

The Economics of Blockchain within Africa

Aaron Thegeya

Working Paper DG-007

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

The Economics of Blockchain within Africa

By

Aaron Thegeya¹
Aliquot Ltd

AERC Working Paper DG-007
African Economic Research Consortium, Nairobi
February 2023

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

© 2023, African Economic Research Consortium.

Contents

List of figures

Abstract

| | | |
|----|--|----|
| 1. | Introduction | 1 |
| 2. | Blockchain Innovations in Africa | 3 |
| 3. | Economics of Blockchain: A Literature Review | 7 |
| 4. | Fundamentals of Blockchain Economics | 10 |
| 5. | An African Perspective on Blockchain Economics | 15 |
| 6. | Policy Implications | 18 |
| | Notes | 21 |
| | References | 22 |

List of figures

1. Blockchain innovations in Africa by sector 5

Abstract

Blockchain technology offers the potential to transform economic activity and improve living standards in Africa by overcoming information asymmetry problems, property rights and governance barriers. Blockchain innovations have the ability to boost levels of productivity and unlock capital flows to underserved sectors, in addition to leveraging the increasing returns of information as an input to production to spur economic growth. This background paper discusses the recent advances in blockchain technology within Africa, and investigates the underlying economic principles of blockchain networks, both universally and in an African context. It reviews the enabling infrastructure and supporting technology, including digital identity. Finally, it gives policy recommendations to increase the uptake of blockchain technology on the continent.

Keywords: *Blockchain, Data governance, Africa*

Key Highlights and Policy Implications

Blockchain applications have the potential to overcome information asymmetry problems and property rights and governance barriers, and applications within the continent have already enjoyed a measure of success in doing so. However, there are still many challenges to be overcome in utilization of blockchain technology, such as scalability and security challenges.

Despite high levels of mobile phone ownership in Africa, levels of data accessibility across the continent are low. There are major differences in Internet connectivity both within and across countries, and the costs of data access are high relative to incomes. Blockchain innovations have had varied uptake across the continent, with the highest rates of adoption in Kenya, Nigeria and South Africa. The most successful innovations have been in the financial sector, and the most widespread application within the financial sector is in cryptocurrency trading, although there is significant uptake as well in payments and cross-border transactions.

Public blockchain networks are designed to be distributed and transparent, and the validity of data within these networks is established by imposing an artificial cost of proving validity, a mechanism that replaces the role of a trusted intermediary within a centralized information repository. However, the costs of verification impose a significant constraint within public networks. Conversely, within a centralized system, an agent in a privileged position is trusted to verify and maintain the validity of data, and the agent's status is dependent on ensuring that trust is maintained. This privileged status also allows the agent to extract rents. Private blockchains are an intermediate case where information is shared among a limited number of pre-verified nodes, where participants only join by invitation or permission.

Within an African context, the use of blockchains can potentially be very impactful within informal labour markets by providing a mechanism to increase transparency and secure property rights, thereby increasing allocational efficiency and overcoming credit rationing constraints. There is also great latent potential to increase blockchain adoption in areas related to governance and transparency. Informal contracts and tacit agreements are common in regions where there is uncertainty about the enforceability of contracts, and are typically premised on a reputational foundation or a collective governance framework at the local level. Blockchain can create a framework to enhance the ability to contract, by virtue of the transparency of past contractual obligations to third parties, in a validated and immutable format. Second, blockchain can be leveraged to create smart contracts by automatically executing actions that have been agreed upon ex-ante once certain preconditions have been fulfilled.

In addition, blockchain innovations can help improve institutional governance by enhancing the transparency of legal and judicial processes, thereby improving the accountability of public officials. This can help speed up the improvement of

governance across the continent, where indicators highlight the need to improve the quality of institutions and enforce the rule of law. While the benefits of deploying blockchain technology in this area are clear, the implementation of solutions has been slow and fragmented.

Role of African Economic Research Consortium (AERC)

The AERC has a pivotal role to play in:

- i) Providing recommendations to create an enabling and conducive policy and regulatory framework for blockchain within Africa. Currently, no regulatory authority within Africa has issued any regulations on the use of blockchain technology, although some have created regulatory sandbox environments to provide innovators in financial institutions with licenses to practice.
- ii) Researching mechanisms that can overcome critical incentive compatibility constraints and encourage the adoption of blockchain innovations in the public sector, particularly those that improve governance and transparency within African countries.
- iii) Researching and providing recommendations on cross-continental regulatory issues from the perspective of distributed blockchain ledgers that store data in multiple locations and across many countries, thereby raising jurisdictional and enforceability questions about the data within blockchains.
- iv) Researching and providing recommendations on the regulation of cryptocurrencies, and addressing concerns on the high levels of volatility in the trade of crypto assets.

1. Introduction

The advent of blockchain technology offers massive potential for revolutionary innovations that address fundamental constraints and market failures across a wide span of sectors in Africa. Blockchain applications have the potential to overcome information asymmetry problems and property rights and governance barriers, and applications within the continent have already enjoyed a measure of success in doing so. In turn, these innovations can boost levels of productivity and unlock capital flows to underserved sectors, in addition to leveraging the increasing returns of information as an input to production to spur economic growth.

Blockchain adoption in Africa is supported by high rates of mobile phone adoption, but is hindered by low rates of data access, low quality of Internet connections, and high data access costs. Access to data is therefore inequitable, with higher levels of access among better-off households. The COVID-19 pandemic has contributed to an acceleration of digitization across the continent, with the movement of more social interactions and commercial transactions online. This has in turn increased the need for solutions that allow secure and transparent economic activity. The closure of critical institutions, particularly education facilities, in addition to the need for continued economic activity, has exposed gaps in the quality of Internet infrastructure.

Blockchains enable transparency within decentralized networks by eliminating the need for a centralized intermediary. Within an African context, the use of blockchains can potentially be very impactful within informal labour markets by providing a mechanism to increase transparency and secure property rights, thereby increasing allocational efficiency and overcoming credit rationing constraints. The utilization of smart contracts can further underpin the scope of the impact. However, the use of blockchains is not without cost. Implementation of decentralized networks introduces the need for artificial costs of verification, which creates new constraints.

Policy implications of blockchains, particularly within an African context, touch on some critical dimensions. An enabling and conducive policy and regulatory framework is critical to realizing the untapped potential of blockchains. These frameworks must be incentive-compatible, and therefore internalize the incentives of agents within the networks. This is particularly important within the public sector where failure to implement applications with potentially massive positive externalities may otherwise occur. Additionally, regulatory frameworks should account for the individual data privacy preferences of agents, where the assignment of rights and obligations over

data is a key determinant of growth and equity. A pareto-efficient outcome may be possible through the assignment of rights to consumers, complemented with the development of markets for the sale of data.

The economics of blockchain is still very much a nascent field. This paper gives a background of recent advances in blockchain within Africa, and the key underlying economic principles within blockchain networks, both universally and within an African context. It also discusses policies that would be impactful in increasing the use of blockchain to improve governance and transparency. The document is structured as follows: section two gives a background of blockchain innovations Africa, and section three gives a review of the existing literature on the economics of blockchain. Section four discusses the economic theory of blockchains, and section five discusses economic aspects particularly relevant within an African context. Section six discusses policy implications of blockchain networks, and section seven concludes.

2. Blockchain innovations in Africa

Blockchain is a relatively new technology that has seen rapid global growth since its first commercial implementation in 2008. A blockchain is a digital ledger of transactions that is duplicated and distributed across an entire network of computer nodes. Each entry in the ledger is known as a block, and the addition of new entries is done by appending a new block to the existing set of blocks, resulting in a chain of blocks. Each block in the chain contains a number of transactions, and every time a new transaction occurs, a record of that transaction is added to every participant's ledger. The nodes within a blockchain network may be anonymous, and therefore untrusted across the participants. Therefore, mechanisms such as proof of work or proof of stake are implemented to establish trust among the network participants so that there is no need for a central trusted authority or clearinghouse within the network. These mechanisms work by introducing costs that discourage malicious behaviour among network nodes.

Blockchain innovations in Africa have been most successful in the financial sector. The most widespread application of blockchain within the financial sector is in cryptocurrency trading, and in payments and cross-border transactions. Blockchain offers alternative payment solutions to existing payment systems and allows cross-border remittances. With 63% of Africa's population unbanked², there is enormous untapped potential for further adoption of blockchain-based solutions as an alternative to traditional payment options. In addition, the adoption of mobile money payments has lowered the costs and cultural barriers to entry for digital payments solutions. Countries with high currency depreciation risk and capital controls have tended to be the first adopters of cryptocurrencies to protect against inflation.³ This combination of factors has contributed to rapid blockchain technology adoption within the financial sector.

In particular, there has been a rapid rise of cryptocurrency trade on the continent, which is now well developed in Africa. Peer-to-peer payments with digital currencies have started to become an alternative to local currencies, with a number of growing blockchain African-run startups.⁴ Global cryptocurrency market capitalization reached nearly US\$ 2 trillion in the first quarter of 2021. Despite many currency exchanges, the cryptocurrency market is highly segmented, with the largest ten cryptocurrencies globally accounting for roughly 82.0% of the market by volume. Bitcoin is the largest exchange, accounting for 46.4% of market capitalization

(US\$ 750.5 billion), followed by Ethereum, which constitutes 17.7% of market capitalization.⁵

Additionally, Central banks in Africa and around the world have begun to explore the possibility of introducing central bank digital currencies (CBDCs). A CBDC is a form of virtual currency that is issued and backed by the Central Bank. Globally, 76 countries are exploring the introduction of a CBDC with 5 of the countries - Grenada, Saint Kitts and Nevis, Antigua and Barbuda, Saint Lucia and the Bahamas – having already launched digital currencies. Fourteen (14) other countries are in the pilot stage while three countries within Africa (Nigeria, South Africa and Mauritius) have their CBDCs in the development stage.⁶

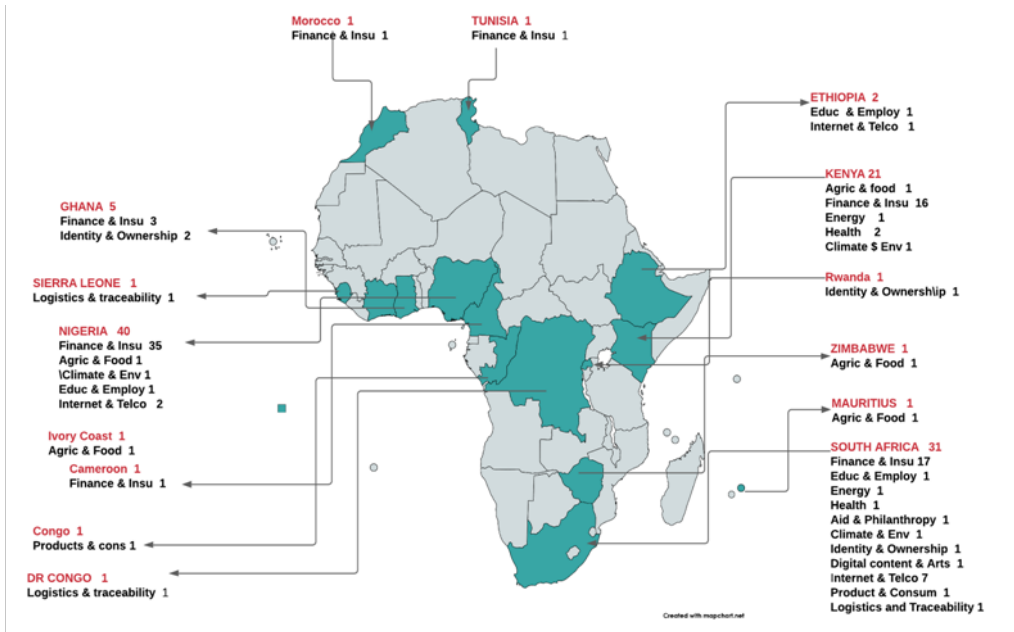
Other sectors that have seen a significant number of blockchain innovations within the continent are insurance, telecommunications, agriculture, and in the securing of identity and property rights. The traceability aspect of blockchain has eased the complexity and opacity of processes within agricultural supply and value chains and has facilitated proof of asset ownership as a means to enabling access to resources and unblocking credit rationing, and allowing better exercising of property rights. The capacity to track the origins of consumer goods has also increased the visibility of local producers along supply chains, and improved logistical efficiencies.

Blockchain traceability and digital identity has gained momentum in Africa as seen from a few large blockchain innovations within Africa. For example, a scheme launched in 2018 by the Democratic Republic of Congo uses blockchain technology to monitor cobalt mining in the country. This process involves organizations throughout the supply chain, from on-the-ground monitors checking that sites are not using child labour, through the refining process to end users. An additional innovation utilizing artificial intelligence and blockchain traces coffee from Uganda to Colorado and from Ethiopia to Amsterdam while cutting intermediaries out of the coffee supply chain. The blockchain platform also ensures instantaneous payments to producers. Additionally, De Beers of South Africa imprints a digital fingerprint into its diamonds, which is then tracked by blockchain as gems are sold, giving a forgery-proof record of the movement from the mine to cutter and polisher, then through to a jeweler.

The leading innovators in blockchain technology are Nigeria, South Africa and Kenya. These countries account for over 80% of blockchain innovations. Within these countries, the major innovations are in finance and insurance, Internet and telecommunications, and the health sector. The key innovations by sector in each country are given in Figure 1.

Africa's blockchain footprint is small, and accounts for a small portion of the global blockchain network. For example, when the Bitcoin network is considered, there are 12,867 nodes globally, of which only 16 nodes are in Africa, representing less than 1% of the total. The distribution of nodes is across South Africa, which accounts for 14 nodes, and Nigeria and Egypt, which each account for one node.⁷ The largest share of bitcoin nodes is in Europe, which has a total of 4,258 nodes.

Figure 1: Blockchain innovations in Africa by sector



Source: Positive blockchain.io and Internet searches

While there has been significant growth in blockchain adoption, there is great latent potential in a number of areas related to governance and transparency. While the benefits of deploying blockchain technology are clear, the implementation of solutions has been slow and fragmented. In public spending and governance, blockchain-based workflow tools allow for efficient project implementation by enabling expenditure tracking in a collaborative and transparent way. The deployment of blockchain technology has also increased the transparency of property rights and transfers of asset ownership, particularly related to land registration. This addresses challenges in many developing countries where a large share of landowners lack accurate documentation of property ownership. Additionally, to increase trust in educational certificates, blockchain-based systems are being deployed for the verification of digital documents. This helps to establish trust in labour markets.

Digital identity is a key innovation on which the success of some critical blockchain innovations rests. Of digital technologies, biometrics technology is the most common means of identity authentication. In the public sector, governments in almost 50 African nations have issued e-passports.⁸ However, some countries are looking into deploying the technology to other sectors, including health and security. The African biometrics industry is estimated at US\$ 1.6⁹ while globally its estimated at US\$ 24.1 billion, with Africa and Middle East biometrics market forecasted to grow at an annual rate of 21%.¹⁰ Digital identity innovations have been implemented to provide trusted identities for economically excluded individuals and small businesses, and to enhance the security of transactions through digital authentication.

The World Bank estimates that one billion people worldwide lack the means to prove their identity, and approximately 51% of this population lives in Africa (GSMA).¹¹ Within the African continent, 33% of the population lacks legal proof of identity, with more than half of the population in 9 African countries being unregistered.¹² Therefore, leveraging mobile technology, especially in developing countries, is seen as an enabler of digital identity and associated services, given that a large percentage of countries around the world require mandatory prepaid SIM card registration.

Enabling infrastructure is also critical for implementation and utilization of blockchain innovations. At the end of 2019, 651 million people were connected to mobile services in Africa, comprising 477 million people in Sub-Saharan Africa (45% of the population) and 176 million people in North Africa (70% of the population).¹³ Half of the total connections are through smartphones, as cheaper devices have become available, with the number of smartphone connections projected to reach 67% of Africa's population by the end of 2025 (65% of the population in Sub-Saharan Africa and 75% of the population in North Africa, respectively).

Despite high levels of mobile phone ownership, levels of data accessibility across the continent are low. Additionally, there are major differences in Internet connectivity both across countries in Africa, and within countries. On average, only 24% of individuals are connected to the Internet in Africa, which is 60 percentage points lower than the proportion of individuals connected in Europe, which has the highest level of Internet connectivity. Morocco has the highest connectivity rates in Africa, with a connectivity rate of 62%. Conversely, a total of 11 countries have connectivity rates below 10%. The lowest connectivity rates across the continent are in Burundi, Somalia and Eritrea, where less than 3% of the population are connected to the Internet.

Additionally, there are major differences in the costs of data access across the continent. A standard metric to gauge the relative cost of access to data is the average price of one gigabyte of data. Africa has the second-highest cost of data access globally, second only to North America, with a cost of US\$ 5.80 per gigabyte of mobile data. Comparatively, the price of 1 gigabyte of data is US\$ 8.21 in North America, and US\$ 1.79 in Asia, which has the lowest average cost. The costs of broadband access are even higher. In Africa, the average price of a broadband Internet connection is US\$ 77, excluding Mauritania, which is an outlier with an average cost of US\$ 695.¹⁴ In comparison, the average cost of broadband access in the United States is US\$ 60, while the cost of access in Europe, the lowest globally, is US\$ 30.

3. Economics of blockchain: A literature review

A nascent but growing literature on the economics of blockchain is beginning to emerge. Blockchain networks have brought attention to some areas of economics that have a long history of research. These include the economics of information, and more recently the economics of data, which has been spurred by advances in processing power, machine learning and storage. Additionally, the economics of privacy is a relevant topic within the context of blockchains.

Catalini and Gans (2016) discuss how blockchain technology can shape innovation and competition in digital platforms. In their discussion, two key costs affected by the technology are considered: the cost of verification and the cost of networking. By reducing the costs of running decentralized networks of exchange, blockchain technology allows for the creation of ecosystems where the benefits from network effects and shared digital infrastructure do not come at the cost of increased market power and restricted data access by platform operators. Reduction in the cost of networking allows open-source projects and startups to directly compete with entrenched incumbents through the design of platforms.

Abadi and Brunnermeier (2018) note that although blockchains keep track of ownership transfers, a centralized record-keeping best complements the enforcement of possession rights. They note that the ideal qualities of any record keeping would be correctness, decentralization and cost efficiency. However, blockchain fails to satisfy all the three properties simultaneously. Unlike centralized record-keepers that extract rents due to monopoly power based on restricted access to their ledgers, blockchains allow for free entry of record-keepers and thus drives down rents. Blockchains provide static incentives for correctness through expensive proof-of-work algorithms and giving permission to record-keepers to undo fraudulent reports by rolling back history.

Jones (2020) discusses the non-rival property of data, and argues that because of its infinite usability, there are large social gains to allocations in which the same data is used by multiple firms simultaneously. However, firms are incentivized to hoard data to avoid competition, leading to inefficiencies and lower productivity. The paper indicates that giving data property rights to consumers can lead to allocations that are close to optimal, and is more efficient than government-imposed restrictions on selling data.

Gans and Gandal (2019) discuss the economic limits of blockchain, and find that an economically sustainable network will involve the same cost of running a network

regardless of whether it is proof of work or proof of stake. Additionally, the authors find that regulation of the number of nodes permitted within a network does not lead to additional cost savings relative to networks in which free entry is allowed.

Chen et al. (2021) examine recent research on the economics of blockchains. They opine that a game-theoretical approach to understanding consensus challenges is the most promising. Further, the authors find that solutions to blockchain challenges that involve local consensus, local centralization, or local scalability are the most promising. The authors also find that blockchain innovations are likely to emanate from mechanism design approaches to consensus protocols that have clear objectives for specific applications. The core of blockchain economics, according to the paper, are agent and incentive issues, and key problems are thus likely to arise from information asymmetry.

There is an expansive literature on cryptocurrency as a subset of blockchain applications. Chiu and Koepl (2017) examine the optimal design of cryptocurrencies to assess whether they can support bilateral trade and find that adopting an optimal design based on money growth instead of transaction fees to finance mining rewards could lower the welfare loss caused by cryptocurrency mining. Zimmerman (2020) analyzes the model of cryptocurrency price formation and concludes that speculation could crowd out monetary use, limiting the ability of cryptocurrencies to act as a medium of payment. Halaburda et al. (2020) conducted a literature review of studies spanning different disciplines, focusing on the emergence of cryptocurrency, its demand, supply, trading price and competition.

The economics of blockchain builds upon the extensive literature on the economics of information. Within this literature, agents interact in economic environments characterized by perfect or imperfect information. In their famous paper, Rothschild and Stiglitz (1978) showed that imperfect information caused market disequilibrium in the insurance market. In addition, Akerlof's (1978) seminal article on quality uncertainty and market mechanisms explored adverse selection in markets where sellers are better informed than buyers about the quality of goods.

The dimension of privacy is a key element of consideration within blockchain networks. Acquisti et al. (2016) highlight three themes that connect diverse insights on the economics of privacy: first, they highlight that there are situations where the protection of privacy can both enhance and detract from individual and societal welfare. Second, consumers' ability to make informed decisions about their privacy is hindered because of imperfect or asymmetric information, especially in digital economies. And third, they note that because privacy issues of economic relevance arise in widely diverse contexts, it is hard to characterize a single unifying economic theory on privacy.

Cecere et al. (2017) reviewed literature on the importance of personal data in markets. The authors highlight the puzzle that individuals face in sharing data to enable access to customized products and information, while at the same time protecting their personal information from misuse. Further, Cecere et al. (2017) elaborate that personal data can spur growth in new industries but highlight that

tension exists within regulatory frameworks that aim to protect personal data without hindering firms' ability to innovate.

Chellappa and Sin (2005) highlight that a consumer's intent to use personalization services is positively influenced by their trust in the vendor. However, they note that although online vendors offer useful web-based personalization products, these products increase switching costs and are an important means of acquiring valuable customer information. They note that investments in online personalization may be severely undermined by privacy concerns.

4. Fundamentals of blockchain economics

Blockchains are immutable records of information that encode some form of economic activity, such as the value of an asset or evidence of a transaction. Therefore, the economics of blockchains build upon the foundations of the economics of information. Data can be defined as a collection of symbols that encode the properties of observables or the representation of facts, while information can be defined as data within a given context.¹⁵ Ideas in turn can be defined as novel processes that generate economic value from data.

While there is a rich economic literature on the economics of information, and more recently an expanding literature on the economics of data spurred by advances in data storage that generate big data, and machine learning that allows leveraging of big data in new productive ways, a distinction is typically rarely made between data and information. For our purposes, we define information as the sum-total of data and ideas, and focus on the dynamics of information within blockchains.

Information is an input to production in addition to capital and labour that typically leads to an increase in productivity. Returns to information are recorded as gains in total factor productivity, and in practice are recorded as a residual in a growth decomposition. Given that information builds upon existing information, it is likely that returns to information are increasing in scale (Romer, 1990). For example, binary representation of information leads to the creation of a programming language, which in turn leads to the creation of programming libraries that significantly increase the efficiency of coding and, therefore, production. It is thus possible that productivity gains to information are not linear but exponential. Measurement of the contribution of information to growth is challenging due to the difficulty in quantifying information in terms of level and increase, unlike other factors of production. For example, unlike information, labour input can be measured in terms of hours worked and capital can be measured by asset value.

Productivity gains from information are a function of the ability to generate and utilize ideas, which is determined by the quality of human capital. The maximization of gains from information is therefore cross-sectoral, and must be integrated across other key social functions. For example, this stresses the need to protect human capacity to learn, through access to healthcare systems that protect learning capacity all the way from conception, with proper maternal nutrition, to early stage childhood development that prevents stunting of growth and brain development, to access to

quality educational systems that develop the capacity of human capital to create and use ideas. Network infrastructure is then critical to ensure the dissemination of information.

Information is non-rival and partially excludable. Therefore, there are massive positive externalities to the sharing of information, as information is infinitely usable at the same moment in time and without depletion over time. The excludability of information is a function of the security of storage and transmission, and the ability of others to generate the same information independently. This makes information only partially excludable based on the likelihood of circumventing network security systems, keeping data secure on stand-alone password-protected systems, or the ability of other agents to generate the same information from first principles. The costs of information vary between data and ideas. While the costs of data relate only to its storage, the costs of generating ideas include the necessary investment to learn.

The excludability of information generates incentives for those who collect big data to over-invest in data collection and to hoard their data, while at the same time incentivizing under-investment in data privacy, thereby generating negative externalities. By virtue of the productivity gains that accrue from utilization of information, agents with access to information enjoy a competitive advantage over those without access. Additionally, information has resale value. These features allow those in control of big datasets to generate economic rents, and therefore create incentives for them not only to over-invest in collecting big datasets, but also to hoard their data. Conversely, these dynamics also create incentives to under-invest in data privacy, as those collecting data do not internalize the costs of privacy that data subjects may place a high value on.

The excludability of information within blockchain networks is dependent on the type of network. Public blockchain networks are fully transparent by design, and hence data within these networks is not excludable. Transparency is enabled by imposing an artificial cost of proving the validity of data within a distributed network, through methods such as proof of work, and replaces the mechanism of trust in a centralized information repository. Within a centralized system, an agent in a privileged position is trusted to verify and maintain the validity of data, and the agent's status is dependent of ensuring that trust is maintained. This privileged status also allows the agent to extract rents.

Private blockchains are an intermediate case where information is shared among a limited number of pre-verified nodes, where participants only join by invitation or permission. Therefore, a measure of trust is inherent in these networks. Information is not excludable for participants within the network, but it is excludable from those not part of the network.

By virtue of their transparency, public blockchains lower the costs of verification without need for a central intermediary and improve allocational efficiency. Further, these networks lower the ability of those with privileged status in centralized networks to extract rents, or those with incentives to hoard data to extract rents by excluding others from access to data. However, data collection and hoarding incentives also serve as dis-incentives for big data collectors to utilize blockchains.

Blockchains have significant implications within the context of the economics of information. A rich literature discusses markets under perfect information and those under imperfect information. Some key papers are included in the literature review. Imperfect information results from adverse selection, due to the inability to tell the quality of a given agent, and due to moral hazard, due to the inability to ensure that agents apply a desired level of effort to complete projects. Within the context of contracting, investors typically require higher returns as a consequence of these informational problems, or agents incur costs to signal their quality. In instances where information constraints are not overcome, a sub-optimal level of investment occurs, leading to allocational inefficiencies within the economy.

Blockchains drive the ability to overcome imperfect information constraints and therefore increase allocational efficiency. Data-driven machine learning algorithms have improved the capacity to gauge quality by leveraging an agent's past transaction history. Through use of this historical information, an agent's preferences, action tendencies or quality may be uncovered. For example, transaction history in an online store will give an indication of a person's preferences, while loan history records will indicate a firm's likelihood of defaulting on a future loan. However, electronic data are not immutable, and malicious agents can either change a transaction history or create a false history. Blockchains, by tracking transaction history, implementing hashing and requiring verification, lower the likelihood of data manipulation.

Fundamentally, blockchains can form the basis of smart contracts whereby the fulfilment of obligations by contracting parties is embedded and executed automatically, thus ensuring contract enforceability. Smart contracts are enabled within blockchains by virtue of the ability to encode contractual obligations through code. Contractual pre-conditions, actions and the timing of execution can all be embedded a-priori into a contract. This in turn precludes the ability of contracting agents to renege on their promises at a future date, as their ability to do so is eliminated at the very beginning of the contract. The design of the blockchain, through implementation in a distributed network, reinforces the integrity of contractual obligations.

However, smart contracts have limited scope in applicability. Smart contracts are enforceable when the embedded instructions can be executed electronically, and are not dependent on other exogenous factors. A key challenge in the adoption of smart contracts is that parties need to rely on a trusted, technical third party to verify the accuracy of the contractual code between two contracting parties. Further, the immutability of a smart contract, once executed, complicates subsequent amendments to the contract. Additionally, smart contracts may contain unintended programming errors that could result in erroneous execution, or may contain weaknesses that could be exploited by hackers.

Within a contracting perspective, blockchains raise important questions on information ownership, custody and property rights. Data within blockchains are stored on multiple servers that may be distributed across multiple borders. Under this distributed framework, it is imperative to define clear ownership rights, custody rights

and authority over regulation. Additionally, information is frequently generated as a byproduct of economic activity. For example, the repeated purchase of a particular commodity indicates a person's preference profile, and is visible to the retailer of the commodity. Clear delineation of the rights to such data is necessary. Further, in many instances, information is collected not on an individual but on a collective level, such as on a household or location basis. For example, satellite data is informative of a particular location, and is reflective of the individuals living in that location. In this case, the clear delineation of rights to collect and own such collective data is also important.

Although blockchains provide a decentralized solution to overcome challenges related to asymmetric information, they do not overcome the costs of verification. The implementation of blockchains is costly, and is dependent on the use of an energy-intensive verification mechanism within a proof-of-work context. Proof-of-work requires network participants to solve a complex encryption problem to gain the rights to amend a given blockchain. The complexity of the encryption problem can be pre-determined by the network, and accordingly amended as a function of computing capacity. Proof-of-work solutions are found through brute-force algorithms that iterate through a list of possible solutions until the correct solution is found.

Proof-of-work algorithms impose new barriers to entry in place of those eliminated through the distributed nature of blockchains, through investment requirements in processing power, memory and technical know-how. As the popularity of blockchains has grown, network nodes have invested in dedicating processing power and memory to blockchains, and as a result have massively increased energy requirements. For example, the energy consumed by the bitcoin network is greater than total energy consumption in Argentina.¹⁶ The distributed nature of blockchain networks also demands high memory bandwidth within those networks that require each node to store copies of the chain. Additionally, proof-of-work demands limit the number of transactions that can be executed within a block during any given period. Within the bitcoin network, on average seven new block transactions are executed within an hour.

Alternatives to proof-of-work have been developed to overcome processing constraints, including proof-of-stake, proof-of-burn and proof-of-capacity. However, none of these alternatives provide a comprehensive solution, and this is still an area of active research. Proof-of-stake is a type of consensus mechanism that works by requiring users to stake their assets to become validators. The value of assets at stake determines the validation power of a given node. Validators are responsible for checking and confirming blocks they do not create and stand to lose their stake for bad behaviour on the network.

Proof-of-burn is an alternate consensus algorithm, which aims to reduce energy consumption relative to proof of work. Proof-of-burn functions by providing a different incentive for miners to validate transactions. A network node utilizes existing assets rather than wearing out electricity and hardware, therefore encouraging miners to be good actors. For example, within a cryptocurrency context, network nodes utilize or 'burn' existing coins. The more coins miners send to burn, the higher their likelihood

of mining a block. Moreover, miners receive a reward each time they correctly validate and mine a block. Proof of activity is a combination of proof of work and proof of stake algorithms, which works by making it more difficult to mine as time elapses. However, increasing the difficulty of mining causes a spiraling in energy consumption and hardware costs.

These methods are not without drawbacks. For example, proof-of-stake encourages hoarding due to the link between returns and the amount held in escrow, rather than spent on transactions. It may also defeat the purpose of decentralization by leading to a concentration of validation markets.

Further, while blockchain can improve transparency, it is not possible for blockchain to enforce the transfer of physical assets. Blockchain can give a transparent account of the transaction history relating to a given asset, and smart contracts can enforce the electronic transfer of ownership rights for a given asset, based on a set of *apriori* agreed to conditions. However, the scope of a blockchain contract remains electronic, and the physical transfer of an asset is dependent on the transferor honoring the promise to turn the asset over to the transferee. A well-functioning justice system is critical to support successful implementation of blockchains and build trust in their deployment. Additionally, blockchains cannot verify the correctness of information about inputs, which requires external verification before introduction into a blockchain.

Blockchains do not resolve public sector incentive compatibility constraints. While blockchain is an impactful solution, it does not address private incentives that agents face in deciding contractual obligations. Additionally, blockchains remove the ability for agents to generate rents on the basis of control of the custody and dissemination of information. The implementation is therefore likely to face resistance, which is particularly important in the case of public sector contracts, where failure to internalize the positive benefits of blockchain adoption is particularly costly, and thus the negative impact may be substantial and spread over a large number of agents. Where a blockchain is likely to lower the rents receivable to an agent that is in control of the decision of whether or not to use a blockchain, there are likely to be upfront costs in incentives or policy to push implementation through.

5. An African perspective on blockchain economics

While blockchains have been gaining traction across many economies, several distinguishing features are particularly relevant in the African context. These include fundamental issues ranging from digital inclusiveness of much of the continent, to governance issues related to supporting the implementation of blockchains in an equitable manner.

Africa's relatively lower levels of Internet access, lower quality of Internet connections, and higher cost of access mean that a smaller share of individuals participate in the data economy relative to the rest of the world. Thus, the impact of blockchain innovations is likely to be segmented at the household level, with higher levels of adoption among better-off households. This also means that the greatest impact of blockchain innovations is likely to be felt in those sectors that have a public good element or that have the potential for positive externalities. These sectors would have a direct benefit on those that are digitally included, while also indirectly benefitting those that are not. For example, a blockchain innovation that digitally tracks land registries is a public service that increases the transparency of transactions, and those public records are beneficial to the entire population.

Low levels of digital access across large segments of the African population also mean that most Africans are unable to leverage data to increase their levels of productivity, or directly benefit from the utilization of blockchains. By leaving those without access behind, blockchains may contribute to a widening gap in living standards. The development of blockchain therefore needs to be complemented with a concurrent increase in access to data.

Africa's markets are characterized by large informal labour markets. On average, 83% of jobs in Africa are accounted for in the informal sector, with the greatest share among the youth.¹⁷ The pivotal role played by the informal sector is expected to continue for the foreseeable future, as the formal sector is not creating jobs quickly enough to absorb Africa's growing labour force. The visibility of informal sector labour is limited, and therefore asymmetric information problems are particularly acute within this sector, as it is costly to overcome adverse selection and moral hazard problems. In addition, individuals within this sector are much more likely to have a low asset base, lower levels of income, and higher income volatility than formal sector workers, lowering their ability to pledge collateral. Therefore, the flow of capital to

this sector is severely restricted. The integration of blockchain to improve the visibility of the informal sector, through transparent tracing of transactions or securing of property and asset rights, would potentially have a transformative impact on the sector by reducing levels of credit rationing.

Digital currencies, especially within the cryptocurrency market, thrive highly on speculation, which in turn results in high volatility. Volatility is influenced by the fact that markets for cryptocurrencies remain very small in comparison to traditional currencies, and therefore there is a concentration of individuals with large holdings of crypto coins. For instance, there are approximately 18.9 million bitcoins in circulation in comparison to Ksh 288.2 billion and US\$ 2.2 trillion that is in circulation.¹⁸ Large transactions by these individuals, therefore, have the potential to cause swings in the market.

Informal contracts and tacit agreements are common in regions where there is uncertainty about the enforceability of contracts and are typically premised on a reputational foundation or a collective governance framework at the local level. Within this context, the use of blockchain can create a framework to enhance the ability to contract. First, it can substitute the critical role of reputation through transparency, whereby visibility of past contractual obligations among any contracting parties is visible to third parties. As a consequence, the costs of renegeing on contractual obligations are significantly increased through the potential for reputational repercussions, and this creates a strong incentive for parties to adhere to contracts.

Second, the utilization of smart contracts can strongly enhance the ability to contract by automatically executing actions that have been agreed upon ex-ante once certain preconditions have been fulfilled. This in turn means that control of contract execution is taken away from the contracting parties and, therefore, the contract is secured. These innovations are efficiency-enhancing, and are particularly relevant in countries where there are weak governance frameworks or weak rule of law.

In addition, blockchain innovations can help improve institutional governance by enhancing the transparency of legal and judicial processes, thereby improving the accountability of public officials. This can help speed up the improvement of governance across the continent, where indicators highlight the need to improve the quality of institutions and enforce the rule of law.

However, private incentive compatibility constraints indicate that regulatory intervention may be necessary to introduce the use of blockchains to contribute to the solution of governance problems. Individuals in privileged positions of information or authority are frequently able to extract rents as a consequence of their status. Where the decisions to implement blockchains are also within the domain of their control, they face disincentives to carry through implementation, due to the significant loss of private gain, despite the welfare-enhancing properties of blockchains. Incentive compatibility problems are found in both the private and public sectors, but the welfare implications are particularly acute in the public sector where externalities

tend to be larger. As a consequence, external intervention is necessary to ensure that implementation occurs.

Economies of scale, such as minimum account requirements and account maintenance fees, and the location of mainstream retail banking services in high-income neighbourhoods, work against disadvantaged populations. According to Kshetri (2017), blockchain-based solutions can be used to develop offerings that are appropriate to meet the needs of disadvantaged groups, such as by enabling small transactions at low cost. Kshetri (2017) also argues that the combination of decentralized access and immutability, which makes it difficult to engage in opaque transactions that take place between companies, individuals, and institutions, is likely to reduce or even eliminate fraudulent lending practices such as insider lending.

6. Policy implications

While blockchains carry transformative potential for Africa, the realization of this potential is unlikely to happen without an enabling and conducive policy and regulatory framework. A number of important policy considerations must be taken into account, as detailed in this section. The large number of individuals that do not yet have a digital presence, coupled with the large variations in the quality of data access, create an opportunity to put an appropriate data infrastructure in place as new users come online.

The regulatory environment for blockchain in Africa is uneven. Currently, no regulatory authority within Africa has issued any regulations on the use of blockchain technology.¹⁹ However, Mauritius and Kenya have created regulatory sandbox environments to provide innovators in financial institutions with licenses to practice. With regard to data privacy, 28 countries in Africa have enacted personal data protection legislation.²⁰

The assignment of rights and obligations over data to various stakeholders will determine growth and equity. Assignment of rights to consumers may provide the most optimal equilibrium if complemented with the development of markets for the sale of data. This is because under these conditions, households will appropriately reveal their individual preferences in terms of benefiting by sharing data relative to the costs of doing so, and price their relative value accordingly. Additionally, the regulatory landscape must allow for sufficient transparency to determine the rate of data collection and data distribution. This will allow a clear mapping of the landscape to understand privacy concerns in addition to data utilization and productivity.

Blockchain policy and regulatory frameworks must be incentive-compatible. This means that frameworks must internalize private incentives of participants within blockchain networks. For example, the excludability of data creates incentives for agents to hoard data to stifle competition, which allows incumbents to benefit, but also leads to data under-utilization. An appropriate framework will account for these incentives and implement policies that promote data sharing to result in more optimal outcomes.

A successful blockchain policy for Africa must be an integrated policy and must also promote the development of an enabling environment by closing access gaps in social and physical infrastructure. A clear policy to close gaps in education across and within countries is a critical foundation necessary to maximize the benefits of

blockchain. Additionally, improvement of infrastructure and lowering the costs of access are necessary preconditions to increase productivity.

Data privacy is a critical component of the policy environment. Privacy has some characteristics of a final good, valued for its own sake, and an intermediate good valued for instrumental purposes. These are crucial considerations for a blockchain governance framework. As a final good, individuals gain different levels of utility from maintaining privacy, with a spectrum ranging from those who are highly sensitive to privacy to those who are very comfortable with an open digital presence.

The regulation of privacy can have some unintended effects. Individuals have incentives to disclose favourable information and hide unfavourable or negative information. This results in inefficient outcomes. Therefore, regulatory interference that prohibits the flow of personal information can remove signals of quality from the marketplace and introduce inefficiencies. However, reputational effects can also lead to sub-optimal private decisions if information disclosure reveals negative information about an individual. For example, in a transparent environment, the stigma associated with checking into a rehabilitation centre may deter an individual from seeking treatment.

The optimal level of information disclosure should take into account accountability versus privacy concerns. The Coase Theorem, Coase (1960), states that whether or not a person's private information will be disclosed is dependent on the relative valuations of the parties interested in the information. If trade in an externality is possible and there are sufficiently low transaction costs, bargaining will lead to a Pareto efficient outcome regardless of the initial allocation of property rights. Thus, assigning property rights to information and allowing trade in information is likely to lead to an ex-post efficient outcome.

While private blockchains provide a measure of privacy, they are not truly decentralized. This is because private blockchains delegate specific actors to verify blocks and transactions. Although this provides efficiency and security, it raises concerns that private blockchains are not truly decentralized because the verification of transactions and control are put back into the hands of a central entity. In contrast, public blockchains lower the likelihood of a malicious attack as more people become part of the network.

From a legal perspective, the enforceability of blockchain contracts may face jurisdictional issues, when it is unclear where the agents sit. Given that the nodes of a decentralized ledger can span multiple locations around the world, there is a risk that transactions performed by an organization could fall under every jurisdiction in which a node in the blockchain network is situated, resulting in an overwhelming number of laws and regulations that might apply to a certain transaction. For example, there have been difficulties in the application of existing regulatory regimes on crypto assets, whereby in some countries, regulators have banned cryptocurrencies, while others have issued varying levels of regulations and investor warnings.

Agent domicile is also important particularly from the perspective of recognizing income for taxation purposes, and building appropriate structures for taxation. Poor

coordination in establishing taxation frameworks can result in multiple taxation, competition or conflict across authorities in the recognition of revenues or asset gains within blockchain networks, for the purposes of establishing tax bases.

The lack of a centralized coordinator increases the vulnerability of blockchains to volatile fluctuations and limits the ability of a central authority to intervene because of the volatility. This property is particularly prevalent in cryptocurrency markets. It raises the concern that without appropriate regulation, there could potentially be welfare-reducing swings in volatility, and makes the case for a regulatory authority. However, cryptocurrencies by nature have no specific legal and regulatory jurisdiction due to their global portability, making it difficult for policy makers to develop cryptocurrency regulations. Additionally, cryptocurrencies have underlying tokens that are not subject to existing regulations.

Appropriate infrastructure must implement checks and balances to avoid data-based discrimination. While data-driven innovations are often viewed as a positive development, discriminatory biases embedded in these technologies have the potential to create racial and social inequalities. Specifically, in running algorithms, data can be poorly selected, incorrect, incomplete or outdated, and can even incorporate historical biases, for example in the case of employment selection based on previous job recruitment data. Also, given that the programming decisions are essentially human judgments, concerns regarding the design of the algorithm that is using the data inputs often arise.

7. Conclusion

Blockchains have grown rapidly since their first application with the invention of cryptocurrency markets a little over a decade ago, and their potential for additional applications appears endless. In this background paper, we have considered the current state of blockchains within Africa, and explored the underpinning economic elements of blockchain networks. Additionally, we have explored the economic aspects of blockchains that are particularly relevant within an African context.

Policy implications of blockchains touch on some important dimensions. An enabling and conducive policy and regulatory framework is critical to realizing the untapped potential of blockchains. These frameworks must be incentive-compatible, and therefore internalize the incentives of agents within the networks, as failure to implement applications with potentially massive positive externalities may otherwise occur, particularly within a public blockchain context. Additionally, the frameworks should account for the individual data privacy preferences of agents within blockchain networks, where the assignment of rights and obligations over data will be a key determinant of growth and equity. A pareto-efficient outcome may be possible through the assignment of rights to consumers, complemented with the development of markets for the sale of data.

Blockchain research is still nascent, and the economic theory of blockchain networks is far from well established. Additional research on blockchain economics is necessary to contribute to the growing literature. These papers will incorporate an element of computer network dynamics from computer science as a matter of necessity, in terms of the efficiency, technical capacity and deficiencies inherent in networks of anonymous users. In addition, the literature will continue to explore new economic incentives that arise out of interactions within distributed networks. For example, while blockchain networks solve the problem of establishing trust within distributed networks and maintaining accurate data within those networks, it does so at the expense of generating costly verification. While alternatives to costly verification are under experimentation, there is no clear solution, and this remains an active area of research.

Notes

1. Correspondence concerning this paper should be addressed to Dr Aaron Thegeya. Email: athegeya@gmail.com. This paper has been funded through a grant from the African Economic Research Consortium (AERC).
2. The banked population is defined as individuals, aged 15 years and above, that have an account at a financial institution or with a mobile money service provider.
3. All Africa, How Hyperinflation is Driving Cryptocurrency Adoption in Africa; <https://allafrica.com/stories/202109100733.html>.
4. African blockchain startups include Kenya's BitPesa and Bitsoko, Ghana's bitcoin exchange BTCGhana, and South Africa's Luno, Ice3X and GeoPay.
5. See <https://coinmarketcap.com>.
6. Atlantic Council Research: Central Bank Digital Currency (CBDC) Tracker <https://www.atlanticcouncil.org/cbdctracker/>
7. Total reachable bitcoin nodes that were active as of 6 August 2021; <https://bitnodes.io/>.
8. UN.org :African countries embracing biometrics, digital IDs. <https://www.un.org/africarenewal/magazine/february-2021/african-countries-embracing-biometrics-digital-ids>
9. As estimated by Acuity Market Intelligence.
10. Biometrics – Global Market Trajectory and Analytics 2020.
11. GSMA, The commonwealth Digital Identity Initiative.
12. The Equatorial Guinea, Chad, South Sudan, Zambia, Angola, Ethiopia, Eritrea, Nigeria and Somalia.
13. GSMA.

14. How do U.S. Internet costs compare to the rest of the world? See: <https://www.broadbandsearch.net/blog/internet-costs-compared-worldwide>.
15. See Russell Ackoff, Data, Information, Knowledge and Wisdom (DIKW) pyramid.
16. Digiconomist.net: Cambridge University's Bitcoin Energy Consumption Index.
17. Kenya National Bureau of Statistics, Economic Survey, 2020, p. 44.
18. Total Kenya Shillings in circulation are given by the Central Bank of Kenya, depository corporation survey, <https://www.centralbank.go.ke/statistics/monetary-finance-statistics/>; total US currency in circulation is tracked at <https://fred.stlouisfed.org/series/CURRCIR>; total number of bitcoins in circulation are tracked at <https://www.blockchain.com/charts/total-bitcoins>.
19. Baker McKenzie, Blockchain and Cryptocurrency in Africa: A comparative summary of the reception and regulation of Blockchain and Cryptocurrency in Africa, 2018.
20. UNCTAD, Data Protection and Privacy Legislation Database.

References

- Acquisti, A., Taylor, C. and L. Wagman. 2016. "The economics of privacy". *Journal of Economic Literature*, 54(2): 442–92.
- Akerlof, G.A. 1978. "The market for lemons: Quality uncertainty and the market mechanism". In *Uncertainty in economics* (pp. 235–251). Academic Press.
- Cecere G., Le Guel F., Manant M. and N. Soulié. 2017. "The economics of privacy". In *The New Palgrave Dictionary of Economics*. London: Palgrave Macmillan.
- Chellappa, R.K. and G.R. Sin. 2005. "Personalization versus privacy: An empirical examination of the online consumer's dilemma". *Information Technology and Management*, 6(2): 181–202.
- Chen, L., Cong, L.W. and Y. Xiao. 2021. "A brief introduction to blockchain economics". In *Information for Efficient Decision Making: Big Data, Blockchain and Relevance* (pp. 1–40).
- Chiu, J. and T.V. Koepl. 2017. *The economics of cryptocurrencies–bitcoin and beyond*. Working Paper 3048124, SSRN.
- Friedman, E.J. and Resnick, P. 2001. "The social cost of cheap pseudonyms". *Journal of Economics and Management Strategy*, 10(2): 173–199.
- Gans, J.S. and N. Gandal. 2019. *More (or less) economic limits of the blockchain* (No. w26534). National Bureau of Economic Research.
- Halaburda, H., Haeringer, G., Gans, J.S. and N. Gandal. 2020. *The microeconomics of cryptocurrencies* (No. w27477). National Bureau of Economic Research.
- Kenya National Bureau of Statistics. 2020, *Economic Survey*, Nairobi: Kenya National Bureau of Statistics.
- Kshetri, N. 2017. "Potential roles of blockchain in fighting poverty and reducing financial exclusion in the global south". *Journal of Global Information Technology Management*.
- Romer, P. 1990. "Endogenous technological change". *Journal of Political Economy*, 98(5): S71–S102.
- Rothschild, M. and J. Stiglitz. 1978. "Equilibrium in competitive insurance markets: An essay on the economics of imperfect information". In *Uncertainty in economics* (pp. 257–280). Academic Press.
- World Bank. 2021. *Minimum data consumption: How much is needed to support online activities, and is it affordable? Analytical Insights*. World Bank, Washington, DC.



Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

www.aercafrica.org

Learn More

- | | | | |
|--|--|---|--|
|  | www.facebook.com/aercafrica |  | www.instagram.com/aercafrica_official/ |
|  | twitter.com/aercafrica |  | www.linkedin.com/school/aercafrica/ |

Contact Us

African Economic Research Consortium
Consortium pour la Recherche Economique en Afrique
Middle East Bank Towers,
3rd Floor, Jakaya Kikwete Road
Nairobi 00200, Kenya
Tel: +254 (0) 20 273 4150
communications@ercafrica.org