What is the future construct of price-formation in the 'computing fog'?

1. Abstract

Fog computing represents a fundamental shift towards decentralization of computing and processing ability which has in turn given rise to numerous applications including the Internet of Things. But perhaps the most important application has been the rise of the blockchain which has itself spawned tokenization of securities and the rise of decentralized exchanges (DEXs). Together, these two developments have the potential to revolutionize financial markets by decentralizing and disintermediating transactions. Hence, it is to these developments that this paper focuses on.

Of foremost inquiry then is perhaps the implications for price formation given the crucial role of centralized exchanges today in the process of price formation. Hence, this paper looks at the old and new mechanisms of price formation that have emerged on orderbook DEXs and liquidity pools. Thereafter, it examines the state of fragmentation and liquidity among DEXs and between DEXs and their centralized counterparts given the potential of DEXs to compete the order flow. At the same time, the paper also considers how decentralized finance (DeFi) can lead to new efficiencies in the form of tokenization.

Lastly, the crucial implications for regulation of this decentralized space is offered through a consideration of the challenges faced in adopting punitive measures before advocating for a more collaborative approach. Through demonstrating the ability of the DeFi community to implement technologically superior solutions that also utilizes the structure of the DeFi stack to their advantage, this paper argues for the treatment of

certain fundamental solutions as public goods, hence necessitating the support of regulators.

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2. Blockchain in the Computing Fog

Distributed ledger technology (DLT) was pioneered by the introduction of Bitcoin. More commonly referred to as blockchain, it has since expanded vastly beyond its initial cryptocurrency functionality. Today, blockchain is poised to revolutionize the financial industry by enabling a trustless and permission-less system of interaction between users, thereby removing the need for intermediaries. This phenomenon has been termed decentralized finance (DeFi) and while still in its nascency, has the potential to radically alter market dynamics with implications for participants and regulators alike.

But it is not that decentralization is new to capital markets. After all, alternative trading options such as dark pools and over-the-counter facilities already exist. In fact, the majority of equity trading in Europe already takes place off primary exchanges, with the latter consistently capturing less than 40% of total trading[1].

Rather, decentralization in DeFi refers not only to localization but also disintermediation. This is possible because blockchain enables the creation of an immutable and transparent distributed ledger that is held and verifiable by all users in the network. Therefore, there is no need for an authority to maintain secure records as

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[1] Oxera. *The design of equity trading markets in Europe.* Mar 2019. p. 42. Retrieved from https://fese.eu/app/uploads/2019/03/190321-The-design-of-equity-trading-markets-in-Europe-full-report.pdf

distributed ledgers are tamper-proof. In addition, 'blocks' are added via consensus

mechanisms which entail cooperative decision-making and encryption. Therefore, the

verification and publishing of transactions is democratized. Most significantly, there is

also now no need for authorities to act as counterparties to insure a trade – this transfer

of risk onto central exchanges is often one of their key functions - because protocols like

Ethereum on which much of DeFi is built upon allows for smart contracts and

instantaneous 'atomic' swaps. Written into code, they ensure that a trade only goes

through if both parties have the required holdings, without the assets ever leaving their

wallets to be held by an intermediary.

Therefore, blockchain and decentralized exchanges[2] (DEXs) in particular,

appear to make redundant much of the key functions of centralized exchanges such as

trade execution, clearing and custody. Indeed, they offer a new vision of capital markets

where direct peer-to-peer trading is safe, transparent, and viable. And this has been

facilitated by the expansion of fog computing capabilities which bring greater

decentralization and shift in processing and storage away from a central cloud server,

providing more access points for the DeFi network as more devices become capable of

participation[3]. Therefore, despite the small size of DeFi today with only over a billion

USD locked into protocols, the movement is surely growing and growing fast (Figure 1).

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[2] Decentralized exchanges are exchanges built on the blockchain that offer the abovementioned benefits of non-custodial trading that is governed by smart contracts and the distributed ledger.
[3] Naveen Joshi. *Fog Computing and Blockchain Go Hand in Hand.* Nov 2019. Retrieved from
https://www.bbntimes.com/technology/fog-computing-and-blockchain-go-hand-in-hand

Figure 1: Total valued locked (USD) in DeFi[4]

Henceforth, it is crucial to consider how DeFi will evolve and how DEXs would impact the capital markets of the future. Specifically, given the role of centralized exchanges in price formation today, thought should be given to the mechanisms and implications for price formation in a new DeFi world populated by DEXs.

3. Price Formation in Central Exchanges

Firstly, price formation has traditionally been a key function of central exchanges which serve as benchmark markets for asset valuation. This function is crucial because as opposed to other goods with inherent use or labour value, securities such as equities derive much of their value from future expected flows of income which are by nature uncertain and impossible to precisely estimate. Therefore, prices must be discovered through a process of price formation in which information and expectations are pooled

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[4] 30 June 2020. Retrieved from https://defipulse.com/

and incorporated into the consensus price. The change in prices itself then serves also to inform other participants.

Typically, such a function is achieved through trading at 'lit' exchanges with the operation of a central limit order book (CLOB) where crossing bids and asks are matched while outstanding limit orders are posted publicly for traders to act on. The difference between the highest bid and lowest ask on the CLOB then constitutes the bid-ask spread which provides a good estimate for the value of the security, i.e. price formation. Hence, centralized exchanges enable price formation through maintaining a transparent order book, adopting an appropriate matching engine and providing a common meeting place (albeit electronic).

In addition, to have efficient price formation, central exchanges seek to ensure sufficient liquidity as low liquidity leads to high friction costs (wide bid-ask spreads) in changing one's position, impairing trading and price formation. SGX has for example, a Market Maker and Liquidity Provider Programme[5] which offers clearing fee rebates to induce additional liquidity. Also, an exchange must attract a variety of participants, particularly informed traders who exploit and trade on non-public or inferred knowledge[6] as "the quality of price formation is affected by the relative proportion of informed and uninformed traders on a particular trading venue"[7] given that uninformed traders create noise. Therefore, central exchanges impose fair rules regarding trading to prevent unfair practices such as frontrunning which may drive informed traders elsewhere where pre-

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[5] SGX. Retrieved from https://www.sgx.com/securities/trading
[6] Oxera. p. 29.
[7] Ibid. p. 33.

trade transparency is absent. The recent prosecution and punishment of three Singaporeans for this practice in 2019 is a case in point.[8]

4. Price Formation Mechanisms in DEXs

However, this all may change with the rise of securities (tokenized[9]) trading on DEXs such as EtherDelta. Therefore, despite DEXs today being mostly used for trading cryptocurrencies and utility tokens[10], a study of their price formation mechanisms provides a useful model for extension to the case for tokenized securities.

But to group all DEXs together would be a mistake. Indeed, for much the same reasons that traditional capital markets have been fragmented, DeFi is likely to spawn DEXs for different needs. Quote-driven peer-to-peer platforms such as AirSwap for example, provide protection from market impact by eliminating pre-trade transparency. Instead of matching bids and asks, Airswap matches users based on intent to trade, allowing the parties to quote and negotiate privately – a system similar to OTC trading[11]. Hence, DEXs are likely to see trading split between platforms – not all of which contribute equally to price formation.

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[8] Seow Bei Yi. *3 Singaporeans jailed for 'front-running' in landmark share trading case*. Jul 2019. Retrieved from https://www.straitstimes.com/singapore/courts-crime/3-singaporeans-jailed-for-front-running-in-landmark-share-trading-case

[9] Tokenization is the process of representing an asset digitally on the blockchain so that it can be easily traded and processed in the blockchain network.

[10] Utility tokens refer to tokens which grants users access to an ecosystem and which has 'use' value. Generally, they are not created for investment purposes like security tokens. However, the distinction is not always clear as some tokens can have both functions.

[11] Schär, Fabian. "Decentralized Finance: On Blockchain- and Smart Contract-based Financial Markets". Mar 2020. p. 11. Retrieved from https://www.researchgate.net/publication/340061422_Decentralized_Finance_On_Blockchain-_and_Smart_Contract-based_Financial_Markets

Nonetheless, blockchain-based orderbook exchanges and liquidity pool exchanges do contribute. The former refers to a whole class of DEXs that operate an order book and conduct all settlement on-chain, lending itself to the aforementioned benefits of DLT, particularly non-custodial trading. However, they differ in their choice to host the order book on-chain or off-chain (private network). Regardless, blockchain-based orderbook exchanges employ a similar mechanism to price formation as typical centralized exchanges by matching crossing bids and asks while maintaining an order book of outstanding limit orders (the bid-ask).

Far more interesting are liquidity pool exchanges which do not use order books for price discovery. Instead, liquidity pool exchanges allow users to trade tokens against their common pool which is formed from the deposits of other users seeking to profit from the transaction fee. Hence, liquidity pools are bilateral trading facilities that do not match parties with one another. Unique to DeFi, liquidity pools rely on smart contracts that deploy algorithms to set a price for each token. Termed constant product model, these algorithms set "relative price [as] a function of the smart contract's token reserve ratio"[12]. This means that tokens get more expensive as reserves dwindle and because prices rise exponentially, "a liquidity pool using this model cannot be depleted"[13]. This is an interesting and elegant approach to price formation since it smoothens out the prices and depths of an order flow and guarantees access to liquidity[14] (the pool always takes

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[12] Ibid. p. 10.
[13] Ibid. p. 10.
[14] Totle. *Decentralized Exchanges: Three Types That Will Be Essential For The Crypto Economy*. Jul 2018. Retrieved from https://medium.com/totle/decentralized-exchanges-three-types-that-will-be-essential-for-the-crypto-economy-91461b330f50

the opposite position) which is beneficial given the illiquidity of some tokens and small trading share of DEXs.

However, such exchanges, unlike market makers who may aggregate data across exchanges, may be disconnected from external forces of demand and supply. This makes it reliant on arbitrageurs which are usually automated bots to equalize prices quoted by the pool vis-à-vis other exchanges. While this means that prices on liquidity pools such as Uniswap may lag other exchanges, the prices formed there are nonetheless reliable and quick enough that they are used as oracles (reference prices) for other platforms[15].

5. Liquidity & the Quality of Price Formation

Beyond the different mechanisms of price formation however, it is also crucial to examine how DeFi would affect liquidity and the quality of price formation. Given the lack of significant trading in tokenized securities, it is helpful to likewise extend the analogous case in existing crypto markets.

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[15] Guillermo Angeris. *When is Uniswap a good oracle?.* Feb 2020. Retrieved from https://medium.com/gauntlet-networks/why-is-uniswap-a-good-oracle-22d84e5b0b6c

Figure 2: Ratio of DEX volume to centralized crypto exchanges[16]

For one, despite the growing but miniscule share of trading that takes place on DEXs today (Figure 2), there is already significant fragmentation within DEXs given that the largest DEX, Uniswap, has little more than a quarter of the market trading volume (Figure 3) which could "divide liquidity and inhibit efficient arbitrage across these exchanges"[17].
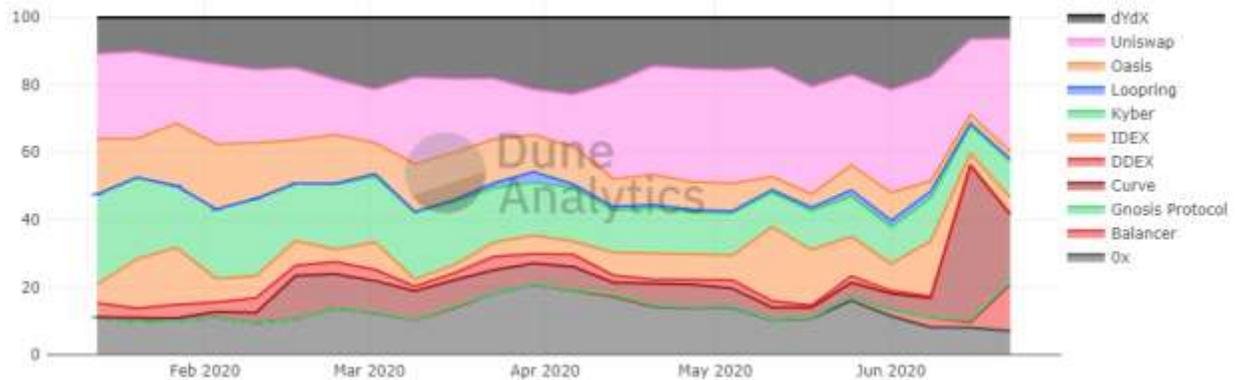

Figure 3: Market share of DEXs[18]

[16] Retrieved from https://www.theblockcrypto.com/linked/70166/bitcoin-spot-volume-june
[17] Justine Humenansky. *Trade-Offs: Decentralized Exchange (Part 2). Jul 2019.* Retrieved from https://medium.com/coinmonks/trade-offs-decentralized-exchange-part-2-f3ac0e8a08e1#b558
[18] 30 June 2020. Retrieved from https://explore.duneanalytics.com/public/dashboards/c87JEtVi2GlyIZHQOR02NsfyJV48eaKEQSiKplJ7

This in turn could lead to a multitude of prices (no efficient market price) and create uncertainty as to the real value of assets, causing them to trade at a discount, especially for tokens listed exclusively on DEXs.

In addition, the small market share and limited liquidity of most DEXs mean that price impact is likely to be significant. Without oversight, this could lead to price manipulation on DEXs which erodes trust in the price discovery process and prejudices fairness. This was made apparent in recent bZx exploits where traders artificially inflated the price of certain tokens on Uniswap which acted as a price oracle for bZx to collateralize loans on bZx before absconding with the loaned assets, costing bZx close to a million USD in losses[19].

Therefore, it is unlikely that prices formed on DEXs would be used in isolation given significant price impact and fragmentation. Rather, it is likely that until the DeFi movement matures – with sufficient liquidity to allow low friction and minimal price impact to prevent bad actors – centralized exchanges will coexist alongside DEXs and possibly play the larger role in price formation (for cross-listed assets).

Even then, however, DEXs could attract order flow away from centralized exchanges. This could lead to greater fragmentation than what already exists in traditional markets, especially since unregulated DEXs are not restricted by preexisting regulations such as MIFID II that has limited dark trading at traditional venues. With

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[19] Will Heasman. *Are the BZx Flash Loan Attacks Signalling the End of Defi?.* Feb 2020. Retrieved from https://cointelegraph.com/news/are-the-bzx-flash-loan-attacks-signaling-the-end-of-defi

lesser traders congregating on any one platform, liquidity and the quality of price formation suffers in centralized exchanges too.

But DEXs are unregulated because of their novelty and not due to a lack of will, as the SEC's recent charges against EtherDelta demonstrate[20]. Hence, it is unlikely that significant capital will flow towards DEXs in search of regulatory arbitrage, especially for dark trading, lest it invites swifter regulation.

Furthermore, as Zhu has argued in the case of dark pools, market fragmentation could improve price discovery if the alternative venue attracts a disproportionate number of uninformed traders vis-à-vis informed traders as "this lowers the noisiness of demand and supply on the [central] exchange and improves price discovery"[21]. Hence, DEXs might not harm price discovery to the extent expected because its use has thus far been limited to enthusiasts and crypto-natives rather than among institutional or otherwise 'informed' traders because of trade-offs such as speed and privacy in addition to the learning curve associated[22].

Therefore, it is unlikely in the short term for DEXs to compete away the order flow from centralized exchanges due to teething issues.

Conversely, DeFi might even improve price formation by increasing access. For one, DeFi is reducing monetary barriers to entry either through enabling greater

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[20] SEC. *SEC Charges EtherDelta Founder With Operating an Unregistered Exchange.* 2018. Retrieved from https://www.sec.gov/news/press-release/2018-258

[21] Zhu, Haoxiang. "Do Dark Pools Harm Price Discovery?". Forthcoming, *Review of Financial Studies* (Nov 2013). Retrieved from http://www.mit.edu/~zhuh/Zhu_darkpool_RFS.pdf

[22] Justine Humenansky. *Trade-Offs.*

fractionalizing of equity than exists in traditional markets[23] via highly divisible tokenized securities, providing secondary markets for assets that previously had none such as private securities[24] and illiquid assets like fine art[25] or by innovation giving rise to products like flash loans which remove the need for collateralization and democratizes arbitrage opportunities[26], enhancing efficiency.

And all this is possible because DeFi offers a much safer, trustless alternative with on-chain escrows and smart contracts. Henceforth, fractionalized securities for example could abolish minimum sums and lead to greater participation and volume which enhances liquidity, so asset prices become more responsive. The creation of new secondary markets on the other hand, would create liquidity where there was none. As opposed to relying on expert valuation then, these assets benefit from the price formation process – the wisdom of the (trading) crowd and their pooled information. Lastly, financial innovations that remove barriers to credit improve speed and reduce reliance on key players to correct markets, amongst other uses, which leads to greater competition and price uniformity.

6. Looking to the Future

[23] Chermaine Ng. U*S FinTech Firm Increases User Accessibility to Fractional Equity Investments with Crypto*. Jun 2020. Retrieved from https://www.supercryptonews.com/uphold-increases-accessibility-to-fractional-equity-investments-with-crypto/

[24] CapBridge Pte Ltd & ConsenSys Pte Ltd. "Project Endor: Blockchain-based Securities Exchange Final Report". Mar 2019. Retrieved from https://capbridge.sg/wp-content/uploads/2019/03/CapBridge-POC-Final-Report.pdf

[25] Aislinn Keely. *Wave and Vertalo start by tokenizing yield, with race horses and whiskey as long term possibilities.* Oct 2019. Retrieved from https://www.theblockcrypto.com/post/43714/wave-and-vertalo-start-by-tokenizing-yield-with-race-horses-and-whiskey-as-long-term-possibilities

[26] Gaurav. *Flash Loans.* Feb 2020. Retrieved from https://blog.coincodecap.com/what-are-flash-loans-on-ethereum#Use_cases_of_Flash_Loan

Therefore, it cannot be gainsaid that DeFi has its pros and cons. Other than offering new mechanisms for price formation, DeFi also impacts liquidity and markets in a nuanced way. Hence, DEXs are likely to coexist with centralized exchanges in the near term as traders seek out different platforms based on their priorities given that DEXs excel in niches – the chief of which are security and tokenization – but also suffer failures regarding price impact and potential for manipulation.

Hence, the question of regulation is fast becoming a pressing one. But the answer does not lie in punitive regulation. This is because DEXs are increasingly seeing control as a liability given the SEC's charges against EtherDelta which alleged Coburn's control over the platform caused it to violate a securities trading act[27]. Hence, developers are "beginning to design their networks in a way that ensures they are considered sufficiently decentralized by regulators"[28]. This means it would be much harder to enforce compliance via action against a platform or its founder, rendering punitive laws a tool of last resort.

Therefore, compliance must go beyond correction. Instead, it must be compliance by design for which the DeFi community is a surprising ally. Rather than decry intervention, DeFi proponents actually support regulation because they are aware that regulatory uncertainty is detrimental to the adoption and growth of the ecosystem. As such, multiple projects have emerged to address regulatory concerns. Hence, the way forward is not for authorities to reinvent the wheel by implementing their own

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[27] Mel Zhou. *How Decentralized Exchanges Are Regulated – Part 1 (Securities).* Jan 2019. Retrieved from
https://medium.com/@melzhou/how-decentralized-exchanges-are-regulated-part-i-securities-3e999bc52e86
[28] Ibid

procedure for compliance which is often less technically elegant and efficient but rather, to adopt and support the growth of promising solutions in the ecosystem.

For one, rather than encourage consolidation or rely on conventional liquidity providers such as market makers, the DeFi community has developed innovative solutions to improve the state of liquidity and fragmentation persistent among DEXs – the most notable of which is the open-sourced 0x protocol[29] which creates a state of networked liquidity to harness the best of both decentralized security and centralized efficiency. Likewise, developers have sought to improve the robustness of prices formed and reduce manipulation on liquidity pools by averaging prices across multiple time periods and exchanges. Perhaps a product of competition or goodwill, these self-initiated projects and others demonstrate the community's willingness to address the inefficiencies of the DeFi space and to create fair markets. Hence, unlike primary exchanges that may have protected markets, perhaps regulators should harness competitive forces to drive efficiency in DEXs.

Furthermore, by tapping on the community, regulators are able to utilize wide-reaching and more efficient solutions than they otherwise would be able to. The reason for this has to do with the structure of the DeFi stack.

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[29] Fulvia. *Access all DEX liquidity through 0x API*. Jan 2020. Retrieved from https://blog.0xproject.com/access-all-dex-liquidity-through-0x-api-d5dd9a45af31
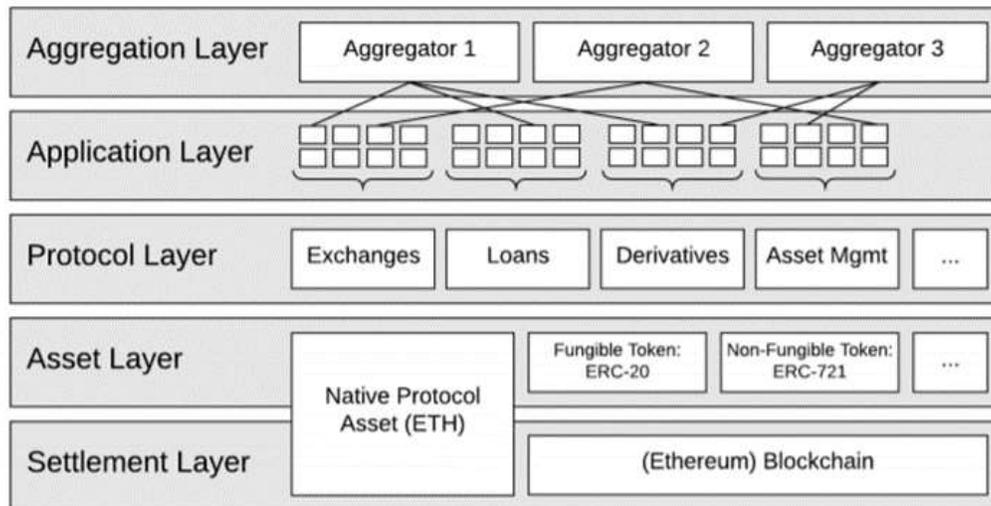
Figure 4: DeFi 'stack'[30]

Illustrated above, the DeFi stack refers to the layers of code that constitute a user-facing interface such as DEXs. Built as a stack, each layer is built upon and constrained by the layer beneath it. Regulators, however, are likely only able to enforce compliance at the protocol layer and beyond as it is at this layer that individual DEX platforms are created by developers who may be subject to an authority's jurisdiction. However, oftentimes it is more efficient to embed solutions at the open-sourced, community-moderated asset and settlement layers. Take the example of Know-Your-Customer and Anti-Money-Laundering requirements: rather than have DEXs each develop and maintain individual whitelist of addresses, implementing new ERC[31] token standards developed by the community (e.g. ERC 1400[32]) for securities trading that ensures each token issued or transferred must first satisfy the whitelist before being

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[30] Retrieved from https://www.researchgate.net/publication/340061422_Decentralized_Finance_On_Blockchain-_and_Smart_Contract-based_Financial_Markets/link/5e767d9b92851cf2719d9e37/download

[31] ERC is an abbreviation for Ethereum Request For Comments which is the blockchain equivalent of an internet standards-setting publication. The most common ERC token standard is the ERC 20 which enables the interoperability and therefore tradability of most utility tokens on platforms without the need for specialized code.

[32] Retrieved from https://thesecuritytokenstandard.org/

sent for settlement ensures that every transaction is compliant because otherwise, the transaction fails.

Not only does this remove duplicity, it is efficient and guarantees compliance unlike protocol-layer solutions because instead of creating compliant exchanges which require non-compliant platforms to be banned to be effective (difficult since DEXs cannot be taken offline easily), token standards create compliant transactions.

Likewise, each layer is only as secure as the layer beneath it. Hence, rather than have DEXs adopt provisions to protect against smart contract failure or manipulation of the distributed ledger (e.g. 51% attacks[33]) through insurance[34] or preventing concentration of mining (validation) nodes by malicious actors, it is far more efficient to bolster the underlying settlement layer – perhaps through encouraging the shift towards new consensus mechanisms like delegated proof-of-stake[35] which enables only trusted nodes to validate transactions. Ethereum is after all, already planning the migration from proof-of-work to proof-of-stake[36] which disincentivizes bad behavior by having parties stake coins that they stand to lose otherwise, proving that wide-ranging community-driven changes are possible and already happening.

So, perhaps decentralized finance requires decentralized governance and authorities would be better off working with the community to devise innovative

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[33] Verification of fraudulent transactions on the blockchain by actors who control more than 50% of the validating (mining) nodes.
[34] Luke Duncan. *Insuring Against Smart Contract Failure*. Apr 2018. Retrieved from https://medium.com/@lkngtn/insuring-against-smart-contract-failure-86d0d9206d90
[35] Lauren Harrington. *Proof of What? Top 3 Most Common Consensus Protocols*. Mar 2018. Retrieved from https://www.intelligenthq.com/proof-top-3-common-consensus-protocols/
[36] Daniel Won. *Ethereum Proof of Stake Date: Date + What You Need to Know*. Feb 2020. Retrieved from https://www.exodus.io/blog/ethereum-proof-of-stake-date/

compliance strategies through creating a regulatory economy where expertise,

resources and rewards are provided to promising solutions. This is especially crucial for

foundational solutions that appear to be public goods since they may lack specific

monetization opportunities and are thereby reliant on goodwill for development. Of

course, this is easier said than done and requires alignment between different

regulatory regimes. Nonetheless, this is the only way if we are to realize DeFi's promise.

7. Conclusion

In closing, fog computing has in part enabled the rise of DeFi which presents an

exciting opportunity to create trustless and thereby global capital markets. However, as

with the internet before it, DeFi in its nascency today faces teething issues that prevent

it from scaling and displacing its centralized counterparts. Nonetheless, DeFi is here to

stay and to realize its huge promise, regulators should look to partnering the community

as they are just as, if not more vested in improving the state of things.

Word Count: 2991 (excluding footnotes & figures)