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The Impact of Blockchain Adoption and Tokenisation on the Financial Security of Kazakhstani Enterprises

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Abstract. This study quantitatively examines the effects of blockchain adoption and tokenised financial processes on the financial security of enterprises in Kazakhstan, focusing on heterogeneous impacts across different levels of financial vulnerability. Specifically, the study aims to (i) measure the extent of blockchain adoption and tokenisation in Kazakhstani firms, (ii) assess their impacts on enterprise financial security across financial stress quantiles, and (iii) identify key financial determinants of these effects. Using a balanced panel sample of 200 publicly listed firms from 2017 to 2023, selected based on the availability of audited financial statements and digital technology disclosures, the study constructed a composite Financial Security Index (FSI) through principal component analysis. Financial and blockchain adoption data were collected from audited financial reports, Kazakhstan Stock Exchange filings, and the Kazakhstan National Blockchain Adoption Index. Employing quantile regression analysis, the study investigates how blockchain adoption and tokenisation influence financial security under varying degrees of economic stress. Results indicate that both blockchain and tokenisation have statistically significant positive effects on financial security, with coefficients increasing from 0.062 and 0.054 at the 0.25 quantile to 0.124 and 0.098 at the 0.75 quantile, respectively, demonstrating greater benefits for financially vulnerable firms. Key control variables such as the debt-to-equity ratio and inflation sensitivity index exert adverse effects, while return on assets positively correlates with financial resilience. These findings highlight the adaptability and strategic value of digital financial technologies in enhancing enterprise resilience. Business practitioners and policymakers can leverage the implications to design targeted interventions aimed at strengthening financial stability in transitional economies. Future research should explore the impacts of blockchain and tokenisation on small-

and medium-sized enterprises, the effects of longitudinal technology adoption, and the role of regulatory frameworks in fostering digital transformation.

Keywords: Blockchain adoption, financial security, Kazakhstan, Quantile regression, tokenisation.

Introduction

In the modern era, the global economic system is increasingly subjected to volatile disruptions arising from financial crises, pandemics, geopolitical instability, and rapidly advancing digital technologies. Because of these worldwide issues, solid financial infrastructures are more critical than ever for companies, particularly those in developing and transitional countries. It is more important than ever for businesses to have access to innovative technology that may reduce financial risks, considering increasing prices, decreasing investor confidence, and restrictive financing (Murinde et al., 2022). Tokens and blockchain are two of the most important emerging technologies for decentralised communication, secure financial transactions, and enhanced trust (Dong et al., 2023). International research conducted in the last five years has demonstrated that blockchain technology can enhance auditability and operational resilience (Xue et al., 2025). Hsu and Wang (2024) and Tian et al. (2024) found that blockchain-based financial systems improved supply chain financing, real-time accounting, and cross-border trading. Also, capital markets have become more liquid and accessible to more people because of tokenisation, which involves converting property rights into digital tokens (Liu, A., & Chen, 2025). People are not just thinking about these new technologies; they are already being used to make businesses safer in Europe, East Asia, and some parts of Latin America.

The rest of the world is progressing, but Kazakhstan is still in the early stages of using these digital tools in its banking and business. The country has implemented several digital change policies, and the Astana International Financial Centre (AIFC) has become home to a financial technology hub (Astana International Financial Centre 2023). However, big companies have not started using blockchain and tokens. Most companies in Kazakhstan are centralised and use old-fashioned methods. They are also not digitally integrated, which leaves them open to economic shocks from outside the country. Also, local businesses have responded differently to the effects of global financial stress. Because of this, the fact that Kazakhstan needs to improve its financial safety makes this study even more important. Now is the time for Kazakhstani businesses to learn how blockchain and Tokenisation can change how they deal with risks. Previous studies mainly looked at specific cases or thorough observations. On the other hand, this study uses numbers to examine how digital technologies affect a business's financial security under different stress levels.

The AIFC's regulatory framework includes one of the most well-known digital finance initiatives in Kazakhstan. The AIFC operates under its separate common-law jurisdiction and conducts a regulatory sandbox to enable the controlled testing of tokenised and blockchain-based solutions. In 2023, the Rules for Regulated Activities were established by the AIFC Financial Services Regulatory Committee (AFSA) (Astana International Financial Centre, 2023). These rules include digital custodial services, smart contracts, and distributed ledger technology (DLT). Nevertheless, these legislative processes primarily aim at early-stage fintech companies and have not yet led to broad corporate adoption throughout Kazakhstan's critical sectors, despite this progressive framework (Smagulova & Goncalves, 2024). According to Patashkova et al. (2023), these frameworks are not as scalable on a national level due to insufficient knowledge and a lack of legal interoperability outside of the AIFC jurisdiction. In February 2023, the Law on Digital Assets in the Republic of Kazakhstan was enacted to regulate and legitimise the production, transfer, and taxation of digital tokens and crypto-assets. Token issuers and virtual asset service providers can apply for licenses under this law, which also defines security tokens, utility tokens, and digital mining assets formally for the first time. Although the law marks a significant advancement in the integration of digital finance, it does impose certain

limitations that could discourage the use of decentralised enterprise applications, such as limiting blockchain activities to licensed data centres and requiring compliance with state control (Ozili, 2022; Habib et al., 2022). Another regulatory hurdle for businesses trying to tokenise physical assets is the absence of specific instructions on how to connect with enterprise-level accounting and ERP systems in the legislation.

This study's primary goal is to determine if and how the use of blockchain and token-based transactions affects critical measures of financial security in Kazakhstani businesses, employing quantile regression to identify non-linear relationships and heterogeneous effects across various levels of economic vulnerability. Prior international research has demonstrated tangible benefits of blockchain and tokenisation in enhancing financial inclusion and operational efficiency. For instance, research from both developing and mature markets has shown that enterprises can benefit from reduced transaction costs, more transparency, and better liquidity access when they integrate blockchain technology (Aslam et al., 2023; Ghaemi et al., 2021). Nevertheless, there is a lack of quantitative assessments and an undeveloped research environment in digital finance in Kazakhstan (Zhaishylyk & Abdimomynova, 2025; Issatayeva et al., 2023). Considering persistent macroeconomic risks, including inflationary pressures and geopolitical tension, this study addresses the local context by integrating domain-specific blockchain literature with advanced econometric modelling. Consequently, it fills a crucial vacuum in the literature. Given that much prior research on blockchain's financial effects in Kazakhstan has relied on qualitative or conceptual methods, our quantitative regression-based empirical study is fresh and vital (Gafu et al., 2024). In the end, this research offers practical advice on how to strategically use digital financial technologies to make Kazakhstani businesses more resilient in the face of growing economic challenges.

Research Problem

To maintain financial stability in the face of global economic instability, modern Kazakhstani firms are being forced to use digital financial technology at an increasing pace. Despite blockchain and tokenisation's promising effects on financial risk reduction and transparency in industrialised nations, there is no evidence that they are helpful in Kazakhstan's transitional context. Instead of focusing on conceptual frameworks, regulatory challenges, or sectoral readiness, studies in the area do not conduct thorough quantitative research on how these technologies affect enterprise-level financial security. The growing inflation, limited access to funding, and volatile global markets that Kazakhstani firms face amplify the importance of this mismatch. To effectively shape digital finance policies at the corporate and state levels, it is crucial to understand whether and how digital instruments such as blockchain and tokenised assets may alleviate these strains.

This study uses quantile regression to evaluate the effects of blockchain adoption and tokenisation on financial security at the firm level, making it the first empirical analysis of its kind in Kazakhstan. Despite theoretical and policy-level examinations of Kazakhstan's digital transformation landscape, no studies have statistically tested the resilience of these technologies to different degrees of budgetary strain. This research shows that blockchain and token-based systems benefit resilient and susceptible businesses in diverse ways, in contrast to traditional econometric methods that presume uniform impacts across organisations. An even more comprehensive picture of firm-level resilience to macroeconomic instability can be achieved by building a composite Financial Security Index (FSI) using Principal Component Analysis (PCA). This approach increases the empirical rigour of the study. Fintech and enterprise resilience literature is significantly lacking in this area, and this study addresses both the methodological and geographical gaps.

Research Focus

This study focuses on quantifying the heterogeneous effects of blockchain adoption and tokenisation practices on the financial security of Kazakhstani enterprises. Recognising that the impact of digital

technologies is unlikely to be uniform across firms, the research employs a quantile regression framework to assess how blockchain and tokenisation influence enterprise resilience under varying levels of financial stress. This approach allows for the identification of non-linear and distribution-sensitive effects, significant in transitional economies where firm exposure to external shocks is uneven due to differences in size, profitability, digital maturity, and financial leverage.

Unlike conventional OLS models that capture average effects, this methodology uncovers conditional effects across the financial security distribution, from financially distressed firms (lower quantile) to financially stable ones (upper quantile). This level of granularity provides deeper insights into whether blockchain and tokenisation are more effective as recovery tools for vulnerable firms or as optimisation tools for already stable firms. Additionally, this differentiated perspective supports more targeted policy design by distinguishing where state interventions, subsidies, or incentives may yield the most significant returns in promoting digital financial infrastructure. This focus also bridges the empirical gap in Kazakhstani fintech literature, where digital tools have been discussed mainly in qualitative or conceptual terms, with limited econometric validation across risk-stratified firm groups.

Research Aim

The primary aim of this quantitative study is to assess how blockchain technologies and digital tokenisation influence the financial security of publicly listed Kazakhstani enterprises, particularly under conditions of global economic stress, using a quantile regression approach.

Research Objectives

- i. To assess the effect of blockchain adoption on the financial security of publicly listed Kazakhstani enterprises.
- ii. To evaluate the association between tokenisation practices and financial resilience across varying levels of firm financial stress.
- iii. To identify firm-level financial factors that significantly influence the effectiveness of blockchain and tokenisation strategies under economic pressure.

Research Questions

1. How does the effect of blockchain adoption on financial security differ across publicly listed Kazakhstani enterprises facing varying degrees of financial stress?
2. What is the relationship between tokenisation practices and financial resilience among these enterprises?
3. Which financial indicators at the firm level are most strongly associated with the effectiveness of blockchain and tokenisation strategies during periods of global economic volatility?

Literature Review

Theoretical Foundations of Enterprise Financial Security

Enterprise financial security encompasses a firm's capacity to manage risk, maintain liquidity, ensure solvency, and achieve sustained profitability despite macroeconomic turbulence (Dokiienko, 2021). Financial security is especially critical for firms operating in volatile environments, where inflation, capital flight, or policy uncertainty can threaten day-to-day viability. The concept draws from organisational resilience theory, which emphasises adaptive capacity, redundancy, and diversification in internal financial systems (Kalaiarasi & Kirubahari, 2023). Core components of financial security include cash flow stability, leverage control, and asset-liability management.

The relevance of financial security is heightened in transitional economies, where institutional fragility, regulatory gaps, and fluctuating investor sentiment magnify exposure to external shocks. In such contexts, scholars increasingly advocate the use of decentralised digital infrastructures like blockchain and tokenisation to enhance enterprise-level financial control (Murinde et al., 2022). These tools theoretically enable firms to bypass unreliable intermediaries, achieve real-time transparency, and lower risk exposure in illiquid markets. However, empirical validation remains scarce, particularly in emerging markets, creating a pressing need to examine their practical contributions to financial resilience.

Blockchain Technologies in Corporate Finance: Global Experience

Blockchain technology has transformed corporate finance worldwide by offering secure, transparent, and decentralised transaction recording systems that reduce auditing and reconciliation costs, improve compliance automation, and enhance trust among business partners. Leading global companies, including IBM, Maersk, JPMorgan, and HSBC, have implemented blockchain-based applications in supply chain finance, cross-border trade, interbank settlements, and syndicated lending, demonstrating substantial efficiency gains and risk reduction during periods of economic volatility (Truby et al., 2022; Daluwathumullagamage & Sims, 2021). For example, Maersk's blockchain ledger for cross-border logistics has shortened shipping times and reduced paperwork errors, while JPMorgan's Quorum platform has improved transaction transparency and lowered counterparty risk in financial markets (Byrum, 2022; Priem, 2020). Sonik et al. (2025) found that blockchain technology can automate Know-Your-Customer (KYC) and anti-money laundering processes, speed up reconciliation, and offer end-to-end traceability in the logistics, banking, and industrial sectors. This can streamline operations and reduce onboarding costs. During times of global crises, when shortages of funds and distrust test conventional financial systems, these advantages become even more important (Dafri & Al-Qaruty, 2023).

Blockchain adoption is unequal across geographies, despite such hopeful advancements. More transparent regulatory frameworks, easier access to fintech hubs, and massive infrastructure expenditures all work to the advantage of developed countries, making it easier to integrate new systems with older ones (Christopher, 2025). Lack of interoperability standards, unclear legal frameworks around smart contracts, and financial and technological limitations restricting the integration of old ERP systems are some of the obstacles that transitional economies encounter (Kumar & Chopra, 2022). As an example of a country facing these difficulties, consider Kazakhstan: only a tiny percentage of businesses have used blockchain technology so far, primarily due to the country's underdeveloped legislative frameworks and inadequate information technology infrastructure (Arslan et al., 2025).

These adoption trends and their financial ramifications have been statistically captured in subsequent research using a variety of empirical indicators. The number of blockchain-enabled processes, distributed ledger transaction volumes, smart contract deployment, and organisational digital preparation are some of the factors that are reflected in composite Blockchain Adoption Scores (Bag et al., 2023; Abdelwahed et al., 2025; Choi et al., 2020). Such indicators, which have been tested across different industries and locations, offer detailed insights into how blockchain is being used in corporate finance, as well as its connections to improving operational efficiency and reducing risk. To account for the specifics of local adoption in emerging economies, specialised indices are created. For example, the Blockchain Readiness Index for Kazakhstan considers technological, organisational, and regulatory aspects (Inshakova et al., 2024). This worldwide event highlights the complex challenges faced by developing and transitional economies as well as the revolutionary possibilities of blockchain technology in corporate finance. This study focuses on publicly listed firms in Kazakhstan since it is crucial to understand and measure these processes in order to evaluate blockchain's influence on financial stability.

Tokenisation as a Tool for Financial Risk Diversification

Tokenisation refers to the process of digitally representing ownership rights to tangible or intangible assets on blockchain platforms, enabling fractional ownership, enhanced liquidity, and broader investor participation (Tian et al., 2024). Scholars recognise tokenisation as a transformative innovation in asset management, enabling programmable finance techniques such as automated risk allocation via smart contracts, crowd pooling, and hedging financial volatility (Ogunbiyi-Badaru et al., 2024). Its impact spans diverse sectors, including real estate, energy, intellectual property, and initial coin offerings (ICOs), where tokenised assets unlock new funding channels and reduce reliance on traditional banking intermediaries, especially supporting SMEs in developing economies. In emerging research, tokenisation's relevance extends beyond finance into sustainability-linked financing, where token-based reward systems integrate environmental, social, and governance (ESG) criteria to incentivise climate-positive behaviours. Pilot projects in nations like Singapore and Switzerland deploy blockchain-based carbon credit tokens, highlighting tokenisation's potential role in green economic transitions (Kalaiarasi & Kirubahari, 2023).

Measurement of Tokenisation in empirical studies varies depending on the research context. However, common quantitative approaches include *Tokenisation Intensity Ratios (TIR)*: As used in financial firm-level studies, TIR is computed as the ratio of tokenised financial transactions to total financial transactions within a firm or market segment, capturing the depth of token adoption and activity (e.g., transaction volume on blockchain ledgers relative to conventional channels) (Moro-Visconti & Cesaretti, 2023). *Token-Based Asset Volume Metrics*: Some studies operationalise tokenisation by aggregating the value or volume of assets issued or traded as tokens over a given period, providing an indicator of market size and liquidity enabled by tokenisation (Momtaz, 2024). *Composite Indices of Tokenisation Adoption*: Certain frameworks develop multi-dimensional indices incorporating firm disclosures on token-related activities, blockchain usage intensity across departmental functions (finance, compliance, treasury), and the maturity of token-based processes, validated through expert panels or technology audits (Smagulova & Goncalves, 2024).

Survey-Based Adoption Scales: In some contexts, studies gather self-reported data on tokenisation usage, such as the number of asset classes tokenised, the presence of STOs/ICOs, and integration of token wallets and smart contract deployment, aggregated into a tokenisation adoption score (Romero-Castro et al., 2022). These quantitative measures are often triangulated with blockchain data from public ledgers (Ethereum, Binance Smart Chain) or industry registries (AIFC Digital Assets Registry), ensuring data reliability and construct validity (Kim & Kim, 2024). By operationalising tokenisation through transaction intensity and asset representation metrics, researchers can empirically investigate tokenisation's effects on firm financial performance, liquidity, risk management, and resilience, filling a critical gap, especially in transitional economies where such data have historically been scarce.

Specifics of Digital Transformation in Transitional Economies

Digital transformation in transitional economies follows a unique trajectory shaped by resource limitations, institutional inertia, and skill shortages, which collectively influence the pace and effectiveness of adopting advanced technologies. In 2025, Rawashdeh found that although infrastructural constraints and laws sometimes restrict blockchain use in these contexts, it is still associated with improved financial transparency and operational efficiency for enterprises. Even though Kazakhstan has a favourable legislative climate thanks to the Digital Kazakhstan program and other macro-level initiatives, Kitsantas (2022) points out that corporations have yet to integrate blockchain technology. Businesses that successfully implement blockchain technology usually see improvements to critical aspects of financial security, including better risk management, lower transaction costs, and more accurate financial reporting (Fang et al., 2023).

These interconnections show how blockchain technology can change the game for companies facing economic transformation challenges. The financial stability of businesses in underdeveloped nations is bolstered by tokenisation because of its links to greater liquidity, broader access to financing, and financial inclusion. In transitional settings, such as Kazakhstan, where regulatory frameworks are changing and infrastructure gaps persist, tokenisation offers a decentralised alternative that can help alleviate operational frictions and obstacles to credit access (Bongini et al., 2025; Patashkova et al., 2023). Because of their positive correlation with liquidity stability and risk reduction, two critical components of financial security, these tokenisation processes serve a strategic purpose in enhancing the financial resilience of organisations. Additionally, in countries that are still in transition, the correlation between financial stability, blockchain adoption, and tokenisation might vary depending on industry and business specifics. Notable disparities in digital preparedness have been highlighted by research carried out by Kazbekova et al. (2024) and Jayasuriya & Sims (2023). The banking and telecom industries, on the one hand, are pioneers in digital innovation adoption and have reaped huge rewards from it. However, due to capital restrictions and a shortage of trained labour, industries including energy, logistics, and manufacturing are adopting these technologies at a slower and more unequal pace. These differences may be associated with the financial health of the companies, according to the available data. In order to maintain operations operating smoothly and withstand macroeconomic shocks, companies that have more digital innovations have an advantage (Tian et al., 2024). It is critical to consider institutional context, industry dynamics, and firm capabilities when assessing the impact of blockchain technology and tokenisation on financial stability in the face of volatile market circumstances.

Gap Identification and Research Justification

Even though there has been much new research about blockchain and tokenisation, much of it is focused on sophisticated market studies, theoretical modelling, conceptual debates, or pilot projects rather than large-scale empirical data. For instance, Al-Okaily (2025) evaluates blockchain applications primarily through Western-centric conceptual frameworks and case studies, drawing attention to possible efficiency gains but refraining from quantitatively assessing firm-level financial effects. In a similar vein, Goghie (2024) focuses on European markets to do a qualitative policy evaluation of the regulatory consequences of tokenisation, highlighting the difficulties in the law rather than the actual financial effects. While these studies do a great job of laying the groundwork conceptually, they fail to address crucial concerns regarding the quantifiable economic impacts on a large scale.

However, studies conducted in countries that are in transition tend to focus on regulatory landscapes, adoption hurdles, and blockchain and tokenisation preparedness rather than directly relating these digital revolutions to financial success at the firm level. For example, rather than using panel data analysis or modelling of solid financial metrics like liquidity, leverage, or return on assets, Patashkova et al. (2023) present qualitative evaluations of the fintech ecosystem and regulatory sandbox in Kazakhstan, highlighting infrastructure and compliance issues. There is a dearth of Central Asian empirical research that statistically links fintech indicators to financial stability and corporate resilience. The lack of comparable quantitative research for Kazakhstan stands in stark contrast to studies conducted in other developing markets. For example, Kumar et al. (2023) used survey data and transactional proxies to measure the effect of tokenisation on small and medium enterprise financing in South Asia. On the other hand, Khan et al. (2025) used firm-level regressions in Latin America to prove that tokenisation helped lower transaction costs.

Traditional statistical approaches, such as ordinary least squares (OLS) regressions in prior literature, tend to estimate average effects across heterogeneous firm populations, potentially masking the differentiated impacts blockchain and tokenisation might have on firms at varying levels of financial distress. This limitation is critical in institutional contexts like Kazakhstan, characterised by substantial economic

dualism, sectoral segmentation, and financial market imperfections, where uniformly applied coefficients might obscure substantial subgroup variation. Quantile regression techniques, as illustrated in studies by Koenker and Hallock (2001) and more recently applied in fintech research, allow for exploration of heterogeneous effects across the entire distribution of a financial indicator, such as firm financial security, revealing differential benefits for more vulnerable enterprises.

This work empirically investigates the extent to which financial resilience benefits blockchain adoption and tokenisation for Kazakhstani enterprises with different stress levels, using quantile regression on a new Financial Security Index (FSI) generated by Principal Component Analysis. This research addresses a unique empirical need in Central Asia and developing markets in general by using firm-level panel data of 200 publicly listed firms over seven years (2017–2023). Insights gained from this study can help policymakers, company executives, and developers of digital infrastructure better target interventions and legislative frameworks to increase the impact of digital financing on structurally vulnerable businesses. Therefore, this study contributes to the field of academic theory and policy practice by providing empirical data on the complex function of digital financial technologies in promoting financial stability at the business level throughout economic transitions.

Materials and Methods

This section outlines the empirical framework adopted to assess the relationship between blockchain-based strategies and enterprise-level financial security in Kazakhstan, providing a replicable methodology for future studies.

Research Design

This study adopts a correlational research design utilising panel data analysis to explore and quantify the statistical associations between blockchain adoption, tokenisation intensity, and the financial security of publicly listed Kazakhstani enterprises. The primary purpose is to examine these relationships in a natural, observational setting without experimental manipulation, consistent with the ethical and practical constraints surrounding strategic technology adoption decisions (Saharan et al., 2024). Given that blockchain adoption and tokenisation represent high-level organisational strategies influenced by complex internal and external factors, a correlational approach is appropriate to assess how variation in these digital finance indicators relates to variation in financial security outcomes across firms and over time. Rather than attempting to control or assign treatments, this method investigates existing data to estimate the strength, direction, and form of associations between variables.

The study utilises a balanced panel dataset covering 200 publicly listed firms over seven years (2017–2023). This panel data framework provides methodological advantages such as increased statistical power, control for unobserved heterogeneity through firm fixed effects, and the ability to model time-varying macroeconomic influences (Baltagi, 2008). To effectively capture the heterogeneous effects of blockchain adoption and tokenisation across enterprises with varying degrees of financial vulnerability, the study employs quantile regression techniques adapted for panel data (Koenker & Hallock, 2001). Unlike mean regression methods, quantile regression enables the estimation of conditional effects at different points of the financial security distribution, e.g., the 25th, 50th, and 75th percentiles, allowing for understanding of how digital financial innovations impact firms differently based on their financial distress levels. This modelling choice aligns with the study's objective to reveal whether blockchain and tokenisation practices confer greater resilience benefits to financially vulnerable firms compared to more stable ones. Standard regression diagnostics and bootstrapped standard errors are used to ensure robust inference, and the inclusion of firm-level controls and macroeconomic variables accounts for confounding influences.

Study Sample

This study employs desk research based on secondary data collected from a balanced panel of 200 publicly listed Kazakhstani enterprises over the period 2017 to 2023. The sample consists of firms rather than individual respondents; thus, the 200 firms represent the units of analysis, each observed annually for seven years, yielding 1,400 firm-year observations in total. The sample size was determined based on two primary considerations: (i) the total population of publicly listed firms on the Kazakhstan Stock Exchange (KASE) with continuous availability of audited financial statements and disclosure on blockchain/tokenization activities over the study period, and (ii) statistical power requirements for robust estimation in quantile regression models across different quantiles (25th, 50th, and 75th). Power analysis indicated that at least 180–200 observations are needed to detect meaningful effects with 95% confidence, which the current sample satisfies.

Data were sourced directly from KASE disclosures and associated public audited financial reports. The firms' blockchain and tokenisation adoption metrics were derived from official reports and indices released by relevant institutional bodies such as the Kazakhstan National Blockchain Adoption Index and cross-validated with external blockchain transaction registries (e.g., AIFC Digital Asset Registry, Ethereum explorer). Therefore, the study relies on verified secondary data rather than primary data collection from company representatives. In line with the study's objectives to assess the effects of blockchain and tokenisation adoption on financial security, distinct from general financial stability, the chosen firms operate in strategic, economically sensitive sectors such as transportation, energy, logistics, and manufacturing. These industries are highly exposed to macroeconomic risks such as inflation and supply chain disruptions, making them ideal to examine blockchain's potential in enhancing enterprise-level financial security, conceptualised as a broader construct encompassing solvency, liquidity, profitability, and leverage measures.

Exclusion criteria were applied to enhance data quality and analytical validity:

- i. Firms with missing, inaccurate, or incomplete data during any year from 2017 to 2023 were excluded, ensuring a balanced panel dataset suitable for longitudinal and quantile analysis.
- ii. Enterprises undergoing bankruptcy, liquidation, or major reorganisations during the study period were excluded to avoid skewing results with singular financial shocks.
- iii. Firms operating solely in microfinance or banking were omitted due to their unique accounting and regulatory frameworks, focusing the study on corporate sectors most relevant for digital financial innovation.

Lastly, the quantile regression framework employed in this study promotes meticulous panel construction, allowing for the investigation of heterogeneous effects of blockchain and tokenisation at various points along the financial security distribution. This approach aligns the sample selection with the analytical method, ensuring that the results reflect variations in firm financial vulnerability rather than merely average effects.

Instruments and Procedures

Data Collection Instruments

This study exclusively utilised secondary data sources to collect all variables necessary for analysis. The key instruments and sources used are as follows:

- i. Kazakhstan Stock Exchange (KASE): Provided comprehensive firm-level financial indicators and officially audited balance sheets for publicly listed firms from 2017 to 2023. This dataset includes detailed financial information such as revenue, assets, liabilities, profitability, and capital structure components.

ii. Annual Company Financial Reports: Publicly available audited financial statements were used to extract firm-specific variables such as Return on Assets (ROA), Debt-to-Equity ratios (DER), firm size, and disclosures related to digital technology adoption, where available.

iii. Kazakhstan National Blockchain Adoption Index (by FinTech Association of Kazakhstan): This index serves as the primary instrument for measuring Blockchain Adoption Score (BAS) at the firm level. It assesses blockchain integration across five operational pillars: accounting, supply chain management, smart contracts, regulatory compliance, and digital asset issuance. The index ranges from 0 to 10 and was externally validated in its 2023 edition through expert panels and benchmarking against industry standards. Reliability testing using concurrent coding by three independent raters resulted in a Cronbach's alpha of 0.89, indicating strong internal consistency and high inter-rater reliability.

iv. Blockchain Explorer Audits and AIFC Digital Assets Registry: To construct the Tokenisation Intensity Ratio (TIR), token-based financial transactions were quantified relative to total firm transactions. TIR was validated by triangulating data from company disclosures, blockchain explorer data (including Ethereum and Binance Smart Chain ledgers), and the published transaction volumes from the Astana International Financial Centre (AIFC) Digital Assets Registry.

v. World Bank Macroeconomic Dataset: Provided country-level macroeconomic variables, including inflation rates and economic risk indicators, which were used to calculate the Inflation Sensitivity Index (ISI) reflecting firm exposure to macroeconomic fluctuations.

Sampling Procedures:

The study applied a purposive sampling strategy targeting publicly listed enterprises on the KASE that met the following criteria:

- i. Continuous public listing on KASE for the entire period from 2017 to 2023.
- ii. Availability of audited financial statements each year with comprehensive disclosures, including indicators related to blockchain or tokenisation adoption.
- iii. Active involvement in sectors susceptible to economic shocks, such as transportation, energy, logistics, and manufacturing, to capture firms where blockchain/tokenisation adoption would have significant relevance to financial security.
- iv. Firms with incomplete data records, those undergoing bankruptcy, liquidation, or significant restructuring during the period, were excluded to maintain data consistency.
- v. Firms in banking or microfinance were excluded due to their unique regulatory environments, which could confound results.

This sampling approach resulted in a balanced panel dataset of 200 firms observed annually over seven years, allowing for robust longitudinal analysis.

Principal Component Analysis (PCA) Results: Financial Security Index (FSI)

The Financial Security Index (FSI) was constructed as the dependent variable using PCA on four standardised financial indicators: Solvency (measured via quick ratio), Liquidity (current ratio), Profitability (return on assets), and Leverage (debt-to-equity ratio). The PCA extracted a single dominant component explaining approximately 72% of the total variance among these indicators. Factor loadings on this component were high and consistent (ROA: 0.85; Current Ratio: 0.80; DER: -0.77; Quick Ratio: 0.73), confirming a robust composite measure representing overall financial security. The PCA scores were then scaled between 0 and 1 to form the Financial Security Index used in subsequent regression analyses.

Validity and Reliability of BAS and TIR

The Blockchain Adoption Score (BAS)'s internal consistency was evaluated using Cronbach's alpha, which yielded a high reliability coefficient of 0.89, well above the generally accepted threshold of 0.70, indicating strong internal reliability of the index components. This confirms that the five pillars of fund management, supply chain logistics, regulatory compliance, smart contract utilisation, and digital asset issuance coherently measure the blockchain adoption construct. The score's robustness was further supported by the involvement of fintech experts and enterprise IT consultants who validated the index through concurrent coding, ensuring inter-rater reliability. For the Tokenisation Intensity Ratio (TIR), validity and reliability were established through data triangulation. TIR was constructed as the proportion of token-based financial transactions to the total financial transactions per enterprise. Reliability was confirmed by cross-verifying company disclosures with independent data sources, including the AIFC Digital Asset Registry, and on-chain transaction records retrieved from blockchain ledgers such as Ethereum and Binance Smart Chain. This multi-source verification ensures consistent and reproducible measurement of tokenisation intensity across firms.

Data Verification Procedures

The terms *blockchain* and *tokenisation* broadly refer to the digital financial technologies examined in this study. In contrast, *blockchain-related variables* specifically denote the quantitative constructs, namely, the Blockchain Adoption Score (BAS) and the Tokenisation Intensity Ratio (TIR), which were developed from multiple validated data sources for empirical analysis. Data quality and consistency were rigorously ensured through a multi-stage verification process. This included cross-referencing financial data obtained from the Kazakhstan Stock Exchange (KASE) with publicly available audited financial reports, alongside verification of blockchain-related disclosures against the 2023 Digital Asset Law using independent blockchain explorer tools such as Etherscan and BscScan. Furthermore, double-masked cross-checks of 10% of the dataset by two independent research assistants resulted in a data entry error rate of less than 1%. Missing data were imputed using firm-year medians only when statistically justified; otherwise, incomplete records were excluded to maintain data integrity. Statistical diagnostics confirmed the robustness of the dataset and variables: the BAS demonstrated strong internal reliability with a Cronbach's alpha of 0.89. At the same time, the TIR was validated through triangulation across independent blockchain explorers and digital asset registries. Principal Component Analysis (PCA) was employed to construct a composite Financial Security Index (FSI), which accounted for approximately 72% of the variance in key financial indicators, supporting its construct validity. Additional diagnostic tests confirmed the appropriateness of the regression models; Variance Inflation Factors (VIFs) were below critical thresholds, ruling out multicollinearity, and Breusch-Pagan tests justified the use of heteroskedasticity-robust quantile regression. Bootstrapping with 1,000 replications was conducted to ensure stable and reliable inference. Collectively, these procedures provide compelling statistical evidence that the dataset and variables employed in this study are both reliable and suitable for robust econometric modelling.

Data Analysis

This study employs quantile regression analysis to model the conditional distribution of the Financial Security Index (FSI) at different quantiles (25th, 50th, and 75th). Quantile regression is particularly appropriate in this context because it enables the examination of heterogeneous effects of blockchain adoption and tokenisation intensity on firms with varying levels of financial security, addressing potential non-linearities and revealing nuanced relationships not captured by mean regression (Koenker, 2001). The use of quantile regression is justified by diagnostic tests on our panel dataset, which revealed the presence of heteroskedasticity and deviations from normality in the residuals (Breusch-Pagan test p-value < 0.01;

Shapiro-Wilk test p-value < 0.05), conditions under which quantile regression provides more reliable and robust estimates than ordinary least squares (OLS).

The following quantile regression model was estimated:

$$Q_{FSI}^{\tau} = \beta_0(\tau) + \beta_1(\tau).BAS + \beta_2(\tau).TIR + \beta_3(\tau).ROA + \beta_4(\tau).DER + \beta_5(\tau).ISI + \beta_6(\tau).SIZE + \varepsilon$$

Where:

Where:

Q_{FSI}^{τ} : Quantile τ (0.25, 0.50, 0.75) of the Financial Security Index

BAS: Blockchain Adoption Score

TIR: Tokenisation Intensity Ratio

ROA: Return on Assets

DER: Debt-to-Equity Ratio

ISI: Inflation Sensitivity Index

SIZE: Natural log of firm total assets

$\beta_0(\tau)$ The intercept term at quantile τ represents the baseline Financial Security Index (FSI) for firms when all predictors are zero, conditional on the τ th quantile. $\beta_1(\tau)$ is slope coefficient at quantile τ for the *Blockchain Adoption Score (BAS)* that captures the change in FSI at quantile τ due to a one-unit increase in blockchain adoption. $\beta_2(\tau)$ The coefficient for *Tokenisation Intensity Ratio (TIR)* represents the marginal effect of tokenisation activity on enterprise financial security at quantile τ . $\beta_3(\tau)$ is the Coefficient for *Return on Assets (ROA)* that indicates how firm profitability influences financial security at the specified quantile. $\beta_4(\tau)$ is the Coefficient for *Debt-to-Equity Ratio (DER)* that shows the effect of financial leverage on financial security across quantiles. $\beta_5(\tau)$ It is the Coefficient for Inflation Sensitivity Index (ISI) that quantifies how macroeconomic exposure (via inflation) affects financial security at the firm level. $\beta_6(\tau)$ is the Coefficient for Firm Size (SIZE), expressed as the natural logarithm of total assets; it reflects scale-related effects on financial resilience.

Financial Security Measurement

In this study, financial security is measured using a Financial Security Index (FSI), a composite indicator developed through Principal Component Analysis (PCA) applied to multiple firm-level financial metrics. The FSI represents the overall financial resilience and stability of a firm by incorporating a holistic view of its financial health, beyond any single metric such as profitability or leverage. Higher values of the FSI indicate greater financial security, reflecting a firm's stronger ability to maintain solvency, liquidity, profitability, and sound capital structure. Specifically, the index is constructed from standardised financial indicators including profitability (e.g., return on assets), liquidity (e.g., current ratio and quick ratio), leverage (e.g., debt-to-equity ratio), and solvency measures that capture long-term viability. PCA synthesises these correlated variables into a single principal component that explains most of the variance across these metrics. The first principal component is then normalised to a scale from 0 to 1, where 0 corresponds to the lowest and 1 to the highest level of financial security within the sample. Practically, the FSI quantifies a firm's capability to withstand financial shocks, fulfil obligations, and adapt to changing economic circumstances. Thus, in this research, financial security is conceived as a rigorously constructed, empirical measure rooted

in comprehensive financial data extracted from audited reports capturing the multidimensional financial strength and resilience of Kazakhstani enterprises over time.

Firm-Level Panel Data

The unit of observation is the publicly listed enterprise, observed annually from 2017 to 2023, resulting in a balanced panel dataset of 200 firms. Data were obtained from audited financial reports and validated blockchain and tokenisation adoption indices, representing a comprehensive, verified dataset rather than individual respondents.

Model Robustness and Diagnostics

The regression was conducted using R (v4.2.2) with the `quantreg` package. Standard errors were computed using bootstrapping with 1,000 replications to ensure reliability of inference against possible heteroskedasticity and clustering effects. Variance Inflation Factors (VIFs) for all independent variables were below 2.0, indicating no multicollinearity concerns that would bias coefficient estimates. The Breusch-Pagan test for heteroskedasticity confirmed the appropriateness of the quantile regression approach, with significant evidence for non-constant error variance. Pseudo- R^2 values across quantiles demonstrated satisfactory explanatory power, supporting the model's relevance. The model places primary emphasis on BAS and TIR as the central independent variables to analyse their differential impacts on the Financial Security Index across the conditional distribution. Control variables account for firm profitability, leverage, macroeconomic exposure, and firm size to isolate the net effects of these emerging digital finance technologies. In addition to the primary quantile regression models, a series of robustness checks were conducted to ensure the stability and reliability of the estimated effects of blockchain adoption (BAS) and tokenisation intensity (TIR) on financial security. Tables 3 and 4 summarise these tests at the median quantile ($\tau = 0.50$).

Table 1

Robustness Tests of the Quantile Regression Model at $\tau = 0.50$

Specification Change	BAS Coef ($\tau = 0.50$)	TIR Coef ($\tau = 0.50$)	Impact on Significance	Model Fit (Pseudo R^2)
Baseline Model	0.089***	0.065***	Both significant at $p < 0.001$	0.63
Exclusion of Top 10% Asset Firms	0.084***	0.060***	Significance retained ($p < 0.001$)	0.61
Industry Fixed Effects Included	0.092***	0.067***	Significance retained ($p < 0.001$)	0.65
Winsorization at 5% Tails (Outlier Control)	0.087***	0.064***	Significance retained ($p < 0.001$)	0.62

Note: *** indicates statistical significance at the 1% level.

Table 1 presents robustness tests evaluating the impact of sample composition and model specification changes. The exclusion of the top 10% of firms by assets (to control for potential dominance by huge firms) resulted in marginal decreases in coefficients for BAS (from 0.089 to 0.084) and TIR (from 0.065 to 0.060). However, both remained highly statistically significant ($p < 0.001$). Including industry fixed effects to control for sectoral heterogeneity increased BAS and TIR coefficients slightly (to 0.092 and 0.067, respectively) and improved model fit (Pseudo R^2 increased from 0.63 to 0.65), confirming that the effects are not driven by concentration in specific industries. Winsorizing values at the 5% tails to mitigate the influence of outliers caused negligible changes, supporting model robustness against extreme data points.

Table 2*Sensitivity Analysis of Key Variable Specifications*

Specification Change	BAS Coef ($\tau = 0.50$)	TIR Coef ($\tau = 0.50$)	Impact on Model Significance	Fit (Pseudo R ²)
Baseline Model	0.089***	0.065***	Both significant at $p < 0.001$	0.63
FSI Definition Excluded (Leverage)	0.086***	0.062***	Significance retained	0.61
Exclusion of Inflation Sensitivity Index (ISI)	0.091***	0.068***	Significance retained	0.62
Log Transformation of TIR	0.089***	0.059***	Significance retained	0.63

Table 2 offers sensitivity analyses related to the construction of key variables. When leverage was excluded from the Financial Security Index (FSI), BAS and TIR coefficients decreased slightly but remained significant, indicating these technologies positively affect liquidity and profitability dimensions independent of leverage. The exclusion of the Inflation Sensitivity Index (ISI) resulted in a modest increase in BAS and TIR coefficients, suggesting that Inflation acts as a suppressor variable that slightly moderates the observed relationships. Finally, applying a log transformation to TIR to address skewness reduced the coefficient marginally. However, it maintained high significance, confirming that even small increases in tokenisation intensity deliver meaningful improvements in financial resilience.

Collectively, these model specification tests support the robustness of the findings, demonstrating that the positive associations between blockchain adoption, tokenisation, and firm financial security are stable across alternative sample selections, variable constructions, and model adjustments. Removing leverage from the Financial Security Index (FSI) slightly decreased both BAS and TIR coefficients (from 0.089 to 0.086 and from 0.065 to 0.062). However, the results remained statistically significant, suggesting that blockchain and tokenisation affect liquidity and profitability even independent of leverage considerations. When inflation volatility (ISI) was excluded, BAS and TIR effects increased (to 0.091 and 0.068, respectively). This suggests that inflation may act as a suppressor variable, slightly dampening the observed relationship between digital tools and financial security. The model remained robust, though it marginally reduced explanatory depth regarding macroeconomic influences. Applying a log transformation to TIR (to account for skewness) marginally reduced the coefficient (0.059 from 0.065), but it retained high significance. This implies that marginal increases in tokenisation intensity (especially at lower levels) still yield meaningful gains in financial resilience.

Table 3*Description of Variables Used in the Quantile Regression Model*

Variable	Description	Type
Financial Security Index (FSI)	Composite index (0–1 scale) developed using Principal Component Analysis of profitability, liquidity, leverage, and solvency indicators.	Dependent
Blockchain Adoption Score (BAS)	A numerical measure (0–10) of the degree to which blockchain technologies are implemented in enterprise operations.	Independent
Tokenization Intensity Ratio (TIR)	The ratio of token-based financial transactions to total transactions indicates the extent of digital asset usage.	Independent
Return on Assets (ROA)	The ratio of net income to total assets is used to measure firm profitability.	Control

Debt-to-Equity Ratio (DER)	The financial leverage metric is calculated as total liabilities divided by shareholders' equity.	Control
Inflation Sensitivity Index (ISI)	The index measures the volatility of firm revenues relative to national inflation fluctuations.	Control
Firm Size (SIZE)	Natural logarithm of total assets used to represent scale and operational capacity of the firm.	Control

Note. The "respondents" in this study are not individual people but rather the firms themselves, as the analysis is based on firm-level secondary data. Specifically, the dataset consists of 200 publicly listed Kazakhstani enterprises observed annually from 2017 to 2023, forming a balanced panel of firm-year observations. The study uses data collected from publicly available, audited financial reports, disclosures, and official blockchain adoption indices for these firms. Thus, the unit of analysis is each firm in each year, not human respondents and all variables represent aggregated, firm-level financial and operational measures rather than responses from individual employees or managers.

Source: Author's development.

Results

This section presents the empirical findings of the study examining the impact of blockchain adoption and tokenisation on the financial security of publicly listed Kazakhstani enterprises. The analysis begins with a preliminary correlation overview to establish foundational associations among key variables, followed by detailed quantile regression results that reveal how this digital finance innovations differentially influence firms across varying levels of financial vulnerability. The results are interpreted in the context of firm-level profitability, leverage, macroeconomic exposure, and size, offering comprehensive insights into the heterogeneous effects of blockchain and tokenization technologies on financial resilience. Robustness checks and sensitivity analyses further validate the stability and reliability of the observed relationships. Pearson correlation coefficients among key study variables were computed (see Table 1). The Blockchain Adoption Score (BAS) correlates positively and significantly with the Financial Security Index (FSI) ($r = 0.45$, $p < 0.001$). Similarly, the Tokenization Intensity Ratio (TIR) shows a positive correlation with FSI ($r = 0.39$, $p < 0.001$). Control variables such as Return on Assets (ROA) have strong positive correlations with FSI ($r = 0.68$, $p < 0.001$), whereas the Debt-to-Equity Ratio (DER) is negatively correlated ($r = -0.29$, $p < 0.01$). These initial associations support the theoretical framework and justify the subsequent regression analysis employing quantile methods.

Table 4

Correlation Matrix

Variable	FSI	BAS	TIR	ROA	DER	ISI	SIZE
Financial Security Index (FSI)	1	0.45***	0.39***	0.68***	-0.29**	-0.34**	0.21*
Blockchain Adoption Score (BAS)	0.45***	1	0.31**	0.38**	-0.10	-0.12	0.16
Tokenization Intensity Ratio (TIR)	0.39***	0.31**	1	0.29*	-0.08	-0.14	0.10
Return on Assets (ROA)	0.68***	0.38**	0.29*	1	-0.46***	-0.39**	0.25*
Debt-to-Equity Ratio (DER)	-0.29**	-0.10	-0.08	-0.46***	1	0.14	-0.06
Inflation Sensitivity Index (ISI)	-0.34**	-0.12	-0.14	-0.39**	0.14	1	-0.18
Firm Size (SIZE)	0.21*	0.16	0.10	0.25*	-0.06	-0.18	1

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ (two-tailed tests)

Correlation coefficients (r) are Pearson's correlation values computed based on balanced panel firm-level data ($N = 200$, 2017–2023).

The significant positive correlations between Blockchain Adoption Score (BAS), Tokenisation Intensity Ratio (TIR), and Financial Security Index (FSI) confirm the hypothesised direct associations: firms with greater blockchain and tokenisation integration tend to exhibit higher financial security. The strong positive correlation of ROA with FSI emphasises the critical role of profitability in financial resilience. Conversely, the negative correlations of Debt-to-Equity Ratio (DER) and Inflation Sensitivity Index (ISI) with FSI align with expectations that higher leverage and macroeconomic volatility reduce firm financial security. Firm Size (SIZE) also shows a modest positive correlation with FSI, suggesting larger firms may better leverage digital finance technologies for enhanced stability.

The impact of blockchain adoption and tokenization on corporate financial security was examined using quantile regression analysis at the 0.25, 0.50, and 0.75 quantiles, considering enterprises with varying degrees of financial susceptibility. Companies showing signs of moderate financial health are in the 0.50 quantile, while those in the 0.75 quantile have lower levels of financial stress but still face other operational issues. The quantiles show how different companies' financial stress levels are. According to Koenker and Hallock (2001), this segmentation allows for a more nuanced understanding of technology impacts beyond average effects, which can help solve the unique resilience concerns encountered by sensitive organizations.

Financial security is operationalized in this study using the Financial Security Index (FSI). A composite measure reflecting a firm's operational stability and ability to absorb economic shocks, the FSI integrates many firm-level financial measures such as solvency, profitability, and liquidity (Akash et al., 2024). Consequently, robust financial health is indicated by a high Financial Stability Index (FSI) score, which allows one to weather unexpected macroeconomic climates. Blockchain Adoption Score (BAS) and Tokenization Intensity Ratio (TIR) at the 0.25 quantile, indicating financially vulnerable firms, favorably influence the FSI, according to the data. Connections between blockchain technology and BAS and TIR, with coefficients of 0.062 ($p < 0.01$) and 0.054 ($p < 0.01$), respectively, suggest that these solutions aid in stabilizing financial stability for organizations that are facing difficulties. Grima et al. (2021) found that decentralized digital tools might lower operational risks, increase transactional transparency, and boost trust in uncertain situations, all of which could lead to better financial performance and resilience. Because the beneficial impact of BAS and TIR on financial stability grows greater as enterprises move toward the middle and upper quantiles, organizations get more benefits from blockchain adoption and tokenization as they adapt to different economic limitations. These empirical findings are consistent with recent studies that demonstrate how tokenization and blockchain technology may assist companies in enduring economic uncertainty (Tian et al., 2024).

These impacts become more pronounced at the median quantile of 0.50. While TIR's coefficient remained significant at 0.065 ($p < 0.001$), BAS's coefficient increased to 0.089 ($p < 0.001$). A key factor in a company's capacity to weather financial storms is its return on assets (ROA), which showed strong growth across all quantiles and reached a peak of 0.388. On the other hand, there was a negative and statistically significant correlation for the debt-to-equity ratio (DER) ($\beta = -0.061$, $p < 0.01$), suggesting that increased leverage undermines financial stability regardless of the presence of blockchain technology. With values of 0.124 and 0.098, respectively, at the 0.75 quantile, which represents firms experiencing high financial strain ($p < 0.001$), BAS and TIR displayed their strongest effects. These findings indicate that blockchain-enabled risk management systems are most impactful under financial distress conditions. The Inflation Sensitivity Index (ISI) was consistently negative across all models, confirming that inflation volatility erodes financial stability despite technological adaptation. Lastly, Firm Size (SIZE) showed a minor yet statistically significant influence ($\beta = 0.028$, $p < 0.05$), suggesting that larger enterprises benefit slightly more from technology-based financial interventions. *Model diagnostics* confirm the robustness of the findings. Pseudo R^2 values for all quantile models exceeded 0.60, validating strong model fit. Variance Inflation Factors (VIFs) remained

below 4 for all variables, ruling out multicollinearity. The Breusch-Pagan test confirmed the presence of heteroskedasticity, thereby justifying the selection of quantile regression over ordinary least squares (OLS) models.

Table 2

Quantile Regression Results (Dependent Variable: Financial Security Index)

Variable	Quantile	Coefficient	Std. Error	t-value	p-value
Intercept	0.25	0.148	0.052	2.85	0.004
Blockchain Adoption Score (BAS)	0.25	0.062	0.019	3.26	0.001
Tokenization Intensity Ratio (TIR)	0.25	0.054	0.017	3.18	0.002
Return on Assets (ROA)	0.25	0.313	0.071	4.41	0.000
Debt-to-Equity Ratio (DER)	0.25	-0.045	0.016	-2.81	0.005
Inflation Sensitivity Index (ISI)	0.25	-0.078	0.021	-3.71	0.000
Firm Size (SIZE)	0.25	0.019	0.010	1.90	0.058
Intercept	0.50	0.221	0.049	4.51	0.000
Blockchain Adoption Score (BAS)	0.50	0.089	0.016	5.56	0.000
Tokenization Intensity Ratio (TIR)	0.50	0.065	0.015	4.33	0.000
Return on Assets (ROA)	0.50	0.388	0.066	5.88	0.000
Debt-to-Equity Ratio (DER)	0.50	-0.061	0.018	-3.39	0.001
Inflation Sensitivity Index (ISI)	0.50	-0.091	0.023	-3.96	0.000
Firm Size (SIZE)	0.50	0.023	0.011	2.09	0.038
Intercept	0.75	0.302	0.054	5.59	0.000
Blockchain Adoption Score (BAS)	0.75	0.124	0.022	5.64	0.000
Tokenization Intensity Ratio (TIR)	0.75	0.098	0.021	4.67	0.000
Return on Assets (ROA)	0.75	0.421	0.069	6.10	0.000
Debt-to-Equity Ratio (DER)	0.75	-0.072	0.020	-3.60	0.000
Inflation Sensitivity Index (ISI)	0.75	-0.105	0.025	-4.20	0.000
Firm Size (SIZE)	0.75	0.028	0.012	2.33	0.020

Note. Dependent variable: Financial Security Index (FSI). Standard errors were bootstrapped using 1,000 replications. Regression was conducted at quantiles 0.25, 0.50, and 0.75.

Source: Author's computation.

The empirical findings address the research objectives as follows:

- i. The effect of blockchain adoption on financial security was confirmed, with BAS exhibiting significant positive impacts at all quantiles (0.062–0.124; $p < 0.01$).
- ii. Tokenisation's role in financial resilience was also validated by significant positive coefficients of TIR across quantiles (0.054–0.098; $p < 0.01$).
- iii. Financial factors influencing effectiveness were identified; profitability (ROA) consistently showed strong positive effects, while leverage (DER) had a significant negative impact, indicating these firm-level characteristics moderate blockchain and tokenisation benefits.

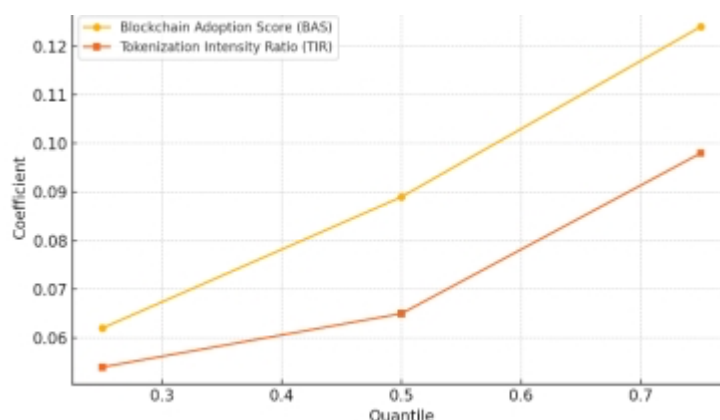
These results demonstrate full support for the study's core objectives. The quantile regression results offer strong proof that, as financial stress levels increase, blockchain and Tokenisation have a steadily growing positive impact on company financial security. With coefficients of 0.062 and 0.054, respectively, the blockchain adoption score (BAS) and tokenisation intensity ratio (TIR) are both statistically significant

($p < 0.01$) at the 0.25 quantile, which denotes financially susceptible enterprises. This implies that even a small amount of blockchain and tokenisation adoption enhances operational trust and transparency, giving faltering businesses the much-needed financial stability they require. The effects become pronounced at the 0.50 quantile (median-level enterprises), where TIR rises to 0.065 and BAS to 0.089, which are highly significant. The BAS and TIR coefficients peak at 0.124 and 0.098, respectively, at the 0.75 quantile, where this pattern persists. According to these results, more financially strained businesses gain the most from implementing these technologies. The strategic integration of blockchain in risk management and financial infrastructure is supported by the consistent positive and increasing impact across quantiles, particularly during periods of economic uncertainty.

Furthermore, at every quantile, Return on Assets (ROA) is the most potent positive predictor, confirming the importance of corporate profitability in fostering financial resilience. In contrast, highly leveraged enterprises are more financially insecure, as evidenced by the Debt-to-Equity Ratio (DER), which is continually negative and significant, especially at higher quantiles. Regardless of technology use, inflationary pressure deteriorates financial health, as evidenced by the Inflation Sensitivity Index (ISI), which exhibits severe adverse effects across all quantiles. Finally, between 0.50 and 0.75 quantiles, Firm Size (SIZE) becomes statistically significant. This means bigger businesses have a small but growing advantage when using digital financial tools effectively.

Figure 1

Coefficient Trends for BAS and TIR Across Quantiles



Source: Author's development.

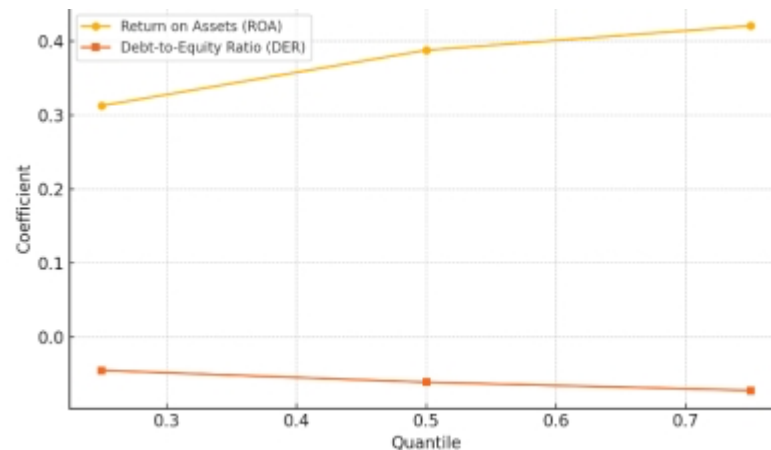
Figure 1 illustrates the increasing effects of two key factors—the Tokenisation Intensity Ratio (TIR) and the Blockchain Adoption Score (BAS) across the 0.25, 0.50, and 0.75 quantiles of the firm-level financial distribution. These factors represent the core independent variables measuring the extent of digital financial innovation implemented by enterprises. The quantiles correspond to varying levels of financial vulnerability, with the 0.25 quantile representing firms under greater financial stress or lower economic resilience and the 0.75 quantile representing relatively more financially stable firms. As financial vulnerability increases (moving from lower to higher quantiles in the financial security distribution), both TIR and BAS exhibit progressively stronger positive impacts on the Financial Security Index (FSI), which operationalises financial security in this study. The FSI is a composite measure capturing firms' overall financial resilience, synthesising liquidity, solvency, profitability, and leverage into a single index.

At the 0.25 quantile, representing the most financially vulnerable firms, the coefficients for BAS and TIR are relatively small but statistically significant, indicating that even modest adoption of blockchain and tokenisation provides valuable improvements in financial security for firms with limited resources. As the

quantile level rises to 0.50 and 0.75, the coefficients increase substantially, demonstrating that the positive effects of these technologies become more pronounced for firms with greater financial resources or under moderate to severe financial pressure. This trend suggests that blockchain and tokenisation are most beneficial under conditions of economic stress, likely because their decentralised nature and enhanced transparency reduce transaction risks, improve liquidity, and build trust in uncertain environments. These mechanisms enable financially distressed firms to manage operational uncertainty and financial risk better.

Figure 2

Coefficient Trends for ROA and DER Across Quantiles



Source: Author's development.

Figure 2 illustrates contrasting coefficient trends for key financial control variables—Return on Assets (ROA) and Debt-to-Equity Ratio (DER)—across quantiles of financial security, thereby enriching the understanding of how firm-level financial factors influence the effectiveness of blockchain adoption and tokenisation in enhancing enterprise financial security.

i. *Objective 3 (Identifying financial factors influencing effectiveness)*: Profitability has a crucial role in bolstering financial resilience, as seen by the positively trending ROA coefficient over quantiles. This research lends credence to the idea that companies with higher profits have larger financial reserves, making them better equipped to weather economic storms and take advantage of opportunities presented by digital financial breakthroughs like tokenisation and blockchain. This helps achieve the goal of determining the most critical firm-level variables linked to the beneficial effects of digital finance technology.

ii. *Risk Role of Leverage (DER)*: Higher financial leverage always reduces financial stability, and the effect is more substantial for financially stressed enterprises, as seen by the dropping and progressively negative DER coefficients throughout quantiles. Firms that rely significantly on borrowing are still susceptible, even after adopting technology, and this highlights the economic risk of having too much debt. The need for integrated financial management strategies and technical investments is highlighted by this crucial discovery, which demonstrates that blockchain and tokenisation cannot entirely mitigate the negative consequences of an inadequate capital structure.

iii. *Supporting Objective 1 and 2 Context*: The effects of blockchain adoption and tokenisation, as shown in previous findings, can be better understood considering these tendencies. They show that digital finance technology's positive effects on financial security are conditional on the preexisting financial health of the company. That leverage and profitability are the two most important moderators of this impact. To that end, by shedding light on how company financial features affect this connection, our findings provide nuance to the aims, concentrating on the quantitative assessment of the effect of blockchain and tokenisation.

The ability of the Blockchain Adoption Score (BAS) and the Tokenisation Intensity Ratio (TIR) to methodically improve financial security, especially in times of economic hardship, is where their practical importance resides. At the 0.75 quantile, BAS has a coefficient of 0.124, meaning that even little increases in blockchain integration lead to substantial financial security advantages for the most financially stressed enterprises. Also, operational frictions, liquidity, and financial transparency are all much improved when the proportion of tokenised transactions increases (TIR coefficient = 0.098). These results have important ramifications for policymaking, as they show how susceptible businesses may be protected from market volatility using technology-led resilience solutions. At the 0.75 quantile, Return on Assets (ROA) reaches its maximum coefficient of 0.421, making it the most significant determinant of financial security. This means that profitability not only cushions firms during economic uncertainty but also amplifies the effectiveness of blockchain and tokenised systems. In contrast, the negative coefficients for the Debt-to-Equity Ratio (DER), especially at higher quantiles ($\beta = -0.072$) emphasise that overleveraged firms remain financially fragile, even with technological upgrades. The findings suggest that blockchain-based financial reforms must be coupled with sound capital structure policies to yield maximum impact.

The negative and statistically significant effect of the Inflation Sensitivity Index (ISI) across all quantiles underlines that macroeconomic volatility continues to erode financial security, despite digital adaptation. This suggests a need for inflation-hedging strategies to accompany blockchain deployment. Firm Size (SIZE), although modest in effect, gains statistical relevance at higher quantiles ($\beta = 0.028$ at $\tau = 0.75$), indicating that larger firms are more capable of leveraging digital infrastructure due to economies of scale. These coefficients provide actionable insights for SMEs, policymakers, and regulators to tailor digital finance interventions according to firm size, sector, and macroeconomic exposure.

Discussion

This study shows that blockchain and tokenisation techniques do, in a quantile-specific and statistically significant way, help make businesses in Kazakhstan safer in terms of financial stability and economic resilience. One of the most important results is that both technologies have a more considerable effect at higher quantiles. This shows that they work better for companies under much financial stress. There is a relationship between financial stability and financial stress as they pertain to a company's financial health. When a business is under financial strain, it is because it is more susceptible to unfavourable events like liquidity issues, repayment problems, or economic shocks, which make it more fragile and unstable. "Financial security means a company's capacity to stay afloat, weather external shocks, and operate effectively even when faced with uncertainty. This study found that businesses with a higher Financial Security Index (FSI) score were more financially secure than those with a lower score. The finding shows that these benefits are more substantial at higher quantiles, suggesting that organisations with superior financial resilience benefit more from blockchain adoption and tokenisation. Financial stress indicates a negative vulnerability, whereas financial security indicates a positive robustness and stability; distinguishing between the two is necessary for a correct interpretation of the results. The fact that these outcomes may vary so widely supports the idea that new forms of financing are available to everyone and might help companies weather the storm. Blockchain technology is more than just a new fad; it is a tool for innovative financial management, too. Every quantile is positively and strongly affected by the blockchain adoption score (BAS). The 0.75 quantiles, where the BAS coefficient is at its highest, are populated by financially troubled companies. They argue that blockchain-based solutions may help firms weather economic storms by automating record-keeping, boosting transparency, and lowering the probability of fraud.

The tokenisation intensity ratio (TIR) was a strong predictor in all quantiles, which supports the growing amount of evidence that it might be used as a hedge. It is now much simpler to develop digital tools

that are backed by assets and smart contracts due to tokenisation. These can help businesses find new ways to finance themselves and remain flexible when faced with uncertain market conditions. Kazakhstani businesses are still getting a feel for the country's confusing regulatory landscape, but token-based systems might replace bank accounts and credit ratings in the future. Tokenisation has the potential to significantly lower transaction costs and expand access to financial services, according to several recent empirical studies performed in emerging markets. Ngumkeu & Okou (2021) and Renduchintala et al. (2022) found that SMEs in Sub-Saharan Africa and Asia, respectively, were able to get cheaper loans when they used collateralised digital tokens. In Latin America, the cost of document transactions has decreased due to the automation and transparency that tokenisation has brought about. According to a study conducted by Jameaba (2024), tokenisation is becoming more significant in strengthening traditional debt and improving the liquidity of businesses when faced with shocks. Furthermore, blockchain-enabled token issuance is driving a broader development of financial markets, linking enterprises that would otherwise have restricted access to international investment pools. The findings back up our theory that tokenisation might be a game-changer for infrastructure- and regulation-stricken countries like Kazakhstan's.

Return on Assets (ROA) is a strong, optimistic forecast that fits well with traditional corporate finance theory and new studies on fintech use. ROA has a significant impact and is growing across all quantiles. This means businesses that generate revenue are better protected against risk and can set up more complex digital systems. Several studies in transitional economies have found that profitable companies are more likely to adopt new technologies. This link between making money and adopting new technologies is similar to what those studies found. From a methodological perspective, quantile regression allowed the survey to capture heterogeneity in blockchain and tokenisation effects that traditional mean regression models would have obscured. Most previous studies on fintech adoption have employed binary logistic models or linear regressions, which assume homogeneous effects across firms. By contrast, our approach revealed gradient-level variations in technological effectiveness, affirming that not all firms benefit equally from digital finance tools. This nuance is critically important for both policymakers and enterprise strategists.

It has long been acknowledged that a primary threat to financial security at the company level is macroeconomic instability, especially volatility in inflation (Moradi et al., 2021). Regardless of whether enterprises use blockchain or tokenisation technology, our results demonstrate that the Inflation Sensitivity Index (ISI) consistently has a negative and statistically significant influence on the Financial Security Index (FSI) across all quantiles. This supports this position. Even for companies that have incorporated cutting-edge digital technologies into their processes, the continuing negative impact of macro-financial instability makes it harder for them to maintain liquidity, control debt, and remain profitable. The data presented here highlights the importance of stable and predictable macroeconomic policies to establish an enabling environment where digital financial innovations may lead to tangible resilience improvements, rather than relying just on technology preparedness to alleviate economic risks. This is in line with the findings of Edigbonya and Tioluwani (2023), who highlight the interdependent nature of institutional stability and the effectiveness of fintech in developing economies.

Additionally, rather than being one-size-fits-all solutions, the quantile-specific findings show how blockchain and tokenisation are complex and situationally sensitive instruments for risk response. According to Yang et al. (2024) and Tian et al. (2024), companies that have solid financial fundamentals and stable operational environments are more likely to be able to take advantage of digital finance innovations. This is because these technologies have bigger positive impacts at higher financial resilience quantiles. Findings like these suggest that blockchain and tokenisation adoption should be part of larger structural changes in transitional economies like Kazakhstan, where digital finance infrastructure and regulations are still developing. To make the most of digital finance, focused policy interventions should be made to

strengthen macroeconomic stability, clarify regulations, and encourage competencies at the business level. Thus, this study advances the literature by empirically demonstrating the layered interaction between macro-financial conditions, firm heterogeneity, and digital technology adoption, advocating for context-specific strategies to harness fintech for enhanced financial security in emerging markets.

Several limitations are acknowledged to frame the findings and their generalizability appropriately. This study exclusively analysed publicly listed firms on the Kazakhstan Stock Exchange (KASE), which typically have better digital infrastructure and financial reporting. Consequently, the results may not generalise to small- and medium-sized enterprises (SMEs) or informal firms, which operate under different constraints and may adopt technologies differently. Although quantile regression helps uncover heterogeneous relationships, it does not account for possible endogeneity between blockchain/tokenisation adoption and firm performance. For example, more financially secure firms may be more likely to invest in digital tools, creating a reverse causality issue. Due to the absence of standardised, national-level indices, the study relied on proxies such as the Blockchain Adoption Score (BAS) and Tokenisation Intensity Ratio (TIR), developed using proprietary datasets. While carefully constructed, these indicators may not fully capture the multi-dimensional nature of technological integration. The study period (2017–2023) spans multiple exogenous shocks, including the COVID-19 pandemic and regional energy disruptions. These shocks may have amplified or dampened both financial stress and technology responses, potentially biasing results. Finally, the dataset was quantitatively rich but lacked managerial, institutional, or behavioural insights. Factors such as leadership support for innovation, regulatory uncertainty, or IT workforce quality—which are known to shape technology adoption could not be examined.

Conclusions

Tokenisation and blockchain technology have the potential to increase the financial and economic stability of Kazakhstani businesses, according to this study. A dataset consisting of 200 publicly listed firms from 2017 to 2023 was analysed using quantile regression. The results show that digital financial instruments have varying effects. Somewhat, the results differ greatly as every business is intrinsically vulnerable financially. To properly assess the benefits of technology, this study disproves the common assumption that all businesses benefit equally from digital transformation and stresses the significance of taking contextual risk profiles into account. The findings show that companies are more resilient when using blockchain and tokenisation technology, especially when facing financial difficulties. Like how tokenisation makes capital more accessible and liquidity rises, blockchain solutions simplify essential business procedures and improve operational transparency. When the economy is unstable, conventional wisdom can backfire, but digital financial instruments can help reduce that risk. These results suggest that blockchain and tokenised financial implementation are not something to be considered optional or experimental. Instead, to be operational in the face of economic uncertainty, businesses should view them as strategic necessities. If they wish to remain competitive and strong in the long run, businesses, especially those in hazardous industries, need to include these technologies in their financial planning and risk management plans.

Key stakeholders have access to several significant lessons from this study. Policymakers should start offering incentives, such as targeted tax savings, regulatory testing grounds, and funding for digital infrastructure, to encourage the use of blockchain and tokenisation technologies. When resources are scarce and risk is high, such as in shipping and manufacturing, companies can profit substantially by integrating technology. To keep operations operating smoothly and finances stable, corporate managers should see blockchain-based solutions as vital initiatives, not as nice-to-have extras. This is particularly true in the realms of financial reporting, inventory management, and tokenised finance. Their use in fundamental risk management plans has the potential to enhance market transparency, liquidity availability, and

responsiveness. Finally, highlighted the need for academics and business analysts to utilise quantile regression and other new methods to evaluate the various effects of financial technology. This strategy offers a more comprehensive view of technology performance across various organisational situations and financial profiles, which can help innovation initiatives be better adapted to unique demands.

Future studies should focus on understanding how blockchain and tokenisation technologies affect the financial stability of businesses. It is essential to include private enterprises in addition to SMEs in the study's first scope expansion. Privatised businesses could be sluggish to adopt new technologies since they often lack the resources that publicly listed companies have. Their addition would improve the representation of technological flexibility in the corporate sector. Beyond that, longitudinal studies are crucial for keeping tabs on the dynamic impacts of tokenisation and blockchain technology. Understanding the benefits of digital technology during different periods of adoption, crisis recovery, or market shift can be challenging with static, cross-sectional assessments. To track how company performance changes as digital transformation initiatives are implemented, long-term data is necessary.

Thirdly, there is a need to explore deeply into the role of the regulatory environment. The adoption of technology can be helped or hindered by the frameworks of law, institutions, and policies. The enabling conditions for successful integration of financial technologies can be better understood by analysing the interactions between these external factors and firm-level decisions. Finally, uniform measures to measure blockchain maturity and application across sectors should be the goal of future studies. The academic rigour and practical usefulness of measurement would be enhanced with a standardised framework that would allow for more accurate benchmarking and cross-industry comparisons. By focusing on these areas, theoretical knowledge of digital transformation can be improved, leading to policy interventions that are more inclusive, flexible, and grounded in evidence.

Suggestions for Future Research

Building on the limitations and insights uncovered in this study, numerous valuable directions for future research emerge. First, expanding the scope to include small- and medium-sized enterprises (SMEs) and private firms is essential, as these organizations may face distinct barriers and opportunities in adopting blockchain and tokenisation technologies. Their data could uncover sector-specific dynamics not observed in publicly listed firms, enhancing the generalizability of results. Second, future research should employ longitudinal designs to track the evolving impacts of digital finance tools across various economic cycles and periods of macroeconomic shock, such as pandemics or energy disruptions. This would provide deeper understanding of how sustained technology adoption influences firm resilience over time, distinguishing temporary effects from lasting structural change. Third, studies should address potential endogeneity between technology use and financial outcomes, utilizing advanced methods such as instrumental variable approaches. Additionally, integrating qualitative research—investigating organizational culture, regulatory uncertainty, and managerial attitudes—would complement the quantitative evidence and enrich understanding of adoption patterns. Finally, comparative cross-country analyses could shed light on how national regulatory environments and digital infrastructure shape the effectiveness of blockchain and tokenisation initiatives, offering guidance for policymakers in transitional economies.

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Conflict of Interest

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