Context Note: The purpose of this literature review is to bring attention to the Blockchain Research Institute (BRI) about the infeasibility of decentralization in the current blockchain ecosystem. Although the BRI is an "independent source for blockchain," it is only independent to the extent of its members and sponsors, the likes of which include the Canadian Government, Microsoft and others. As such, the discussion that pushes for the improvement of a decentralized blockchain technology is motivated by how it can improve aspects of centralized organizations, including supply-chain management. While this paper does highlight the shortcomings of blockchain, it does so with the ultimate goal of motivating the BRI to devote research into how we can work towards a more decentralized notion of blockchain – something that currently is nonexistent in the Institute's public research database.

Terms to Know:

ASIC Miners - application-specific integrated circuit (ASIC) miner is a computerized device or hardware that uses ASICs for the sole purpose of mining bitcoin or another cryptocurrency

P2P - Peer-to-peer computing or networking is a distributed application architecture that partitions tasks or workloads between equally privileged peers.

DeFi - Decentralized finance (DeFi) refers to the infrastructure, processes, and technologies used to democratize financial transactions

Decentralization: A Literature Review of How It Can Benefit Supply-Chain and What Blockchains Need To Improve To Do So

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Abstract

Decentralized blockchain technologies can transform global supply-chain practices, but the technology must first address limitations to its decentralized essence. To understand this concept, this paper highlights when decentralized systems perform better than their centralized counterparts before demonstrating the shortcomings of current decentralized blockchains. Prior to analyzing any relevant literature, we first look into how the notion of decentralization came to be in the blockchain ecosystem. Several key takeaways are that current blockchain mining practices lead to skewed mining power and governance and consensus protocols inherently concentrate power. To address these challenges, we propose and encourage specific research directions to progress the technology and its applications.

Introduction: Decentralization & Blockchain

From published research by the Blockchain Research Institute (BRI) discussing decentralization as an advantageous design feature of blockchain systems[1] to decentralization weaving its way into the definition of blockchain[2], the importance of "decentralization" to blockchain is evident. How this notion became so widespread, however, is not as clear. Bitcoin, the first-generation blockchain, does not directly mention decentralization in its whitepaper[3], but does emphasize the absence of a "central authority." Unlike its predecessor, the Ethereum blockchain explicitly mentions the concept in its description[4] as a "global, decentralized platform for money and new kinds of applications." Since the emergence of blockchain, development of features such as

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[1] https://www.blockchainresearchinstitute.org/project/governance-of-blockchain-systems/
[2] https://www.investopedia.com/terms/b/blockchain.asp
[3] https://bitcoin.org/bitcoin.pdf
[4] https://ethereum.org/en/whitepaper/

distributed mining networks, consensus protocols, and governance mechanisms undeniably facilitate a network that is a lot closer to decentralized relative to its central counterpart.

It is public knowledge that the majority of the BRI's members and funding is composed of mega-corporations such as Protctor & Gamble, Microsoft – who clearly value centralization in their industries. Likewise, it is no secret that these same companies have been increasingly plagued by supply-chain issues, such as P&G failing to stock shelves with basic consumer products like tampons[5] or Coca-Cola being forced to cut product lines due to supply-chain backlog[6]. This is the primary area we believe decentralized technology can co-exist and help a centralized corporation or government, thus motivating the need for the current discussion into how research can address blockchain's shortcomings.

With the increasing interchangeability of blockchain and decentralization, the following questions arise: what exactly is a decentralized platform and, more importantly, how does it achieve decentralization? However, relevant literature on the topic published by the BRI skips over such questions, leading to a central *assumption* that blockchain is decentralized as-is. The following review of literature from academia outside of the Blockchain Research Institute will demonstrate that this cannot be a universal assumption prevailing in all research as it is incorrect and limits the development of the technology to its fullest potential. In other words, the ensuing discussion will analyze various aspects of current blockchain technology that obstruct decentralization, with the ultimate goal of providing future avenues of research that can further progress the technology and its real-world applications.

Review of the Literature: When is Decentralization Better?
Under a Critical Supply-Chain Lens

Although this paper's primary discussion aims to highlight a specific issue in blockchain, we believe this section is necessary as a preface to answer a crucial question: how does one convince centralized actors to work towards decentralization? Literature on the subject demonstrates not only specific cases when decentralization is preferable, but also that the two *should* co-exist. The

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[5] https://time.com/6184644/tampon-shortage-supply-chain/
[6] https://www.fox9.com/news/coca-cola-to-phase-out-honest-tea-products-amid-supply-chain-backlogs-dwindling-sales

debate between centralization and decentralization has been ongoing for centuries; we examine it under the lens of supply-chain and its various facets.

Within a supply-chain, the start and end points, along with all intermediary stages are known from the onset. As such, most of the burden in the process falls on calculating optimal quantities of goods and dates to streamline production and delivery. In other words, reading and writing times are sufficiently small compared to computing times, which is a specific condition that was observed when constructing a decentralized system, given a centralized system, would be preferable (Marschak, 1956, pp. 428). This conclusion was made using a satisfaction function with primarily time-based inputs such as the interval between two successive observation times, aforementioned process times, and a known cut-off time. It is important to note that the observation is only valid when an organization is able to establish a *definitive* cut-off time; consequently, this is of utmost relevance to supply-chain management where cut-off time is a main metric. When the former is true, Marschak was able to generate a sequence of trial solutions for which the satisfaction function was increasingly maximized at a given cut-off time for the model of a decentralized system. The main takeaway from Marschak's *Centralization and Decentralization in Economic Organizations* is that the superiority of decentralized systems over other classes of systems cannot be assumed on the basis of informational autonomy or other properties alone. As such, nowhere is this paper aiming to proclaim the absolute superiority of decentralization. Instead, we aim to highlight the advantages of decentralization (blockchain) in specific instances (supply-chain) that can benefit consumers and corporations alike.

Similar to the above study, a plethora of research aimed at pitting centralization against decentralization ended up concluding that no one system can be absolute. Nevertheless, a principal-agent analysis of the two, in the context of government, found that when there are coordination problems among citizens in controlling the government, decentralized political structures could be optimal, even if all localities have the same preferences (Tommasi & Weinschelbaum, 2007, pp. 382-383). It is important to realize that this is not advocating for a decentralized anarchy, but rather decentralized *elements* within a government that is inherently centralized. These findings, while about government, are still relevant to our previous discussion; supply-chain and government are similar in the sense that both require extensive coordination of goods and individuals. Thus, this comprehensive principal-agent analysis shows that amidst
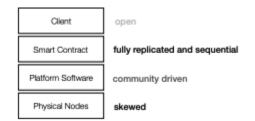
ongoing coordination problems in the world's supply-chain, the corporations involved could massively benefit from integrating decentralized processes within their centralized essence.

Blockchain and supply-chain have the potential to exist in a symbiotic relationship, where the decentralized nature of the former can help solve the latter's problems. Blockchain can greatly improve supply-chains by enabling faster and more cost-efficient delivery of products as well as coordination between partners[7]. However, before it is able to do so, blockchain must look inwards to the problems limiting the decentralized nature of the technology – which is what the next section will address.

Review of the Literature: Limitations of Decentralization in Blockchain

Complete decentralization is as ambiguous in meaning as it is in practice. Nevertheless, factors limiting the current degree of decentralization are reflective of wider problems with the technology.

Blockchain decentralization introduces several inherent problems. These problems, as outlined in a joint study by the University of Washington and Epichain.io, are present in all three platform layers of a full-stack representation of blockchain – this discussion will focus strictly on the bottom two since smart contracts are currently not as applicable to the broader technology.

Client	open
Smart Contract	**fully replicated and sequential**
Platform Software	community driven
Physical Nodes	**skewed**

Chu & Wang, The Curses of Blockchain Decentralization, 2018, pp. 4

The P2P network of miners comprising the bottom physical node layer are assumed decentralized, when in reality limited access to ASIC miners and formation of mining pools heavily skews the mining power distribution away from the majority of participants. In the platform software layer, Chu & Wang (2018) were able to demonstrate how existing consensus protocols exacerbate scalability problems by proving the presence of a low upper bound of

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[7] https://hbr.org/2020/05/building-a-transparent-supply-chain

transaction throughput, independent of what protocol was used. Using the derivative $\frac{dR}{db}$, where R is the maximum transaction throughput and b is block size, when $b \to \infty$, the theoretical maximum transaction throughput cannot be greater than $\frac{w}{s}$, where w is the network's access bandwidth and s is the size of a transaction (Chu & Wang, 2018). The problems outlined in this study provide multiple research directions to solve or circumvent problems with decentralization. Specifically, the Blockchain Research Institute can analyze how to democratize mining power and investigate more efficient alternatives to existing consensus mechanisms.

As we began to see above, governance poses big challenges to decentralization. Apart from hindering scalability, nuances of the mechanisms themselves pose risks to the decentralization of the whole ecosystem. This is especially clear in a recent publication from the Bank for International Settlements that investigates the decentralization illusion and risks of DeFi. The authors talk of a "decentralization illusion" in DeFi due to the inescapable needs for centralized governance and the tendency of PoS blockchain consensus mechanisms to concentrate power (Aramonte et al. 2021). Current participation in on-chain governance is concentrated within a small community of developers and governance token holders. Furthermore, the authors point out that DeFi's inherent governance structures are natural entry points for public policy due to vulnerabilities such as high leverage, liquidity mismatches, and lack of shock-absorbing capacity (Aramonte et al. 2021). Similar to the problems observed by Chu & Wang (2018), the discovered shortcomings of DeFi provide insight into how decentralization can be improved in the broader technology. Problems with *existing* governance mechanisms open the door to *new* solutions, such as more inclusive protocols that maximize entry for participants, while minimizing entry points for public policy or regulation. Existing BRI work that discusses a hybrid approach to governance that combines on-chain and off-chain elements[8] is a great starting point for examining and increasing the degree of decentralization with different governance mechanisms.

Existing literature points to not only how blockchain limits decentralization through skewed mining power and flawed governance mechanisms, but also how decentralization limits blockchain scalability through inefficient consensus protocols. As such, this paves a two-way

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[8] https://www.blockchainresearchinstitute.org/project/governance-of-blockchain-systems/

road for research and improvement opportunities, where driving down one side will inevitably lead back to the other side – improving decentralization and blockchain simultaneously.

Conclusion

Much of our world today, from governments and their financial systems to companies and their business operations, is heavily centralized. On the other hand, decentralized blockchain technology has the potential to disrupt this status-quo, which may seem like a threat to the former.

This is one misconception the paper addresses. In fact, the literature analyzed on the subject shows not only specific instances when decentralized systems are preferred to centralized ones on the basis of higher satisfaction, lower process times and increased coordination, but also that decentralized processes are able to exist within centralized systems. While the studies and models used never mentioned blockchain or supply-chain, conceptual overlap makes the findings very applicable to the current discussion. In other words, decentralized blockchain technology can transform current supply-chain practices.

The second problem the paper addresses is how decentralization and blockchain limit each other, motivated by the need to fix the highlighted problems and progress society with the aforementioned applications. In order to do so, future research needs to involve areas such as democratizing mining power, efficient consensus protocols that do not impede scalability, and governance mechanisms not prone to backdoor centralization.

Blockchain may have the potential to benefit the individuals and institutions of society, but in order to actualize it we must first fix and address aspects of the technology inhibiting its potential. This process should start with research at the Blockchain Research Institute into the areas outlined in this paper.

References

Aramonte, S., Huang, W. and Schrimpf, A., 2021. *DeFi risks and the decentralisation illusion*. BIS Quarterly Review. [online] Bank for International Settlements. Available at: <https://www.bis.org/publ/qtrpdf/r_qt2112b.htm> [Accessed 8 June 2022].

Buterin, V., 2014. *Ethereum Whitepaper*. [online] Available at: <https://ethereum.org/en/whitepaper/> [Accessed 8 June 2022].

Chu, S. and Wang, S., 2018. *The Curses of Blockchain Decentralization*. [online] University of Washington and Ephichain.io. Available at: <https://arxiv.org/pdf/1810.02937.pdf> [Accessed 8 June 2022].

De Filippi, P. and McMullen, G., 2018. *Governance of Blockchain Systems*. [online] Blockchain Research Institute. Available at: <https://www.blockchainresearchinstitute.org/project/governance-of-blockchain-systems/> [Accessed 8 June 2022].

Gaur, V. and Gaiha, A., 2022. *Building a Transparent Supply Chain*. [online] Harvard Business Review. Available at: <https://hbr.org/2020/05/building-a-transparent-supply-chain> [Accessed 8 June 2022].

Marschak, T., 1959. *Centralization and Decentralization in Economic Organizations*. Econometrica. [online] The Econometric Society, pp.399-430. Available at: <https://www-jstor-org.ezproxy.neu.edu/stable/1909469?seq=31> [Accessed 8 June 2022].

Nakamoto, S., 2009. *Bitcoin: A Peer-to-Peer Electronic Cash System*. [ebook] Available at: <https://bitcoin.org/bitcoin.pdf> [Accessed 8 June 2022].

Tommasi, M. and Weinschelbaum, F., 2007. Centralization vs. Decentralization: A Principal-Agent Analysis. *Journal of Public Economic Theory*, [online] 9(2), pp.369-389. Available at: <https://onlinelibrary.wiley.com/doi/10.1111/j.1467-9779.2007.00311.x> [Accessed 8 June 2022].