Cryptocurrencies and Distributed Ledger Technologies – A Literature Review for the SWIFT Institute

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1. Introduction

This academic literature review on cryptocurrencies and distributed ledger technologies (DLTs) is intended to (1) inform the SWIFT Institute leadership in developing Requests for Proposals (RFPs) on focus topics of interest to the SWIFT user community, and (2) identify authors who are academic thought leaders for consideration as interviewees for a general interest article from SWIFT. We expect the existing work that has been published by academics will enable a narrower focus for the yet to be chosen and supported work. In addition, our review will highlight authors and thought leaders that would make good sources for a freelance journalist to contact and interview for a broadly accessible article tapping on his or her expertise.

This review was carried by two advanced undergraduate students, Jonathan Wood (Economics, Entrepreneurship, and Computer Science) and John Roberts (MIS/Operations Management), and Bruce Weber, Dean of the Lerner College, and an engineering faculty member, Andy Novocin, overseeing the work. Prof. Novocin is the director of the UD Cybersecurity Scholars program.

We began the work by identifying 17 significant academic articles, and organizing their contributions in three distinct dimension of interest. The first dimension we looked for academic insights on was the risks associated with cryptocurrencies and reliance on DLT and blockchain. We found that DLT will impact organizational risk management activities. The second dimension is the revolutionary and futuristic research opportunities that will be introduced by cryptocurrencies and blockchain. Some well-established financial operations could be entirely restructured and transformed through the application of these new technologies. The third

dimension is the mindsets of market participants. The dynamics of acceptance and resistance to innovation and new ways of doing business are difficult to forecast. Users' attitudes and mindsets toward change will ultimately determine whether the emerging paradigms of decentralized ledgers will replace today's centralized business systems. A further question researchers are asking is how open and transparent standards will challenge organizations that perform intermediation functions in markets, and how those incumbent firms will respond to the competitive threats.

We next describe the academic papers in these three areas of interest:

- **Risk** – The potential risks of cryptocurrencies and DLT technologies.
- **Revolutionary/Futuristic research** – the transformational uses of DLT and future research directions that authors are calling for.
- **Mindsets** – The innovative mindsets that are shaping the work of researchers and the direction of companies using DLT and seeking broad acceptance and adoption.

2. Risk

A number of academic papers discuss the risks associated with cryptocurrencies, and warn that there are vulnerabilities created by reliance on DLT and blockchain. DLT will impact organizational risk management activities. In addition, we find that DLT systems face challenges scaling economically, often incurring high transaction costs, long verification times occurring during periods of high volume.

2.1. Beck, R. et al. (2016)

An example of this risk is shown by R. Beck, who tested the viability of blockchain technology by implementing a blockchain-based prepaid account system (Similarly, the same design could be used for non-cryptocurrency applications, such as voting systems and business processes). The proof-of-concept demonstration involved a coffee shop located at the University of Copenhagen. Users log into an account that accepts currency payment to setup initial Ether funds

in their account. They can then transfer those Ether funds into a Smart Contract that facilitates the exchange of the Ether for a coffee drink. In effect, the demonstration showed a merchant could accept fiat currency for Ether fund, and the customer can then exchange the Ether value for goods or services. Overall, their system worked, but the transaction time for buying a coffee took 12 seconds, and in terms of scalability did not have enough nodes to ensure security. Scalability is an operational risk associated with blockchain technology. The coffee shop example showed that waiting times for simple purchases and transactions would be non-trivial even at low volumes.

2.2. Brenig, C., Accorsi, R., and Müller, G. (2015)

Another risk would be cryptocurrencies' potential attractiveness as a tool for money laundering. This threat is receiving considerable attention by various law enforcement agencies. After going through the background on money laundering, and the different tools and processes associated with it, Brenig, Accorsi, and Müller (2015) break down the incentives for using cryptocurrencies as an alternative form of money laundering. They considered factors including cryptocurrencies' flexibility, anonymity, payment irrevocability, and transaction cost. They concluded that these factors could make money laundering viable and appealing through the use of cryptocurrencies. Future research will need to examine how money laundering prevention can be adapted to the cryptocurrency environment.

2.3. Walch, Angela (2015)

Other research has identified a 'governance' risk that arises from the decentralized structure of cryptocurrencies and the low barriers to entry. In effect, each blockchain is a 'standard' whose value is a function of its level of adoption. Being accessible, they can be "forked" (i.e., copied) and changed at the will of any individual developer. Furthermore, the open source nature of blockchain technology means no one person or organization is accountable and responsible in times of crisis. The result is a fragmented ecosystem in which the best technology is not necessarily the most widely adopted - i.e., while Bitcoin is presently the most widely held cryptocurrency, its scalability and transaction speeds are not the best available.

2.4. Risk – Conclusion

Academic research continues to identify risks associated with cryptocurrencies and distributed ledgers. The decentralized structure of blockchain innovations and application means that responding to risks and vulnerabilities that arise is more difficult than in centralized organizations that control their own proprietary technologies. Once risks are identified in a DLT application, it is a slow process to implement changes due to the difficulty of achieving coordinated action among independent actors.

3. Revolutionary/Future Research:

Despite the risks and technology challenges, several authors have described how the excitement around blockchain technology comes from its transformational potential. Many new opportunities to revolutionize financial activities will be introduced by cryptocurrencies and blockchain. The transformative projections include individuals regaining control of their personal data and reducing reliance on intermediaries such as banks and payment processors. Firms could be replaced by blockchain technologies that provide new institutional alternatives to organizations operating as centrally governed decision-making authorities.

3.1. Davidson, S., P. deFilippi., and J. Potts (2016)

A transformative concept analyzed by Davidson et al. (2016) is that blockchains are altering the fundamental underlying economics of many industries by displacing centralized systems such as banks and payment intermediaries (i.e., Wells Fargo, Visa, PayPal). The relentless progress of I.T. resulting from Moore’s Law and Kryder’s Law continues to reduce the cost of processing and storing information. For example, Bitcoin in 2009 took 10 minutes to verify transactions while Ethereum in 2015 took a mere 12 seconds. While the longer verification times of Bitcoin are a safety-driven design choice, improved performance and speed can be expected in the future without becoming less safe.

With Litecoin, micropayments can be sent over the Lightning Network today in under a second. As long as computational efficiency continues to improve, progress will continue proportionally. In their conclusions, Davidson et al. state that Blockchain is a general purpose technological innovation that will underpin disruptive new markets and industries. However, they also believe Blockchain is a truly disruptive technology capable of institutional restructuring. This means it will improve existing systems, and may lead to new ways of organizing assets under an independent, decentralized governance system. They claim this could allow blockchain technology to compete with firms, markets and economies, as an entirely new institutional alternative to today's idea of what an institution is (i.e., a centrally governed decision making authority).

Davidson et al. propose the new possibilities as follows:

> *"Blockchains are a new but potentially revolutionary technology as a cryptographically secure decentralized ledger upon which can be placed any information requiring public validation (e.g. money, contracts, property titles, identity, etc.). One way to look at the economics of blockchain is as a new general-purpose technological innovation that is undergoing the Schumpeterian phases of adoption and diffusion through the economy, as a kind of internet 2.0. Yet this nascent characterisation of the blockchain (including bitcoin) as an epochal new ICT, thus emphasising disruptive new markets and industries, while not wrong, is nevertheless misleading. For blockchain is also an 'institutional technology', a governance technology for making catallaxies, or rule-governed economic orders. Blockchains thus compete with firms, markets and economies, as institutional alternatives for coordinating the economic actions of groups of people, and may be more or less efficient depending upon a range of conditions (behavioural, cultural, technological, environmental, etc.)."*

3.2. Sundararajan, A. (2016)

The internet connects people and enables smaller companies to provide more variety, customization, and faster responses in on-demand supply chains. Researchers such as Sundararajan, et al. are exploring the problems that arises around trust: how do you establish trust with a stranger across the world? How do you choose between thousands of merchants offering the same service? In addition to managing the transactions of goods, we need a system

to facilitate discovery of buyers and sellers, and establish trust between them. Currently this is done with third party brands (Amazon, eBay, Etsy, AirBnB, Uber, TaskRabbit), but Blockchain could be an alternative, with lower fees. Blockchain transactions track and verify the transactional part of online purchases. Funds and delivery of the product or service can now be processed through a 'smart contract'. When a smart contract is added to a blockchain, computations are validated as part of the transactions on that blockchain. Funds can even be held in escrow until receipt of the product. Thus, a smart contract can establish and enforce trust in a way similar to third party payment solutions, such as VISA or PayPal. Sundararajan points out that supplier search features, reputation rating, and review systems could also be implemented on a blockchain. Thus blockchains can facilitate discovery through the same methods as ecommerce platforms such as Amazon or eBay. The difference is that DLT systems operate autonomously, lower fees, and give more control to individual users. Without a central authority controlling the system, DLT provides more options for competition and open participation.

3.3. Dyhrberg, A.H. (2016)

Many researchers have identified financial risk management as a function that could be transformed by cryptocurrencies. Unlike national currencies that can suffer from inflation and devaluation, cryptocurrencies can function like a deflationary store of value much like gold functions as a commodity used by investors. Research has been done on whether bitcoin can be used in ways similar to gold to hedge the effects of market movements. A statistical time series technique using a method called GARCH (generalized autoregressive conditional heteroskedasticity) was used to address this hypothesis. The authors use the method employed in a paper by Baur and Lucey (2010) that applied GARCH to examine the relationship between returns for gold and the stock market.[1] They found them to be uncorrelated and therefore effective in hedging and risk control. To analyze Bitcoin's utility in hedging, Dyhrberg compared its returns to the FTSE Index (Financial Times Stock Exchange Index), as well as the US Dollar to see if there is any merit in this idea. For the FTSE Index, researchers determined that Bitcoin was capable of being used as a hedging mechanism, so that risk of holdings in that

[1] Baur, D. and B. Lucey, "Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold" The Financial Review 45 (2010) pp. 217–229.

market could be reduced with Bitcoin positions. The conclusions for using Bitcoin in hedging against the USD were less conclusive. In the short term, though it appears Bitcoin can also be used to mitigate the risks of exposure to the US Dollar as well.

3.4. Morisse, M. (2015)

Morisse undertakes a survey of published work surrounding cryptocurrencies and outlines the areas of inquiry that are well-researched, and those that are nascent. The paper scoured different journals and databases in search of papers and articles. While not exhaustive, the author discovered 41 relevant papers through 2016. At the end of his paper, the author identifies a handful of new, open research questions:

(1) the influence of cultural norms and ideals on cryptocurrencies,
(2) new business models (banks and intermediaries) that incorporate cryptocurrencies,
(3) qualitative research on cryptocurrencies, and
(4) interdisciplinary research into cryptocurrency applications.

Morisse points out that "a full understanding about cryptocurrencies has not been reached yet", and recommends that *"more investigation should also be done in the field of the influence of culture on cryptocurrencies."*

He highlights several possible area for future research:

- *"Understand the motivation of the entrepreneurs and merchant to participates, which business models they use and which approaches they use to form the ecosystem."*
- *How banks and intermediaries like consultants or insurance firms "have to change and adapt their business models to become member of the cryptocurrency ecosystem or built up trust or alternatives to be more attractive for these potential clients."*
- *Extreme events and disruptions have impacted the largest Bitcoin exchanges – "It is not clear, how and why these crisis and disruptions occur and how the users of the cryptocurrencies react to this events."*

3.5. Kosba, A. (2016)

A YouTube presentation by Kosba (2016) shows that the benefits of blockchains and DLT rely on the continued improvement of Smart Contracts. While this seems likely, it is also not sufficient for moving all transactions to public blockchains. In practice, privacy is necessary in many transactions, such as healthcare, insurance claims, and medical and educational data. Kosba and the other authors propose 'HAWK: Zero-Knowledge Proof framework for privacy-preserving smart contracts.' Zero-Knowledge Proofs give the ability for publicly auditable transactions with details that remain private. This allows for decentralized computations that are publicly proven to be valid, but where the details of what is computed are kept secret. In the example of a merchant, a buyer can use this system to prove they have sufficient funds to place their purchase (without revealing anything else about their balance). This system relies on a centralized 'manager' to oversee the process. Impressively, the manager cannot manipulate transactions, and all their actions can be publicly verified. However this is a centralized design, as the manager does have some private details of the transactions being placed. This encryption is also complex, taking users about 40 seconds to place transactions, and the manager 3-4 minutes to process. This example is part of a larger research effort into the capabilities of 'Zero-Knowledge Proofs.'

3.6. Ekblaw, et al. (2016)

An important use case for privacy preserving public blockchains is access to electronic health records, and in particular patient records that are compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). HIPAA is the American regulation for how healthcare providers are allowed to store and transfer patient data. Currently, a lack of electronic records policies and standards means that health data are fragmented across multiple providers' systems, which leads to incomplete information for doctors on their patients, and lower quality of care. Security and regulatory concerns however have prevented full digitization of health records. Blockchain can provide a decentralized computing machine (the most popular currently is Ethereum), which can execute encrypted instructions. This enables proper management of data

privacy while enhancing access for care providers. Thus the patient data, through the use of blockchain and Zero-Knowledge Proofs, can be both securely kept in the cloud and accessed by care providers without outsiders knowing what is being accessed. Patients' data can be tied to a public key (the identity of the patient), which allows the patient to strictly control access through the Blockchain. Thus the patient maintains control of their data, while being able to grant or revoke access via private keys to any provider they wish. The researchers have worked with MedRec (a product of MIT's Media Lab focused on a blockchain solution for electronic healthcare records) to build a Proof-of-Concept of this system using Ethereum. Many observers are imagining applications of similar system in personal finance that empowers individual investors to control access to their financial data to trusted advisors, and therefore lowers switching costs when an individual seeks to change their advisory relationship.

3.7. Poon and Dryja (2016)

The two previous examples face a common obstacle: decentralized computing, particularly when using Zero-Knowledge Proofs, requires substantial computing time, leading to long transaction times. The Lightning Network is a newly implemented software solution for scaling public Blockchains to permit much faster transaction validation, even with high volumes of transactions occurring. For Bitcoin, the system aims to eventually provide the same scalability as the centrally-controlled Venmo or ApplePay mechanisms. The Lightning Network implements off-blockchain solutions, i.e., using Bitcoin's protocol to conduct micro payments, then bundles them together and finalizes them on-chain. The downside of this is that while many transactions can be completed between a pair of nodes quickly and cheaply, just the net result of those transactions is recorded on the blockchain, and the individual transactions are lost. This loss of transparency is seen by some as a step away from the purpose of Blockchain. Litecoin, another coin that uses a similar protocol to Bitcoin Litecoin, another coin that uses a similar protocol to Bitcoin, has been using a version of the Lightning Network since May 2017. As the Bitcoin Lightning Network is a new system, we recommend SWIFT take interest in its continued developments, and its potential applications in the banking industry.

3.8. Future Research – Conclusions

Academic research has described exciting developments with blockchain technology that will transform financial activities and reduce early inefficiencies with cryptocurrencies and blockchain implementations. It is evident that many functions of existing financial institutions could be replaced by blockchain technologies. Research shows Blockchain is a disruptive technology that could lead to large scale restructuring of institutions and customer-bank relationships. The alternatives to today's centrally governed decision making authorities are interesting but anxiety-provoking.

4. Mindsets

A blockchain can be thought of as a public ledger with a transparent, decentralized architecture. It permits updates by trusted parties, without a central arbiter of trust. Today, blockchain implementations can prevent forgeries, settle disputes over ownership, and allow for smart property, where goods are tracked throughout a supply chain and receipt recorded at each stage. With such impressive capabilities, many researchers have examined the route to adoption for major implementations of DLT that could influence or disrupt industries. In effect, adoption dynamics and public perception will strongly influence the rate of take-up of these innovative blockchain implementations.

4.1. Lindman, et a. (2017)

Bitcoin, as a blockchain implementation, was originally conceived as a decentralized system for authorizing financial transactions moving value from a payor to a payee. Lindman and co-authors identify a key debate, however, over the primary purpose of Bitcoin. Researchers and other actors have debated whether it should be a payment system, competing with VISA for instance, or a store of value, acting as a digital form of gold. The balance of trust and anonymity within a cryptocurrency systems is also not settled. The authors show there are varying levels of

anonymity possible in cryptocurrency systems with mistrust of centralized government financial institutions leading to a desire by some for maximum anonymity. The authors identify three areas that need more research: (1) Organizational: the incentives to different parties and costs; (2) Market Environment: how a Cryptocurrency is influenced by Demand and Competitors; and (3) How and with what decision making process these Blockchain networks are developed. Much of this research the authors argue should focus on consumer behavior and the economics of cryptocurrency, and ask, for instance, *how strong are the network effects?*, and *what are the viable pricing strategies?*

4.2. Morisse, M. and C. Ingram (2016)

Morisse and Ingram (2016) look at the system structures that balance flexibility and stability in blockchain organizations, such as cryptocurrency exchanges. The authors identified eight firms, and examine their responses and adaptability to the Mt. Gox crisis, which was the first major breach of a Bitcoin exchange in 2013. Traditionally, entrepreneurial enterprises have valued flexibility over resilience, but successful blockchain organizations have pursued both simultaneously. Those that showed organizational resiliency were able to distinguish themselves in the eyes of the crypto community, which realized the value of stability and the need for committed resources and backing to operate over the long term. The authors also note that decentralized systems are designed to pool resources from many sources, and thus smaller companies can operate with high capacity. In other words, crypto-exchanges and DLT-supported business can access, or ‘rent’, resources at a very large scale, but must be capable of providing extra resiliency when a crisis emerges. Some groups in such decentralized ecosystems, however, have no unique assets or formal management structures of their own, and therefore struggle to distinguish themselves from competitors, or the blockchain industry overall.

4.3. Atzori, M. (2015)

Researchers in the political science field point out that blockchains have the potential to decentralize governance structures. This means more transparent systems that are harder to corrupt, but that also become harder to change according to Atzori (2015). In practice, existing Distributed Autonomous Organizations (DAOs) have been weighed down by competing incentives, and some have been effectively swayed by separate, centralized organizations. The fear of some observers is that DAOs could lead to a techno-dystopia, where DAOs replace the roles of the state with some services that are delivered more efficiently to citizens by DAOs. In this environment, other needed public services, though could be withdrawn in the absence of the traditional, legacy structures that the public sector and states have in place. This opens the risk for public governance to become dominated by corporatized industries, with citizens becoming customers of services from privatized entities that may not be equipped to best serve the public interest. This debate is critical to the effectiveness in adopting blockchain technology as an alternative to existing public structures, as well as who controls the aforementioned blockchain.

4.4. Mindsets – Conclusions

Blockchains are transparent, decentralized ledgers. They permit updates by users running the corresponding protocol for a particular blockchain. Unlike a traditional online market or e-commerce firm, there is no central arbiter of trust. In this setting, researchers are considering how adoption of major, disruptive implementations of blockchains could take place. Public perception of how governance and decision-making will be carried out by a blockchain to provide services or support will be critical to gain support and overcome resistance to changing the mechanisms and institutions that support private enterprises and public sector organizations. In spite of technological and cost advantages, the adoption of innovative blockchain implementations is not assured.

5. Overall Conclusions

We identified 13 significant academic articles, and organized their contributions into three distinct dimension of interest:

- **Risk** – the risks of cryptocurrencies and DLT technologies
- **Revolutionary/Future research** – revolutionary uses of DLT and future research needed to assess these transformational opportunities
- **Mindsets** - How adoption dynamics and user mindsets will shape the acceptance and the deployment of DLT

The academic research to date on DLT and blockchain suggests there is substantial promise for these technologies to transform many business and organizational activities. Simple trials of blockchains have shown they are robust and capable of safely handling many traditional functions carried by financial services firms and payment processors. The implications for disruption of the financial industry and its incumbents are important to assess.

In spite of the potential, several challenges and adoption barrier remain for these blockchain technologies. On the technology side, scalability and speed of processing are outstanding issues facing broad implementation of blockchains. Furthermore, research points to the complex social processes, and possible regulatory interventions, involved in the adoption of new technology as a formidable barrier to broad and rapid development of blockchain applications.

Several projects, such as Lighting Network, built on top of blockchain can be considered “next generation” technologies that beginning to address the initial technical barriers. Many financial services leaders however will remain justifiably skeptical because of the uncertainty and risk surrounding the open and transparent standards. This will challenge all organizations that

perform intermediation functions in markets to keep up with new technologies and define their place in the future financial ecosystem.

6. Recommendations

We found the following three authors offered the most relevant and compelling contributions among the research papers we read.

1. Claire Ingram (Stockholm School of Economics)
   email: Claire.Ingram@hhs.se

2. Marcel Morrisse (University of Hamburg, and Hermes Germany)
   email: https://www.linkedin.com/in/marcel-morisse-5a1036123/

3. Prof. Arun Sundararajan (Stern School of Business, New York University)
   email: arun@stern.nyu.edu
   https://www.linkedin.com/in/digitalarun/

Interviews, or digests of the work, of these three by a journalist or communications professional could lead to an accessible article that would be of interest to the SWIFT user community.

We also recommend the following areas of research for future calls for proposals from the SWIFT Institute.

1. **Transformational, Visionary Applications of DLT** – While cryptocurrencies receive the most attention, what other blockchain applications will be developed and how might they transform the financial services industry

2. **Governance of Blockchains and Cryptocurrencies** – Blockchains are public ledgers with a transparent, decentralized architecture that permits updates by trusted parties. Without a central arbiter of trust, who, if anyone, controls a blockchain protocol and its rules and logic?

3. **Adoption Dynamics of Blockchain Applications** – When alternative DLT-based mechanisms (e.g., smart contracts) are in competition with legacy mechanisms, what will determine the adoption of the new entrant, and its impact on the mature, incumbent technologies and firms?

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