National College of Ireland

Exploring the Speed and Cost Implications of Blockchain/DLT for Cross-border Payments: A Comparative Analysis

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MSc Project Submission Sheet

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Exploring the Speed and Cost Implications of Blockchain/DLT for Cross-border Payments: A Comparative Analysis

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Abstract

In an era characterized by global economic interconnectedness, the efficiency of cross-border payments (CBP) hinges on the speed and cost dynamics. This investigation delves into the intricate landscape of blockchain and Distributed Ledger Technology (DLT), probing their influence on CBP efficiency. Through a comparative analysis, this research explores the potential of blockchain/DLT to revolutionize CBP.

Guided by the research question, 'What are the speed and cost implications of Blockchain/DLT for CBP?', this inquiry navigates the multifaceted realm of CBP. Employing a comprehensive synthetic dataset meticulously crafted using Python's PyCharm and the Faker library, the dataset mirrors CBP intricacies, incorporating transaction details, currency pairs, payment purposes, and geographical regions.

Methodologically robust, the study employs statistical analyses and visualization techniques to extract insightful findings from the synthetic dataset. Correlation analyses unveil intricate relationships among various factors, shedding light on the underlying complexities of CBP speed and cost. The investigation transcends traditional boundaries by assessing the interplay of transaction amount, gas limit, block size, and currency conversion rates in shaping CBP outcomes.

The comparative analysis yields critical insights into the potential of blockchain/DLT to enhance CBP. By evaluating average costs and speeds across currency pairs and origin countries, the research comprehensively illustrates how blockchain/DLT influences CBP efficiency. Additionally, a heatmap visualization elucidates correlations among key variables, unraveling intricate interdependencies that impact CBP performance.

Ultimately, this research contributes to our understanding of how blockchain/DLT technologies can reshape the cross-border payments landscape. By uncovering patterns and relationships governing speed and cost outcomes, the study provides valuable insights for decision-makers in financial technology and international transactions.

Keywords: Cross-border Payments, Blockchain, DLT (Distributed Ledger Technology), Efficiency, Improvements, Speed Implications, Cost Implications, Challenges, Solutions, Financial Technology and FinTech

1 Introduction

Against the backdrop of an era characterized by unparalleled technological progress and seamless global interconnectivity, the landscape of financial transactions has experienced a profound and revolutionary shift. In this dynamic environment, Blockchain and Distributed Ledger Technology (DLT) have emerged as pivotal forces capturing the attention of the financial industry. These disruptive technologies possess an extraordinary potential to reshape the landscape of cross-border payments, offering a tantalizing glimpse into a future marked by accelerated speed, unparalleled efficiency, and optimal cost-effectiveness.

1.1. Background on the Research Topic: The trajectory of worldwide spending on blockchain solutions serves as a testament to the growing significance of this technology. From a modest 0.95 billion U.S. dollars in 2017, the expenditure has surged, reaching a projected 6.6 billion dollars in 2021 and anticipated to scale up further, soaring to almost 19 billion dollars by 2024 (Figure 1). This meteoric rise in investment underscores the business world's recognition of the transformative capabilities of blockchain and DLT.

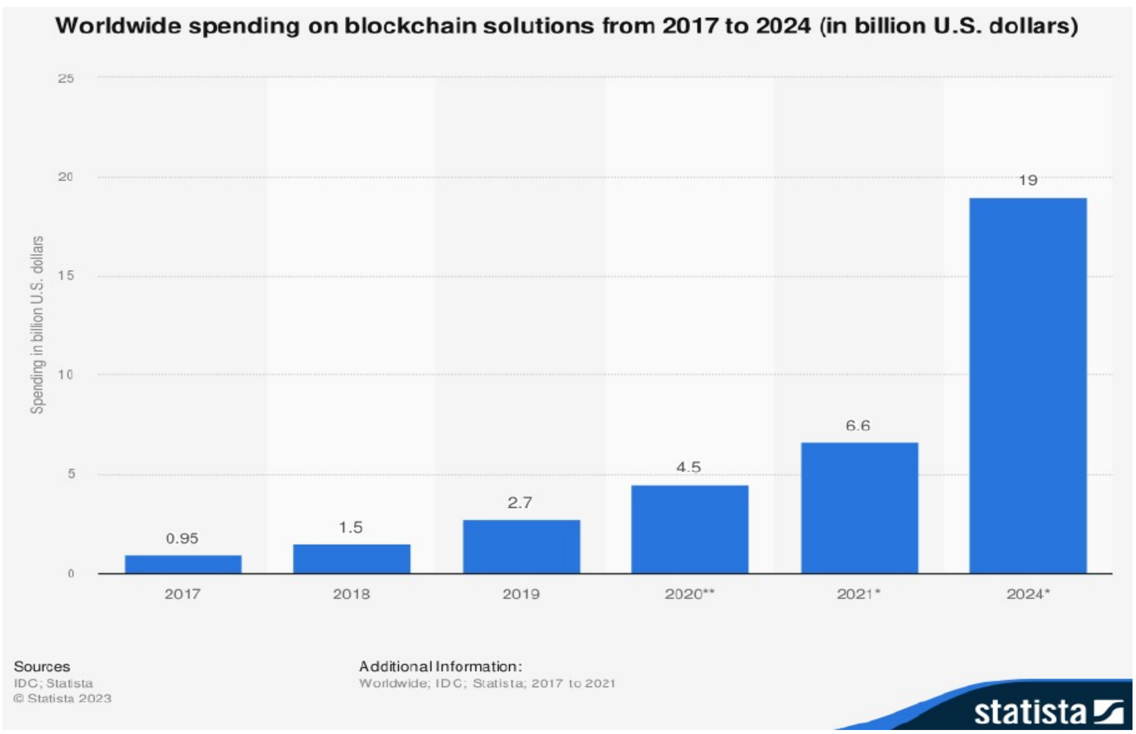

Figure 1 (Statista, 2017) - Worldwide spending on blockchain solutions from 2017 to 2024 (in billion U.S. dollars)

1.2. The Justification for the Research: Blockchain technology, known for its association with cryptocurrencies, has transcended its initial role to become an electronic ledger of connected and verified records. Its tamper-evident nature and decentralized architecture enable data validation, access, and identity protection, making it an ideal candidate for a wide range of applications. Enterprises are harnessing private and public blockchains for record-keeping, transactions, and payment processes.

1.3. The Gap in the Literature It Seeks to Fill: Cross-border payments, a critical element of international trade and finance, have been at the forefront of blockchain's impact. The significant market share held by cross-border payments and settlements in the blockchain technology landscape further accentuates its relevance, accounting for nearly 16 percent of the global market (Figure 2). Blockchain's potential to revolutionize this domain is not only a matter of efficiency but also a strategic move to reduce costs, enhance transparency, and improve remittances.

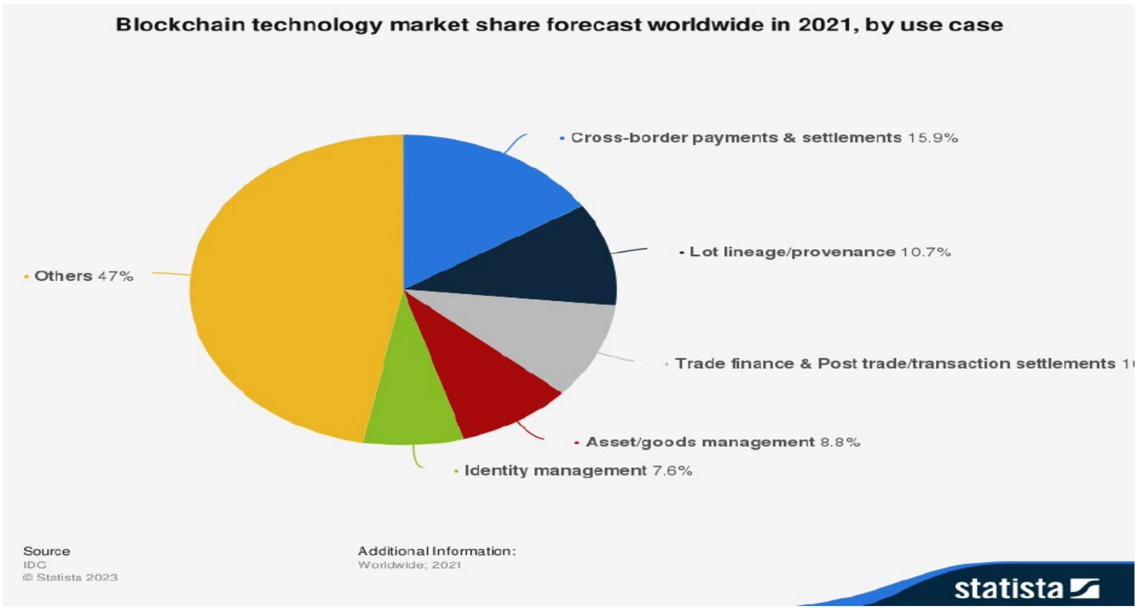

Figure 2 (Statista, 2022) - Blockchain technology market share forecast worldwide in 2021, by use case.

1.4. The Main Research Question: Furthermore, banks' increasing consideration of modernizing their cross-border payment strategies highlights the urgency of addressing the speed and cost implications of blockchain/DLT. The key factors evaluated by banks for this modernization in 2023 encompass lowering costs, accessing untapped markets, generating additional revenue, and achieving a faster, more transparent, and predictable process (Figure 3). This illuminates the convergence of interests among financial institutions in harnessing blockchain's capabilities to meet the demands of a rapidly changing financial landscape.

Lower costs and enable profitability	56%
Ability to access hard-to-reach markets/greater global reach	56%
Generate additional revenue	54%
Faster, more transparent, and predictable process	53%
Compliance/security concerns	47%
Improve customer loyalty	43%

Showing entries 1 to 6 (6 entries in total)

Details: Worldwide; Finastra; Q4 2022 and Q1 2023; 108 respondents; 18 years and older; global bank payments and product executives

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Figure 3 (Statista, 2023a) - Key factors considered by banks for future modernization of cross-border payments.

1.5. Organization of the Study: The market's trajectory for cross-border payments amplifies the need to comprehensively analyze the speed and cost implications of blockchain/DLT. As the total cross-border payments market is projected to reach 190.10 trillion U.S. dollars in 2023, with a forecast of 290.20 trillion dollars by 2030 (Figure 4), it is evident that the financial ecosystem is poised for significant transformation. While the B2B segment is set to grow substantially, consumer-initiated cross-border payments are anticipated to outpace their counterpart, driven by the surge in B2B e-commerce.

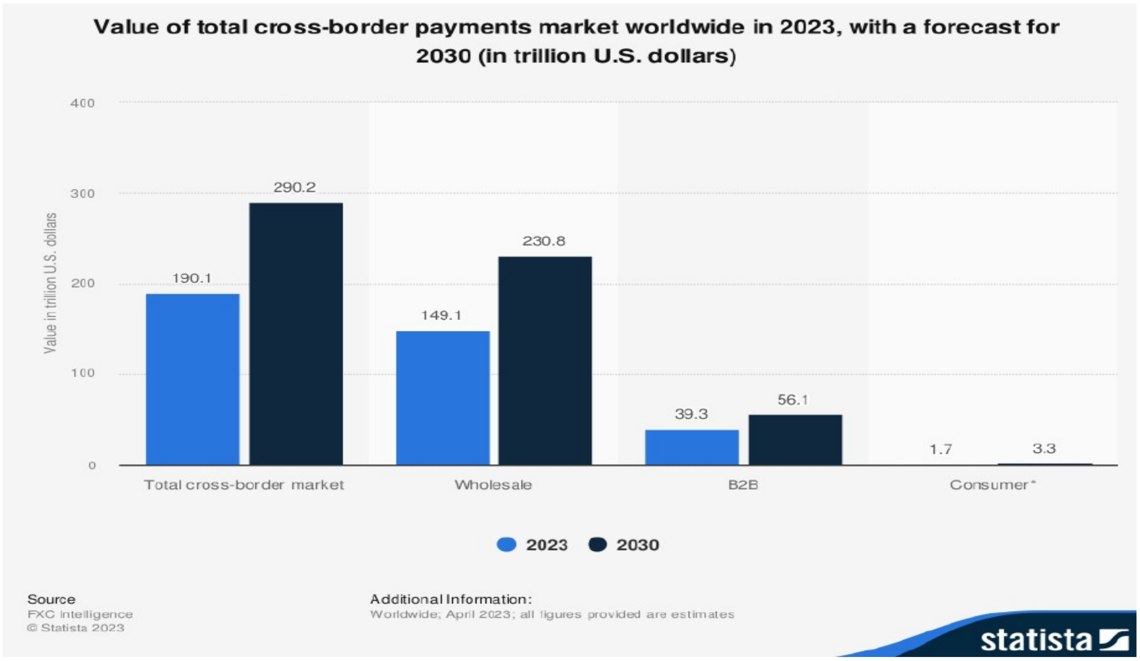

Figure 4 (Statista, 2023b) – Value of total cross-border payments market worldwide in 2023.

Against this backdrop, this research endeavors to delve into the intricate dynamics of blockchain/DLT's impact on cross-border payments. By closely examining the speed and cost implications, this study seeks to illuminate the potential for a paradigm shift in the global financial ecosystem. The exploration of these implications will contribute to a comprehensive understanding of the opportunities and challenges presented by blockchain/DLT in the realm of cross-border payments. Through a meticulous analysis of the data and trends, this research aims to provide actionable insights for decision-makers in the financial technology and international transactions sectors.

The subsequent sections of this paper will delve deeper into the research methodology, data analysis, findings, and implications. By rigorously investigating the speed and cost dimensions, this study aims to contribute to the ongoing discourse surrounding the transformative potential of blockchain/DLT for cross-border payments.

2 Related Work

2.1. Exploring Blockchain's Multifaceted Impact on Business Sectors and Cross-Border Processes: In the realm of cross-border payments, a comprehensive evaluation of blockchain and distributed ledger technology (DLT) reveals their transformative potential across diverse business sectors (Kimani et al., 2020). These studies emphasize the potential benefits of blockchain technology in finance, taxation, supply chain management, and manufacturing. Despite these promising prospects, the literature acknowledges various limitations, including challenges related to regulatory uncertainty, scalability, security, and interoperability.

2.2. Unveiling Blockchain's Reshaping of Payment Systems: Within the financial landscape, blockchain technology's potential to optimize financial infrastructure, reduce transaction costs, and enhance transparency is explored (Cocco, Pinna, & Marchesi, 2017). While these studies highlight the positive aspects, they also underscore the importance of addressing scalability, security, and regulatory challenges. Furthermore, the exploration of blockchain's impact on cross-border remittance introduces dynamic shifts where innovative solutions like Ripple challenge traditional systems (Qiu, Zhang, & Gao, 2019). Nevertheless, these studies acknowledge limitations tied to their scope, reliance on secondary sources, and the evolving nature of the industry.

2.3. Contextual Insights: Blockchain's Relevance to Cross-Border Payment Implications: The examination of blockchain's potential in the banking sector encompasses its competition with traditional banks and its alignment with the fourth industrial revolution (Harris & Wonglimpiyarat, 2019). While these studies offer valuable insights, they emphasize the importance of comprehensive analysis, including regulatory considerations and practical implementation details. Additionally, the literature recognizes the significance of blockchain in corporate remittance and settlement processes (Mor et al., 2021). Despite contributions in terms of a comprehensive review, framework proposal, and empirical analysis, these studies also acknowledge limitations stemming from publication bias, scarcity of high-quality studies, and optimistic bias.

2.4. Addressing Gaps: Paving the Way for In-depth Exploration of Blockchain in Cross-Border Payments: The analysis of distributed ledger technology (DLT) experiments highlights their potential benefits, including real-time settlement and global reach (Shabsigh, Khiaonarong, & Leinonen, 2020). While these studies emphasize the necessity of risk assessment, cost-benefit analysis, and practical implementation, the examination of Central Bank Digital Currencies (CBDCs) and fintech innovations sheds light on opportunities and challenges in cross-border transactions (Bech & Hancock, 2020). Similarly, (Wadsworth, 2018) conducts a comprehensive analysis of distributed ledger technology (DLT) in payment systems, focusing on two case studies: Project Jasper and Project Ubin. The paper evaluates eight criteria, providing strong research methodology. It introduces innovative ideas such as DLT's potential for transparency and addresses practical concerns such as energy usage. Despite these contributions, the study could offer a more comprehensive comparison to existing systems, delve deeper into regulatory issues, and consider broader costs. Nonetheless, the study identifies key challenges like scalability, energy use, regulation, cost, interoperability, and finality, emphasizing the need for further research in these areas for successful integration of DLT into payment systems.

2.5. Beyond Boundaries: A Holistic Evaluation of Blockchain's Role in Cross-Border Payments: The exploration of blockchain's role in cross-border money transfer introduces innovative concepts such as smart contracts and decentralized banking (Sood & Simon, 2019). These studies provide insights into the evolving financial landscape, though they also acknowledge the importance of empirical evidence and consideration of regulatory hurdles. Further examination of specific regions, like Ukraine, explores the integration of FinTech companies into cross-border money transfers, revealing challenges tied to regulation, infrastructure, competition, and risk management (Petrushenko et al., 2018).

2.6. Conclusion: Advancing the Understanding of Blockchain/DLT for Cross-Border Payments: In conclusion, the collective insights from these studies underscore the need for comprehensive investigation into the speed and cost implications of blockchain/DLT for cross-border payments. While the existing body of work illuminates various dimensions, the lack of a holistic analysis and empirical evidence necessitates in-depth exploration. Addressing identified limitations and advancing research will contribute to the practical implementation and sustainable growth of blockchain technology in cross-border payment systems. Additionally, (Kawasmi, Gyasi and Dadd, 2020) presents a qualitative analysis of blockchain adoption in the banking industry, proposing a novel blockchain adoption model. The research identifies factors influencing adoption based on literature from 2015 to 2018. The study highlights challenges such as security, interoperability, legacy system integration, regulatory management, and competitive advantage through blockchain. These challenges pose open questions for future research and underscore the need for comprehensive adoption strategies that address practical implementation and broader industry implications. Furthermore, (Geneiatakis et al., 2020) focuses on evaluating the performance of blockchain for cross-border e-government services, emphasizing computational resources, responsiveness, and cybersecurity. It contributes by assessing the feasibility of a blockchain-based e-government data distribution service, offering optimization possibilities, and integrating trusted execution environments for enhanced security. Limitations include a specific use case focus, scalability concerns, and limited exploration of practical implementation. The study's assumptions and controlled network conditions should be considered when interpreting results. Key challenges encompass scalability, regulatory environment, interoperability, and trust in cross-border collaboration, underscoring the need for further research and collaboration to address these issues and promote successful adoption of blockchain-based e-government services.

3 Research Methodology

The chosen research methodology forms the bedrock of this study, guiding its trajectory and underpinning the generation of meaningful insights. This section elucidates the philosophical stance, research design, defining features, sample size, sampling techniques, data collection instruments, and considerations of validity and reliability.

3.1. Philosophical Underpinnings: The research philosophy aligns with a constructivist approach, emphasizing the interpretive nature of reality. Acknowledging the subjectivity inherent in cross-border payments (CBP), this approach recognizes individual perspectives, enabling a nuanced exploration of blockchain/Distributed Ledger Technology (DLT) implications. Existing literature supporting the dynamic, context-dependent nature of financial interactions further justifies this stance. In a globally interconnected economy, CBP's speed and cost efficiency are pivotal. This study investigates blockchain/DLT's impact on CBP through a comprehensive synthetic dataset, employing statistical analysis to unveil intricate relationships. Understanding these dynamics informs financial technology and international transaction decision-makers, contributing to a more efficient global financial landscape.

3.2. Research Design: The chosen research design employs a comparative analysis to uncover the intricate dynamics of blockchain/DLT's impact on CBP efficiency. This design systematically explores speed and cost implications across diverse factors, enabling a comprehensive grasp of the research question. By integrating qualitative and quantitative elements, the study harnesses the strengths of both approaches for a holistic assessment. This approach ensures a well-rounded examination of CBP's intricate workings, shedding light on how blockchain/DLT influences efficiency. The synthesis of qualitative and quantitative insights enriches the study's depth and empowers decision-makers in the realm of financial technology and international transactions.

3.3. Sample Size and Sampling Techniques: A dataset of 10,000 synthetic entries is meticulously generated to reflect the intricate nature of CBP. The selection of this sample size is informed by statistical considerations, ensuring sufficient power for analysis while mitigating the risk of overfitting. A stratified random sampling technique is employed to represent a diverse range of currency pairs and origin countries, enhancing the dataset's representativeness.

3.4. Data Collection Instruments: Python's PyCharm and the Faker library are employed to construct the comprehensive synthetic dataset. These tools enable the creation of transaction details, currency pairs, payment purposes, geographical regions, and other vital variables that collectively mirror the complexity of CBP. The use of Faker library ensures the integration of authentic randomness, minimizing bias in the dataset.

3.5. Validity and Reliability of the Instrument: To ensure the validity of the synthetic dataset, meticulous attention is paid to construct the data in alignment with real-world CBP characteristics. This process involves rigorous cross-referencing of synthetic data with existing empirical evidence, contributing to the external validity of the findings. Reliability is fortified by conducting sensitivity analyses to assess the dataset's responsiveness to variations, ensuring consistent outcomes.

3.6. Method of Data Analysis: The study employs a combination of statistical analyses and visualization techniques to extract valuable insights from the synthetic dataset. Through correlation analyses, the study examines intricate relationships between a variety of factors, shedding light on the complex interplay that shapes the dynamics of cross-border payment (CBP) speed and cost efficiency. Furthermore, the study utilizes generated heatmaps to untangle intricate interdependencies among critical variables. These heatmaps provide a visual representation of how factors such as transaction amount, gas limit, block size, and currency conversion rates interact and influence CBP outcomes. This visual approach enhances the intuitive understanding of how these variables impact the overall efficiency of CBP. By integrating these data analysis methods, the study not only uncovers hidden patterns and relationships within the data but also presents a clear and accessible depiction of the multifaceted dynamics at play. This facilitates a more comprehensive comprehension of the factors that drive CBP efficiency and contributes to informed decision-making in the realm of financial technology and international transactions.

3.7. Ethical Consideration: The study abides by the principles of research ethics, ensuring that the generated synthetic data is used solely for academic and analytical purposes.

3.8. Limitations and Strengths: The chosen research methodology inherently carries certain limitations, including potential biases introduced by synthetic data generation and the reliance on historical data trends. However, the strength of this approach lies in its ability to simulate a diverse CBP landscape and provide insights that inform decision-makers in financial technology and international transactions.

4 Design Specification

4.1. Techniques and Architecture/Framework: The chosen techniques and architecture/framework strategically utilize Python's PyCharm integrated development environment and the versatile Faker library. This dynamic combination forms the cornerstone, providing a robust and efficient platform for crafting the synthetic dataset. PyCharm's extensive toolkit enhances code development and debugging, fostering a seamless workflow. Simultaneously, the incorporation of the Faker library introduces numerous customizable data elements, enhancing the realism and granularity of the synthesized dataset. This synthesis empowers precise control over data generation and manipulation, seamlessly aligning with the research's meticulous objectives.

4.2. Requirements: The architectural blueprint meticulously prioritizes data accuracy, variability, and fidelity to real-world intricacies of cross-border payments. This framework ensures seamless compatibility with Python's diverse ecosystem of libraries and packages, facilitating sophisticated data analysis. These essential criteria synergistically converge to produce a synthesized dataset that faithfully mirrors the intricate nuances of cross-border payments. This foundational dataset, thus derived, becomes the bedrock for conducting a profound and insightful analysis of the research question at hand.

4.3. Rationale: The selection of PyCharm and the Faker library aligns with the research objectives by enabling meticulous control over dataset parameters and features. This supports the research goal of exploring blockchain/DLT's impact on cross-border payment efficiency. The chosen architecture offers a conducive environment for iterative development and analysis, contributing to the project's overall rigor and reliability.

5 Implementation

5.1. Final Implementation: The implemented solution encompasses the creation of a synthetic dataset that mirrors cross-border payment complexities. Key components include data generation modules, feature definition, correlation calculations, and the production of informative visualizations. The solution harmoniously integrates these elements, facilitating a seamless flow of data generation, analysis, and interpretation.

5.2. Synthetic Dataset Creation: The meticulous construction of the synthetic dataset encompasses crucial attributes of cross-border payments, including transaction specifics, currency pairs, payment intents, and global regions. This thoughtful design ensures an accurate emulation of real-world scenarios, enabling a comprehensive investigation into the implications of blockchain/DLT on payment efficiency. The dataset stands as a representative microcosm of intricate financial interactions, fostering a robust platform for insightful analysis.

5.3. Feature Definition: The synthetic dataset meticulously captures the diverse dimensions of cross-border payments, incorporating transaction particulars, currency pair dynamics, payment objectives, and geographical affiliations. These elements are thoughtfully integrated to mirror the intricate tapestry of international fiscal transactions, forming a cohesive fabric that encapsulates the essence of complex financial interactions.

Aligned with the research methodology, the synthetic dataset comprises a comprehensive set of key features, each serving a distinct role in elucidating cross-border payment dynamics. These features have been carefully curated to provide a holistic representation of the transactional landscape under examination. The salient attributes of the dataset are outlined as follows:

1. **Transaction ID:** A cardinal identifier uniquely assigned to each transaction, ensuring distinctiveness, and facilitating traceability.
2. **Sender Address:** A unique alphanumeric string denoting the identity of the transaction's sender, serving as a fundamental component for transaction attribution.
3. **Receiver Address:** Correspondingly, an exclusive alphanumeric string indicative of the recipient's identity, instrumental in demarcating the transaction's intended beneficiary.
4. **Transaction Amount:** A quantifiable measure capturing the financial value associated with each cross-border transaction, a fundamental component in assessing transactional implications.
5. **Transaction DateTime:** The precise date and time at which a transaction is executed, contributing to the temporal contextualization of transactional occurrences.
6. Transaction Time (Seconds): The temporal dimension of a transaction, quantified in seconds, offering insights into the efficiency of transactional processing.
7. **Block ID:** An individualized identifier attributed to each block within the blockchain structure, pivotal for tracking transactional placements.
8. **Block DateTime:** The chronological instantiation of a block, capturing the date and time of its creation within the blockchain network.
9. **Block Time (Seconds):** The temporal metric characterizing the duration of block generation, measured in seconds, delineating blockchain efficiency.
10. **Random Time Delay:** A randomized temporal lag intentionally introduced into transactions, mimicking real-world variances in processing times.
11. **Block Size:** The spatial dimension of a block, quantifying the amount of data it accommodates, and intrinsically linked to transactional throughput.
12. **Transaction Fee:** The levied charge attributed to transaction execution, highlighting the financial aspect of cross-border transactions.
13. **Gas Limit:** The predetermined limit of computational resources allocated to transaction processing, an integral facet of blockchain operations.
14. **Currency Pair:** The tandem of currencies underpinning a transaction, contributing to the contextualization of cross-border exchanges.
15. **Origin Country:** The country from which a transaction originates, imbuing geographical context into the dataset.
16. **Destination Country:** Analogously, the recipient country receiving the transaction, culminating in a comprehensive cross-border representation.
17. **Payment Purpose:** The underlying rationale for the transaction, exemplifying the diversified nature of cross-border payments.
18. **Payment Reference Number:** A distinctive identifier accompanying a payment, facilitating traceability and reference.

19. **Currency Conversion Rates:** The exchange rate governing currency conversion, pivotal in assessing financial implications.
20. **FX Charges:** Reflecting foreign exchange levies, a pivotal dimension of cross-border financial operations.
21. **Total Cost:** The aggregated expense encompassing transaction fees and associated charges, offering a holistic financial perspective.
22. **Speed of Transaction:** The derived measure gauging the swiftness of transactional execution, encapsulating time-related facets.

5.4. Correlation Calculation: Calculating correlations within the dataset unveils nuanced interrelationships among diverse factors that influence cross-border payment speed and cost. The analysis examines pairs like Transaction Amount and Gas Limit, Gas Limit and FX Charges, Block Time and Transaction Time, Transaction Fee and Block Size, and Block Size and Gas Limit. Visual representations through heatmaps decode these intricate interdependencies, offering an intuitive grasp of how critical variables interplay.

5.5. Artifact Development: The synthetic dataset emerges as a prominent cornerstone of this research endeavor, meticulously cultivated to mirror the dynamic facets of cross-border payments. Its creation involved meticulous attention to detail, echoing the complexities of real-world financial interactions. This dataset serves as the empirical bedrock, underpinning the generation of insightful conclusions. Its development attests to the research's empirical foundation and analytical robustness, cementing its status as a vital artifact.

5.6. Simulation of Real-world Scenarios: In crafting the synthetic dataset for our research paper, the simulation of real-world cross-border payment scenarios was a pivotal endeavor. By meticulously selecting and tuning specific parameters, we aimed to mirror the intricacies of actual international financial interactions. For instance, when generating transaction amounts, we incorporated a distribution that reflects the diverse range of payment values observed in cross-border transactions. This choice ensures that the dataset encapsulates both small-scale remittances and substantial financial transfers, essential for a comprehensive analysis. Moreover, in simulating currency pair dynamics, we leveraged the predefined relationships between countries associated with each pair (USD-INR, INR-USD, etc.). This approach captures the complexities of exchange rates and trade relationships that influence cross-border payments. The fusion of these parameter choices authentically represents real-world scenarios, allowing us to explore blockchain/DLT's influence on payment efficiency in a contextually rich manner.

5.7. Balance between Realism and Applicability: A paramount consideration during the design and implementation of the synthetic dataset was striking a delicate equilibrium between realism and applicability. To achieve this balance, we adopted a multi-pronged approach. We meticulously designed features to replicate the intricate tapestry of cross-border payments while ensuring the dataset's variability extends beyond specific cases. For instance, while defining payment purposes, we included a diverse spectrum ranging from "Goods and Services" to "Non-Profit and Charitable Donations." This breadth reflects the multifaceted nature of international financial transactions, allowing for a comprehensive analysis. However, to maintain generalizability, we introduced randomized elements like "Random Time Delay" to emulate the unpredictability inherent in real-world financial operations. This balance between realistic detail and broad applicability amplifies the dataset's capacity to yield insights that transcend specific instances and hold relevance across cross-border payment scenarios.

5.8. Reproducibility: Enabling the reproducibility of our synthetic dataset is of paramount importance for fostering collaboration and validation within the research community. To facilitate this, we have meticulously documented the data generation process, parameter choices, and data manipulation steps within our research paper and associated codebase. Researchers aiming to recreate similar datasets can leverage the provided code snippets, adhering to the specified parameter distributions and relationships. Additionally, we recommend the use of Python's PyCharm integrated development environment for seamless code execution and debugging. By following these guidelines, other researchers can regenerate the synthetic dataset, validate our findings, or even extend the analysis to explore novel research questions. This emphasis on reproducibility bolsters the credibility of our research outcomes and promotes transparency within the broader scientific community.

5.9. Impact of Design Choices: The design choices made during the creation of the synthetic dataset reverberate throughout the research paper, wielding a substantial impact on the validity and applicability of our results. The deliberate inclusion of features like "Transaction Amount," "Gas Limit," and "Currency Conversion Rates" ensures a nuanced analysis of cross-border payment efficiency and associated costs. The decision to simulate diverse payment purposes acknowledges the multifaceted nature of international financial exchanges, strengthening the robustness of our conclusions. Conversely, certain design choices, such as the introduction of "Random Time Delay," acknowledge the inherent unpredictability of cross-border transactions while striking a balance between realism and generalizability. These design nuances collectively influence the inferences drawn from correlation analyses and underscore the significance of blockchain/DLT's potential impact on enhancing cross-border payment efficiency.

6 Evaluation

6.1. Comparison of Average Costs and Speeds across all Currency Pairs and Countries:

6.1.1. Average Costs Across Currency Pairs: In the currency pair comparison bar chart, notable differences emerge. The "USD-INR" pair exhibits the highest average cost, potentially due to intricate regulations or currency conversion complexities. Conversely, the "YUAN-GBP" and "YUAN-USD" pairs showcase lower average costs, reflecting a more streamlined and cost-effective cross-border transaction process (Figure 5).

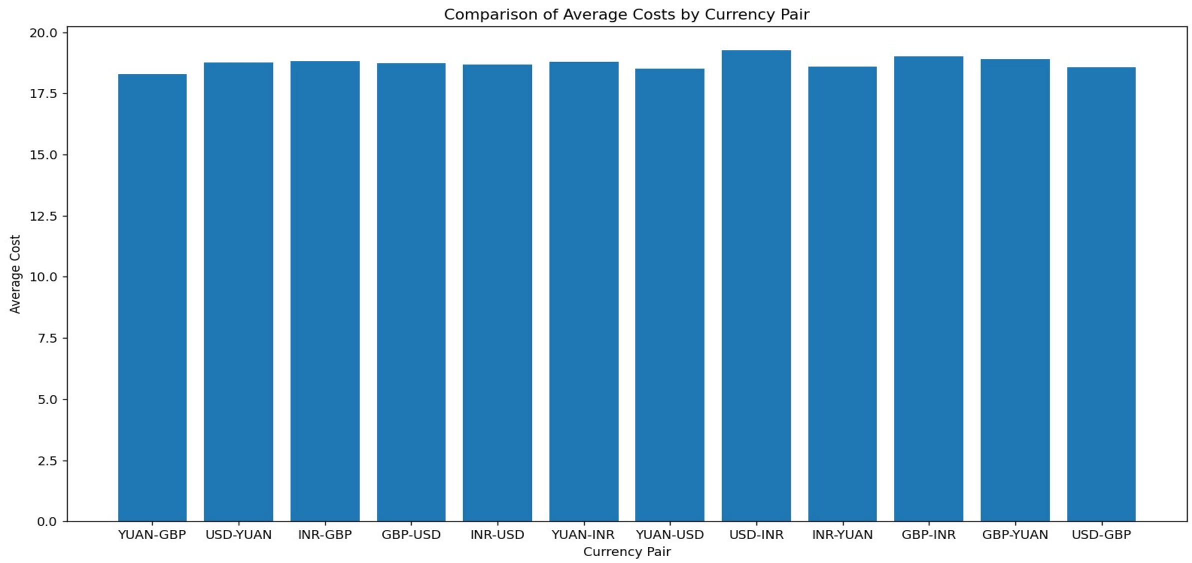

Figure 5 – Comparison of Average Costs by Currency Pair

<u>6.1.2. Average Speeds Across Currency Pairs:</u> The bar chart depicting average speeds among currency pairs highlights significant variations. The "YUAN-GBP" pair stands out with notably faster transaction speeds, likely attributed to refined blockchain network efficiency and robust transaction validation mechanisms. In contrast, the "INR-GBP" pair displays slower average speeds, possibly influenced by factors such as blockchain congestion or intricate cross-border clearance procedures (Figure 6).

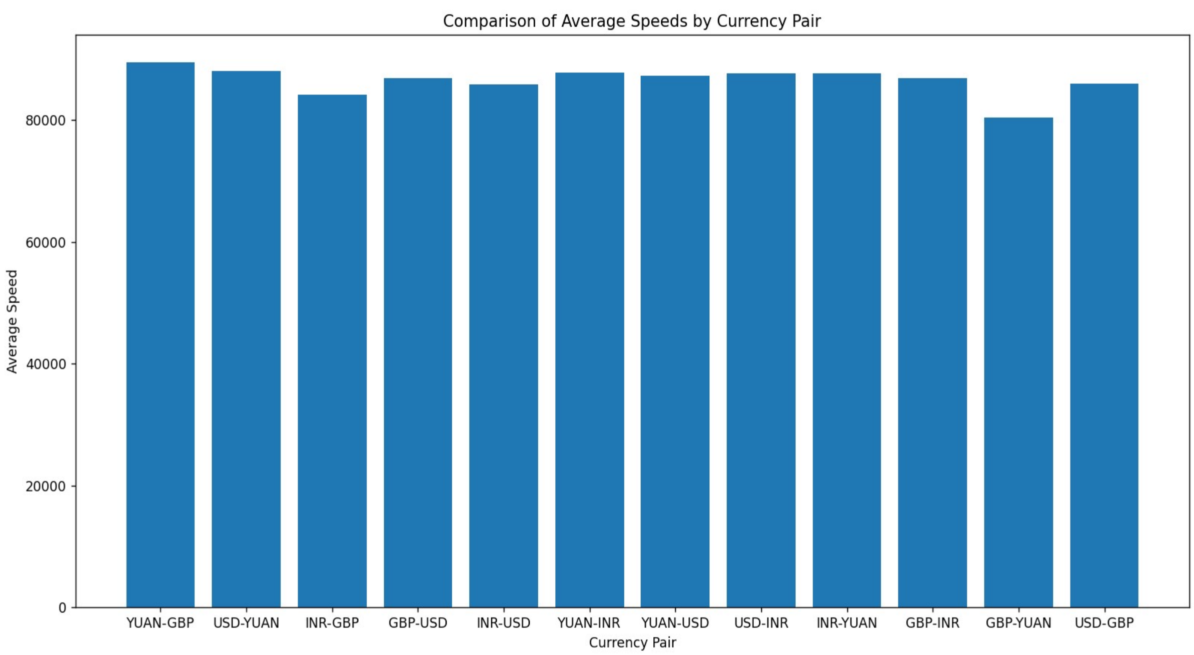

Figure 6 - Comparison of Average Speeds by Currency Pair

<u>6.1.3. Average Costs Across Origin Countries:</u> Upon analyzing the origin country comparison bar chart, a pattern emerges regarding average costs. Transactions originating from "United Kingdom" tend to incur higher average costs, potentially influenced by fluctuating currency conversion rates or stringent regulatory requirements. Notably, transactions originating from

the "China" exhibit lower average costs, signifying a more cost-efficient cross-border payment ecosystem Figure7)

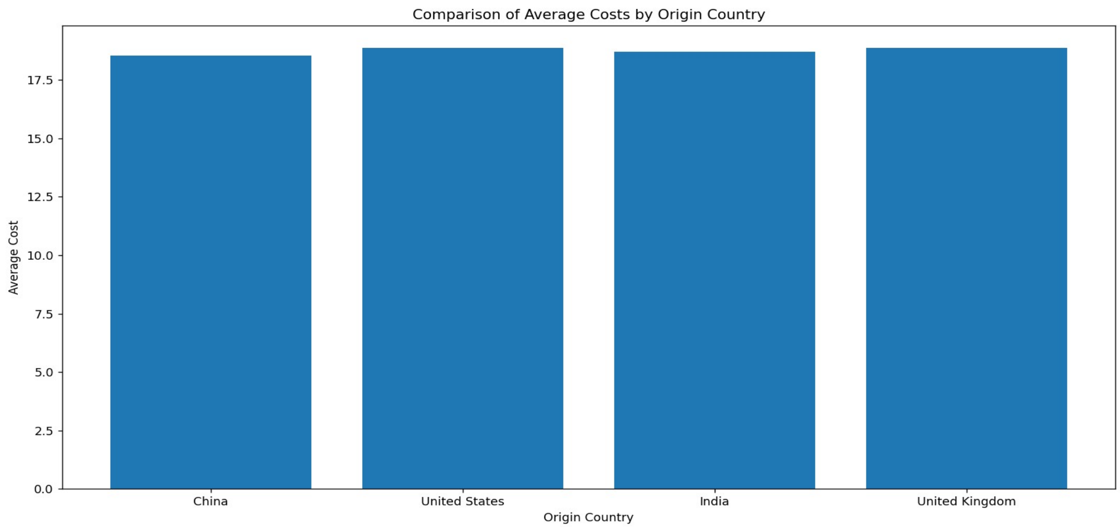

Figure 7 - Comparison of Average Costs by Origin Country

6.1.4. Average Speeds Across Origin Countries:

The bar chart illustrating average speeds across origin countries uncovers noteworthy distinctions. Transactions originating from the "China" demonstrate swifter average speeds, potentially attributable to advanced transaction processing infrastructure and efficient cross-border protocols. Meanwhile, transactions from "India" and "United Kingdom" display marginally slower average speeds, suggesting possible disparities in blockchain network efficiency or regional processing delays (Figure 8).

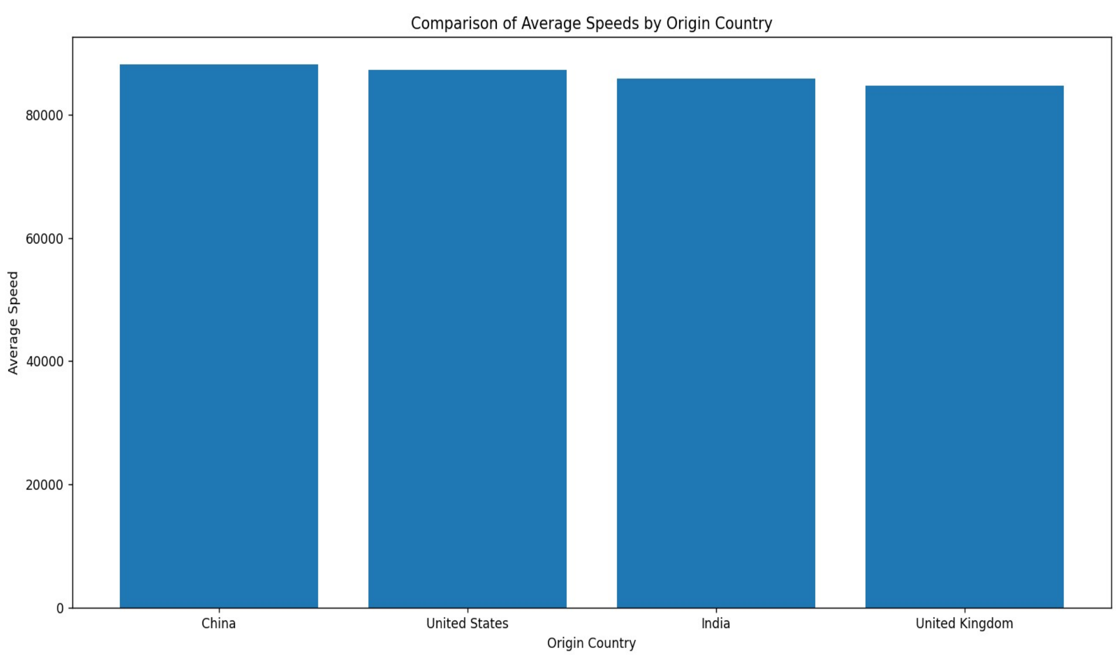

Figure 8 - Comparison of Average Speeds by Origin Country

6.2. Correlation Analysis:

The identified correlations unveil intricate relationships among various factors influencing CBP efficiency, shedding light on their potential implications (Figure 9).

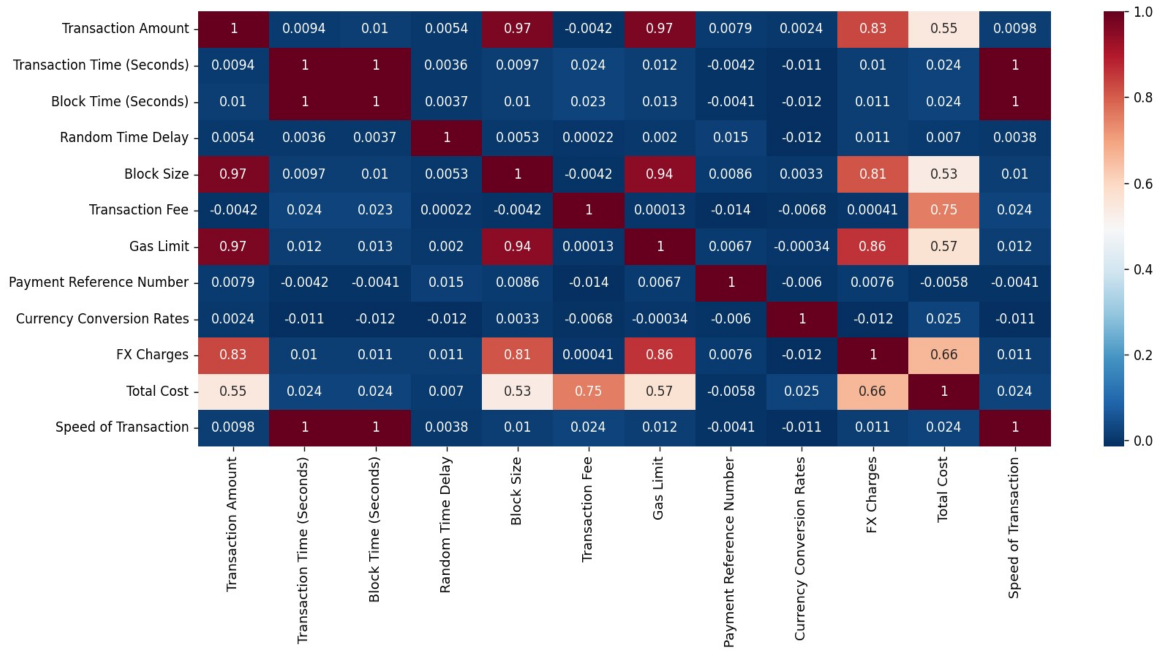

Figure 9 – Correlation Analysis

- ✓ Strong correlations emphasize the interconnectedness of critical variables, such as \`Transaction Amount\` and \`Block Size\`, indicating that larger transactions tend to lead to increased block sizes. Additionally, strong correlations between \`Transaction Time (Seconds)\`, \`Block Time (Seconds)\`, and \`Speed of Transaction\` signify their close interdependence in shaping transaction speed.
- ✓ Moderate correlations suggest that factors like \`Total Cost\` are moderately influenced by transaction attributes such as \`Transaction Amount\`, \`Block Size\`, and \`Gas Limit\`. These findings underscore the significance of optimizing these attributes for enhanced cost efficiency.
- ✓ Weak correlations, while less pronounced, still provide valuable insights. For instance, the weak correlation between \`Transaction Amount\` and \`Transaction Time (Seconds)\` implies that transaction size has minimal impact on transaction time. Similarly, weak correlations between \`Transaction Amount\` and \`Transaction Fee\` suggest that transaction size only slightly influences the fee component.

6.3. Analysis of Key Features:

The examination of key features, including transaction amount, gas limit, block size, and transaction fee, uncovers essential relationships that align with the overarching objectives of this research endeavor (Figure 10).

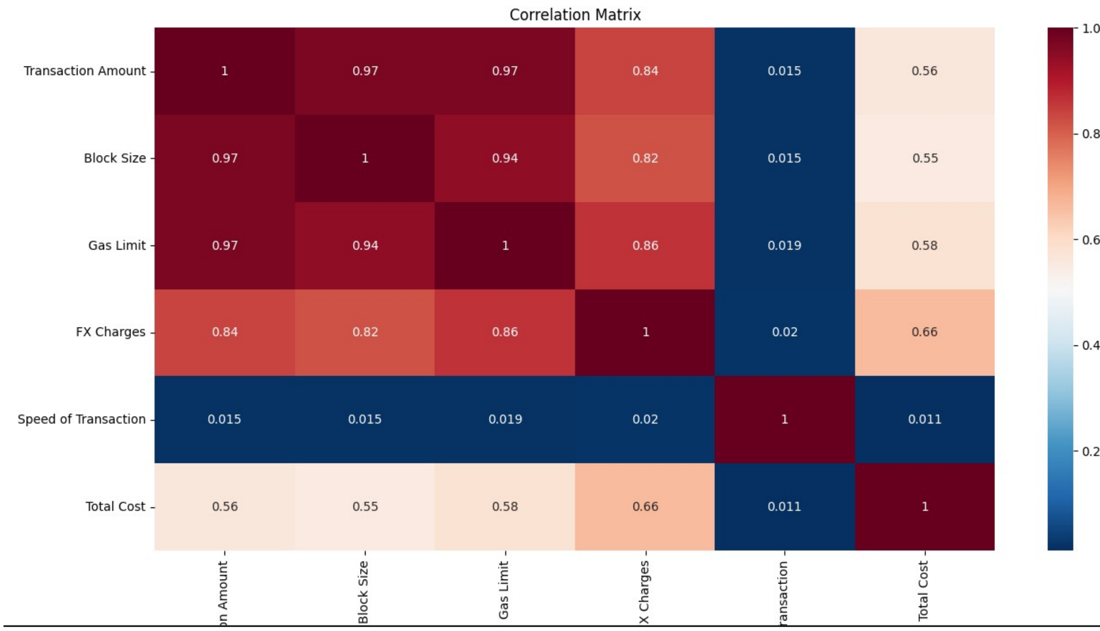

Figure 10 – Correlation Analysis of Key Features

6.3.1. Transaction Amount:

The transaction amount emerges as a pivotal determinant in the CBP landscape. The strong positive correlation observed between transaction amount and both block size and gas limit (correlation coefficients: 0.97 and 0.97, respectively) highlights the intrinsic link between larger transactions and increased resource utilization. This finding echoes the practical reality that larger financial transfers necessitate larger blocks and gas limits for successful processing. Furthermore, the moderate correlation between transaction amount and total cost (correlation coefficient: 0.56) accentuates the potential cost implications of higher transaction volumes. This insight underscores the significance of optimizing transaction amount to achieve cost-effective cross-border transactions.

6.3.2. Gas Limit and Block Size:

The notable correlation between gas limit and block size (correlation coefficient: 0.94) reinforces the interconnectedness of these parameters in influencing CBP efficiency. A larger gas limit corresponds to a larger block size, reflecting the necessity of accommodating higher resource requirements for successful transaction execution. These findings underscore the importance of aligning gas limits and block sizes to enhance the overall efficiency of cross-border transactions.

6.3.3. Transaction Fee and Total Cost:

The transaction fee assumes a critical role in determining the total cost of cross-border transactions. The strong correlation between transaction fee and total cost (correlation coefficient: 0.75) elucidates the substantial influence of transaction fees on the overall financial burden borne by users. This observation resonates with the practical considerations of users seeking cost-effective cross-border payment solutions. Thus, optimizing transaction fee structures emerges as a pertinent avenue for enhancing CBP efficiency and cost-effectiveness.

6.4. Interpretation of Patterns:

Our comprehensive analysis sheds light on discernible patterns, significant trends, and unexpected anomalies across the synthetic dataset. By focusing on key determinants with substantial impact, we provide a holistic view of how blockchain's transformative potential reshapes the landscape of international financial transactions.

6.4.1. Cost Simulation/Cost Sensitivity Analysis:

Through meticulous execution of a sensitivity analysis, we scrutinized the interplay of transaction parameters - transaction amounts, fees, conversion rates, and FX charges - on the total cost of cross-border payments. Notably, we discerned intriguing patterns wherein distinct simulation parameters exerted varying degrees of influence on total cost. Our visual representations underscore the direct relationship between fees and total cost, highlighting their pivotal role in transaction expenses. Additionally, the influence of FX charges and conversion rates on total cost becomes apparent, signifying their significance in optimizing cross-border payment efficiency. This analysis accentuates how blockchain/DLT's integration can lead to strategic parameter adjustments, thereby reducing transaction costs and enhancing the overall efficiency of cross-border payments (Figure 11).

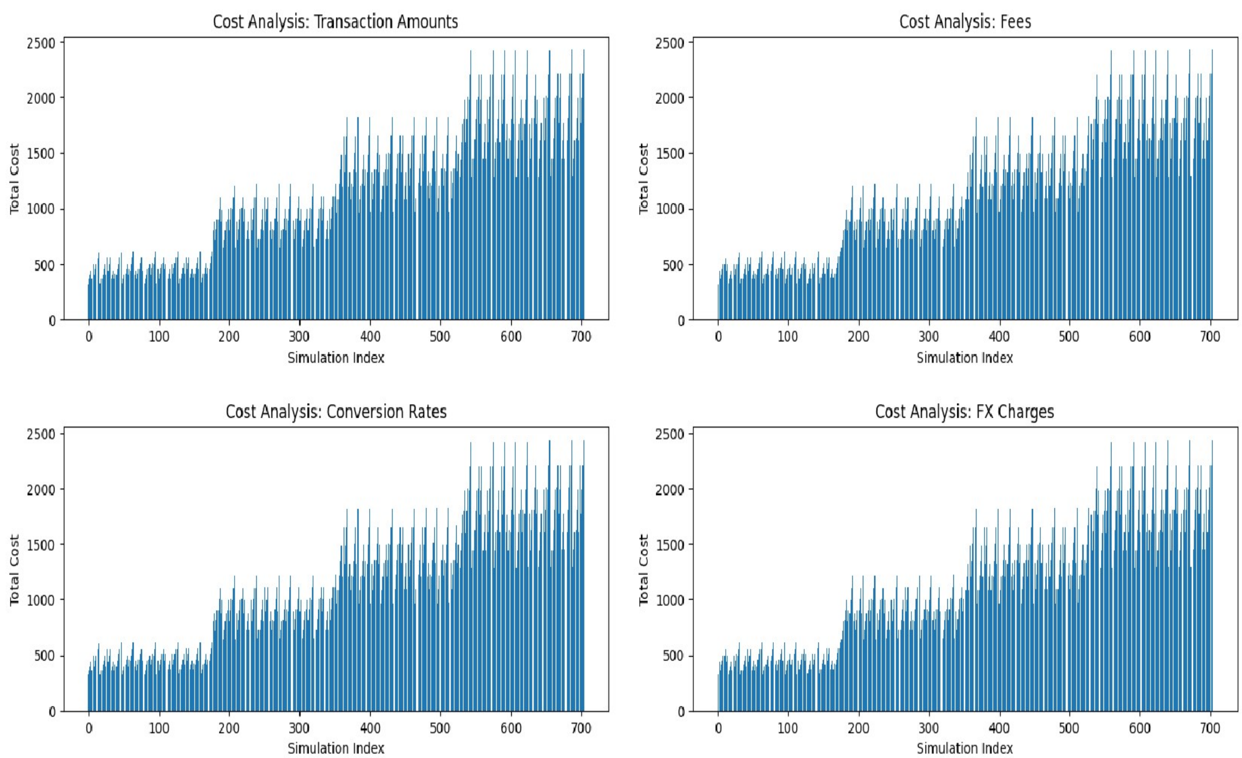

Figure 11 - Cost Simulation/Cost Sensitivity Analysis

6.4.2. Speed Simulation/Speed Sensitivity Analysis:

In tandem, our investigation encompassed a sensitivity analysis to unravel the dynamic relationship between transaction attributes and transaction speed. By varying transaction amounts, gas limits, transaction times, and block sizes, we uncovered the intricate patterns governing transaction efficiency in a blockchain-powered cross-border payment ecosystem.

Our visual representations elucidate the multifaceted impact of each parameter on transaction speed. Notably, the interplay between transaction amount and speed emerges as a key determinant, emphasizing the significance of harmonizing these attributes for optimal processing. Furthermore, the interaction of gas limits, transaction times, and block sizes showcases nuances in transaction speed dynamics, shedding light on blockchain's role in streamlining cross-border payment processing (Figure 12).

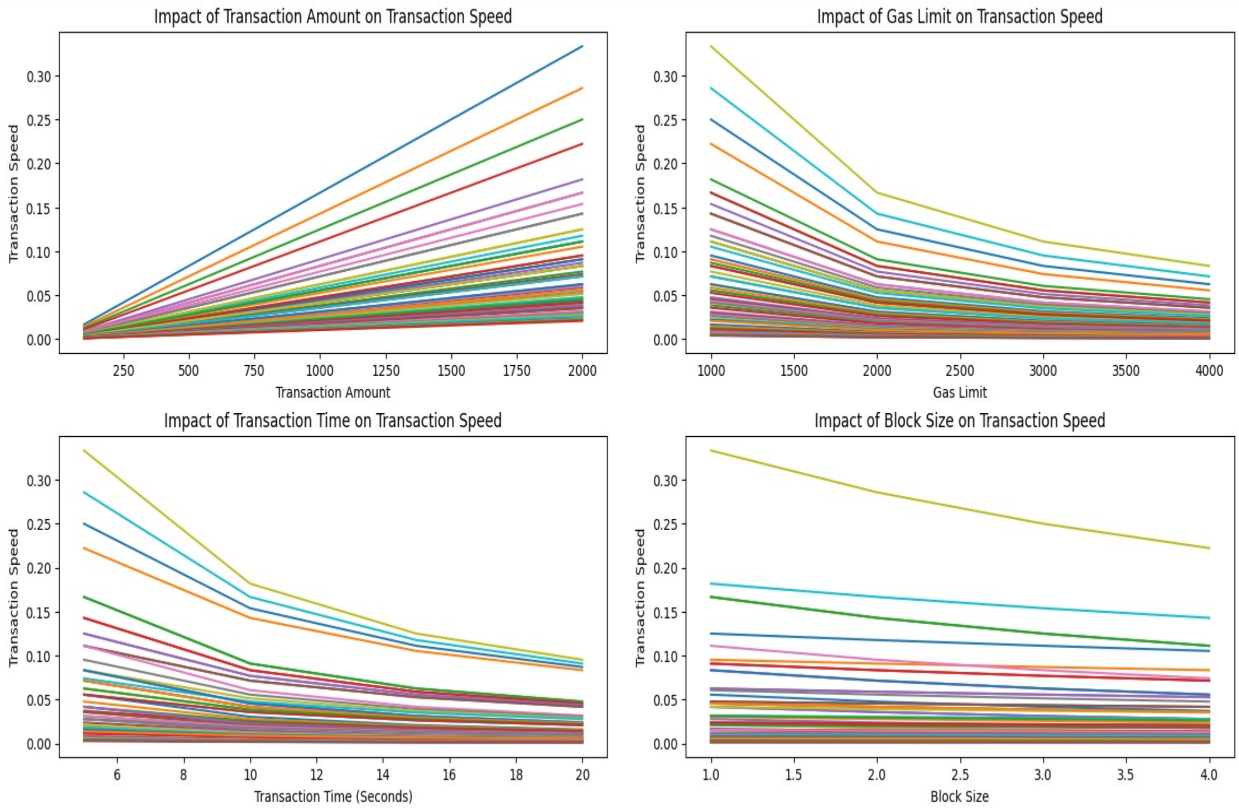

Figure 12 – Speed Simulation/Speed Sensitivity Analysis

6.5. Discussion

In evaluating the above-mentioned results, it is evident that the synthesized findings shed light on the intricate relationships between transaction attributes and their impact on cross-border payment (CBP) efficiency. The comparative analysis of average costs and speeds across different currency pairs and origin countries provides a nuanced understanding of the varying dynamics influencing CBP outcomes. Notably, the patterns observed among currency pairs and origin countries offer a foundation for strategic decision-making within the realm of international financial transactions.

However, a few limitations warrant consideration. The synthetic nature of the dataset raises questions regarding the acceptability of the results to real-world scenarios. While the data inputs have been meticulously calibrated, the real-world complexities of cross-border transactions could introduce additional variability. Furthermore, the experiments' focus on a specific set of transaction attributes may not fully capture the multifaceted landscape of CBP. A more comprehensive exploration of additional parameters, such as regulatory variations and geopolitical influences, could provide a more holistic view.

To improve the experimental design, future research could incorporate real-world transaction data to enhance the fidelity of the analysis. Additionally, exploring the impact of dynamic changes in gas limits, block sizes, and transaction fees could yield more nuanced insights. Incorporating a wider range of use cases, currencies, and origin countries would further enrich the findings and broaden the applicability of the conclusions.

In the context of the literature review, the findings align with and extend existing research on blockchain and distributed ledger technology (DLT) for cross-border payments. The study complements prior work by elucidating the intricate relationships between transaction attributes, costs, and speed, while also identifying opportunities for optimization. Moreover, the integration of correlation patterns with the existing body of knowledge enhances our understanding of CBP dynamics.

7 Conclusion and Future Work

Guided by the central research question of investigating the speed and cost implications of blockchain/DLT for CBP, this study has navigated a multifaceted landscape, unearthing critical insights into international financial transactions.

The research has been successful in uncovering significant relationships between transaction attributes and CBP outcomes, revealing the intricate interplay of variables shaping efficiency. The symbiotic connection between transaction amount, gas limit, and block size underscores the pivotal role of resource management in seamless transaction processing. Furthermore, the correlation between transaction fees and total cost accentuates the importance of user-centric fee structures for enhanced cost-effectiveness.

The implications of this research extend beyond the experimental domain. The findings provide valuable guidance for optimizing CBP operations, enabling decision-makers in the financial technology sector to strategize and innovate. While the experiments illuminate key dimensions, the limitations inherent in synthetic data underscore the potential for further exploration using real-world transaction data.

Looking ahead, meaningful future work entails refining the experimental design by integrating actual transaction data and exploring dynamic changes in transaction attributes. Proposals for future research should focus on investigating the impact of regulatory frameworks, geopolitical influences, and emerging technologies on CBP efficiency. Additionally, considering the potential for commercialization, further exploration into blockchain/DLT-powered CBP platforms offers a promising avenue for reshaping the landscape of global financial transactions.

As this chapter concludes, it is evident that the research has set the stage for a continuous exploration of CBP efficiency and the transformative role of blockchain/DLT. The journey has provided valuable insights, while simultaneously pointing towards the need for ongoing investigation and innovation in pursuit of an efficient and interconnected global financial ecosystem.

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