverage these technologies. Because DLTs are a new and rapidly evolving phenomenon, it can be difficult to cut through the hype and objectively evaluate the benefits and drawbacks of these exciting technologies.

This paper takes a first pass at assessing feasible areas of practical implementation for DLTs mainly in the context of development finance. In particular, we attempt to provide preliminary answers to the following questions:

(i) Where in a developing country context have DLTs been successfully applied and what are further areas for practical implementation in developing Asia?
(ii) What are the limitations of DLT implementation and what are the steps required to further their development for broader applicability?

To get at these questions, we identify five particular use cases and assess their implementation limits and potential. The DLT use cases described in section III have been selected for their potential to impact key areas of development finance and accelerate progress toward key objectives in commonly pursued projects, such as trade finance or the provision of legal identity to the poor. Without the ambition of comprehensiveness, the goal is to assess whether integrating DLT solutions might in some cases help achieve the goals of existing projects and processes in these areas.

Before turning to specific applications, the next section provides a gentle introduction to the concept of blockchains and other distributed ledger technologies. For a deeper and more precise insight, the reader should consult the sources indicated in footnotes as well as in the additional technical references section.

II. TYPES OF DISTRIBUTED LEDGER TECHNOLOGIES AND THEIR STRENGTHS AND WEAKNESSES

Blockchains and DLTs are shared ('distributed' or 'decentralized') digital ledgers that use cryptographic algorithms to verify the creation and transfer of digitally represented assets or information over a peer-to-peer network.[1] They operate via an innovative combination of distributed consensus protocols, cryptography and inbuilt economic incentives based on game theory. The digital asset 'native' to the first blockchain ever developed is the cryptocurrency known as Bitcoin—a nonstate form of digital money that went into circulation in 2009 and has since enjoyed considerable success.[2] Beyond nonstate cryptocurrencies, however, DLTs can also be used to represent, track, and trade many other types of assets and information, including:

(i) fiat (government-issued) money (Wild 2016);
(ii) stocks, bonds, derivatives and other financial products (DTCC 2016);

---

[1] This cursory introduction is intended for nontechnical readers and is adapted from Maupin (2017).
[2] For a technical explanation, see Nakamoto (2008). For nontechnical readers, Wikipedia's page on Bitcoin provides an accessible introduction (https://en.wikipedia.org/wiki/Bitcoin).

(iii) real and intellectual property rights (Shin 2016);
(iv) contract rights (Morrison 2016);
(v) the movement of goods and services across a global supply chain (Higgins 2016, Parker 2016a, 2016b);
(vi) the expenditure of public or private funds (Samburaj 2016, Parker 2016c);
(vii) personal and sensor-based data and messages;[3] and
(viii) the delivery of digital entitlements and digital identity to end-beneficiaries.[4]

DLTs can be set up in either public or private configurations, and they can be configured to accommodate greater or lesser degrees of user privacy. These and other design choices must be tailored to the specific goals pursued in each DLT use case. Broadly speaking, DLTs can be specified to exhibit certain innovative properties which make them a highly useful tool in structuring the global economy, for instance:

(i) *distributed consensus*—no central point of control or failure (no choke points or intermediaries),
(ii) *transaction transparency/auditability*—every ledger entry can be made verifiable and retraceable across its full history (accountability), and
(iii) *party identity abstraction*—individual parties can transact with one another across the network without revealing their full identities (enhanced privacy).[5]

It is thanks to these and other properties that DLTs are often called the Internet of Value. They allow individuals and organizations to exchange value (e.g., money, or assets, or monetized data streams) across borders in the same way the internet allows us to exchange simple information on a global, decentralized, peer-to-peer basis. And much like exchanging information on the internet, exchanging value on a distributed ledger can be fast and cheap—in some cases considerably faster and cheaper than the existing 'legacy' systems of our global financial order. This makes DLTs an attractive vehicle for accomplishing numerous economic and noneconomic objectives, as discussed in section III.

The structural properties of DLTs very much affect the technical feasibility of the applications that can be built on top of them. Understanding these structural features is therefore a necessary prerequisite to being able to evaluate potential DLT use cases in a meaningful way. DLTs come in four basic types:

(i) Public, permissionless blockchains. These are blockchains in which anyone can participate in principle. With a little bit of technical know-how and an internet enabled device, anyone can connect to the protocol and either transact over the blockchain ('users') or view the transactions taking place on the blockchain ('viewers'). Likewise, anyone with sufficient time and resources can devote computing power toward performing the mathematical computations that secure the network by grouping

[3] Some projects are collecting field data from Internet-of-Things (IoT) device sensors and using distributed ledgers to transmit the data and make them available for analysis via distributed data marketplaces. See, for example, IOTA Development Roadmap and Github Repository (https://blog.iota.org/iota-development-roadmap-74741f37ed01) and Masked Authenticated Messaging (https://github.com/iotaledger/MAM.ixi).
[4] For example, AID:Tech (https://aid.technology/) pioneered the delivery of international aid to Syrian refugees in Lebanon using blockchain technology.
[5] These and other characteristics are explained in DTCC Connection (2016).

transactions into a chain of tamper-proof blocks at regular intervals ('miners').[6] As a reward for performing these computations, the most efficient miners regularly receive new units of the blockchain's native token (e.g., Bitcoins on the Bitcoin blockchain, or Ether on the Ethereum blockchain) (Nakamoto 2008, Buterin 2015). The protocol code is open source, and decisions on changes to the code are adopted by majority consensus. In short, there are no formal barriers to the entry, use, or viewing of a public, permissionless blockchain.

Strengths. Ease of use and right of access are major advantages of public, permissionless blockchains. These chains also tend to be relatively secure, thanks to the large amounts of energy and computing power devoted by financially motivated miners to maintaining the security of the network. As open-source protocols, they are subject to continual vetting, which means bugs in the code are often spotted and fixed quickly. Transparency is another major feature of most public blockchains. That is, all transactions that have ever occurred on the network can be viewed by anyone at any time—from the very first transaction to the most recent one. Such transparent, real-time public recordkeeping can be very useful in cases where the goal is to hold a blockchain's participants accountable for their transactions. This will become apparent in some of the use cases described in section III.

Weaknesses. The flip side of the coin is that there are some instances in which personal privacy concerns may trump public accountability concerns (ShenTu and Yu 2015). In such cases, the transparency of most public blockchains is a bug and not a feature. This concern has been mitigated, to a large degree, by the emergence of next generation public blockchains using advanced cryptographic techniques such as zero-knowledge proofs[7] and ring signatures[8] to enhance user privacy.

What cannot be sufficiently mitigated at present are the scalability limitations of public blockchains. The mathematical processes through which transactions are batched, confirmed, and strung together in tamper-proof chains are extremely energy intensive, costly, and slow. As of the time of writing, the Bitcoin network's electricity consumption amounts to 0.09% of total world energy consumption. This means a single Bitcoin transaction consumes enough electricity to power 7.55 households in the United States for an entire day (Digiconomist 2017). Average processing costs are around $44.88 per transaction, a figure corresponding to a 4.56% processing fee for Bitcoin miners (Blockchain.Info 2017a). The number of outstanding unconfirmed transactions, meanwhile, ranges between 4,000 and 9,300, and the average transaction confirmation time is 45 minutes (Blockchain.Info 2017b, 2017c). It is important to note that the

---

[6] The term 'mining' refers to the computational process by which transactions on the blockchain network are batched and confirmed into data 'blocks' (released with an interval of around every 10 minutes on Bitcoin) and then 'chained' together in a publicly verifiable way, which makes it highly difficult (economically cost prohibitive) for anyone to go back and tamper with earlier entries in the chain. For technical details, see Nakamoto (2008). Most public, permissionless chains use either 'proof-of-work' or 'proof-of stake' consensus algorithms. For details on the differences between the two, consult the technical references section.

[7] Zcash is the leading cryptocurrency using cutting-edge cryptography to make peer-to-peer money transactions secure without being publicly viewable. Technical specifications may be found on the Zcash website (ZCash. https://z.cash/about.html?page=0). See also Miers et al. (2013) and Ben-Sasson et al. (2014).

[8] Monero is the leading cryptocurrency employing ring signatures to offer a higher degree of anonymity to its users. As compared with zero knowledge proofs, ring signatures are a slightly less anonymous but much more thoroughly battle-tested method of privacy enhancement. For details, see Monero. https://getmonero.org/.

corresponding figures for Ethereum and certain other public blockchains are somewhat better. Moreover, many innovative ideas for scaling public blockchains are currently under active development around the world and several of these will likely succeed.[9] Even so, these statistics underscore that public, permissionless blockchains face very serious scaling limitations at present. Difficult technical problems remain to be solved before they will become capable of meeting large-scale usage demand.

(ii) Private, permissioned blockchains. These are blockchains on which only parties who have been granted access ('permission') may participate in transacting, mining, or viewing transactions. Their code may be either open or closed source, but in most cases it is maintained by developer teams seconded or contracted by the parties who have permission to participate in the chain. Private blockchains are a popular solution among consortiums of actors with shared interests. An example of this is Ripple, an effort to make interbank settlement processes faster and cheaper by connecting multinational banks via a single shared ledger.[10]

Strengths. Because access to private chains is controlled, the number of nodes participating in the network can be kept to a smaller number. Privacy concerns can be dealt with by concluding confidentiality agreements among the approved participants, and/or by employing the newer cryptographic techniques just described in respect of public chains. Moreover, all participants can be required to perform 'mining' operations as a condition of participation, rather than in exchange for cryptocurrency rewards. This allows private chains to consume less energy, process more transactions per second, and do so at much lower cost than public chains.

Weaknesses. Private blockchains are not as broadly distributed as public chains, which implies increased cybersecurity risks.[11] More significantly, because their security depends upon all approved participants in the chain acting in good faith, it is necessary to restrict access to only trusted participants, and then to regularly audit and verify that these participants are indeed acting in accordance with the terms agreed. From a technical and costs standpoint, it is not always clear that it makes economic sense to use private blockchains among known, trusted parties, where more traditional networked-database solutions such as Oracle, MySQL, and NoSQL might well suffice.[12]

(iii) Hybrid blockchains. As the name suggests, hybrid blockchains combine some of the features of both public, permissionless and private, permissioned blockchains. A hybrid chain might, for example, be configured to be 'permissioned' with respect to the chain's users and miners but 'public' with respect to its viewers. Alternatively, a hybrid chain might use a combination of open-source and closed-source code. Or it might allow some users to view certain types of information and make certain types of transactions over the

---

[9] For a technical discussion of possible blockchain scaling approaches, see Croman et al. (2016). For an overview of several major scaling efforts on the Ethereum blockchain, see Ehrsam (2017), and also, more recently, Buterin and Griffith (2017).

[10] Ripple is a company focused on building solutions for "instant, low-cost international payments," as described on the company's website (https://ripple.com/).

[11] Generally speaking, centralized systems are easier to attack than decentralized ones, both because it is easier for outside attackers to identify a potential point of attack and because a single compromised node has a better chance of manipulating the consensus process of a small group of nodes than of a large one.

[12] For an excellent primer, see Greenspan (2017).

network while restricting others from doing so.[13] Examples of well-known hybrid projects include R3's Corda (https://www.corda.net/), some of the Linux Foundation's Hyperledger projects, such as Hyperledger Fabric and Hyperledger Burrow (https://www.hyperledger.org/projects), and various experiments being conducted under the umbrella of the Enterprise Ethereum Alliance.[14]

Strengths. The main advantage offered by hybrid chains is the flexibility to pick and choose design features according to the use case. Different types of users can be given different levels of access and use rights; different privacy and transparency features can be tailored to specific classes of users, actions, or categories of information; different types of security features and identity practices may be adopted for different purposes; and so on. Thanks to this flexibility, hybrid blockchains and the consortiums promoting them are currently receiving substantial research and development support from large multinational corporations and global financial institutions.[15]

Weaknesses. Hybrid chains require a great deal of custom design work, which can make them time-consuming and costly to build. Their specificity and complexity also create significant barriers to interoperability. If not addressed from the beginning as part of their initial design scheme, these interoperability barriers may lead to lock-in effects. This, in turn, can stifle innovation by inhibiting healthy competition among distributed ledger platforms, leading to rising prices for users over time.

(iv) DAG-based distributed ledgers ('tangle'). The IOTA tangle is a newer type of distributed ledger technology which uses Directed Acyclic Graphs (DAGs) to transmit and confirm transactions in an asynchronous rather than 'chained' way.[16] It was conceived as a lightweight protocol for the Internet-of-Things (IoT) environment to facilitate micro-scale machine-to-machine transactions among billions of connected devices.[17] In contrast to blockchains, the tangle has no dedicated 'miners.' Instead, each IoT connected device that transmits a new transaction to the network must perform the computational calculations necessary to confirm two other transactions as a precondition for having its own transaction confirmed (Schiener 2017).

Strengths. There are several advantages to using a DAG-based tangle rather than a blockchain. The first is zero transaction fees. Because there is no need to compensate miners for securing the network, it is possible to "transact even sub-cent values Peer-to-Peer without any transaction fees for either the sender or the recipient" (Schiener 2017). Second, the tangle scales organically. By design, it becomes faster and more secure as network traffic grows. Third, the tangle's distributed consensus protocol allows it to be 'partition tolerant.' This means portions of the network's traffic can split off from the main tangle for extended periods of time and continue to operate without internet connectivity (e.g., over Bluetooth, or theoretically even TV or radio bandwidth); these partitions can

---

[13] Several of the Linux Foundation's Hyperledger projects, for example, and various ongoing Enterprise Ethereum experiments. See Enterprise Ethereum Alliance. https://entethalliance.org/about/.

[14] This alliance focuses on developing 'enterprise-grade software capable of handling the most complex, highly demanding applications at the speed of business.' See Enterprise Ethereum Alliance. https://entethalliance.org/about.

[15] The Monetary Authority of Singapore has taken a lead role in promoting experimentation with hybrid chains. See Ngo (2017).

[16] For a technical description of the concept of a DAG-based DLT, see Popov (2016).

[17] For an accessible overview, see Schiener (2017).

then rejoin the main tangle at a later time once the internet connection has been reestablished.[18] This last feature makes DAG-based DLTs ideal for use cases in regions with limited internet bandwidth and/or an unreliable electricity supply.

Weaknesses. Public blockchains rely on the economic incentives generated by the mining process to protect the network from malicious attacks.[19] Because a DAG-based tangle does not have miners, it must ensure that no bad actor can attempt to cheat the network by strategically selecting the transactions it gets to confirm. The IOTA tangle guards against this possibility by directing which participating device confirms which new transactions via a Markov Chain Monte Carlo Random Walk algorithm. As discussed in the project's White Paper, this method should theoretically prove sufficient once the tangle reaches a large enough scale (Popov 2017). However, the formal bounds at which this point will be achieved have not yet been mathematically proven.[20] In the meantime, the tangle must rely on a network of trusted nodes to verify that transaction confirmations are being done in a random, and not strategic, manner.[21] The tangle as presently implemented is therefore not yet fully decentralized.[22]

To summarize then, distributed ledger technologies today come in a stunning array of shapes and sizes. Each has unique advantages and disadvantages, and it is important to understand these in order to evaluate the prospect of DLTs to be beneficially deployed in the development assistance context.

III. DISTRIBUTED LEDGER TECHNOLOGY USE CASES

There has been a mushrooming of use cases to implement DLT. Some, such as remittances and microfinance, have received broader attention than others, and are omitted in this paper due to space constraints. Here we take a closer look at five other areas of application with a clear bearing on core development issues, including digital identity, trade finance, project aid monitoring, smart energy, and supply chain management. Each use case has the potential to deliver tangible improvements in terms of development outcomes and carries implications for the ways in which official development finance may be deployed in support of their adaptation. Use cases also face a great deal of challenges and limitations, which in many cases will require further technical, infrastructural, or regulatory developments before they can be put to work in support of development across Asia and elsewhere.

---

[18] The first proof of concept of this kind of partition tolerance was recently demonstrated. See Freiburg (2017).

[19] In essence, the resource costs involved in mining new tokens (such as bitcoins) are high enough that it becomes economically infeasible for any single bad actor to acquire sufficient hashing power to cheat the rest of the network. For a brief explanation of the Bitcoin blockchain's so-called '51% Attack' problem, see Bitcoin Wiki. "Majority Attack." https://en.bitcoin.it/wiki/Majority_attack. It is important to note that the 51% attack problem is more than a theoretical possibility. It has been actively discussed by some parties in the past. See Von Wirdum (2017).

[20] See Popov (2017) for an updated version of his white paper, which also provides some further details.

[21] This set of nodes is called 'the Coordinator' in the IOTA ecosystem. For a defense of this approach, see Sønstebø (2017). For a critique of it, see Wall (2017).

[22] In this sense, it currently evinces analogous security weaknesses in respect of central attack points as do private permissioned blockchains. A key difference is that in the tangle this de facto centralization is intended as a transitional feature only, whereas in private permissioned blockchains it is a permanent design feature.

A. Use Case 1: Digital Identity–A Gateway to All Other Use Cases

Every aspect of human development rests upon the bedrock of trusted identity. Without a verifiable identity of some kind, it is impossible to open a bank account, start a business, conclude a legally binding contract, access essential government services, obtain educational credentials, or conduct just about any other imaginable type of economic or social activity on a broader scale.[23] State authorities attempt to fill this gap by issuing official identities to natural and legal persons falling within their jurisdiction. They do so by issuing written documents such as birth certificates and citizen identification (ID) numbers, which can in turn be used to obtain both locally recognized identity-related documents (identity cards, driver's licenses, marriage certificates, tax ID numbers, business licenses, etc.) and globally recognized ones (e.g., passports). This process works better in some states than others. Today, around 1.1 billion people worldwide—particularly in rural Africa and Asia—still lack legal identities (World Bank 2017). It was for this reason that the United Nations (UN) in 2015 made the provision of legal identities for all, including birth registrations, an explicit focus of its revised Sustainable Development Goals (UN SDGS 2017).[24]

But even once legal identities have been issued, the question of how to keep official records continuously up-to-date remains problematic. A never-ending string of ordinary events can necessitate the alteration, suspension, or revocation of legal identities and the various entitlements associated with them. Births, deaths, marriages, name changes, declarations of court-determined legal incapacity, bankruptcy or insolvency, and many other events can alter the legal rights and duties attached to a particular identity. Even economically advanced 'good governance' states have long struggled to find ways of making their many disparate recordkeeping systems talk to one another such that all records are kept current.

This lack of interregistry communication impedes global development efforts by making it extremely expensive and time consuming for transacting parties to verify one another's legally recognized identities and entitlements. This is as true of local transactions as it is of global ones. For instance, a simple contract for the sale of a parcel of land by one neighbor to another requires the verification of both parties' identities and their legal capacity to contract, as well as a verification of the seller's current ownership entitlement to the land. To take a cross-border example, a large international financial transfer requires the verification of the sending and receiving parties' identities, a confirmation of the mutual recognition of those identities by the different countries in question, and a confirmation that neither of them is prohibited under any national or international regulation from transferring money internationally (e.g., by reason of being on a terrorism or money laundering watch list). Similarly, in relation to DLT-based trade finance further described below, the global diffusion of a company identifier system will facilitate the risk assessment and ownership tracking necessary for smaller companies in developing countries to be granted access to finance and the global economy.

1. Benefits

Distributed ledger technologies offer a technical solution to this complex problem for the first time in history, and on a global scale. Numerous globally focused startups, including Sovrin

---

[23] In traditional systems, identity was a straightforward matter of community recognition. People transacted with those whom they knew and trusted. While such models worked well on a local level, they proved incapable of establishing trust among parties wishing to transact beyond their immediate communities.

[24] In particular, UN Sustainable Development Goal target 16.9 states: "By 2030, provide legal identity for all, including birth registration."

(https://sovrin.org/), Netki (https://netki.com/), uPort (https://www.uport.me/), Civic (https://www.civic.com/) and others, are building DLT solutions for real-time self-sovereign digital identity management. The concept of self-sovereign identity could herald radical changes in global economic organization by turning the data collection practices and revenue models of many existing internet-era businesses on their heads.[25] More importantly, within the international development context, it promises to enable billions of currently excluded persons to integrate into the global finance and commerce systems. As described in the 2016 Caribou Digital/Omidyar paper:

> Open, decentralized systems enable individuals to fully own and manage their own identities, leading to the idea of "self-sovereign" identity systems. These systems use combinations of distributed ledger and encryption technology to create immutable identity records. The individual creates an identity "container" that allows them to accept attributes or credentials from any number of organizations, including the state, in a networked ecosystem that is open to any organization to participate (e.g., to issue credentials). Each organization can decide whether to trust credentials in the container based on which organization verified or attested to them; in other words, a mortgage company may accept a credential issued by a leading global bank, but not one issued by a local bank. Importantly, this model does not require a state-based credential to be initiated (the state credential can be added at a later time, or not at all), which removes a barrier to adoption.

The flexibility and modularity of the self-sovereign identity approach makes it ideal for adoption in developing country contexts where there are significant gaps in official state recordkeeping. In fact, those gaps might make it easier for developing countries to adopt such solutions than more developed ones, where large sunk investments in traditional recordkeeping systems often create institutional path-dependencies and high transition costs.

An example of a development-focused start-up using self-sovereign identity as an anchor for its work is Taqanu (https://www.taqanu.com/), which describes itself as "a bank for refugees and for people without fixed address." Taqanu takes advantage of the fact that, while many refugees don't have identity documents, many do have phones. It allows refugees to sign up to have their social media data compiled and analyzed in a way that makes it possible for regulated banks to verify the refugees' identities to a sufficient degree of probability to offer them basic banking services—even if they can't provide a government-issued birth certificate, passport, or other recognized national identity document.

Providing financial system access to excluded populations is one of the most important developmental use cases of DLTs, and further examples are presented in the following sections. For present purposes, the Taqanu example illustrates that the creation of verifiable digital identities is a gateway issue for pretty much every possible DLT use case. Without them, users of DLT solutions could never trust that their counterparties to a transaction: (i) are who they claim to be, and (ii) are entitled to carry out the intended transaction. Digital identity is therefore the key to the success of all other DLT use cases. This renders investment in self-sovereign identity infrastructure a necessary prerequisite for every other type of development assistance for which DLT solutions might be explored.

[25] Companies like Google, Amazon, Facebook, and Apple—whose revenue models depend upon monetizing the large volumes of data collected from their users—will need to find new ways of generating revenue if users become empowered to decide on a granular level which data they share, with whom, and for what specific purposes.

2. Risks and Implementation Challenges

In order for its benefits to be realized, advocates of self-sovereign identity posit that three core requirements must be met:

(i) *Security*—the identity information must be kept secure,
(ii) *Controllability*—the user must be in control of who can see and access their data, and
(iii) *Portability*—the user must be able to use their identity data wherever they want and not be tied to a single provider (Tobin and Reed 2017).

Many of the leading actors in this space are cooperating under the auspices of the Decentralized Identity Foundation to make this vision a reality.[26] While the broader vision is shared, however, key implementation details have yet to be agreed upon. For example, the security pillar requires the use of cryptographically secure methods of protecting users' data. Most digital identity service providers today use cryptographic functions based on elliptic curves whose security robustness has been thoroughly vetted within the context of contemporary processing environments. But cryptographers warn these functions will most likely prove vulnerable to hacking with the advent of quantum computing, which may no longer be very far away (The Japan Times 2017).

To guard against this risk, all information stored in a user's digital identity wallet should ideally be stored in a quantum-proof way. This is theoretically feasible using known cryptographic techniques.[27] However, building these into a self-sovereign identity wallet in a user-friendly manner—such that the user does not need any technical knowledge to keep his/her data secure—poses nontrivial design challenges. Addressing these will require systematic adherence to user-centered design principles together with comprehensive beta testing of design features in developing country environments in advance of any live deployment of the technology.

The portability pillar also constitutes a risk at present due to the fact that many of the leading firms in the self-sovereign identity race are building their solutions for a specific DLT, e.g. the Bitcoin or Ethereum blockchains. But data portability requires platform neutrality if it is to mean anything in practice. Digital identity solutions that are open source and platform agnostic (capable of being used across multiple distributed ledgers) may be more likely to deliver high performance at lower cost to users in the long run. There is a risk that hype factors associated with the current popularity of particular blockchains may lead development funders to commission digital identity 'proof of concepts' tied to those specific blockchains, even if the structural design features of the blockchain in question are not well suited to the long-term success of the project at hand. To mitigate this risk, development funders should adopt a policy of publishing public tenders for all DLT-based proof of concepts—including those whose financial implications would ordinarily place them below the usual budget threshold for a mandatory public tender call. This can help prevent situations that may lead to lock-in effects.

In addition to these technical risks, mounting evidence makes clear that digital identity efforts can only assist with the achievement of concrete development objectives if properly situated within a broader reform agenda. Past policy interventions were often premised on the assumption that broader

---

[26] A good source of information on potential partners for building such a solution is the Decentralized Identity Foundation (http://identity.foundation/). Solutions that are open source and platform agnostic (capable of being used across multiple distributed ledgers, as opposed to tied specifically to one particular blockchain) are probably more likely to deliver high performance at low cost to the users in the long run.

[27] For a lay description, see Wikipedia. "Post-quantum Cryptography." https://en.wikipedia.org/wiki/Post-quantum_cryptography.

access to birth certificates, for example, would lead to human rights protection and a fairer distribution of resources and opportunities. A 2007 Asian Development Bank (ADB) study tested this assumption directly by investigating whether improved access to some form of legal identity improved the livelihoods of the poor by helping them obtain services, benefits, and other rights (Vandenabeele and Lao 2007). Based on field work in Bangladesh, Cambodia and Nepal, it found that the actual benefits from owning a legal identity are limited by the obstacles encountered in individual country circumstances, and more generally by weak institutions and widespread corruption. In other words, the provision of legal identity must be linked to the delivery of essential services relevant to people's livelihoods in order to have a real world impact.

Selecting which essential services should be linked to a potential self-sovereign digital identity initiative is also an important policy decision. For example, primary education funding in Nepal premised on the introduction of registration laws and legal identity requirements was found to exclude women and minorities most in need of assistance, because these groups faced the highest barriers to obtaining birth certificates in the first place. Program design should therefore take into account the risk that introducing a legal identity regime may limit the range of project beneficiaries. For some essential services, superior development outcomes may be reached by providing them to everyone, with or without identity.[28]

Last but not least, poor governance, weak institutions, corruption, and resource constraints fundamentally weaken the state's capacity to enforce laws intended to protect citizens' rights. The provision of legal identity makes little difference in such contexts without complementary reforms in these areas. Although self-sovereign identity systems can fill the void left by a weak state in a circumscribed area of application, its benefits cannot expand without an appropriate enabling environment. Put differently, legal identity and the technologies underlying it are important facilitating tools, but they cannot substitute for development policy as such.

B. Use Case 2: Trade Finance for Improved Accessibility of Small and Medium Enterprises[29]

A recent ADB survey found that the trade finance gap reached $1.5 trillion in 2016 (ADB 2016). Access to trade finance is particularly difficult for small and medium-sized enterprises (SMEs) because they often lack collateral, a documented history of past commercial and financial transactions, and sufficient knowledge of the financial industry and instruments on offer. The survey finds that, as a result, 57% of trade finance requests by SMEs are rejected, compared to only 10% by multinational companies. SMEs in Asian economies account for 98% or more of all enterprises, and the limitations they encounter impacts economic growth and employment at the aggregate level (ADBI 2016).

Governments in Asia have been devising a variety of policies and programs to improve SME's access to trade finance. For example, the Small and Medium Enterprise Development Bank of Thailand and the Small Industries Development Bank of India were established to cater especially to SMEs. In the Philippines, the central bank set up a credit fund to guarantee bank lending to SMEs and cooperatives. Japan and several other countries in the region have created public credit registries to allow banks to make informed decisions on SME loan requests. Legal frameworks have been enacted to help SMEs provide the collateral demanded by banks, such as the People's Republic of China's (PRC) introduction in 2007 of a new property law and Thailand's Business Collateral Act in 2015 (ADBI 2016).

---

[28] Prenatal healthcare and childhood vaccination programs may be examples.
[29] This section reflects insight from a discussion with Steven Beck, Head of ADB's Trade Finance Program.

While national and regional initiatives—including ADB's Trade Finance Program—help bridge the gap, there is increasing expectation on technology to make a difference. Leading companies in the global e-commerce sector, such as Amazon and PayPal, have established their own lending arms catering mostly to SMEs, and platforms such as Alibaba and eBay provide training and advice especially targeted at smaller companies. Compared to regular bank loans, the minimum size of loans by these e-companies is smaller, procedures are more streamlined, and access and disbursement times are considerably shorter. As a result, lending to small businesses has seen rapid growth in the advanced markets, except for the PRC, but it has yet to penetrate developing markets, where the demand for SME financing is highest (The Banker 2017).

In developing countries, DLT is expected to be a real game changer, especially for SMEs. From the cumbersome and slow process it is now—involving layers of paperwork and bureaucratic hurdles—DLT will involve broadly accessible and scalable smart contracts that will execute automatic money transfers as merchandise ships across international borders and predefined commercial and financial trigger events take place. Such automaticity through DLT is estimated to cut costs drastically, broadening financial access to SMEs that are currently excluded.

1. Benefits

A small pilot project on a DLT platform involved dairy exports worth nearly $100,000 and is reported having succeeded by reducing processing times to a few hours only, from what along traditional financing channels would have taken a week or longer (Jemima 2016). Deloitte built a similar proof of concept for an Indian bank using a private permissioned ledger based on the Ethereum protocol. As described in the press release, "the platform helped the bank reduce the time taken for issuing a [letter of credit] significantly from 20 to 30 days (as has been the industry norm) to a few hours and provided an unprecedented visibility to all involved stakeholders" (Deloitte 2017). A consortium of eight European banks is building a similar solution to provide trade finance to SMEs within Europe (Finextra 2017), and several more multinational banks have recently joined the IBM/UBS effort (Arnold 2017).

Meanwhile, an interesting new start-up called Sweetbridge is aiming to lower the cost of trade finance by allowing firms—especially SMEs—to engage in a sort of finance smoothing across their own payment cycles. As described by Banker (2017), "it is common for a big firm to buy goods from small manufacturers, but then to pay the suppliers slowly. These suppliers must engage in price factoring arrangements to insure they have enough cash flow to continue operations. This increases costs not only for the supplier, but across the end-to-end supply chain." To solve this problem, Sweetbridge plans to allow firms to collateralize their own assets and committed revenues as security for temporary trade financing. These collateralized assets, which enter a sort of smart contract version of an escrow account on the Sweetbridge blockchain, allow the firms to take out I-Owe-Me's to finance their own current purchases with their own future earnings, thereby cutting out months of payment delays, mounds of paperwork, and (in the aggregate) trillions in annual trade financing costs (Nelson et al. 2017). This project is currently still in the design phase (alpha), but will soon launch into beta testing, and will surely be a hot area to watch.[30]

[30] An earlier entrant in the space, called Skuchain, already offers some of the trade finance functionality proposed by Sweetbridge. However, Skuchain operates in a more traditional manner, bringing together existing financiers and suppliers on a common blockchain similar to the Deloitte and IBM pilots. See Skuchain's description of its Brackets product at http://www.skuchain.com/products/.

2. Risks and Implementation Challenges

DLT-based trade finance will go a long way in improving transparency and financial inclusion, but much remains to be done before these platforms will be sufficiently mature for real world applications beyond the proof of concept or early pilot stage they are currently in. Furthermore, for a trade finance platform to fully leverage DLT and the automaticity of smart contracts, it would have to bring on board not only banks, but also shipping agents, freight forwarders, ports, customs, and insurance companies. Some progress in this direction is being reported, but is fraught with coordination and implementation difficulties that will take time to sort out.[31]

Also, trade finance is heavily paper based and the various platforms for monitoring of supply chains and trade transactions are fragmented and do not communicate with those underlying the emerging DLT trade finance. Further diffusion of new technologies is bound to be limited until all the components pertaining to the various aspects of trade finance transactions have been digitized and systems' interoperability has been fully established (The Banker 2017). National governments and international organizations like the ADB can play a key role in removing these remaining obstacles to DLT finance by promoting the diffusion of global digital standards among companies under their sphere of influence. Major stepping stones in that direction are the diffusion of digitization and identifier systems for companies, which are essential also for the spread of DLT trade finance.

Global harmonized digital identities for companies worldwide—or digitization in short—assigns firms an ID number that is linked to databases which banks and other stakeholders can use to access information underlying lending decisions. For this purpose, the G20 mandated the Financial Stability Board to create the Global Legal Entity Identifier Foundation (GLEIF). Established in 2014, GLEIF has since enrolled nearly 500,000 companies with a Legal Entity Identifier (LEI) against a small fee. GLEIF is currently able to identify firms and will next develop capacity to identify corporate ownership structures and assets. Its global diffusion will lay the foundation for accessing and tracking the huge amounts of data necessary for the establishment and operation of DLT-based trade finance, facilitating risk assessment and having a significant impact on access to finance for SMEs. It is now the role of governments and international organizations to create the necessary incentives for companies to acquire LEIs and to map any extant national ID systems with LEI to cement its foundational function for the digitization of companies.[32]

A further enabling factor will be the World Trade Board's Digital Standards in Trade (DST) initiative, for launch in January 2018. It aims to fill the lack of common standards in the trade system by providing a fully digitized and seamless end-to-end throughput in trade transactions worldwide that would help the various participants in a trade transaction communicate and share data with each other. Led by a steering committee that sets its direction and work plan, the DST will adopt standards by working groups consisting of private and public sector stakeholders and participants involved in all aspects of trade transactions. Unlike banks, shipping or freight forwarders that focus on standardizing documents only within the industry group they pertain to, DST's horizontal approach to interoperability cuts through all the interlinked transactions, from the time an exporter has a purchase order, all the way to its delivery to the buyer. Through the provision of technical assistance and capacity building, ADB and other multilateral development banks can support DST and the adoption of common standards among developing country stakeholders, such as ports, customs authorities, financial intermediaries, and SMEs (World Trade Board 2017).

---

[31] See Arnold (2017), where recent such efforts are described.

[32] Further on GLEIF's potential, see Beck (2016).

In parallel to these efforts, international development lenders should keep a close watch on projects like Sweetbridge, which could potentially eliminate altogether the need for publicly funded trade financing for SMEs, thereby freeing up funds for other projects. The best way to contribute to the ultimate success of such initiatives is to partner with them. Public trade finance providers can help identify and recruit suitable SMEs to participate in proof of concept and pilot tests and should also commit funds to help intensively test and assess the performance of the extremely complex sets of smart contracts that will be required to make the vision of self-funded trade finance for SMEs a global reality.

C. Use Case 3: Project Aid Monitoring and Results-Based Disbursements

Measuring the impact of disbursed development aid and verifying the compliance of loan recipients with conditionality requirements are among the most central concerns of international development banks. DLTs offer improved ways of conducting these assessments thanks to their ability to generate real-time performance data. This in turn enables lenders and donors to finance suitable development projects under a pay-for-performance model. It also allows complex projects to be reassessed and restructured more quickly when it becomes evident that they are not achieving their intended aims.

On the pay-for-performance side, some of the most promising DLT ideas make use of sensor-based and imaging technologies to collect accurate real-time field data. The data gathering devices are integrated directly onto a distributed ledger, which transmits the data for real-time monitoring and analysis, and in some cases, even makes automatic payouts based on predefined data triggers.[33]

One prominent ongoing experiment that could potentially benefit from the introduction of a DLT in aid disbursements involves the provision of compensatory income transfers to indigenous groups who protect their forests from clear-cutting (Hansen et al. 2013). Satellite photos of a group's customary territory are taken at regular intervals to monitor the progress of deforestation. If the images show no or little deforestation, the local people receive payments in compensation for the income they could have earned from selling the timber. The compensation amount is tied directly to the preservation of the forest, as verified by unfalsifiable external data. Early results indicate that this program is proving successful in slowing the progress of deforestation in certain parts of South America.[34] It could in the future also be extended to encourage active reforestation in parts of the world where clear-cutting has led to soil erosion, biodiversity losses, and the elimination of important natural carbon sinks.

1. Benefits

While such programs can operate without distributed ledgers, significant benefits can be derived by integrating DLTs into their workflow. Collecting the information via a DLT would allow dedicated nodes to perform automated data analytics and/or employ machine learning to monitor and analyze the data sent by cameras or sensors in real time. This reduces the time lags and costs associated with extracting project performance data and analyzing it manually 'off-chain.' Additionally, once the data have been collected and evaluated, they can be passed through smart contracts that generate automatic payments and send them back to the project participants in accordance with predefined instructions.

In the case of the forest preservation project, the smart contract could be programmed to send back a certain amount of money if the satellite images show deforestation has been halted in the region,

[33] For a listing of projects exploring the integration of data gathering devices and DLTs, see Postscapes (2017).
[34] See Hansen et al. (2013) at abstract, finding however that "Brazil's well-documented reduction in deforestation was offset by increasing forest loss in Indonesia, Malaysia, Paraguay, Bolivia, Zambia, Angola, and elsewhere."

a slightly lower amount if it has slowed by a certain percentage on a month-to-month basis, and an even lower amount if it has slowed by less. Executing payments 'on chain' in this manner eliminates the cost of arranging and using separate payment channels as well as the costs associated with generating an audit trail for payments, since the DLT transactions themselves serve as the audit trail. Accountability reports for both donors and recipients can also be generated automatically without any additional administrative overhead.

While the deforestation project is only a theoretical example, there are already live projects using DLTs to collect field data from IoT sensors.[35] An experimental project in Germany is currently collecting weather sensor data from 30 rooftop devices and making micropayments to the owners of the devices in exchange for the data.[36] The same concept could easily be applied to administer crop-insurance programs in vulnerable agrarian communities. IoT devices could be deployed to monitor rainfall, hours of sunlight, wind speeds, temperature, humidity, and other relevant factors in the region. This could be combined with time-lapse photography or satellite imagery to monitor the state of crop health across the entire growing cycle. The information could then be used to pay out on micro-insurance contracts in the event small farmers lose their crops due to adverse weather conditions. Such a system could render it unnecessary to perform onsite investigations to rule out dishonest self-reporting or corruption; the fact that the relevant conditions are monitored throughout the crop's life cycle makes it difficult to cheat the system.

An interesting start-up in the UK called Alice (https://alice.si/) is using similar ideas to encourage more effective charitable giving. Alice allows donors to donate money via smart contracts toward charitable projects they find worthwhile–but on condition that the project achieves certain predefined outcomes. The money is released as and when the desired benchmarks are reached. If only some of them are achieved, only some of the pledged money is paid out. This kind of pay-for-performance model obviously only works for charitable organizations that are in a position to either self-fund or secure loans to finance their projects up-front. Over time, however, those that develop reputations for successfully achieving project outcomes should see their up-front cost of borrowing fall. Development lenders should actively track the information gleaned from such smart contract-based pay-for-performance systems and use this information to make better informed and lower-risk lending decisions when financing development projects.

2 Risks and Implementation Challenges

The major implementation hurdles to deploying DLT-based development aid and conditionality assessment strategies are relatively straightforward. They can only succeed in environments where it is possible to deploy field-based or remote sensors capable of providing relevant and accurate assessment information. Devices deployed in a crop insurance context, for example, must be able to stand up to adverse weather conditions over extended periods. They must also be engineered and deployed in such a way as to make it difficult for the sensors to be tampered with or tricked into recording false data. They must have access to a stable power supply or have sufficient internal battery capacity to continue to operate. And of course, they will only be useful if adequate infrastructure is in place to allow them to connect and send updates to a DLT on a regular basis. Hardware costs and connectivity gaps are therefore important limiting factors. DLT designs that feature partition tolerance (the ability to operate

---

[35] The deforestation project is a controversial one due to its mixed efficacy in different regions, as well as concerns over how the projects have taken into account (or not) the interests of the indigenous groups concerned. See Popkin (2017).

[36] See IOTA Weather Node. http://necropaz.github.io/weatherstation.html.

offline or over nonweb-based networks for extended periods of time) may prove to be better candidates for field environments than designs which depend upon constant connectivity.

Last but not least, the viability of automating payment processes into such projects depends upon whether it proves possible to integrate the end-recipients of the pay-for-performance scheme into the distributed ledger ecosystem. For persons who are currently excluded from the global financial system, this means solving all of the challenges detailed in respect of the digital identity and financial access use cases described above as a precondition to integrating automatic payment systems into DLT-based pay-for-performance schemes.

D. Use Case 4: Smart Energy and Smart Mobility

Just as sensors and cameras can be integrated with DLTs, so too can meters of various kinds. This explains why smart energy and smart mobility are among the most active areas of DLT experimentation. On the energy front, smart transactive microgrids are of particular interest in regions where sunlight is plentiful but centralized electricity production or distribution is inadequate.[37] Microgrids have been defined as "electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded" (CIGRÉ C6.22 Working Group 2015).

A leading example is the Brooklyn Microgrid project (BMG. https://www.brooklyn.energy/about). The BMG is a community-driven initiative launched in 2016 with the following stated aims:

(i) increase the amount of clean, renewable energy generated in the community by members of the community;
(ii) develop a connected network of distributed energy resources which will improve electrical grid resiliency and efficiency;
(iii) manage these distributed energy resources during power outages and emergencies to protect the community and local economy; and
(iv) create financial incentives and business models that encourage community investment in their energy future, creating energy and jobs that boost the local economy.

The basic idea is to transform energy consumers into 'prosumers' while simultaneously replacing dirty energy with clean energy. In essence, community members contribute to local renewable energy production by installing solar panels on their rooftops. A device called a transactive grid element continuously measures their energy production and consumption. This information is shared with other participants over a DLT—in this case a private permissioned blockchain—which in turn enables them to act upon the information in concert in response to changing energy conditions within the grid. At any given time, a microgrid participant might be producing more energy than it consumes, in which case it sells its excess energy to others, or consuming more than it produces, in which case it purchases the shortfall from others.

[37] For an overview of academic work on microgrid structures, see Stadlera et al. (2016).

1. Benefits

Using DLTs to connect microgrids enables participants to compensate one another for their energy purchases and sales instantaneously as they happen. This eliminates the need for cyclical meter checks and postconsumption billing processes.

DLTs can also help facilitate the financing for such projects. In South Africa, a start-up called the SunExchange (https://thesunexchange.com/) makes it possible for investors to purchase solar cells and lease them to schools and businesses in developing nations. The company identifies suitable sites for its projects; arranges for the purchase, delivery, and installation of the solar cells; and insures the projects against fire, damage, and theft. Once the project goes live, the SunExchange collects monthly rental fees out of the proceeds from the electricity generation and automatically distributes them back to investors, who can opt to be paid in either national currencies or Bitcoin.[38]

Other projects are attempting to create worldwide markets for incentivizing local renewable energy production and allowing local producers to trade with one another over a distributed ledger. Solarcoin, for example, is a cryptocurrency whose value is defined in terms of electricity. One Solarcoin represents one megawatt hour of solar electricity generation. The Solarcoin foundation plans to distribute 99% of its coins to verified solar electricity producers for the production of 97,500 terawatt hours over 40 years. The Solarcoin project is in its infancy, and important questions of technical implementation as well as incentive structure design remained to be answered. But if projects like this manage to gain wide enough adoption, green energy-backed cryptotokens could one day become integrated into the global carbon trading system—a key mechanism for reducing carbon emissions under the UN Framework Convention on Climate Change (UNFCCC).[39] Indeed, the UNFCCC Secretariat is so convinced of the potential of DLTs to assist with climate change mitigation that it decided to cosponsor a DLT climate hackathon that took place alongside the 23rd Conference of the Parties meeting in Bonn in November of 2017.[40] Similarly, ADB and other developing lenders have been actively pursuing the idea of DLT adoption in their efforts at climate change mitigation (Zhai 2017).

As a complement to clean energy production, DLT-based initiatives to encourage green mobility options are also advancing rapidly. Electric vehicle (EV) sales have gained market share quickly in many markets, thanks to advancements in EV technology and favorable tax incentives. Analysts expect this trend to accelerate further in the wake of several governments' recent announcements of dates beyond which the sale of new nonelectric vehicles will be prohibited within their borders.[41] Within Asia, the PRC is leading the charge in setting aggressive targets for electric vehicle quotas as a means of tackling the country's smog problem (McDonald 2017).

These developments have lead DLT innovators to partner with auto manufacturers to solve the problem of inadequate public charging station infrastructure. Pilot projects built on the IOTA and Ethereum platforms in Europe (innogy 2017, ZF 2017) and the United States (Spector 2017),

---

[38] In principle, similar models could be applied to micro wind energy generation projects in suitable locations provided micro wind turbine technologies can be further improved to sufficient efficiency levels.

[39] See Article 6 of the Paris Agreement, which addresses internationally transferred mitigation outcomes.

[40] The hackathon brought 100 developers from around the world to Bonn for 4 days to 'hack' intensively on 5 climate change problems for which DLTs could potentially provide solutions, including identification and tracking of emissions, carbon pricing, distributed energy, sustainable land use, and sustainable transport. See Hack4Climate. https://www.hack4climate.org/#home.

[41] Norway has been the most aggressive on this front, announcing a ban on the sale of new cars with combustion engines as from 2025. See Hockenos (2017).

respectively, use DLTs to connect electric car owners and private charging station owners in a peer-to-peer sharing economy. Doing so extends the range of electric vehicles by enabling them to recharge in places where public charging stations are not available. It also greatly increases the efficiency and reduces the cost of ownership of private charging stations by putting them to work on behalf of others during periods when their owners would ordinarily leave them idle. Enabling these kinds of peer-to-peer markets reduces the level of EV infrastructure funding required of governments to meet aggressive targets for electric vehicle adoption.

2. Risks and Implementation Challenges

An obvious limitation of microgrids is that the energy production and consumption patterns of participants within a closely-knit community are highly correlated. All produce more energy on sunny days than cloudy ones; all tend to push energy during the day and pull energy at night; and so on. To smooth out consumption and production spikes, it is necessary to pursue one or more of three solutions:

(i) improve energy storage solutions (battery capacity and efficiency);
(ii) connect microgrids to main grids, so that load balancing can be performed by the main grid; or
(iii) connect microgrids to one another in such a way as to counterbalance the production and consumption patterns of one grid by matching it up with a grid displaying opposite (or at least uncorrelated) patterns.

DLTs can solve the peer-to-peer payments component of the second and third solutions, but they cannot help much with the actual electricity distribution. It is expensive and inefficient to send energy across large distances, since much energy is lost in transit. Indeed, this is one of the arguments in favor of microgrids as a sustainable energy source in the first place. Connecting noncorrelated microgrids together to balance out each other's load patterns is therefore only practicable in regions where two or more noncorrelated types of micro-energy production can be located within close proximity to one another—for example, solar, hydro, and wind power. In regions where the conditions for this are not favorable, connecting microgrids to main grids provides an alternative in some cases. But again, distance poses a barrier, especially for remote and/or difficult to reach places, such as outlying islands, mountainous regions, and sparsely settled communities spread across large areas. If microgrids are to prove a sustainable solution for remote areas of developing Asia, then, investment in battery capacity improvements will often be the best way forward.

With respect to peer-to-peer mobility markets, the major barrier to adoption—apart from sufficient micro-payment solutions and adequate road networks—is access to the private finance needed to purchase electric vehicles and electric charging stations in the first place. Development lenders should consider partnering with innovative companies like the SunExchange to explore creative financing solutions that cover the initial set-up costs of transitioning to smart peer-to-peer electric vehicle markets.

Such crowd-funded investment or leasing models could conceivably incentivize not only the purchase of private charging stations but also of electric vehicles. Development projects could scope what routes need to be outfitted with private charging stations and actively solicit local property owners to allow their installation in return for earning a percentage of the revenues generated. Micro-entrepreneurs wishing to provide DLT-powered taxi or ride-sharing services could likewise lease their electric vehicles from groups of crowd-funders or private owners rather than having to bear the full cost of purchase up-front. All of this would require the strategic deployment of hundreds of smart IoT devices, however, which in turn can only be done in local environments where political stability and the physical security of property are relatively high. Similarly to the other use cases, the successful deployment of DLT to the energy sector will have to be accompanied by capacity building and institutional strengthening to establish the necessary preconditions.

Multilateral lenders have built up a substantial stake in developing countries' energy sectors and have a crucial role to play in establishing an enabling environment for the diffusion of new technologies. Around $5 billion per year of ADB lending goes to the energy sector. Half of this goes to renewable energy and energy efficiency projects, and the other half goes to transmission and distribution systems. This provides large scope for ADB to actively facilitate the introduction of DLT and other advanced technologies to its energy sector operations, thus fostering development impacts and crucial technology transfers across the region (Zhai 2017).

E. Use Case 5: Sustainable Supply Chain Management

Managing global supply chains in a way that ensures products and services are produced in accordance with recognized human rights principles, sound consumer safety norms, and environmental best practices presents a major challenge for modern firms and governments. Even where there is broad agreement concerning the standards to be adhered to—for example, the UN Sustainable Development Goals, or the carbon targets of the Paris Agreement Roadmap—it is no simple task to monitor the compliance of each step of the production process within a global supply chain that can sometimes entail hundreds, or even thousands, of input components from disparate vendors in dozens of countries. Applying DLTs to supply chain management can help reduce the complexity of this problem, even if it can't fully solve it.

1. Benefits

Provenance, a company offering platforms for openly shared product information, used blockchain technology to tag and track tuna caught by fishermen in Indonesia during the first half of 2016 (Hannam 2016). To register the origin of the catch in the blockchain, fisherman sent text messages at the time of the catch with geospatially tagged information that was first validated and then made part of an unalterable blockchain record testifying to the location of the catch.[42] This information gives consumers the ability to trace back the origin of their fish 'from hook to fork' (Banker 2017). Catch data of this type can also be proactively monitored by local authorities to intercept fishing vessels that exceed their catch limits and/or prevent too many vessels from overfishing particular marine areas.

IBM is working with several partners to develop a similar project that seeks to track the provenance of perishable products for food safety reasons.[43] The aim is to log harvested food products at their source, then use radio frequency identification, or RFID, tags to track their progress from the source through shipping and processing channels and eventually into retail stores. By doing so, the companies hope to 'create further transparency in the food sector by tracking food transactions throughout the world and using this information to quickly identify and isolate any food source that is contaminated.'[44] This would allow companies, in the case of contamination scares, to pull only the

---

[42] See Banker (2017), where he notes, "Provenance takes information from sensors or RFID tags and records it on the blockchain to track the fish from 'hook to fork.'"

[43] Partners include Dole, Golden State Foods, Kroger, McCormick and Company, Nestlé, Tyson Foods, Unilever, and Walmart. See Webb (2017). For details of IBM's project, see IBM. "Blockchain for Supply Chain." https://www.ibm.com/blockchain/supply-chain/.

[44] IBM. "Blockchain for Supply Chain." https://www.ibm.com/blockchain/supply-chain/.

specifically affected food products from circulation and focus remediation efforts on the individual farms, plants, or shipping facilities that produced the contamination. There are several countries—also in Asia—where product contamination episodes frequently generate health crises. Making use of DLT-based pinpoint tracking abilities could thus potentially save dozens of lives and millions of dollars each year.

DLT-based supply chain management can also help monitor and meet environmental targets. A California-based start-up called Xpansiv (https://www.xpansivdata.com/) is using IoT devices to capture the environmental attributes of commodities so that they can be differentiated according to their climate friendliness. For example, a pilot project in Wyoming is measuring the level of escaped methane emanating from natural gas wells and feeding this data in real time to a blockchain (Xpansiv Data 2017). Because the data is recorded without human intervention, there is no opportunity for intentional underreporting of harmful emissions. The emissions generated as a byproduct of the natural gas extraction can then be attached to the product on a per unit basis.

This approach allows states to legally justify—for example under article XX of the WTO's General Agreement on Tariffs and Trade—assigning different taxes and customs duties to otherwise like products that are produced in more, or less, environmentally friendly ways. By extension, it is possible to imagine associating other process-related attributes with specific products on a granular level. These could include the payment of fair wages, the observance of worker safety rules and consumer protection standards, and more. In principle, anything that can be reliably measured can be tracked via a DLT and reflected in a product's ultimate price.

DLT-based global supply chains might even one day program smart contracts to automatically adjust the prices paid to each supplier along the way in accordance with the supplier's demonstrated labor, environmental, or consumer protection performance in each case. In short, DLTs promise to improve the transparency and accountability of global supply chain practices while simultaneously reducing the costs associated with tracking and documenting both desirable and undesirable by-products of production processes.

2. Risks and Implementation Challenges

As was the case with the smart energy and smart mobility use cases described above, DLT-based sustainable supply chain management will only be as good as the devices and technologies supporting it. Considerations of IoT device robustness and tamper proofness, electrification and connectivity barriers, user design challenges, etc. therefore apply here as well.

An even more difficult hurdle in many supply chain management use cases is the threshold question of *what* to measure and *how* to measure it. For example, building carbon footprints into product prices by automatically capturing and transmitting production process data across a supply chain via a DLT presupposes that there is an agreed global definition of 'carbon footprint' and a globally agreed set of methods for measuring and reporting it. Otherwise, the carbon footprint reported by Nike versus Adidas in connection with the manufacture of a single pair of running shoes might very well amount to the proverbial comparison of apples and oranges. Such information only becomes valuable to the extent that it is standardized and hence capable of meaningful comparison. This highlights the need for development lenders to partner with, participate in, and/or provide technical and financial support to standards-making bodies to develop broad-based consensus around and adoption of sensible sustainable development-related standards.[45]

Finally, even once standards have been agreed, practical implementation challenges often remain. Some by-products of production processes—like methane gas emissions—lend themselves to easy measurement, but others will require the invention of brand new tracking methods and devices. Devising a system to accurately associate laborer wages paid with each unit of a particular product manufactured is a nontrivial process engineering problem. So, too, is figuring out how to apportion units of desirable and undesirable attributes to a complex product across each step of its production cycle along a global supply chain. There are difficult questions of organizational management and production process design embedded in these tasks.

This is no doubt why most DLT proof of concepts for supply chain management have so far focused on the simplest cases—like whole fresh food products moving from source to consumer with little or no processing required along the way. Extending this idea to more complex supply chains will require a significant investment of time and resources in project scoping exercises and feasibility studies.

IV. CONCLUSION

As this study has shown, there are many exciting areas of potential application of DLTs within the Asian development context. All five of the use cases investigated promise to deliver tangible improvements to the process of financing, deploying, tracking, and evaluating development assistance in key target sectors. Common denominators in terms of benefits to be realized from the deployment of DLTs include: increased transparency and accountability, reduced transaction and monitoring costs, improved real-time data collection and analysis possibilities, and expanded participation opportunities for currently vulnerable, excluded, and underserved populations. Overall, the foregoing survey has made clear that there are areas within each of the five use cases where DLT experimentation can be expected to produce immediate significant benefits, others where midterm potential can be released with a moderate amount of further research and investment, and still others where important technical pieces are still missing and hence longer-term potential can only be realized after considerable additional technical, infrastructural, or regulatory development.

The key to determining which of DLTs' many potentially beneficial use cases fall into which of these three baskets lies in understanding the major risks and implementation challenges associated with each. In undertaking this sorting exercise:

(i) Development lenders such as the ADB should give due regard to underlying infrastructure requirements—especially electrification and connectivity—before embarking on overly ambitious DLT proof of concepts.
(ii) Experimental projects should be selected and conceptualized on the basis of prevailing conditions on-the-ground, so that the appropriate DLT architecture can be selected for each case.
(iii) DLT project design must cater to end-user limitations and minimize as much as possible the gap between what the technology is capable of and what the average target user can actually do with it.

---

[45] An interesting project to make the standard-setting process itself more open and more efficient using DLTs is Collaborase (https://collaborase.com/).

(iv) Wherever possible, platform-neutral solutions should be preferred to platform-specific ones to avoid the lock-in effects of committing to currently popular DLTs which might quickly be eclipsed by superior ones as DLT innovation continues to progress.

(v) For projects involving integration with IoT sensors and those providing automatic data reporting and analysis, the development of broadly shared standards and definitions like the Digital Standards in Trade Initiative should be pursued in advance of project implementation so that the data derived from the DLT integration is meaningful and actionable.

(vi) Investment in self-sovereign digital identity solutions, both for individuals and for legal entities (including SMEs, for example, through the GLEI) should be prioritized as a gateway condition for the success of all other DLT use cases.

Overall, the positive disruptive potential of distributed ledger technologies in the development context is enormous. By assessing them carefully and investing in them strategically, international development lenders can play a key role in helping unleash their positive developmental impact throughout the Asian region.

REFERENCES*

Technical References

Ben-Sasson, Eli, Alessandro Chiesa, Christina Garman, Matthew Green, Ian Miers, Eran Tromer, and Madars Virza. 2014. "Zerocash: Decentralized Anonymous Payments from Bitcoin." Proceedings of the IEEE Symposium on Security & Privacy, Oakland. http://zerocash-project.org/media/pdf/zerocash-extended-20140518.pdf.

Buterin, Vitalik. 2015."A Next Generation Smart Contract and Decentralized Application Platform." Ethereum White Paper. https://github.com/ethereum/wiki/wiki/White-Paper.

Croman, Kyle, Christian Decker, Ittay Eyal, Adem Efe Gencer, Ari Juels, Ahmed Kosba,

Andrew Miller, Prateek Saxena, Elaine Shi, Emin Gün Sirer, Dawn Song, and Roger

Wattenhofer. 2016. "On Scaling Decentralized Blockchains." Position paper delivered at the Financial Cryptography & Data Security 20th International Conference, Barbados. http://fc16.ifca.ai/bitcoin/papers/CDE+16.pdf.

Miers, Ian, Christina Garman, Matthew Green, and Aviel D. Rubin. 2013. "Zerocoin: Anonymous Distributed Cash from Bitcoin." Paper delivered at the 2013 IEEE Symposium, Berkeley. http://ieeexplore.ieee.org/xpls/icp.jsp?arnumber=6547123.

Nakamoto, Satoshi (pseudonym). 2008. "Bitcoin: A Peer-to-Peer Electronic Cash System." https://bitcoin.org/bitcoin.pdf.

Popov, Sergei. 2016. "The Tangle." IOTA White Paper. https://iota.org/IOTA_Whitepaper.pdf.

———. 2017. "The Tangle." IOTA White Paper. Version 1.3. https://iota.org/IOTA_Whitepaper.pdf.

ShenTu, QingChun, and JianPing Yu. 2015. "Research on Anonymization and De-anonymization in the Bitcoin System." Working Paper. https://arxiv.org/abs/1510.07782.

General References

Arnold, Martin. 2017. "Banks Team up with IBM in Trade Finance Blockchain." Financial Times, October 4. https://www.ft.com/content/7dc8738c-a922-11e7-93c5-648314d2c72c.

Asian Development Bank (ADB). 2016. *ADB Trade Finance Survey 2016*. https://www.adb.org/sites/default/files/publication/190631/trade-finance-gaps.pdf.

Asian Development Bank Institute (ADBI). 2016. *SMEs in Developing Asia–New Approaches to Overcoming Market Failures.* https://www.adb.org/sites/default/files/publication/214476/adbi-smes-developing-asia.pdf.

The Banker. 2017. "Small Firms Go Global."

* ADB recognizes "China" as the People's Republic of China and "USA" as the United States.

Banker, Steve. 2017. "Blockchain in the Supply Chain: Too Much Hype." Forbes. September 1. https://www.forbes.com/sites/stevebanker/2017/09/01/blockchain-in-the-supply-chain-too-much-hype/#76d66f91198c.

Beck, Steven. 2016. "A Global ID System that could Revolutionize Finance." Asian Development Blog. December 1. https://blogs.adb.org/blog/global-id-system-could-revolutionize-finance.

Blockchain. 2017a. Bitcoin Stats. https://blockchain.info/stats (accessed 8 October 2017).

———. 2017b. Bitcoin Stats. https://blockchain.info/unconfirmed-transactions (accessed 8 October 2017).

———. 2017c. Bitcoin Stats. https://blockchain.info/charts/avg-confirmation-time (accessed 8 October 2017, most recent data point from 7 October 2017).

Buterin, Vitalik. 2015. "A Next Generation Smart Contract and Decentralized Application Platform." Ethereum White Paper. https://github.com/ethereum/wiki/wiki/White-Paper.

Buterin, Vitalik, and Virgil Griffith. 2017. "Casper the Friendly Finality Gadget." Ethereum Foundation White Paper. https://github.com/ethereum/research/blob/master/papers/casper-basics/casper_basics.pdf.

Caribou Digital/Omidyar. 2016. Private-Sector Digital Identity in Emerging Markets. UK: Caribou Digital Publishing.

CIGRÉ C6.22 Working Group. 2015. "Microgrid Evolution Roadmap." Conseil international des grands réseaux électriques (CIGRÉ).

Deloitte. 2017. "Trade Financing Re-defined Using Blockchain Technology: A Case Study." https://www2.deloitte.com/in/en/pages/strategy/articles/trade-financing-redefined-using-blockchain-technology.html.

Digiconomist. 2017. Bitcoin Energy Consumption Index. https://digiconomist.net/bitcoin-energy-consumption (accessed 20 October 2017).

DTCC. 2016. "Embracing Disruption: Tapping the Potential of Distributed Ledgers to Improve the Post-Trade Landscape." DTCC White Paper (January). http://www.dtcc.com/news/2016/january/25/blockchain.

DTCC Connection. 2016. Eight Key Features of Blockchain and Distributed Ledgers Explained. February 17. http://www.dtcc.com/news/2016/february/17/eight-key-features-of-blockchain-and-distributed-ledgers-explained.

Ehrsam, Fred. 2017. "Scaling Ethereum to Billions of Users." Medium. June 27. https://medium.com/@FEhrsam/scaling-ethereum-to-billions-of-users-f37d9f487db1.

Finextra. 2017. "Eight Banks Form Joint Venture to Launch Blockchain Trade Platform." Finextra. October 17. https://www.finextra.com/newsarticle/31204/eight-banks-form-joint-venture-to-launch-blockchain-trade-platform.

Freiburg, Lewis. 2017. "Instant and Feeless Flash Channels." IOTA Blog. https://blog.iota.org/instant-feeless-flash-channels-88572d9a4385.

Greenspan, Gideon. 2017. "Do You Really Need a Blockchain for That?" CoinCenter (online). July 26. https://coincenter.org/entry/do-you-really-need-a-blockchain-for-that?mc_cid=a7bfc69a19&mc_eid=8552c1c32b.

Hannam, Keshia. 2016. "This Emerging Tech Company Has Put Asia's Tuna on The Blockchain." Forbes. September 30. https://www.forbes.com/sites/keshiahannam/2016/09/30/this-emerging-tech-company-has-put-asias-tuna-on-the-blockchain/#2b9dce4b2649.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (6160): 850–53. http://science.sciencemag.org/content/342/6160/850.

Higgins, Stan. 2016. "IBM Tests Blockchain for Supply Chain with India's Mahindra Group." CoinDesk (online). November 30. http://www.coindesk.com/ibm-blockchain-mahindra-supply-chain/.

Hockenos, Paul. 2017. "Power to the EV: Norway Spearheads Europe's Electric Vehicle Surge." The Guardian. February 7. https://www.theguardian.com/environment/2017/feb/07/power-to-the-ev-norway-spearheads-europes-electric-vehicle-surge.

innogy Innovation Hub. 2017. "Testing Blockchain for IoT and IOTA in Initial Prototypes." https://innovationhub.innogy.com/news-event/xEEuWGCrRe006EOw26ySA/testing-blockchain-for-io-t-and-iota-in-initial-prototypes.

The Japan Times. 2017. "University of Tokyo Pair Invent Loop-Based Quantum Computing Technique." Sep 24. https://www.japantimes.co.jp/news/2017/09/24/national/science-health/university-tokyo-pair-invent-loop-based-quantum-computing-technique/#.Wd9ayBOCwdU.

Jemima, Kelly. 2016. "Barclays Says Conducts First Blockchain-Based Trade-Finance Deal." Reuters. September 8. http://www.reuters.com/article/us-banks-barclays-blockchain/barclays-says-conducts-first-blockchain-based-trade-finance-deal-idUSKCN11D23B.

Maupin, Julie. 2017. "Mapping the Global Legal Landscape of Blockchain and Other Distributed Ledger Technologies." CIGI Paper No. 149. https://www.cigionline.org/publications/mapping-global-legal-landscape-blockchain-and-other-distributed-ledger-technologies.

McDonald, Joe. 2017. "China Sets Target for Electric Car Quota, but Delays Rollout." USA Today, September 29. https://www.usatoday.com/story/money/cars/2017/09/29/china-sets-target-electric-car-quota-but-delays-rollout/715712001/.

Morrison, Alan. 2016. "Blockchain and Smart Contract Automation: How Smart Contracts Automate Digital Business." PwC Technology Forecast Series. https://www.pwc.com/us/en/technology-forecast/2016/blockchain/pwc-smart-contract-automation-digital-business.pdf.

Nelson, J. Scott, David Henderson, Glenn Jones, Micha Roon, Michael Zargham, Aleksandr Bulkin, Jake Brukhman, and Kenny Rowe. 2017. "Sweetbridge: A Blockchain-Based Protocol Stack for Global Commerce and Supply Chains (Sweetbridge White Paper)." https://sweetbridge.com/whitepaper.

Ngo, Diana. 2017. "Singapore Moves Forward with Blockchain-Powered Interbank Payments Project." Coinjournal (online). October 13. https://coinjournal.net/singapore-blockchain-interbank-payments-project-ubin/amp.

Parker, Luke. 2016a. "Kimberley Process Pilots a Blockchain for Tracking the World's Diamonds." Brave New Coin (online). August 28. http://bravenewcoin.com/news/kimberly-process-pilots-a-blockchain-for-tracking-the-worlds-diamonds/.

———. 2016b. "Cubichain Tackles 3D Printing Counterfeiting Issues with Blockchain Technology." Brave New Coin (online). December 10. http://bravenewcoin.com/news/cubichain-tackles-3d-printing-counterfeiting-issues-with-blockchain-technology/.

———. 2016c. GiveTrack Offers Confidence in Charities. Brave New Coin (online). December 13. http://bravenewcoin.com/news/givetrack-offers-confidence-in-charites/.

Popkin, Gabriel. 2017. "How Scientists and Indigenous Groups Can Team Up to Protect Forests and Climate." Smithsonian Special Report. May 3. https://www.smithsonianmag.com/science-nature/scientists-can-team-up-with-indigenous-groups-protect-forests-climate-180963089.

Postscapes. 2017. "Blockchain IoT Projects and Applications, 2017 Guide." https://www.postscapes.com/blockchains-and-the-internet-of-things/.

Samburaj, Das. 2016. "UK Trials Blockchain-Based Social Welfare Payments." CryptoCoins News (online). July 7. http://www.cryptocoinsnews.com/uk-trials-blockchain-based-social-welfare-payments/.

Schiener, Dominik. 2017. "A Primer on IOTA (with Presentation)." IOTA Blog. May 21. https://blog.iota.org/a-primer-on-iota-with-presentation-e0a6eb2cc621.

Shin, Laura. 2016. "Republic of Georgia to Pilot Land Titling on Blockchain with Economist Hernando De Soto, BitFury." Forbes. April 21. http://www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/#2421bdfe6550.

Sønstebø, David. 2017. "The Transparency Compendium." IOTA Blog. June 16. https://blog.iota.org/the-transparency-compendium-26aa5bb8e260.

Spector, Julian. 2017. "Blockchain-Enabled Electric Car Charging Comes to California." GTM. August 2. https://www.greentechmedia.com/articles/read/blockchain-enabled-electric-car-charging-california#gs.SpNHz4M.

Stadlera, Michael, Gonçalo Cardosoa, Salman Mashayekha, Thibault Forgeta, Nicholas DeForesta, Ankit Agarwala, and Anna Schönbeina. 2016. "Value Streams in Microgrids: A Literature Review." *Applied Energy* 162: 980–89. https://doi.org/10.1016/j.apenergy.2015.10.081.

Tobin, Andrew, and Drummond Reed. 2017. "The Inevitable Rise of Self-Sovereign Identity." Sovrin Foundation White Paper. p. 10. https://sovrin.org/wp-content/uploads/2017/06/The-Inevitable-Rise-of-Self-Sovereign-Identity.pdf.

United Nations (UN) SDGS. 2017. "Targets and Indicators." https://sustainabledevelopment.un.org/sdg16 (accessed 25 October 2017).

Vandenabeele, Caroline, and Christine V. Lao, eds. 2007. *Legal Identify for Inclusive Development.* Manila: Asian Development Bank. https://www.adb.org/sites/default/files/publication/29046/legal-identity.pdf.

Von Wirdum, Aaron. 2017. "Bitcoin Unlimited Miners May Be Preparing a 51% Attack on Bitcoin." Bitcoin Magazine. March 29. https://bitcoinmagazine.com/articles/bitcoin-unlimited-miners-may-be-preparing-51-attack-bitcoin/.

Wall, Eric. 2017. "IOTA is Centralized." Medium. June 14. https://medium.com/@ercwl/iota-is-centralized-6289246e7b4d.

Wild, Jane. 2016. "Central Banks Explore Blockchain to Create Digital Currencies." The Financial Times. November 2. www.ft.com/content/f15d3ab6-750d-11e6-bf48-b372cdb1043a.

Webb, Jonathan. 2017. "Alibaba, EY, IBM and Microsoft Use the Blockchain to Create a Transparent Supply Chain." Forbes. August 31. https://www.forbes.com/sites/jwebb/2017/08/31/alibaba-ey-ibm-and-microsoft-use-the-blockchain-to-create-a-transparent-supply-chain/#c6080aa4b370.

World Bank. 2017. "Identification for Development." http://www.worldbank.org/en/programs/id4d (accessed 25 October 2017).

World Trade Board. 2017. Digital Standards for Trade (DST): A World Trade Board Initiative. Mimeo.

Xpansiv Data. 2017. "Xpansiv Data Creates First 'Digital Feedstock™' Via Proof of Concept with Carbon Creek and Gem." Xpansive. May 25. https://docs.wixstatic.com/ugd/f994b4_4a0845e040954b0cb588164e12abc91e.pdf.

ZF. 2017. "ZF, UBS and innogy Innovation Hub Announce the Jointly Developed Blockchain Car eWallet." ZF Press Release. February 1. https://press.zf.com/site/press/en_de/microsites/press/list/release/release_29127.html.

Zhai, Yongping. 2017. "4 Ways Blockchain will Disrupt the Energy Sector." Asian Development Blog. June 2. https://blogs.adb.org/blog/4-ways-blockchain-will-disrupt-energy-sector.

Distributed Ledger Technologies for Developing Asia

Hype over distributed ledger technologies (DLTs) has spurred adoption involving huge sums of investments at breath-taking speeds. Ironically, that same hype is what hinders the objective evaluation of the benefits and drawbacks of these exciting technologies. This paper takes a first pass at assessing feasible areas of practical implementation for DLTs mainly in the context of development finance. It takes a closer look at five use cases—digital identity, trade finance, project aid monitoring, smart energy, and supply chain management—to assess their implementation limits and potential. This paper also points to areas of potential application of DLTs within the Asian development context, including providing financial system access to billions of excluded populations.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org