EVALUATING THE MARKET PERCEPTION OF PROOF OF WORK AND PROOF OF STAKE PROTOCOLS: A DIFFERENCE-IN-DIFFERENCE ANALYSIS

by

Nicolas Aaron Mirsky

A Dissertation Submitted to the Faculty of the

College of Business

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

Florida Atlantic University

Boca Raton, FL

August 2024

Copyright 2024 by Nicolas Aaron Mirsky

EVALUATING THE MARKET PERCEPTION OF PROOF OF WORK AND PROOF OF STAKE PROTOCOLS: A DIFFERENCE-IN-DIFFERENCE ANALYSIS

by

Nicolas Aaron Mirsky

This dissertation was prepared under the direction of the candidate's dissertation advisor, Dr. William Luther, Department of Economics, and has been approved by all members of the supervisory committee. It was submitted to the faculty of the College of Business and was accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

SUPERVISORY COMMITTEE:

William J. Luther
William J. Luther (May 13, 2024 22:43 GMT+7)

William Luther, Ph.D.
Dissertation Advisor

Douglas Cumming
Douglas Cumming (May 23, 2024 21:42 GMT+8)

Douglas Cumming, Ph.D.

CHRISTOPHER BOUDREAUX
CHRISTOPHER BOUDREAUX (May 23, 2024 09:47 EDT)

Christipher Boudreaux, Ph.D.

Mark Kohlbeck
Mark Kohlbeck (May 23, 2024 15:14 EDT)

Mark Kohlbeck, Ph.D.
Director of College of Business PhD Program

Daniel Gropper
Daniel Gropper (May 23, 2024 15:17 EDT)

Daniel Gropper, Ph.D.
Dean, College of Business

Robert W. Stackman Jr., Ph.D.
Dean, Graduate College

May 28, 2024
Date

ACKNOWLEDGMENTS

The pursuit of my doctoral degree has been an extensive and demanding journey, marked by years of rigorous academic work and professional obligations. I could not have reached this significant achievement without the unwavering support of my family. My most profound appreciation goes to my wife, Paula, whose love, patience, and endless belief in me have been an unyielding source of strength. To my daughter, Ava, for the joyful light that she brings to my life, which has been a source of inspiration.

I extend my profound gratitude to my dissertation chair, Dr. Luther, for his unwavering guidance and mentorship. His expertise and insightful feedback were critical in raising my work at every stage. I also want to express my sincere thanks to my committee members for their expertise, professionalism, and constructive direction, which have been invaluable in shaping this research.

ABSTRACT

Author:	Nicolas Aaron Mirsky
Title:	Evaluating the Market Perception of Proof of Work and Proof of Stake Protocols: A Difference-in-Difference Analysis
Institution:	Florida Atlantic University
Dissertation Advisor:	Dr. William Luther
Degree:	Doctor of Philosophy
Year:	2024

I assessed the impact of the Merge in Ethereum by analyzing the change in its market capitalization following the event. This study can provide insights into market preferences for proof-of-work versus proof-of-stake protocols. A difference-in-difference analysis was conducted, using Ethereum Classic as the control group and Ethereum as the treatment group to estimate the local average treatment effect following the Merge as the intervention. As a robustness check, the analysis was repeated using the Top 100 cryptocurrencies as the control group. I find no evidence that the Merge improved the market capitalization of Ethereum relative to Ethereum Classic or the Top 100 cryptocurrencies.

EVALUATING THE MARKET PERCEPTION OF PROOF OF WORK AND PROOF OF STAKE PROTOCOLS: A DIFFERENCE-IN-DIFFERENCE ANALYSIS

LIST OF TABLES

CHAPTER 1: INTRODUCTION

On September 15th, 2022, the Ethereum network changed its consensus mechanism from Proof of Work to Proof of Stake. This event, known as the Ethereum Merge, was the result of a years-long debate regarding the appropriate protocol for the Ethereum network. Proof of Stake proponents argued that the Ethereum Merge would solve scalability and transaction cost issues. Proof of Work proponents argued it would compromise security and decentralization. Both sides implicitly argued that their preferred protocol would bolster the future demand for Ethereum.

The Ethereum merge has prompted calls for other cryptocurrencies to transition from Proof of Work to Proof of Stake. For example, Dogecoin, an open-source, peer-to-peer digital currency, and Zcash, a secure digital currency that protects privacy, are considering transitioning.

Those urging cryptocurrencies to transition from Proof of Work to Proof of Stake typically take it for granted that (i) the Ethereum Merge was an improvement to the Ethereum protocol and (ii) other cryptocurrencies would similarly be improved by transitioning from Proof of Work to Proof of Stake. Was the Ethereum Merge an improvement? Are other cryptocurrencies likely to benefit from a similar transition? Answering these questions requires further research.

Using a similar before-and-after analysis by Luther and Salter[1] (2017), one way to assess whether the Ethereum Merge was important is to consider the change in its market capitalization following the Merge. Ethereum's market capitalization—i.e., its price multiplied by the quantity of ether outstanding—measures the overall demand or willingness to pay to hold for Ethereum (Hazlett & Luther, 2020). If the Merge improved the Ethereum protocol, more people would be willing to hold Ethereum following the Merge, and correspondingly, its market capitalization would be higher. If it is not important, its market capitalization will remain unchanged. If the Merge made the Ethereum protocol worse, its market capitalization will decline.

In what follows, I consider the effect of the Ethereum Merge on the market capitalization of Ethereum. I present the relevant background information in Chapter 2. Specifically, I review the blockchain technology, consider arguments for Proof of Work and Proof of Stake, and briefly review the history of Ethereum. I specify the research questions and develop 2 hypotheses in Chapter 3. I describe the data and approach in Chapter 4. Results are presented in Chapter 5. In brief, I find no evidence that the Merge improved the market capitalization of Ethereum relative to Ethereum Classic or the Top 100 cryptocurrencies. I discuss the limitations and implications of this research in Chapter 6 and after concluding remarks in Chapter 7.

---

[1] Luther, W. J., & Salter, A. W. (2017). Bitcoin and the bailout. *The Quarterly Review of Economics and Finance*, *66*, 50-56.

CHAPTER 2 – BACKGROUND

Blockchain proponents argue that the Ethereum Merge is a new era for the blockchain and cryptocurrencies (Kessler, 2022). The Ethereum Merge occurred on September 15th, 2022, when the Ethereum network transitioned from the Proof of Work protocol ("PoW") to the Proof of Stake protocol ("PoS"). As with any disruption from the status quo, the Ethereum Merge had proponents speak about the pros and cons of the transition (Viewpoints, 2023).

The question of why the Ethereum network transitioned from Proof of Work to Proof of Stake can be answered after understanding the history of Ethereum. The main reasons are energy consumption and scalability (Kim, 2020). Proof of Work requires significant energy to solve computational-intensive problems to maintain the network in check and secure, translating into transactional costs (Giuseppe Antonio Pierro, 2019). As the network grows in volume and participants, the Proof of Work protocol becomes a disadvantage rather than a solid force to support a fast and efficient processing, limiting scalability (Mahmoud, 2019). Individuals who favored the transition argued that PoS reduces transaction costs and increases scalability, while those who did not favor the transition argued that PoS compromises centralization, increases complexity in the code, and exposes the overall ecosystem to unknown risk (Miller, 2022).

Ethereum's unique history allows me to study the market preference between Proof of Work and Proof of Stake. To address the “Which protocol is better” question, it is important to understand the advantages and disadvantages of each protocol. An individual may prefer one protocol over another depending on their needs (Erik Anderson, 2022). In other words, the best protocol may be project-specific.

Each project has specific scalability, security, and decentralization delimitations that an individual should consider before adopting a protocol (Ismail & Materwala, 2019). Regarding security, both protocols are highly secure. Proof of Work is arguably the most secure, as it has never been hacked. Although Proof of Stake is also secure, it may have some weaknesses that could make the network vulnerable to specific attacks (Dorai, 2021). Regarding scalability, Proof of Stake is superior to Proof of Work as it does not require intensive computational work to validate transactions. Regarding centralization, Proof of Work may be considered more decentralized than Proof of Stake, as it is designed to give all miners the same opportunity to validate a transaction (Sai et al., 2021), while Proof of Stake is designed to provide such opportunity based on the validator’s size in the network (Nguyen et al., 2019).

Considering all factors, users must first identify their needs and determine priorities regarding security, scalability, and decentralization. Second, users must compare both protocols and determine which protocol will perform better in each area. Both protocols have advantages and disadvantages; therefore, the proper way to evaluate each protocol is on a case-by-case basis. These competing narratives provide a third alternative answer: it depends.

Blockchain Technology

Blockchain technology is a shared ledger and a protocol for updating that ledger (Meunier, 2018). As a ledger, it records who owns how much of some available asset. As a shared ledger, it can be read, updated, and broadcast by multiple parties. A blockchain's protocol governs precisely who is authorized to access and revise the shared ledger and how those updates are executed. By enabling multiple parties to participate in the record-keeping process, blockchain technology has the potential to bolster trust and transparency, improve efficiency, offer faster transaction processing times, enhance data security, streamline operations, and reduce costs (Ammous, 2016)

In principle, a shared ledger could convey ownership of any asset. Consider the set of assets $!$, where all $!_{!}$ assets in $!$ are recorded on a shared ledger. At any point in time, the shared ledger indicates who owns $!_{"}$, who owns $!_{\#}$, who owns $!_{\$}$, etc., for all $!_{!}$. The shared ledger, in other words, is a registry of titles to the assets contained in X. Suppose that the owner of $!_{"}$ transfers her title to someone else. The shared ledger is then revised to reflect the new allocation of ownership. The ledger can indicate ownership of any asset. It can be shares of a corporation, limited liability company membership units, partnership interest in a limited partnership, title deeds, physical or intangible assets, or claims to contractual obligations, among other items.

In the context of cryptocurrencies, a shared ledger records who owns how much of a given cryptocurrency. For example, the Bitcoin blockchain records who (i.e., which public address) owns the available Bitcoin balances. The Litecoin blockchain records who owns the available balances of Litecoin. The Ethereum blockchain records who owns the available balances of ether. The Cardano blockchain records who owns the available balances of Cardano.

Ledgers are useful for indicating who owns what, but ownership changes over time (Weigand et al., 2020). That requires the ledger to be updated. If a single entity controls the ledger, that entity has the right to update that ledger. A bank, for example, accepts deposits and creates redeemable claims in the form of checking account balances. When an individual transfers funds to another customer at the bank, the bank debits and credits the respective ledger accounts. When an individual transfers funds to a customer at another bank, the clearing occurs at a higher level (i.e., between the respective banks) yet still relies on a centralized clearing process (Caytas, 2016; Luther & Smith, 2020).

A shared ledger must also be updated. The protocol indicates who is eligible to update the ledger and how the ledger is updated. In principle, if a transaction is recorded incorrectly, then a shared ledger should have the capability to be amended. How can an individual trust that a shared ledger is recording balances correctly?

In general, an individual can trust that an update to a shared ledger is legitimate if the entity updating the ledger is randomly selected, no single entity has more than fifty percent control over the ledger, and individuals can choose what version of the ledger to update. Suppose a transaction $!_{!}$ is initiated. Each participant in the network receives a copy of the ledger reflecting the proposed transaction. The protocol randomly selects participants to verify and update the $!_{!}$ ledger. The proposed transaction will become permanent on record if the number of participants verifying the ledger's authenticity reaches a consensus. Participants will then choose to store that ledger version as the latest record.

Blockchain is a shared ledger system, also known as distributed ledger technology. It is named for how it records transaction data: blocks of transactions linked together in a chain (Singhal et al., 2018). Suppose an individual transfers money to another individual. That transaction is grouped with other transactions into a block. The block is added to the previous existing blocks. This chain of blocks forms the blockchain. Simply put, a block is a collection of ledger entries, and a blockchain is a collection of blocks.

The hash is the thread that connects blocks in the blockchain. A hash function is a mechanism to transcribe data into a unique string of characters (Konashevych & Poblet, 2018). In the context of blockchain, each block has a unique hash known as the block header. Think of a digital fingerprint. When a new block is created, the previous block header is passed through a hash function to generate a header for the new block. Hence, the new block is chained to the previous block by the hashed header.

The blockchain is a chain of blocks. The links in that chain are hashed block headers. One may think of a blockchain as a book and blocks as individual pages in that book. Each page has a top and bottom. The top of the page is connected to the bottom of the previous page. The bottom of the page flows naturally into the top of the next page. Together, the pages in this book form a story of the transactions users have made.

Proof of Work versus Proof of Stake

Proof-of-Work ("PoW") is a consensus protocol used in some blockchain networks. Network participants, referred to as miners, work to solve complex cryptographic problems to validate transactions and create new blocks. A miner is an individual or entity operating a computer within a PoW network of computers working together to reach a consensus.

The protocol is called Proof-of-Work because work, in the form of intensive computational power, must be completed and verified before a new block can be added to the blockchain (Vashchuk & Shuwar, 2018). The more work, the better the proof of the network's current state (Moroz et al., 2020). The computational work is designed to be challenging and expensive to solve but easy and affordable to verify.

Proof of Stake ("PoS") is another consensus protocol to record transactions in some blockchain networks. Certain network participants, called validators, validate and update blocks. A validator is an individual or entity operating a computer within a PoS network of computers working together to reach a consensus.

The protocol is called Proof-of-Stake because participants must "stake" an economic position as collateral to participate as validators in the network. The validator's "stake" refers to some cryptocurrencies in the form of the network's coin. For example, validators of the Ethereum protocol must commit ETH in the network's custody. In this fashion, validators are economically vested in adhering to the protocol's rules to maintain the network's integrity. Otherwise, the vested economic interest is used to penalize the validator's misconduct.

An utterly decentralized consensus protocol must have a vast network of participants. No single entity should control most decisions regarding what ledger can be added or updated to the database (Long et al., 2022). Both proponents of PoW and PoS claim their preferred protocol addresses this.

In a PoW consensus protocol, the level of decentralization depends on several factors. The first factor is mining power distribution, which refers to the distribution of computational power among the network participants. If mining power is scattered across a vast network of participants, then no single entity or group could control most of it. Conversely, if certain participants concentrate on the mining power, it becomes less decentralized. The second factor is accessibility to the hardware required for mining. More participants could participate in the mining process if specialized hardware is affordable. If mining requires expensive or specialized hardware, it may limit participants to mining. The third factor is the governance model of the consensus protocol, which refers to the concentration of decision-making power. If decision-making power is concentrated in a few participants by design, then such participants may influence the overall decentralization of the system. The fourth factor is the network effect, which refers to the protocol's popularity and adoption. The network effect influences decentralized networks' adoption, security, and resilience by promoting a distributed ecosystem.

The PoW mining process involves four steps. First, miners collect pending transactions and validate their authenticity. Second, miners bundle the proposed transactions into a candidate block. Third, miners compete to solve a complex cryptographic problem, and the first one to solve it broadcasts the solution to the network. Fourth, other mines verify the block validity. The block is added to the blockchain if at least 51% consensus exists.

In a PoS consensus protocol, the level of decentralization depends on the validator's stake size in the network. PoS does not require extensive computational resources, such as energy or specialized equipment, to reach a consensus. Therefore, PoS is accessible for any participant to join the network using a regular computer (ethereum.org, 2023), as long as the staking requirements are reasonably low. Lower pre-investment amounts permit lower barriers to entering the validation process, which, in principle, reduces centralization risk. Regarding security, an attacker would need a supermajority of the network's total coins to be staked to complete a malicious activity, which is improbable in a protocol like Ethereum.

A PoS protocol has five straightforward steps to reach a consensus among participants, making it simpler than other protocols. PoS protocol is designed to be easy and fast to validate transactions. First, participants must stake their cryptocurrencies to become validators. Second, a validator is selected to verify a transaction. Third, the validator broadcasts a block creation to other validators. Fourth, other validators verify the block according to the rules of the protocol. Fifth, the block is added to the "supermajority chain" and is considered finalized when a supermajority of validators has attested to 66% of the total coins staked on the network. After the process is completed, validators receive a reward (ethereum.org, 2023).

Proponents of both protocols may agree that PoW and PoS reach a consensus, but not without debating on each protocol's perceived problems in doing so. The major complaint against Proof of Work is its energy use, and the major complaint against Proof of Stake is centralization issues.

In PoW, remember that specialized hardware is required for compute-intensive and complex calculations. Although this process is designed to maintain network integrity, computational tasks require significant energy to solve complex computational problems and reach a consensus for creating a block. The more popular a PoW network is, the more miners participate in it. Therefore, popularity leads to an overall increase in energy consumption. The combination of scaling economic reward, competition, and a network's popularity may cause miners to ramp up their operations, which increases electricity consumption even further (Xue et al., 2018). The high energy usage is subject to criticism from energy conservationists, pointing to the increase in greenhouse gas emissions and carbon footprint. For example, the Bitcoin network electricity demand is comparable to the energy demand of an entire industrialized nation (Zhang & Chan, 2020). According to the Cambridge Bitcoin Electricity Consumption Index, the Bitcoin Network's total annual electricity consumption of 173 TWh ranks 24th behind South Africa’s 191 TWh (Cambridge, 2024). Although unlikely, yet in principle, miners with access to lower energy costs and higher computational power may increase the risk of centralization. Miners with more computational power at a lower energy cost may increase their dominance in the process.

The PoW protocol's transactional capacity is also subject to energy consumption criticism (Vashchuk & Shuwar, 2018). During periods of high activity, transactions are often backed up, resulting in energy consumption peaks and higher processing costs. Scalability is a significant challenge for PoW, making micropayments, real-time processing, and smaller everyday transactions impractical. For example, the Bitcoin network had a daily estimated power demand of 14 GW on September 28th, 2023, and 18 GW on December 24th, 2023 (Cambridge, 2024).

In a PoS protocol, deliberations surrounding centralization is a main concern. Remember that validators with greater economic power may have advantages over smaller validators in the network. Greater economic power means greater chances of being selected to validate a transaction. The more PoS holding at stake, the more influence the validator has over the network, compromising centralization and exacerbating wealth inequality (Shifferaw & Lemma, 2021). In principle, if an individual subscribes to a blockchain network, it is because of the individual's need for a decentralized system. Therefore, power concentration undermines the egalitarian proposition of decentralized systems, undermining the principle of a shared ledger.

A PoS protocol requires a minimum stake to become a validator, and a higher entry barrier is another centralization concern. If the minimum stake is high in value, it is reasonable to think that the network may have fewer participants. Consequently, high barriers may exclude small participants from the network, reducing decentralization. If a PoS protocol has a low entry barrier, smaller participants could easily join the network, increasing decentralization. This means that participants who engage in dishonest behaviors could also easily exit the network, decreasing security. It is reasonable to think that small participants have fewer resources at stake, encouraging malicious activities and sybil attacks (Orcutt, 2019). A preventive measure against sybil attacks is for the PoS protocol to make the attack economically unfeasible. Blockchain technology has a trilemma between decentralization, scalability, and security. PoS, in this case, by increasing decentralization, also decreases security.

In a PoS protocol, how can wealth be equally distributed, and what entry levels are proportionate? The balance between smaller and bigger validators may be obtained in the initial distribution and pre-mining stage. However, an unfair distribution or pre-mining of PoS coins allocated to specific groups before the network launches may be counterproductive. Decentralized networks gravitate around the principle of fairness and equality. Any act of unfairness during a network's pre-launch may promote wealth inequality and centralization. Higher pre-investments incentivize validators to follow the protocols and rules for maintaining network integrity. Stake positions may be considered a deductible deposit in case of moral hazard, making validators personally liable for not maintaining the network's security.

In the ongoing debate surrounding the implementation and usability of blockchain protocols, frequently revolve around the benefits and limitations of Proof of Work and Proof of Stake, with the objective to determine which protocol is better. But the relative attractiveness of a particular protocol—i.e., which is "better"—is application-specific. A mechanism might be better in one application and worse in another. Hence, one must carefully avoid falling into the "all-or-nothing" fallacy when evaluating protocols.

To see the importance of avoiding the all-or-nothing fallacy more clearly, consider distinct applications and the protocol attributes one would want in these cases. For example, the proof of work protocol consensus mechanism requires intensive computational power to solve mathematical tasks. Therefore, an application focused on private and censorship-resistant transactions and egalitarian mining, such as Monero, may consider using the PoW protocol as the best option. The Proof of Stake protocol is energy efficient, and users have low transaction fees. A smart contract non-custodial financial application where depositors earn interest on their excess liquidity, and borrowers can use that liquidity for other purposes by paying interest, such as Aave, may consider using PoS protocols as the best option, given the low transaction fees.

The implications of the “all-or-nothing” dichotomy may lead to oversimplifying the strengths and weaknesses of each protocol. Consequently, proponents of each side ignore the protocols' intricacies while promoting its preferences, obstructing productive discussions. For example, PoW proponents argue that their preferred protocol is truly decentralized, discarding the role of honest validators in PoS. On the other hand, PoS proponents argue that their preferred protocol is energy efficient, discarding technological improvements in PoW.

These examples show that falling into an “all-or-nothing” dichotomy leads to dismissing application-specific factors and asserting extreme positions. Remember that the common denominator of blockchain protocol architecture is the trilemma, which balances decentralization, security, and scalability, involving a tradeoff by design. An individual's choice to subscribe to a protocol includes but is not limited to the following reasons: Security, efficiency, environmental impact, decentralization, long-term sustainability, network upgrades and maintenance, attack resistance, and user incentives, among others.

Since Proof of Work and Proof of Stake have different attributes and different purposes, there are three potential answers to the “which is better” question: PoW, PoS, and it depends. The third answer suggests that a co-existence equilibrium may be optimal, with individuals choosing one protocol for some purposes and another for other purposes.

A participant's choice to join a blockchain network typically occurs after an individual recognizes the need for a decentralized and secure system to verify transactions. Adoption is a multi-step process involving many stakeholders (hereafter called “Community”). After identifying the need, the Community evaluates what protocol should be used. Each project has different scalability, security, and governance model necessities, resulting in the Community selecting the best-suited consensus protocol for a given purpose. The Community or individuals may have diverse needs requiring different solutions. Therefore, PoW may be better under specific scenarios than PoS, and vice-versa.

When could Proof of Work be better suited than Proof of Stake?, Remember that PoW is better suited for applications that demand high security and decentralization. Such applications could be for ledgers that convey sensitive data or high-value financial transactions. PoW is the oldest blockchain and has proven resistant to sybil attacks. A Community concerned with bad actors creating multiple fake entities can mitigate the risk through a PoW protocol. The preference is due to the protocol’s resource-intensive design. For bad actors to profit, they must pre-invest a significant amount of resources to control 51% of the network, which makes it economically unreasonable, mathematically nearly unfeasible, and virtually impossible (Dubloin, 2023). A Community interested in prioritizing objective decentralization and security may elect PoW as this protocol facilitates a fair consensus distribution.

When could Proof of Stake be better suited than Proof of Work? Remember that PoS is better suited for applications that demand higher levels of scalability and speed. A Community concerned about costs associated with verifying a high volume of transactions will prefer a PoS over PoW protocol (ethereum.org, 2023). PoW is a protocol that offers low transactional fees for multiple reasons, primarily due to its low energy consumption, more affordable equipment requirements, and less friction between validators than PoW. Applications that require speedy transactional confirmation, such as micro-payments, liquidity pools, or IoT use cases, may choose this protocol. PoW is the best choice for real-time and cost-effective use cases.

In summary, a coexistence equilibrium may exist based on the advantages and disadvantages of each protocol and the Community's needs. These advantages and disadvantages are based on functionality, security, transaction cost, economic deliberations, and market confidence. All in all, in ecosystems such as Bitcoin, a community that requires functionalities, security measures, and decentralization mechanisms to have intensive computational calculations to foster market confidence may prefer the Proof of Work protocol. In ecosystems such as Ethereum, a community that requires scalability, speed, low transactional costs, and environmentally friendly solutions may prefer Proof of Work protocols.

History of Ethereum

The establishment of Bitcoin introduced the world to the innovation of decentralized systems applicable in trustless digital currency. The underlying technology, blockchain, was a robust and unprecedented system to securely transfer payments outside the traditional financial system. As Bitcoin's popularity grew, its utility and limitations did not go unnoticed. The scripting programming language restricted the functionalities outside its main purpose as a peer-to-peer payment system, limiting other desirable decentralized applications. The growing number of users experienced transaction cost inefficiencies (elevated fees) during high periods of activity, detecting scalability issues. While trying to address potential solutions in the Bitcoin network, developers encountered a lack of programming versatility, halting any possible efforts to address these issues.

In 2013, Vitalik Buterin, a prominent Bitcoin enthusiast, saw the potential of blockchain technology and proposed a similar system to solve Bitcoin's limitations: the Ethereum network. Ethereum may be seen as a Bitcoin spin-off created from necessity. At this stage, the Ethereum network was a blueprint describing a new versatile programming language for self-executing contracts for decentralized applications. The Ethereum network proposed a new foundation for a worldwide computer system similar to Bitcoin that could execute smart contracts in a trustless and decentralized environment.

In 2014, the founders of the Ethereum network began fundraising efforts and secured $18 million US dollars to start the development, calling this stage Frontier. In 2015, the Frontier version was completed and launched to the public, becoming the second-biggest blockchain network in existence behind Bitcoin. Frontier was a success, giving birth to its native currency, ETH, and providing access to developers to build decentralized applications.

Decentralized applications included self-executing smart contracts under the principle of automation, where individuals could register digital contracts, maintain balance, and convey assets of any kind without a central authority. For example, in a real estate transaction, two individuals could have a lease agreement where the landlord obtains monthly rent from a tenant via a digital contract. Similarly, a financial institution could issue bonds where investors obtain a coupon payment until redemption using digital contracts. The calculation of interest, balances, other payments, and transfer of titles can be executed in the same fashion.

In 2016, interest in creating decentralized environments fueled the conception of projects such as the DAO, which used the Ethereum network and became one of the largest venture capital campaigns in blockchain at the time. DAO stands for Decentralized Autonomous Organization, and its core mission was to provide a trustless environment to automate decisions and facilitate transactions. The DAO project marked an important event in the Ethereum network as the project was hacked, implicating controversial consequences. Hackers stole almost one-third of the DAO's funds priced in ETH, and the Ethereum community had to find a solution. The decision was to create a "hard fork" on the Ethereum chain, reversing the hack, and returning the stolen ETH to its original owners.

Creating a hard fork had two intertwined implications: the first was technical, and the second was conceptual. Technically, developers had to split the Ethereum chain into two, creating a new chain that continued to return the ETH to its original owners and a second chain that remained committed to the unaltered chain (Ethereum Classic). Conceptually, hard forking the chain is philosophically controversial because it attempts to go against the principle of immutability of decentralized systems.

The founders of Ethereum remained committed to the hard-forked chain, and the Ethereum community grew in popularity. However, popularity also caused the system to face challenges of scalability and computational limitations of the Proof of Work consensus protocol, translating inefficiencies into high transaction costs. The solution to this issue was not found in modifying the Proof of Work protocol given its fundamental design, so the next option was to change its consensus protocol to a more efficient one. The vision was to transition from Proof of Work to Proof of Stake, but the task had never been seen or done before. Years of research and development starting in 2017 paved the way to the transition, including other hard forks known as Byzantium, Constantinople, and London, Shanghai, to the Merge on September 15th, 2022.

The Merge was successfully implemented but did not come without deliberated controversies. Criticism about the Proof of Stake protocol included concerns about centralization, security, and uncertainty. Regarding centralization, critics argue that this protocol may create mining dominance as bigger entities with large proportions of ETH have an advantage over smaller players with lower ETH holdings, influencing the validation process. The implication is that bigger entities will consistently earn more ETH rewards, widening the wealth gap (the rich getting richer). Regarding security concerns, critics argue that the Proof of Stake protocol is relatively new compared to Proof of Work, which has a consistent track record of safety and could otherwise compromise the network security long-term. Regarding uncertainty, remember that a transition of protocols has never been seen or done in the past. Therefore, switching the consensus mechanism on a multi-billion-dollar blockchain is a risky proposal that may affect those who are heavily vested.

CHAPTER 3 – RESEARCH QUESTION AND HYPOTHESIS DEVELOPMENT

This study aims to explore the market preference between Proof of Work or Proof of Stake consensus protocol by analyzing the market capitalization of Ethereum and Ethereum Classic after the Merge. To my knowledge, this is the first research study using a difference-in-difference analysis to explore the market preference between these protocols at the time of this writing.

The market is currently engaged in a discussion regarding the preferred consensus protocol. While each protocol has advantages and disadvantages, it is fundamental to assess both options carefully to make an informed decision. This decision will have important implications for participants who wish to digitalize assets using blockchain technology. Evaluating which consensus protocol will provide the most effective and efficient outcome for the market is essential.

Market preference can influence the investor decision-making process, increasing the network's market capitalization. Whether the market prefers Proof of Work or Proof of Stake is decisive for developers investing significant resources in developing new applications or corporations worldwide considering blockchain options for issuing corporate bonds. By studying what protocol the market prefers, this paper can provide valuable insight to investors and other participants and help their decision-making process.

I address four ideas for the research questions. First, understand if Merge had any impact on the market capitalization of ETH. Second, if the Merge had any impact on the market capitalization of ETC. Third, compare the market capitalization of ETH and ETC to each other after the Merge. Fourth and last, if the Merge had a lagging or long-term effect on ETH.

The market capitalization of a blockchain network may signal its adoption growth and, in turn, indicate a participant's preference for a given network. If the market capitalization of one protocol continuously increases relative to the other, then the effect may suggest that such an increase is derived from the adoption trend.

Developers supply applications to the market, which must be coded in a protocol that the market will absorb. The answer to my research question will help developers make strategic decisions based on market trends. In principle, the protocol with a greater level of adoption will likely lead to an increase in innovation. On the other hand, the protocol with lower adoption will have to reinvent and redefine its protocol to meet market demands.

The primary benefit of blockchain technology relative to legacy ledger technology is its ability to foster transparency and increase trust at low costs. Proof of Stake more closely resembles legacy ledger technology, given its potential for centralization. PoS is a relatively new technology and has never been used as the backbone to run today's most extensive smart contract network. Although both protocols have advantages and disadvantages, in principle, the advantages should offset the disadvantages, given that no technology is perfect. In the case of the Ethereum network, most of the community believes that the advantages of Proof of Stake are greater than its potential disadvantages. Indeed, it is for this reason that the protocol transitioned from Proof of Work to Proof of Stake.

H1: The market capitalization of Ethereum will rise relative to Ethereum Classic on news of Ethereum's transition from proof of work to proof of stake.

PoS is a relatively newer technology than PoW, and Ethereum has the most significant participant base of any smart contract platform. The Ethereum protocol has a history of controversies and hackers exploiting vulnerabilities. One of the biggest concerns in blockchain is smart contract hacking. Although Ethereum is a secure platform, participants may use the protocol longevity as a proxy to evaluate security risks. If stakeholders consider these factors, then there may be a degree of uncertainty surrounding the Merge, making them to choose other protocols.

The transition from PoW to PoS is a challenging process. Remember that a protocol transition has never been seen or done before. Significant expertise and time are required to successfully migrate from one protocol to the other. The success of the Merge may only be fully identified sometime after the transitioning date. If participants recognize the complexity of the event, then there must be some uncertainty about whether the process will be successful or not.

Participants may want to wait until they feel secure or more comfortable to go back to Ethereum. Developers may also want to see how successful the transition is before they invest time and resources into developing new applications in Ethereum. An individual may consider the Merge event as a reason to explore alternative protocols that provide the same benefits as Ethereum, such as Solana or Avalanche. These blockchain networks have been using PoS since their inception long before Ethereum, meaning that any potential vulnerability within these protocols has been addressed.

Ethereum is more popular than Ethereum Classic. Most of the Ethereum Community continues to build applications using Ethereum. If developers choose Ethereum over Ethereum Classic, there will be more demand for Ethereum and less for Ethereum Classic.

When compared with Bitcoin, ETH is not predominantly a cryptocurrency used to store value, as Bitcoin is. Instead, it is a cryptocurrency mainly used to pay for transactional costs. Nonetheless, there are “investors” who speculate and trade this cryptocurrency. Investors may also find these alternative protocols more attractive than before.

One may contend that ETC is not an appropriate control for ETH. To address this concern, I repeat the analysis using the top 100 cryptocurrencies as the control group, excluding ETH. It is reasonable to think that these top 100 cryptocurrencies may respond similarly to a general market shock in the crypto market. However, it is not reasonable to think that these top 100 cryptocurrencies would be affected by Ethereum’s transition from PoW to PoS. If the stakeholders are hesitant about the success of the Merge, they may want to withdraw their funds from the Ethereum network and move these monies to other cryptocurrencies.

It is difficult to predict how the market will react before or after the Merge. Furthermore, it is difficult to predict the market capitalization of any cryptocurrency, especially Ethereum, as the complete value of the technology is not perfectly measured by its market capitalization. Technically speaking, the market value of any cryptocurrency is the total value of coins in circulation. The market capitalization today does not consider the technology's potential applications, the number of active users, or transactions being processed. I expect that uncertainty will decrease after the Merge has been successfully implemented, and the market capitalization of the ETH and ETC will reflect such information.

H2: The market capitalization of Ethereum will rise relative to the Top 100, excluding ETH on news of Ethereum's transition from proof of work to proof of stake.

CHAPTER 4 – DATA AND APPROACH

Following a similar approach by Luther[2] (2022), I use a difference-in-difference approach to estimate the impact of the Merge on the value of Ethereum. In the baseline approach, I use Ethereum Classic as the control group. As a robustness check, I expanded the control group to include the Top 100 Cryptocurrencies by market capitalization (excluding Ethereum). In both cases, Ethereum is designated as the treatment group, with the treatment being the move from PoW to PoS. Specifically, I estimate the following equation:

$$!_{!"} = \#_{\#} + \#_{\$}\%_{!"} + \#_{\%}\&_{!"} + \#_{\&}\%_{!"}\&_{!"} + '_{!"} \quad (1)$$

Where:

- $"_{!\%}$ is the natural logarithm of the market capitalization of cryptocurrency *i* at time *t*;
- $\$_{!\%}$ is a dummy variable equal to 1 if the observation of cryptocurrency *i* at time *t* is after the Merge, 0 otherwise;
- $\%_{!\%}$ is a dummy variable equal to 1 if the observation of cryptocurrency *i* at time *t* is ETH, 0 otherwise;
- $\$_{!\%}\%_{!\%}$ is an interaction term; and
- $\&_{!\%}$ is an error term with a mean of 0.

---

[2] Luther, W. J. (2022). Pornhub and the Value of Bitcoin. *AIER Sound Money Project Working Paper*(2022-04).

The estimated coefficient $'_{\$}$ is the local average treatment effect—i.e., the change in the natural log of the market capitalization of Ethereum following the Merge relative to the control group.

I collect data on the market capitalization of the Top 100 cryptocurrencies from CoinMarketCap.com from September 1, 2020, to December 19, 2022. I cleaned the data and dropped 8 cryptocurrencies with missing values, which left 92 cryptocurrencies, including Ethereum. I selected this date range for two reasons. First, 24 months of observations prior to the Merge is sufficient to establish that my treatment and control groups are similar in the pre-treatment period. Second, it is reasonable to think the effects of the Merge will be realized within a 3-month period following the Merge.

I use market capitalization as an indicator of the perceived worth and market size of a given cryptocurrency. The market capitalization is calculated by multiplying the price of a cryptocurrency by its circulating supply, making it a relevant dependent variable for this study. The market's perceived worth may reflect an investor's consideration of the utility of a given cryptocurrency, and as a dependent variable, it allows me to assess any changes in the broader market sentiment.

To address heteroskedasticity concerns, I took the natural logarithm of the market capitalization. As such, the estimated coefficients should be interpreted as relating to a percent change in the market capitalization

In the baseline approach, I use ETC as the control group to isolate the effect of the intervention from other external influences. To the extent that ETC serves as an effective control group, any differences observed between the treatment group and control group can be attributed to the intervention. ETC and ETH share a common history, and prior to the merge, both groups used the Proof of Work consensus protocol. Hence, there are many reasons to think ETC might serve as an effective control group.

As a robustness check, I expand the control group to include the top 100 cryptocurrencies by market capitalization, excluding ETH. Relative to the control group in the baseline approach, the top 100 cryptocurrencies do a better job controlling for general market trends in the cryptocurrency market. Although not all the cryptocurrencies in this broader control group use a PoW mechanism, none, to my knowledge, switch from PoW to PoS or vice versa during the sample period.

In principle, the difference-in-difference analysis estimates the local average treatment effect following an intervention. Specifically, the approach compares the change in the treatment group following an intervention to that of the control group, where no intervention occurs. The validity of the estimated local average treatment effect depends crucially on the choice of control group.

One common way to assess the extent to which a group is an effective control is to test whether the trend of the dependent variable time series for the control group is parallel to that of the treatment group in the pre-treatment period, with the idea being that a parallel trend indicates that the two groups are affected similarly by similar shocks. If the trend of these two groups is parallel in the pre-treatment period, a change in the average difference between the time series following the treatment can be reasonably interpreted as reflecting the effect of the treatment. If the trends of the time series of the two groups are not parallel in the pre-treatment period, the results are not a reliable estimate of the local average treatment effect.

To consider the assumption that ETC and the top 100 Cryptocurrencies are reasonable control groups for ETH, I conducted a parallel trends analysis for the pre-treatment period. First, I generated a dummy variable for each week in the pretreatment period. For example, the dummy variable (1!% is equal to 1 in the week beginning September 1st, 2020, and ending September 7th, 2020, and 0 otherwise; the dummy variable (2!% is equal to 1 in the week beginning September 8th, 2020 and ending September 14th, 2020, and 0 otherwise; and so on. Second, I generate an interaction term with ETH for each week. For example, (1!%%!%; (2!%%!%, and so on. Finally, I estimate the following equation:

!!" = ## + #$%!" + #%(1!" ... + #$#'(106!" + #$#((1!"&!" + ⋯ + #%$)(106!"&!" + ℰ!"

(2)

If the two groups have parallel trends, the weekly dummy variables will explain all the time-varying differences in the two series. Hence, the coefficients of interest in the parallel trends analysis are those associated with the interaction terms. If any of the coefficients on these interaction terms are statistically significant, it implies that some of the time-varying differences is specific to one-and-not-both of the two groups. In other words, if the interaction terms are statistically significant, I must reject the assumption that the trends are parallel.

The results of the parallel trends analysis are presented in Appendix A. Using ETC as the control variable, results indicate that the interaction terms are statistically significant over the pre-treatment period. Consequently, I must reject the parallel trends assumption. Using the Top 100 Cryptocurrencies as the control variable, results indicate that the interaction terms are not statistically significant over the pre-treatment period. Hence, I am not able to reject the parallel trends assumption.

Descriptive statistics are presented in Table 1. The sample of Panel A is limited to ETH and ETC. The sample of Panel B includes the Top 100 Cryptocurrencies. For Panel A, the mean of the market capitalization variable is 23.935, and the standard deviation is 2.263. The minimum is 20.144, representing the lower bound of the observed values, and a maximum of 27.062, representing the upper bound of the observed values. Hence, the average value of all observations was 11.6% below the market's upper bound of the observed values –i.e., $\frac{\#\&.()\#*\#\$.+\$,}{\#\&.()\#}$.

For Panel B, the mean of the market capitalization variable is 21.389, and the standard deviation is 1.904. The minimum is 8.426, representing the lower bound of the observed values, and a maximum of 34.304, representing the upper bound of the observed values. Hence, the average value of all observations was 37.6% below the market's upper bound of the observed values.

Recall that the Merge occurred on September 15th, 2022. I created a dummy variable that is equal to 0 prior to September 15th, 2022, and 1 thereafter. In the primary specification, I denote the period prior to September 15th, 2022, as the pre-treatment period and the period thereafter as the post-treatment period. In Panel A, the mean of the Merge variable is 0.115, meaning 11.5 percent of the observations occurred in the post-treatment period as defined in the primary specification. In Panel B, the mean of the Merge variable is 0.133.

I also considered several alternative specifications, where I increased the treatment window. Specifically, I expand the treatment window to (i) +/- 1 day, (ii) +/- 3 days, (iii) +/- 7 days, and (iv) +/- 14 days. These alternative specifications permit me to identify how sensitive the estimated local average treatment effect is to the treatment window. This is potentially important if the merge is to get priced in with a lag or in advance.

I created a dummy variable that is equal to 1 for Ethereum and 0 otherwise from September 1st, 2020 to December 19th, 2022. In Panel A, the mean of the Ethereum variable is 0.503, as there are only two cryptocurrencies in the sample: Ethereum and Ethereum Classic. In Panel B, the mean of the Ethereum variable is 0.013, meaning that Ethereum accounts for 1.3 percent of all observations.

I created a dummy variable that multiplies the Ethereum dummy variable and the Merge dummy variable, which is equal to 0 for Ethereum prior to the Merge and 1 for Ethereum thereafter. In Panel A, the mean of the interaction effect variable is 0.057, meaning 5.7 percent of the observations are treated (i.e., Ethereum) and occurred in the post-treatment period in the primary specification. In Panel B, the mean of the interaction effect variable is 0.001.

Table 1

Summary Statistic: Panel A and Panel B

Panel A: ETH and ETC

Variable	Obs	Mean	Std. Dev.	Min	Max
Market Capitalization (Natural Log)	1668	23.935	2.263	20.144	27.062
Eth x Merge	1668	.057	.232	0	1
Eth	1668	.503	.500	0	1
Merge	1668	.115	.319	0	1

Panel B: Top 100 Cryptocurrencies

Variable	Obs	Mean	Std. Dev.	Min	Max
Market Capitalization (Natural Log)	62286	21.389	1.904	8.426	34.304
Eth x Merge	62286	.001	.039	0	1
Eth	62286	.013	.115	0	1
Merge	62286	.133	.340	0	1

CHAPTER 5 – RESULTS

A difference-in-difference analysis was conducted to examine the relationship between the market capitalization of ETH ex-ante and ex-post the Merge. The results of the study can be observed in Table 2**.** Using the baseline case of ETC as the control group, the interaction effect, which is the coefficient of interest in the study, indicates that ETH had a lower growth rate relative to ETC after the Merge, as expressed by the negative coefficient ETH x Merge (-0.359). The results are statistically significant. However, since the parallel trends assumption was rejected, the estimated coefficients do not reflect the local average treatment effect.

Considering the four alternative specifications for the Merge. In general, the results are consistent with the baseline case across all alternative specifications. Results of the interaction effect indicate that the growth rate of ETH declined by 0.361 relative to ETC following the Merge when a +/- 1-day window was used. For the +/- 3 days, it declined by 0.356; for the +/- 7 Days it declined 0.345.; and for the +/- 14 Days it declined 0.331. The results are statistically significant. Again: since the parallel trend assumption was rejected, the estimated coefficients do not reflect the local average treatment effect.

Recall that H1 indicates that the market capitalization of Ethereum will rise relative to Ethereum Classic on news of Ethereum's transition from proof of work to proof of stake. The results described above are not consistent with H1. Following the Merge, the market capitalization of ETH declined relative to ETC.

Table 2

Difference-in-Difference of Panel A: ETH and ETC

		Alternative Specifications for Merge			
Market Cap (Natural Log)		**+\- 1 Day**	**+\- 3 Day**	**+\- 7 Day**	**+\- 14 Day**
ETH x Merge	-0.359***	-0.361***	-0.356***	-0.345***	-0.331***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ETH	4.294***	4.296***	4.298***	4.301***	4.307***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Merge	0.089***	0.090	0.083	0.069	0.054
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	21.782***	21.781***	21.779***	21.776	21.771***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1668	1664	1656	1638	1610

*Robust standard errors are noted parenthetically. *** p<.01, ** p<.05, * p<.1*

As part of the robustness check, I conducted a second Difference-in-Difference analysis using the top 100 cryptocurrencies as the control group. The results of the study can be observed in Table 3. Using the top 100 cryptocurrencies as the control group, I find that ETH had a *lower* growth rate relative to the Top 100 Cryptocurrencies after the Merge, as expressed by the negative coefficient ETH x Merge (-0.001). However, the estimated coefficients are not statistically significant and should therefore be interpreted as having no effect.

As with the baseline estimation, I repeat the analysis using four alternative specifications for the Merge using the Top 100 Cryptocurrencies as the control group. In general, the results are consistent across all alternative specifications. Results of the interaction effect suggest that the growth rate of ETH declined by 0.001 relative to ETC following the Merge when a +/- 1 Day window was used. For the +/- 3 days, it declined by 0.001; for the +/- 7 Days it declined 0.000; and for the +/- 14 Days it declined 0.006. The results are not statistically significant.

Recall that H2 indicates that the market capitalization of Ethereum will rise relative to the Top 100, excluding ETH on news of Ethereum's transition from Proof of Work to Proof of Stake. The results described above are inconsistent with H2: following the merge, the market capitalization of ETH declined relative to the Top 100 cryptocurrencies (excluding ETH).

Table 3

Difference-in-Difference of Panel B: ETH and the Top 100 Cryptocurrencies

		Alternative Specifications for Merge			
Market Cap (Natural Log)		**+\- 1 Day**	**+\- 3 Day**	**+\- 7 Day**	**+\- 14 Day**
ETH x Merge	-0.001	-0.001	-0.001	-0.000	0.006
	(0.070)	(0.071)	(0.071)	(0.072)	(0.073)
ETH	4.923***	4.922***	4.922***	4.921***	4.919***
	(0.164)	(0.164)	(0.164)	(0.164)	(0.164)
Merge	-0.268***	-0.269***	-0.271***	-0.275***	-0.282***
	(0.070)	(0.071)	(0.071)	(0.072)	(0.073)
Constant	21.154***	21.155***	21.155***	21.156***	21.159***
	(0.164)	(0.164)	(0.164)	(0.164)	(0.164)
Observations	62286	62114	61770	60996	59805

*Robust standard errors are noted parenthetically. *** p<.01, ** p<.05, * p<.1*

CHAPTER 6 – DISCUSSION AND EMPIRICAL ANALYSIS

The difference-in-difference analysis provides no evidence that the Merge improved the market capitalization of ETH relative to control groups. The local average treatment effect was not identifiable for the baseline and alternative specifications, though the results were statistically significant. When the Top 100 cryptocurrencies served as the control group, the difference-in-difference analysis indicates that the Merge had no effect on the market capitalization of ETH relative to the control group: the estimated coefficients were negative but not statistically significant.

In Appendix B, Table 5, and Table 6, I consider an additional alternative dependent variable, trading volume instead of market capitalization, to explore what may drive the results. Trading volume measures market activity, meaning that it directly reflects the number of cryptocurrencies that are bought and sold—i.e., the market liquidity. For Tables 5 and 6, I obtained trading volume data that was consistent with the cryptocurrencies of my sample. Other researchers may use this document as a baseline to explore other dependent variables when isolating the effect of the Merge.

In light of the evidence, the interpretation of these results may be caused due to an array of factors. It is possible that ETH developers were mistaken about the benefits of the Merge, which ultimately reduced the market capitalization of ETH. It is also reasonable to think that users may have concerns about the success of the transition given its technological complexity. Users may find temporary comfort in other cryptocurrencies. Therefore, funds are temporarily moved away from Ethereum and placed into other protocols. Another possible explanation is uncertainty. The Ethereum network has a history of controversy and hacks that may trigger stakeholders' security concerns. Cautious stakeholders may want to withdraw funds from both ETH and ETC.

It is important to note that my study is focused narrowly on the value of transitioning from PoW to PoS. Other factors, such as regulations, market sentiment, or other news, potentially affect the market capitalizations of cryptocurrencies. I do not attempt to explain the overall market capitalization of ETH or other cryptocurrencies. Instead, I attempt to control for broader changes in the market capitalizations through the use of control groups: ETC in the baseline specifications and the Top 100 cryptocurrencies, excluding ETH in the robustness check. To the extent that these groups serve as effective controls, the estimated local average treatment effect explains the change in the market capitalization of ETH resulting from the merge. Additional research is required to explain the market capitalization of ETH more generally.

All in all, the study's results using ETC and the top 100 cryptocurrencies as the control groups indicate that the Merge did not have a positive impact on Ethereum's market capitalization. Hypotheses 1 and 2 are rejected.

CHAPTER 7 – CONCLUSION

Blockchain technology is the backbone of shared ledgers. Shared ledgers provide a secure, transparent, and decentralized alternative to record, transfer, and track ownership of any asset without central authorities. Although a shared ledger increases transparency at lower costs, these may be vulnerable to security attacks.

The Ethereum protocol has a history of controversies. First, the DAO incident led to the creation of Ethereum Classic by hard forking the Ethereum chain. It was controversial due to the argument of infringing the principle of immutability. Second, the Merge, which may increase centralization risk. The Ethereum Merge was one of the most anticipated events in the blockchain space. It was the first blockchain protocol to make a move of such magnitude with far-reaching implications for the future of blockchain. The decision to transition from PoW to PoS was a meditated conclusion and time-consuming. The factors behind this transition included reducing transaction costs, satisfying scalability demand, and arguably increasing security. According to the Ethereum Community, the outcome and benefits of transitioning from PoW to PoS, in the long run, outweighed the risk in the short run.

Both PoW and PoS have advantages and disadvantages as viable consensus mechanisms. It is uncertain which protocol is better, yet the Merge is a possible indication of where the industry may be directed. The two most popular consensus mechanisms for shared ledgers are Proof of Work and Proof of Stake. An individual may evaluate which protocol is better after analyzing the specific needs of each project. The best protocol may be subject to the specific requirement. Projects with high levels of security may choose PoW over PoS. A project with high levels of transactional volume may consider PoS over PoS. If centralization is concerning, then PoW is less risky than PoS by design.

I used a quantitative approach to investigate the impact of the Merge on the market perception of Proof of Work and Proof of Stake. I addressed this question by conducting a difference-in-difference analysis to measure the impact of the Merge on the market capitalization of Ethereum and Ethereum Classic. I collected data on the daily market capitalization of the top cryptocurrencies from September 1, 2020, to December 19, 2022. I answer three main questions: (i) did the Merge impact the market capitalization of Ethereum and Ethereum Classic? (ii) how did the market capitalization of Ethereum and Ethereum Classic compare after the Merge? (iii) does the collected data answer the research question? Results suggest that the market capitalization of Ethereum decreased relative to Ethereum Classic. As a robustness test, I used the top 100 cryptocurrencies as a control group. I found results indicating that Ethereum market capitalization decreased relative to the top 100 cryptocurrencies after the Merge.

Although I have used a causal inference technique, the results are only valid to the extent that the control group is adequate. In this case, it is important to determine whether a change in one factor, the merge, directly causes a change in another factor. The difference-in-difference analysis helps me to interpret results beyond mere correlations or misleading correlations. I use a single control group to represent the Proof of Work protocol, yet it is not the only protocol using this consensus mechanism. I do not control for specific factors, such as regulations or market sentiment, given that my control group, in principle, contains all controlling factors. Nonetheless, this study is the first to measure the market perception of the Ethereum and Ethereum Classic using the Merge as a treatment event. My results provide some insight into the value of both protocols, as results suggest a bearish sentiment on POS relative to PoW, at least in the short term. This study may be relevant for developers considering developing applications and are concerned about whether the market may better absorb their offering using PoW or PoS.

APPENDICES

Appendix A: Pre-Treatment Market Caps

Market Cap (Natural Log)	ETC	Top 100	Market Cap (Natural Log)	ETC	Top 100
week1_x_eth	0.266***	-0.525	week15_x_eth	0.592***	-0.200
	(0.047)	(0.44)		(0.047)	(0.769)
week2_x_eth	0.282***	-0.577	week16_x_eth	0.63***	-0.177
	(0.047)	(0.396)		(0.047)	(0.794)
week3_x_eth	0.311***	-0.562	week17_x_eth	0.753***	-0.024
	(0.047)	(0.408)		(0.047)	(0.972)
week4_x_eth	0.238***	-0.579	week18_x_eth	0.936***	0.154
	(0.047)	(0.394)		(0.047)	(0.821)
week5_x_eth	0.232***	-0.689	week19_x_eth	1.075***	0.321
	(0.047)	(0.31)		(0.047)	(0.636)
week6_x_eth	0.249***	-0.54	week20_x_eth	1.056***	0.209
	(0.047)	(0.426)		(0.047)	(0.758)
week7_x_eth	0.292***	-0.513	week21_x_eth	1.173***	0.211
	(0.047)	(0.45)		(0.047)	(0.756)
week8_x_eth	0.33***	-0.44	week22_x_eth	1.228***	0.205
	(0.047)	(0.517)		(0.047)	(0.763)
week9_x_eth	0.333***	-0.411	week23_x_eth	1.34***	0.221
	(0.047)	(0.545)		(0.047)	(0.744)
week10_x_eth	0.461***	-0.279	week24_x_eth	1.012***	-0.04
	(0.047)	(0.681)		(0.047)	(0.953)
week11_x_eth	0.534***	-0.279	week25_x_eth	0.869***	-0.133
	(0.047)	(0.682)		(0.047)	(0.844)
week12_x_eth	0.473***	-0.25	week26_x_eth	0.962***	-0.264
	(0.047)	(0.713)		(0.047)	(0.697)
week13_x_eth	0.473***	-0.214	week27_x_eth	1.007***	-0.329
	(0.047)	(0.752)		(0.047)	(0.627)
week14_x_eth	0.592***	-0.178	week28_x_eth	1.035***	-0.385
	(0.047)	(0.794)		(0.047)	(0.571)

Market Cap (Natural Log)	ETC	Top 100
week29_x_eth	1.037***	-0.467
	(0.047)	(0.491)
week30_x_eth	1.007***	-0.484
	(0.047)	(0.475)
week31_x_eth	0.996***	-0.435
	(0.047)	(0.521)
week32_x_eth	0.745***	-0.461
	(0.047)	(0.497)
week33_x_eth	0.397***	-0.469
	(0.047)	(0.489)
week34_x_eth	0.339***	-0.350
	(0.047)	(0.606)
week35_x_eth	0.349***	-0.289
	(0.047)	(0.67)
week36_x_eth	-0.413***	-0.147
	(0.047)	(0.828)
week37_x_eth	-0.281***	-0.066
	(0.047)	(0.923)
week38_x_eth	-0.282***	-0.136
	(0.047)	(0.841)
week39_x_eth	-0.357***	-0.096
	(0.047)	(0.887)
week40_x_eth	-0.226***	-0.042
	(0.047)	(0.951)
week41_x_eth	-0.178***	0.010
	(0.047)	(0.988)

Market Cap (Natural Log)	ETC	Top 100
week42_x_eth	-0.172***	-0.019
	(0.047)	(0.978)
week43_x_eth	-0.08***	-0.053
	(0.047)	(0.937)
week44_x_eth	-0.258***	-0.046
	(0.047)	(0.946)
week45_x_eth	-0.177***	-0.082
	(0.047)	(0.903)
week46_x_eth	-0.201***	-0.157
	(0.047)	(0.817)
week47_x_eth	-0.22***	-0.108
	(0.047)	(0.873)
week48_x_eth	-0.16***	-0.085
	(0.047)	(0.9)
week49_x_eth	-0.078***	-0.017
	(0.047)	(0.98)
week50_x_eth	-0.131***	-0.035
	(0.047)	(0.959)
week51_x_eth	-0.169***	-0.157
	(0.047)	(0.817)
week52_x_eth	-0.105***	-0.213
	(0.059)	(0.754)
week54_x_eth	0.038***	-0.270
	(0.048)	(0.69)
week55_x_eth	0.063***	-0.259
	(0.047)	(0.703)

Market Cap (Natural Log)	ETC	Top 100
week56_x_eth	0.088***	-0.320
	(0.047)	(0.637)
week57_x_eth	0.109***	-0.236
	(0.047)	(0.727)
week58_x_eth	0.137***	-0.188
	(0.047)	(0.782)
week59_x_eth	0.206***	-0.061
	(0.047)	(0.929)
week60_x_eth	0.262***	-0.117
	(0.047)	(0.863)
week61_x_eth	0.347***	-0.112
	(0.047)	(0.868)
week62_x_eth	0.394***	-0.048
	(0.047)	(0.943)
week63_x_eth	0.372***	-0.042
	(0.047)	(0.951)
week64_x_eth	0.404***	-0.064
	(0.047)	(0.924)
week65_x_eth	0.446***	-0.070
	(0.047)	(0.918)
week66_x_eth	0.578***	0.027
	(0.047)	(0.968)
week67_x_eth	0.652***	0.077
	(0.047)	(0.91)
week68_x_eth	0.679***	0.057
	(0.047)	(0.933)

Market Cap (Natural Log)	ETC	Top 100
week69_x_eth	0.661***	0.00
	(0.047)	(0.998)
week70_x_eth	0.648***	-0.10
	(0.047)	(0.878)
week71_x_eth	0.644***	-0.05
	(0.047)	(0.94)
week72_x_eth	0.618***	-0.18
	(0.047)	(0.79)
week73_x_eth	0.567***	-0.18
	(0.047)	(0.795)
week74_x_eth	0.591***	-0.17
	(0.047)	(0.797)
week75_x_eth	0.575***	-0.13
	(0.047)	(0.852)
week76_x_eth	0.475***	-0.11
	(0.047)	(0.867)
week77_x_eth	0.535***	-0.10
	(0.047)	(0.878)
week78_x_eth	0.546***	-0.07
	(0.047)	(0.916)
week79_x_eth	0.53***	-0.10
	(0.047)	(0.886)
week80_x_eth	0.546***	-0.11
	(0.047)	(0.873)
week81_x_eth	0.494***	-0.11
	(0.047)	(0.867)

Market Cap (Natural Log)	ETC	Top 100
week82_x_eth	0.165***	-0.120
	(0.047)	(0.86)
week83_x_eth	0.235***	-0.118
	(0.047)	(0.862)
week84_x_eth	0.315***	-0.090
	(0.047)	(0.894)
week85_x_eth	0.356***	-0.067
	(0.047)	(0.921)
week86_x_eth	0.403***	-0.077
	(0.047)	(0.909)
week87_x_eth	0.537***	-0.010
	(0.047)	(0.989)
week88_x_eth	0.539***	0.038
	(0.047)	(0.955)
week89_x_eth	0.564***	0.123
	(0.047)	(0.856)
week90_x_eth	0.525***	0.124
	(0.047)	(0.855)
week91_x_eth	0.347***	0.082
	(0.047)	(0.903)
week92_x_eth	0.367***	0.072
	(0.047)	(0.915)
week93_x_eth	0.393***	0.054
	(0.047)	(0.936)
week94_x_eth	0.289***	-0.116
	(0.047)	(0.864)

Market Cap (Natural Log)	ETC	Top 100
week95_x_eth	0.233***	-0.163
	(0.047)	(0.81)
week96_x_eth	0.246***	-0.130
	(0.047)	(0.848)
week97_x_eth	0.303***	-0.050
	(0.047)	(0.942)
week98_x_eth	0.281***	-0.023
	(0.047)	(0.972)
week99_x_eth	0.079***	0.090
	(0.047)	(0.895)
week100_x_eth	-0.187***	0.052
	(0.047)	(0.939)
week101_x_eth	-0.226***	0.063
	(0.047)	(0.926)
week102_x_eth	-0.215***	0.068
	(0.047)	(0.92)
week103_x_eth	-0.184***	0.085
	(0.047)	(0.9)
week104_x_eth	-0.21***	0.043
	(0.047)	(0.949)
week105_x_eth	-0.181***	0.028
	(0.047)	(0.967)
week106_x_eth	-0.255***	0.076
	(0.047)	(0.911)

Notes: In Table 4, I conducted a parallel trends analysis for the pre-treatment period. Panel A is restricted to ETH and ETC. Panel B includes the Top 100 Cryptocurrencies. Week 1 to Week 106 are dummy variables equal to 1 in the respective week from September 1st, 2020, to September 14th, 2020, and 0 otherwise. The variables "week1_x_eth", "week2_x_eth", and so on is an interaction for each week and ETH. Robust standard errors are noted parenthetically. *** p<.01, ** p<.05, * p<.1.

Appendix B: Tables

Table 4

Difference-in-Difference of Panel A: ETH and ETC

		Alternative Specifications for Merge			
Volume (Natural Log)		**+\- 1 Day**	**+\- 3 Day**	**+\- 7 Day**	**+\- 14 Day**
ETH x Merge	0.673***	0.672***	0.699***	0.737***	0.771***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ETH	2.940***	2.941***	2.942***	2.945***	2.943***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Merge	-1.401***	-1.400***	-1.444***	-1.507***	-1.584***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	20.788***	20.788***	20.789***	20.785***	20.792***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1668	1664	1656	1638	1610

Note: In Table 5, I conducted a diTerence-in-diTerence analysis to examine the relationship between the trading volume of ETH ex-ante and ex-post the Merge. I estimate the local average treatment eTect of equitation (1) using the baseline case of ETC as the control group. The interaction eTect, which is the coeTicient of interest in the study, indicates that ETH had a higher growth rate relative to ETC after the Merge, as expressed by the positive coeTicient ETH x Merge (0.673). Robust standard errors are noted parenthetically. *** p<.01, ** p<.05, * p<.1.

Table 5

Difference-in-Difference of Panel B: ETH and the Top 100 Cryptocurrencies

		Alternative Specifications for Merge			
Volume (Natural Log)		**+\- 1 Day**	**+\- 3 Day**	**+\- 7 Day**	**+\- 14 Day**
ETH x Merge	0.003	0.004	-0.005	-0.022	-0.045
	(0.089)	(0.089)	(0.090)	(0.090)	(0.092)
ETH	5.327***	5.327***	5.326***	5.324***	5.317***
	(0.288)	(0.288)	(0.288)	(0.287)	(0.287)
Merge	-0.731***	-0.732***	-0.739***	-0.746***	-0.767***
	(0.089)	(0.089)	(0.090)	(0.090)	(0.092)
Constant	18.401***	18.402***	18.404***	18.407***	18.417***
	(0.288)	(0.288)	(0.288)	(0.287)	(0.287)
Observations	57840	57680	57359	56636	55524
R^2	0.054	0.056	0.054	0.055	0.055

Note: In Table 6, I conducted a diTerence-in-diTerence analysis to examine the relationship between the trading volume of ETH ex-ante and ex-post the Merge. I estimate the local average treatment eTect of equitation (1) using the Top 100 Cryptocurrencies as the control group. The interaction eTect, which is the coeTicient of interest in the study, suggests that ETH had a higher growth rate relative to the Top 100 Cryptocurrencies after the Merge, as expressed by the positive coeTicient ETH x Merge (0.003). Robust standard errors are noted parenthetically. *** p<.01, ** p<.05, * p<.1.

REFERENCES

Ammous, S. (2016). Blockchain technology: What is it good for? *Available at SSRN 2832751*.

Cambridge, U. o. (2024). https://ccaf.io/cbnsi/cbeci/comparisons

Caytas, J. (2016). Developing blockchain real-time clearing and settlement in the EU, US, and globally. *Columbia Journal of European Law: Preliminary Reference (June 22, 2016)*.

Dorai, P. R. N. D. R. (2021). Evaluation of Performance and Security of Proof of Work and Proof of Stake using Blockchain. *IEEE Xplore* (March 2021). https://doi.org/10.1109/ICICV50876.2021.9388487

Dubloin, E. T. (2023). *How Long Would It Take To Brute Force A Bitcoin Wallet?* Dubloin. https://www.doubloin.com/learn/how-long-brute-force-bitcoin-wallet#:~:text=However%2C%20with%20current%20technology%2C%20successfully,a%20typical%20Bitcoin%20private%20key.

Erik Anderson, R. d. I., Rohan Reddy. (2022). *Proof of Work vs. Proof of Stake: Why Their Differences Matter*. Global X Funds. https://www.globalxetfs.com/proof-of-work-vs-proof-of-stake-why-their-differences-matter/

ethereum.org. (2023). *Proof of Stake (PoS)*. https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/#:~:text=One%20validator%20is%20randomly%20selected,of%20the%20block%20being%20proposed.

Giuseppe Antonio Pierro, H. R. (2019). 2019 IEEE/ACM 2nd International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB). In: IEEE / Institute of Electrical and Electronics Engineers Incorporated.

Hazlett, P. K., & Luther, W. J. (2020). Is bitcoin money? And what that means. *The Quarterly Review of Economics and Finance*, *77*, 144-149.

Ismail, L., & Materwala, H. (2019). A Review of Blockchain Architecture and Consensus Protocols: Use Cases, Challenges, and Solutions. *Symmetry*, *11*(10), 1198. https://www.mdpi.com/2073-8994/11/10/1198

Kessler, S. (2022, May 11, 2023). *The Ethereum Merge Is Done, Opening a New Era for the Second-Biggest Blockchain*. https://www.coindesk.com/tech/2022/09/15/the-ethereum-merge-is-done-did-it-work/

Kim, C. (2020). *Ethereum 2.0: How it works and why it matters*.

Konashevych, O., & Poblet, M. (2018). Is blockchain hashing an effective method for electronic governance? *arXiv preprint arXiv:1810.08783*.

Long, S., Basu, S., & Sirer, E. G. (2022). Measuring miner decentralization in proof-of-work blockchains. *arXiv preprint arXiv:2203.16058*.

Luther, W. J. (2022). Pornhub and the Value of Bitcoin. *AIER Sound Money Project Working Paper*(2022-04).

Luther, W. J., & Salter, A. W. (2017). Bitcoin and the bailout. *The Quarterly Review of Economics and Finance*, *66*, 50-56.

Luther, W. J., & Smith, S. S. (2020). Is Bitcoin a decentralized payment mechanism? *Journal of Institutional Economics*, *16*(4), 433-444.

Mahmoud, S. S. H. Q. H. (2019). *CCWC : 2019 IEEE 9th Annual Computing and Communication Workshop and Conference : 7th-9th January, 2019, University of Nevada, Las Vegas, NV, USA*. Institute of Electrical and Electronics Engineers.

Meunier, S. (2018). Blockchain 101: what is blockchain and how does this revolutionary technology work? In *Transforming climate finance and green investment with Blockchains* (pp. 23-34). Elsevier.

Miller, H. (2022). *The Merge Was a Success. Crypto Still Has Problems*. Bloomberg. https://www.bloomberg.com/news/newsletters/2022-09-19/ethereum-s-merge-was-a-success-crypto-still-has-problems

Moroz, D. J., Aronoff, D. J., Narula, N., & Parkes, D. C. (2020). Double-spend counterattacks: Threat of retaliation in proof-of-work systems. *arXiv preprint arXiv:2002.10736*.

Nguyen, C. T., Hoang, D. T., Nguyen, D. N., Niyato, D., Nguyen, H. T., & Dutkiewicz, E. (2019). Proof-of-stake consensus mechanisms for future blockchain networks: fundamentals, applications and opportunities. *IEEE access*, *7*, 85727-85745.

Orcutt, M. (2019). *Once hailed as unhackable, blockchains are now getting hacked*. MMIT Technology Review. https://www.technologyreview.com/2019/02/19/239592/once-hailed-as-unhackable-blockchains-are-now-getting-hacked/

Sai, A. R., Buckley, J., Fitzgerald, B., & Le Gear, A. (2021). Taxonomy of centralization in public blockchain systems: A systematic literature review. *Information Processing & Management*, *58*(4), 102584.

Shifferaw, Y., & Lemma, S. (2021). Limitations of proof of stake algorithm in blockchain: A review. *Zede Journal*, *39*(1), 81-95.

Singhal, B., Dhameja, G., Panda, P. S., Singhal, B., Dhameja, G., & Panda, P. S. (2018). How blockchain works. *Beginning Blockchain: A Beginner's Guide to Building Blockchain Solutions*, 31-148.

Vashchuk, O., & Shuwar, R. (2018). Pros and cons of consensus algorithm proof of stake. Difference in the network safety in proof of work and proof of stake. *Electronics and Information Technologies*, *9*(9), 106-112.

Viewpoints, F. (2023). *What is the Ethereum Merge?* Fidelity Investments. https://www.fidelity.com/learning-center/trading-investing/ethereum-merge#:~:text=The%20Ethereum%20network%20has%20completed,it%20up%20to%20new%20attacks.

Weigand, H., Blums, I., & de Kruijff, J. (2020). Shared ledger accounting—implementing the economic exchange pattern. *Information Systems*, *90*, 101437.

Xue, T., Yuan, Y., Ahmed, Z., Moniz, K., Cao, G., & Wang, C. (2018). Proof of contribution: A modification of proof of work to increase mining efficiency. 2018 IEEE 42nd annual computer software and applications conference (COMPSAC),

Zhang, R., & Chan, W. K. V. (2020). Evaluation of energy consumption in block-chains with proof of work and proof of stake. Journal of Physics: Conference Series,