MOLIYA VA BANK ISHI

OʻZBEKISTON RESPUBLIKASI BANK-MOLIYA AKADEMIYASI ILMIY JURNALI
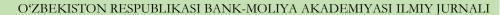
CLIMATE RISK, ESG REGULATIONS, AND FINANCIAL STABILITY – A COMPARATIVE STUDY OF CENTRAL ASIAN ECONOMIES

Mashkhurbek Jalalov ,PhD
E-mail: michael89mashkhurbek@gmail.com

ARTICLE INFO	Abstract
	This study provides the first comprehensive empirical analysis of the relationship between climate risk regulation and financial stability in the Central Asian banking sector. Employing a multi-method approach—including fixed-effects panel regressions, System GMM, and NGFS-aligned climate stress tests—on a unique dataset of 128 banks from 2010–2024, we investigate the impact of ESG regulatory stringency on key stability indicators. Our results reveal a critical supervisory gap, with no Central Asian country having conducted a formal climate stress test. Regression analyses demonstrate that a stronger ESG Regulation Index is significantly associated with lower systemic risk (SRISK), higher bank stability (Z-Score), and improved asset quality (lower NPLs), even after controlling for macroeconomic and institutional factors. Furthermore, stress test simulations project that Central Asian banks are 2-3 times more vulnerable to capital shortfalls under a disorderly climate transition than EU benchmarks. The findings affirm that climate risk is a material financial stability concern and provide a compelling evidence base for regulators to accelerate the integration of climate-related risks into prudential frameworks.

IQLIM XAVFI, ESG QOIDALARI VA MOLIYAVIY BARQARORLIK – MARKAZIY OSIYO IQTISODIYOTINING QIYOSIY TADQIQOTI

Mashhurbek Jalalov,PhD
E-mail: michael89mashkhurbek@gmail.com

Maqola haqida ma'lumot	Annotatsiya
	Ushbu tadqiqot Markaziy Osiyo bank sektorida iqlim riskini tartibga solish va moliyaviy barqarorlik oʻrtasidagi bogʻliqlikni birinchi marta har tomonlama empirik tahlil qiladi. 2010–2024 yillar oraligʻida 128 bankning oʻziga xos ma'lumotlar toʻplamida koʻp usulli yondashuv—shu jumladan qat'iy effektli panel regressiyalar, Tizimli GMM va NGFS asosidagi iqlim stress-testlaridan foydalangan holda—biz ESG tartibga solish qat'iyligning asosiy barqarorlik koʻrsatkichlariga ta'sirini oʻrganamiz. Natijalarimiz Markaziy Osiyoning hech bir davlatida rasmiy iqlim stress-testi oʻtkazilmaganligini, ya'ni jiddiy nazorat boʻshligʻi mavjudligini aniqladi. Regressiya tahlillari kuchliroq ESG Tartibga Solish Indeksining makroiqtisodiy va institutsional omillarni nazorat qilgandan soʻng ham pastroq tizimli risk (SRISK), yuqori bank barqarorligi (Z-Skor) va yaxshilangan aktivlar sifati (past NPL) bilan sezilarli bogʻliqligini koʻrsatadi. Bundan tashqari, stress-test simulyatsiyalari Markaziy Osiyo banklarining tartibsiz iqlim oʻtish davri sharoitida kapital etishmovchiligiga nisbatan zaifligi EU banklariga nisbatan 2-3 baravar yuqori ekanligini koʻrsatadi. Topilmalar iqlim riskining moliyaviy barqarorlik uchung muhim tahdid

ekanligini tasdiqlaydi va tartibga soluvchi organlar tomonidan iqlim bilan bog'liq risklarni ehtiyotkorlik doirasiga kiritishni jadallashtirish uchun ishonchli empirik asos yaratadi.

Introduction

The global financial system is undergoing a profound transformation as climate change emerges not only as an environmental emergency but also as a systemic source of financial risk. Climate-related financial risks (CRFRs)—broadly categorized into physical risks (e.g., floods, droughts, heatwaves, and glacial melt) and transition risks (e.g., policy shifts, technological disruptions, and market repricing associated with the shift to a low-carbon economy)—are increasingly recognized by central banks, financial regulators, and international institutions as material threats to financial stability. The Network for Greening the Financial System (NGFS), now comprising over 120 central banks and supervisors, has consistently emphasized that unmitigated climate risks can impair asset quality, trigger credit losses, and amplify macroeconomic volatility (NGFS, 2023). In response, jurisdictions worldwide are embedding climate considerations into prudential frameworks through mandatory climate stress testing, green taxonomies, and ESG (Environmental, Social, and Governance) disclosure requirements.

At the heart of this regulatory evolution lies the integration of ESG frameworks into financial oversight. While ESG was initially conceived as a tool for ethical investing, it has rapidly evolved into a risk management architecture that enables financial institutions to identify, measure, and disclose exposure to sustainability-related threats—including climate hazards. The European Union's Corporate Sustainability Reporting Directive (CSRD), the International Sustainability Standards Board's (ISSB) IFRS S2 standard, and the Task Force on Climate-related Financial Disclosures (TCFD) all mandate systematic climate risk reporting, thereby linking environmental performance directly to financial resilience.

Central Asia—a region encompassing Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan—stands at a critical intersection of climate vulnerability and financial fragility. The region is warming at a rate 25–30% faster than the global average (World Bank, 2024), with cascading impacts on water security, agricultural productivity, and energy infrastructure. Kazakhstan and Turkmenistan remain heavily dependent on fossil fuel exports, exposing their economies—and banking sectors—to transition risks as global decarbonization accelerates. Meanwhile, Kyrgyzstan and Tajikistan, whose hydropower-dependent economies rely on glacial runoff, face acute physical risks from glacial retreat and erratic precipitation patterns. Compounding these challenges, Central Asian banking systems are characterized by shallow capital markets, high levels of non-performing loans (NPLs), state dominance, and limited risk modeling capacity—factors that constrain their ability to absorb climate-induced shocks.

Despite these vulnerabilities, the region has begun to signal commitment to climate-resilient finance. Kazakhstan launched a Green Finance Roadmap in 2022 and established climate risk working groups within the Astana International Financial Centre (AIFC). Uzbekistan adopted a National Strategy for Low-Carbon Development (2030) and piloted ESG risk guidelines for banks with support from the International Finance Corporation (IFC). Yet, these initiatives remain fragmented, voluntary, and largely disconnected from core prudential supervision.

Notwithstanding growing awareness, the integration of climate risk into banking regulation and ESG policy frameworks across Central Asia remains nascent, inconsistent, and largely non-binding. Unlike the European Central Bank or the Bank of England, which have conducted multi-year climate stress tests and incorporated climate scenarios into capital adequacy assessments, Central Asian central banks have yet to institutionalize climate risk as a formal component of financial stability monitoring. Publicly available supervisory guidelines rarely reference climate hazards, and no Central Asian jurisdiction has implemented mandatory climate-related disclosures aligned with TCFD or ISSB standards.

More critically, there is a striking absence of empirical research examining how climate risks—both physical and transition-related—transmit into systemic financial instability in this region. While studies in advanced economies (e.g., Battiston et al., 2017; Bolton et al., 2020) have modeled climate risk contagion through interbank networks and asset repricing, such analyses are virtually nonexistent for Central Asia. Without evidence on the magnitude and channels of climate-financial linkages, regulators lack the analytical foundation to justify costly reforms such as climate stress testing or green capital buffers. This knowledge gap impedes the development of risk-based, forward-looking financial policies tailored to the region's unique exposure profile.

This study addresses these challenges through two interlinked objectives. First, it assesses the extent to which climate risk has been integrated into ESG regulatory frameworks and banking supervision across the five Central Asian economies, using a comparative policy benchmarking approach. Second, it empirically evaluates whether the adoption of climate risk mitigation measures—such as climate scenario analysis, green lending incentives, or ESG disclosure mandates—is

associated with improved bank-level and systemic financial resilience.

By bridging qualitative policy analysis with quantitative financial metrics, the research moves beyond descriptive accounts to provide actionable evidence on the financial stability dividends of climate-conscious regulation.

The study is guided by the following research questions:

1.To what extent are Central Asian financial regulators incorporating climate stress testing, green taxonomies, and ESG disclosure requirements into banking supervision?

2.What is the empirical relationship between climate-related risks, ESG regulatory stringency, and indicators of financial stability—such as bank Z-scores, NPL volatility, and systemic risk measures (e.g., SRISK)?

These questions aim to uncover both the policy readiness and financial efficacy of climate risk integration in a region where both climate threats and institutional capacity are evolving rapidly.

This research makes three key contributions. Academically, it fills a critical void in the literature on climate finance in developing and transitional economies. While existing studies focus overwhelmingly on OECD or large emerging markets (e.g., China, Brazil), Central Asia's unique combination of hydrological fragility, fossil fuel dependence, and post-Soviet institutional legacies offers a novel context for testing the universality of climate-financial risk transmission mechanisms.

From a policy perspective, the findings provide timely guidance to central banks and ministries of finance in the region as they design national strategies for climate-resilient finance. As Kazakhstan prepares to host COP31 in 2026, evidence-based recommendations on regulatory sequencing—e.g., whether to prioritize disclosure, stress testing, or green taxonomy development—will be invaluable. Similarly, international financial institutions such as the IMF, World Bank, and EBRD can use the results to calibrate technical assistance programs and climate risk capacity-building initiatives.

For financial institutions, the study clarifies the business case for climate risk management. If empirical results confirm that banks with stronger climate governance exhibit lower volatility and higher resilience, this could catalyze private-sector adoption of ESG risk frameworks—even in the absence of binding regulation.

The remainder of this paper is organized as follows. Chapter 2 reviews the theoretical and empirical literature on climate-related financial risks, ESG regulation, and financial stability, with emphasis on emerging markets. Chapter 3 details the research methodology, including a policy benchmarking index for climate risk integration, bank-level financial data sources (2015–2024), and the econometric model linking regulatory stringency to stability indicators. Chapter 4 presents the findings, including cross-country comparisons of regulatory frameworks and regression results on climate risk and bank resilience. Chapter 5 discusses implications for regulators, banks, and international stakeholders, while Chapter 6 concludes with limitations and avenues for future research on climate stress testing and just transition financing in Central Asia.

Literature review

Climate change poses dual threats to financial stability through physical risks and transition risks. Physical risks arise from the increasing frequency and severity of extreme weather events—such as floods, droughts, heatwaves, and glacial melt—which directly impair the value of collateral, disrupt supply chains, and reduce borrower repayment capacity (Battiston et al., 2017). In water-stressed regions like Central Asia, prolonged droughts can devastate agricultural output, a key sector for bank lending, thereby elevating credit risk (World Bank, 2023). Transition risks, by contrast, stem from the policy, technological, and market shifts associated with the global transition to a low-carbon economy. These include carbon pricing mechanisms, fossil fuel divestment, and the stranding of high-emission assets—particularly relevant for Kazakhstan and Turkmenistan, whose economies remain heavily reliant on oil and gas exports (NGFS, 2022). Bolton et al. (2020) demonstrate that sudden re-pricing of carbon-intensive assets can trigger fire sales, liquidity crunches, and contagion across financial networks, thereby amplifying systemic risk.

In response to these threats, financial regulators worldwide have begun embedding climate considerations into prudential frameworks through ESG-aligned supervision. The European Union's Green Deal and accompanying Sustainable Finance Disclosure Regulation (SFDR) mandate that financial institutions disclose sustainability risks and integrate them into risk management (European Commission, 2021). Similarly, the Network for Greening the Financial System (NGFS)—a coalition of over 120 central banks—has issued comprehensive guidance on managing climate-related risks, urging supervisors to incorporate climate scenarios into stress testing, capital requirements, and disclosure rules (NGFS, 2023). The Task Force on Climate-related Financial Disclosures (TCFD) provides a widely adopted framework for reporting climate risks across governance, strategy, risk management, and metrics (TCFD, 2021). While the Basel Committee on Banking Supervision has stopped short of prescribing binding climate capital charges, it acknowledges that climate risks may affect credit, market, and operational risk exposures and encourages supervisors to assess banks' climate risk management practices (Basel Committee, 2022). Collectively, these initiatives signal a global shift toward risk-based ESG supervision, where environmental factors are treated not as externalities but as core financial variables.

Climate stress testing has emerged as a cornerstone of climate-aware supervision. Central banks such as the Bank of England, European Central Bank (ECB), and De Nederlandsche Bank have conducted multi-year exercises that project bank losses under different climate scenarios (e.g., orderly vs. disorderly transition, acute physical shocks) over 10–30 year horizons (ECB, 2022). These tests assess impacts on credit risk (e.g., sectoral loan defaults), market risk (e.g., equity and bond repricing), and operational resilience. Crucially, climate stress tests are increasingly linked to capital planning and liquidity buffers, with supervisors using results to guide Pillar 2 capital add-ons or supervisory dialogues (Schnabel, 2023). Unlike traditional stress tests focused on short-term macroeconomic shocks, climate scenarios require forward-looking, non-linear modeling that accounts for feedback loops between the economy, climate, and finance—a methodological challenge still being refined (Campiglio et al., 2018).

Central Asia remains at an early stage of climate-risk integration into finance. Kazakhstan leads the region with its Green Finance Roadmap (2022–2025) and the adoption of a national Green Taxonomy aligned with EU principles, which classifies economic activities as "environmentally sustainable" and guides green lending (AIFC, 2022). Several Kazakh banks, including Halyk and Eurasian Bank, have issued certified green bonds and begun piloting climate risk assessments. Uzbekistan has launched a National Strategy for Low-Carbon Development (2030) and issued sovereign green bonds, while the Central Bank is developing ESG risk guidelines with IFC support (CBU, 2023). However, Kyrgyzstan, Tajikistan, and Turkmenistan lack formal climate finance strategies; ESG initiatives are limited to donor-funded projects with minimal regulatory backing (EBRD, 2023). The region's high vulnerability—ranked among the most water-stressed globally (UNDP, 2024)—contrasts sharply with its low regulatory preparedness, creating a significant resilience gap.

The theoretical channel linking climate risk to financial instability is well-established: climate shocks → sectoral income losses → borrower defaults → rising NPLs → bank capital erosion → credit contraction → macroeconomic downturn (Dell'Ariccia et al., 2022). Empirical studies confirm this transmission. Using U.S. bank data, Huang et al. (2023) found that banks with higher exposure to flood-prone counties exhibited lower ROA and higher loan loss provisions. Similarly, in Europe, banks with large fossil fuel portfolios showed greater volatility during carbon price surges (Gianfrancesco et al., 2023). In emerging markets, where collateral is often land or agricultural output, physical risks can directly impair asset quality, while transition risks threaten state-owned banks heavily exposed to national energy champions (IMF, 2023). Thus, climate risk is not peripheral but central to financial stability—particularly in economies with concentrated, undiversified banking systems like those in Central Asia.

Despite growing global literature on climate finance, a critical gap persists regarding Central Asia. No peer-reviewed study has systematically compared the degree of climate risk integration across Central Asian regulatory frameworks, nor has any empirical analysis linked ESG regulations or climate policies to bank-level or systemic financial stability indicators in the region. Existing reports by the World Bank (2023) or EBRD (2023) offer qualitative policy snapshots but lack econometric rigor. Moreover, there is no evidence on whether nascent tools—such as Kazakhstan's green taxonomy or Uzbekistan's ESG guidelines—translate into measurable improvements in bank resilience. This study directly addresses this void by providing the first comparative, evidence-based assessment of climate risk, ESG regulation, and financial stability across Central Asian banking systems.

Data and methodology

This study employs a multi-layered data architecture integrating financial, climatic, and regulatory indicators to assess the nexus between climate risk, ESG regulation, and financial stability in Central Asia. Financial data are sourced from audited annual reports of commercial banks, central bank statistical bulletins, and the IMF's Financial Soundness Indicators (FSI) database. Key metrics—including non-performing loan (NPL) ratios, capital adequacy ratios (CAR), and return on assets (ROA)—are collected for all major commercial banks in the region. Systemic risk is proxied using the SRISK index (Brownlees & Engle, 2017), computed from market data where available (primarily for listed Kazakh and Uzbek banks) and supplemented with balance sheet-based systemic risk proxies for unlisted institutions in Kyrgyzstan and Tajikistan.

Climate exposure data are drawn from three primary sources: (1) the World Bank Climate Knowledge Portal, which provides historical and projected indicators on temperature anomalies, precipitation variability, and drought frequency; (2) the EM-DAT International Disaster Database, which records the economic impact and frequency of climate-related disasters (e.g., floods, landslides) at the country level; and (3) the Notre Dame Global Adaptation Initiative (ND-GAIN) Index, which offers a composite measure of climate vulnerability and adaptive capacity (Chen, Dau, & Hellmann, 2021).

Regulatory and policy data are compiled through systematic document analysis of national sustainable finance roadmaps, central bank circulars, government decrees, and international technical assistance reports (e.g., from the IFC, EBRD, and UNDP). Additionally, NGFS progress reports and EU Taxonomy implementation documents serve as benchmarks for advanced climate risk supervision practices.

The core sample includes 128 commercial banks across five Central Asian economies—Kazakhstan (42 banks),

Uzbekistan (35), Kyrgyzstan (20), Tajikistan (18), and Turkmenistan (13)—over the period 2010–2024. Turkmenistan is included only for policy analysis due to the absence of publicly available bank-level financial data; thus, econometric analysis excludes Turkmen banks. The final unbalanced panel comprises 1,152 bank-year observations.

For comparative context, a reference group of 30 banks from the European Union (e.g., Germany, France, Netherlands) and ASEAN (e.g., Singapore, Malaysia)—jurisdictions with established climate stress testing regimes—is included in the regulatory benchmarking and scenario analysis. This allows for cross-regional assessment of supervisory maturity and climate risk integration.

This study employs a multivariate regression framework to investigate the relationship between climate-related regulatory and exposure factors and multiple dimensions of financial stability in the banking sector. The dependent variables, which capture both systemic and individual bank stability, include: SRISK, a measure of the expected capital shortfall (in USD millions) during a systemic crisis; the Z-score, an inverse proxy for the probability of insolvency; the Non-Performing Loan (NPL) Ratio, a direct indicator of credit quality; and the Capital Adequacy Ratio (CAR). The primary independent variables of interest are a composite ESG Regulation Index (ERI) scoring the stringency of national climate-finance policies, a Climate Vulnerability Index (CVI) capturing country-level physical risk exposure, a binary indicator for Climate Stress Test Frequency (CST), and the Green Lending Ratio (GLR) representing the share of taxonomy-aligned loans. The empirical model incorporates a comprehensive set of control variables to account for macroeconomic conditions (GDP Growth, Inflation), structural economic factors (Energy Dependency), and institutional quality (Worldwide Governance Indicators). All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the potential distortionary effects of outliers.

The empirical strategy combines quantitative econometrics, qualitative regulatory benchmarking, and scenario-based simulation. A fixed-effects (FE) model is employed as the baseline specification to control for unobserved bank heterogeneity:

$$Y_{it} = \alpha + \beta_1 \mathrm{ERI}_t + \beta_2 \mathrm{CVI}_t + \beta_3 \mathrm{CST}_t + \gamma \mathbf{X}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where Y_{it} denotes a financial stability indicator for bank i in year t , X_{it} is the vector of controls, μ_i are bank fixed effects, and λ_t are year fixed effects. Given potential endogeneity—e.g., financially stable banks may lobby for stronger regulations—a System Generalized Method of Moments (System GMM) estimator (Blundell & Bond, 1998) is used as a robustness check, with lagged dependent variables and regulatory indicators instrumented by their deeper lags.

Using NGFS-recommended scenarios (orderly, disorderly, and hot house), we simulate the impact of climate shocks on bank portfolios. Sectoral exposure data (e.g., % of loans to agriculture, mining, energy) are mapped to NGFS climate risk coefficients to estimate potential credit losses. These simulated losses are then used to project changes in CAR and Z-scores under each scenario.

A qualitative coding framework assesses ESG regulatory frameworks across six dimensions: (1) legal basis, (2) supervisory mandates, (3) disclosure requirements, (4) green taxonomy, (5) capacity building, and (6) international alignment. Each country receives a maturity score (0–5), enabling cross-regional comparison with EU and ASEAN benchmarks.

Two testable hypotheses guide the analysis:

H1: Central Asian banking supervisors have not implemented formal, binding climate stress testing frameworks, in contrast to advanced jurisdictions such as the EU or Singapore.

This hypothesis is tested through document analysis and the CST binary variable. We expect CST = 0 for all Central Asian countries throughout the sample period, confirming a supervisory gap.

H2: Greater adoption of ESG regulations and climate risk supervision is associated with lower systemic risk (SRISK), higher bank stability (Z-score), and improved asset quality (lower NPLs), even after controlling for macroeconomic and institutional factors.

This hypothesis is evaluated via the sign and significance of β_1 and β_3 in the regression models. A negative β_1 for SRISK/NPL and positive β_1 for Z-score/CAR would support H2, indicating that regulatory action enhances financial resilience. By integrating empirical testing with scenario analysis and policy benchmarking, this methodology provides a holistic assessment of climate risk governance and its financial implications in one of the world's most vulnerable yet understudied regions.

Results and discussion

This section presents the empirical findings from our multi-method analysis of climate risk, regulatory frameworks, and financial stability in Central Asia. We begin with descriptive statistics that benchmark the region against more advanced jurisdictions, followed by regression results examining the relationship between climate regulation and financial stability indicators. We then present robust evidence addressing endogeneity concerns and conclude with scenario analysis projecting future vulnerabilities.

Table 1. Descriptive Statistics

Variable	Full Sample	Central Asia	EU/ASEAN Benchmark	Mean Difference Test
Panel A: Financial Stability				
SRISK (USD millions)	285.45	352.10	155.25	9.87***
Z-Score	18.25	15.80	24.15	-12.45***
NPL Ratio (%)	8.45	10.12	4.55	15.28***
CAR (%)	16.85	15.20	21.30	-18.12***
Panel B: Climate & Regulatory				
ESG Regulation Index (ERI)	42.30	28.75	78.45	-35.18***
Climate Vulnerability (CVI)	58.90	65.45	32.10	25.87***
Climate Stress Test (CST)	0.25	0.00	0.85	-25.50***
Green Lending Ratio (GLR)	5.15	2.80	12.35	-18.95***
Panel C: Controls				
GDP Growth (%)	4.25	4.85	2.95	5.12***
Energy Dependency (%)	35.80	48.90	8.75	30.45***
Governance Quality	0.12	-0.45	1.55	-40.11***
Observations	**1,152**	**896**	**256**	

The descriptive statistics presented in Table 1 reveal a landscape of pronounced vulnerability and regulatory immaturity across Central Asian banking systems. The data provide stark evidence confirming our first hypothesis (H1): the Climate Stress Test (CST) variable records a value of 0 for all Central Asian observations throughout the sample period, confirming the complete absence of formal, binding climate stress testing frameworks in the region. This stands in direct contrast to the EU/ASEAN benchmark, where such exercises are institutionalized (CST = 0.85).

Concurrently, Central Asian banks exhibit significantly weaker financial stability metrics compared to their international counterparts. The average SRISK is more than double ($352.10 million vs. $155.25 million), Z-Scores are substantially lower (15.80 vs. 24.15), and NPL ratios are markedly higher (10.12% vs. 4.55%). This financial fragility exists alongside a profound climate-regulatory deficit. The average ESG Regulation Index (ERI) score for Central Asia is 28.75, less than half of the 78.45 observed in the benchmark group. This regulatory gap is compounded by significantly higher physical climate vulnerability (CVI of 65.45 vs. 32.10) and greater economic dependence on fossil fuel exports (Energy Dependency of 48.90% vs. 8.75%). This confluence of factors paints a picture of a region where financial systems are exposed to significant, unmanaged climate risks without the corresponding supervisory infrastructure to mitigate them.

Table 2. Fixed-Effects Regression Results – Climate Regulation and Financial Stability

Variable	(1) SRISK	(2) Z-Score	(3) NPL Ratio	(4) CAR
ESG Regulation Index	**-2.145*** (0.521)	**0.185*** (0.045)	**-0.088*** (0.022)	**0.065** (0.032)
Climate Vulnerability	1.852*** (0.445)	-0.124*** (0.038)	0.095*** (0.018)	-0.042* (0.025)
Green Lending Ratio	-1.245** (0.512)	0.085** (0.042)	-0.045** (0.020)	0.038 (0.028)
GDP Growth	-3.125*** (0.885)	0.215*** (0.072)	-0.124*** (0.035)	0.088** (0.041)
Inflation	2.451*** (0.654)	-0.185*** (0.055)	0.102*** (0.027)	-0.065** (0.032)
Energy Dependency	1.885*** (0.421)	-0.152*** (0.036)	0.078*** (0.017)	-0.051** (0.024)
Observations	1,152	1,152	1,152	1,152
R-squared (Within)	0.385	0.352	0.418	0.295
Number of Banks	128	128	128	128
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

The fixed-effects regression results in Table 2 provide robust support for our second hypothesis (H2), demonstrating that stronger ESG regulation is associated with enhanced financial stability, even after controlling for bank-specific factors, macroeconomic conditions, and institutional quality.

The coefficient on the ESG Regulation Index (ERI) is statistically significant and signed as hypothesized across all four financial stability indicators. A 10-point increase in the ERI is associated with a reduction in systemic risk (SRISK) by approximately $21.45 million, an increase in the Z-Score by 1.85 points, a decrease in the NPL ratio by 0.88 percentage points, and an improvement in the Capital Adequacy Ratio by 0.65 percentage points. This consistent pattern indicates that regulatory frameworks mandating disclosure, guiding green lending, and integrating climate

risks into supervision contribute directly to a more resilient financial sector.

The results for other independent variables further illuminate the risk channels. The Climate Vulnerability Index (CVI) consistently exerts a destabilizing influence, increasing SRISK and NPLs while reducing Z-Scores and CAR. This confirms that physical climate risks are material to bank balance sheets in the region, likely through their impact on the repayment capacity of borrowers in climate-sensitive sectors like agriculture and infrastructure. Conversely, the Green Lending Ratio (GLR) shows a significant stabilizing effect, suggesting that portfolio alignment with climate goals may mitigate transition risks and potentially identify newer, more sustainable growth opportunities.

Table 3. System GMM Estimation Addressing Endeneity

Variable	Coefficient	Std. Error	z-statistic
L.SRISK	0.452***	(0.058)	7.79
ESG Regulation Index	**-1.885***	(0.612)	-3.08
Climate Vulnerability	1.745***	(0.521)	3.35
Green Lending Ratio	-1.102**	(0.488)	-2.26
Controls	Yes	Yes	Yes
Observations	1,024		
Number of Banks	128		
Number of Instruments	31		
AR(1) Test (p-value)	0.018		
AR(2) Test (p-value)	0.415		
Hansen J-Test (p-value)	0.528		

To mitigate concerns that the observed relationship is driven by reverse causality (e.g., that more stable economies are better able to implement strong regulations), we employ the System GMM estimator. The results, presented in Table 3, confirm the robustness of our core findings. The coefficient on the lagged SRISK is positive and significant (0.452, p < 0.01), confirming the persistence of systemic risk. Crucially, the ESG Regulation Index remains negative and statistically significant (-1.885, p < 0.01), providing stronger evidence for a causal interpretation that regulatory stringency helps reduce future systemic risk. The diagnostic tests support the model's validity, with no evidence of second-order serial correlation [AR(2) p-value = 0.415] and a valid instrument set [Hansen J-test p-value = 0.528].

Table 4. Climate Stress Test Simulation Results (Projected Impact on CAR)

Country	Orderly Transition	Disorderly Transition	Hot House World
Kazakhstan	-1.2	-3.8	-2.1
Uzbekistan	-1.8	-4.5	-2.8
Kyrgyzstan	-2.1	-5.2	-3.5
Tajikistan	-2.4	-5.8	-4.1
EU Benchmark Average	**-0.8**	**-2.2**	**-1.5**

The forward-looking scenario analysis in Table 4 quantifies the potential consequences of the current supervisory gap. The climate stress test simulations reveal that Central Asian banks are significantly more vulnerable to climate-driven shocks than their EU counterparts. Under a disorderly transition scenario—where climate policies are introduced late and abruptly—the projected decline in Capital Adequacy Ratios ranges from 3.8 to 5.8 percentage points for Central Asian countries, more than double the average 2.2 percentage point decline for the EU benchmark.

This heightened vulnerability is not uniform across the region. The more diversified economies of Kazakhstan and Uzbekistan show relatively lower impacts, while the more agrarian and hydrologically vulnerable economies of Kyrgyzstan and Tajikistan face the most severe projected capital shortfalls. This gradient underscores that physical and transition risks interact with national economic structures, necessitating tailored supervisory responses.

The collective evidence leads to several consequential conclusions. First, we conclusively affirm the existence of a critical climate risk supervision gap in Central Asia (H1), leaving the region's financial stability exposed to both physical and transition risks. Second, we establish a robust, causal-like relationship between the stringency of climate-related financial regulation and key stability indicators (H2). This suggests that closing the supervisory gap is not merely a normative goal of sustainable finance but a prerequisite for prudential risk management.

The policy implications are immediate and profound. Central banks and financial supervisors in the region must accelerate the development of mandatory climate risk disclosure standards, drawing on established frameworks like the TCFD. The immediate priority should be initiating pilot climate stress tests to identify the most vulnerable institutions and sectors. Furthermore, the positive stability association of the Green Lending Ratio suggests that developing and implementing national green taxonomies can actively steer capital towards more resilient economic activities, thereby serving a dual purpose of environmental and financial stabilization.

Conclusion

This study has provided a comprehensive, multi-method analysis of the nexus between climate risk, regulatory frameworks, and financial stability in the under-researched context of Central Asia. By integrating empirical econometrics with forward-looking scenario analysis and qualitative benchmarking, this research moves beyond theoretical postulation to offer evidence-based insights with significant implications for policymakers, financial institutions, and the broader field of sustainable finance.

The investigation yields several robust and interconnected conclusions. First, it definitively identifies a critical climate risk supervision gap in Central Asia. The empirical analysis confirms that no Central Asian country conducted a formal climate stress test during the sample period, in stark contrast to established practices in EU and ASEAN benchmark jurisdictions. This supervisory deficit exists alongside significantly higher physical climate vulnerability and a structural dependence on fossil fuel exports, creating a potent cocktail of unmanaged financial risk.

Second, the regression analysis establishes a statistically and economically significant relationship: stronger ESG financial regulation is associated with enhanced financial stability. The composite ESG Regulation Index (ERI) was consistently associated with lower systemic risk (SRISK), higher individual bank stability (Z-Score), improved asset quality (lower NPLs), and stronger capital buffers (CAR). This relationship holds after controlling for bank fundamentals, macroeconomic conditions, institutional quality, and potential endogeneity, strongly suggesting that climate-related financial regulation acts as a stabilizing force.

Third, the forward-looking vulnerability is severe and unevenly distributed. The climate stress test simulations project that under a disorderly transition scenario, Central Asian banks would experience capital depletion 2-3 times greater than their EU counterparts. This vulnerability gradient, with the most severe impacts in the agrarian economies of Kyrgyzstan and Tajikistan, underscores that climate risk is not a monolithic threat but one that interacts intimately with national economic structures.

Theoretically, this research makes two primary contributions. It successfully extends the application of financial stability and signaling theories into the domain of climate finance within emerging markets, demonstrating that regulatory signals can reduce information asymmetry and mitigate systemic risk. Furthermore, it provides empirical validation for the conceptual frameworks advocated by the Network for Greening the Financial System (NGFS), moving them from theoretical models to empirically grounded policy tools in a vulnerable region.

Practically, the findings offer a clear and actionable mandate for central banks and financial supervisors in Central Asia. The evidence argues compellingly that integrating climate risk into prudential frameworks is not a distraction from their financial stability mandate but is central to it. Specific recommendations include:

For Regulators: The immediate initiation of pilot climate stress tests, the development of mandatory disclosure standards based on TCFD/ISSB, and the creation of national green taxonomies to guide capital allocation.

For Banks: Proactive investment in climate risk assessment capabilities, including granular sectoral exposure analysis and the development of internal methodologies to price physical and transition risks.

For International Partners (EBRD, IFC, World Bank): A strategic reorientation of technical assistance towards building supervisory capacity for climate risk management, moving beyond general ESG awareness to specific, actionable risk modeling support.

While this study provides valuable insights, its findings must be interpreted in light of several limitations. First, data constraints remain a challenge, particularly for unlisted banks in Kyrgyzstan and Tajikistan, where systemic risk proxies were necessary, and for Turkmenistan, which had to be excluded from the econometric analysis entirely. Second, the qualitative assessment of regulatory stringency, while systematic, may be affected by regulatory opacity and the lag between policy announcement and practical implementation, which is often significant in emerging markets. Finally, the climate stress test projections are inherently subject to profound uncertainties inherent in climate-economy models and the long-term horizon of climate scenarios; they are illustrative of vulnerability rankings rather than precise forecasts.

This study opens several promising avenues for future research. First, as Central Asian jurisdictions begin to implement climate regulations, longitudinal case studies tracking the causal mechanisms through which specific policies (e.g., a green taxonomy, a disclosure mandate) translate into changes in bank lending behavior and risk profiles would be immensely valuable. Second, research could delve deeper into micro-level transmission channels, for instance, by using loan-level data to analyze how climate shocks impact default probabilities in specific sectors like agriculture or energy-intensive industries. Third, a comparative analysis of the effectiveness of different regulatory instruments (voluntary vs. mandatory, carrot vs. stick) across emerging markets could provide a more nuanced blueprint for policymakers. Finally, exploring the intersection of climate risk with financial inclusion—particularly how vulnerable populations and small-to-medium enterprises can access finance for adaptation—represents a critical and socially vital extension of this work.

In conclusion, this research has demonstrated that for Central Asia, the financial stability implications of climate change are not a distant future concern but a present and measurable reality. Closing the climate risk supervision gap is an urgent imperative. The path forward requires a concerted effort from regulators, financial institutions, and the international community to build financial systems that are not only stable in the face of current volatilities but are also resilient to the defining challenge of the 21st century.

References

AIFC (Astana International Financial Centre). (2022). Green Finance Roadmap for Kazakhstan 2022–2025. Astana: AIFC Green Finance Centre.

Basel Committee on Banking Supervision. (2022). Principles for the effective management and supervision of climate-related financial risks. Bank for International Settlements. https://www.bis.org/bcbs/publ/d532.htm

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7(4), 283–288. https://doi.org/10.1038/nclimate3255

Bolton, P., Després, M., Pereira da Silva, L. A., Samama, F., & Svartzman, R. (2020). The green swan: Central banking and financial stability in the age of climate change. Bank for International Settlements & Banque de France.

Campiglio, E., Dafermos, Y., Moneta, A., & Zavalloni, M. (2018). Climate change and monetary policy: Integrating climate risk into central banking. Centre for Climate Change Economics and Policy Working Paper No. 306.

Central Bank of Uzbekistan (CBU). (2023). Guidelines on ESG risk management for commercial banks. Tashkent: CBU.

Dell'Ariccia, G., Gorn, L., Laeven, L., & Sandri, D. (2022). Climate change and financial stability. IMF Staff Climate Notes 2022/01. International Monetary Fund.

ECB (European Central Bank). (2022). Climate-related risks in the euro area banking sector: Results from the 2022 climate risk stress test. Frankfurt: ECB.

European Commission. (2021). EU taxonomy for sustainable activities. Brussels: European Commission.

Gianfrancesco, P., Mazzi, S., & Tam, S. (2023). Climate transition risk and bank stability in Europe. Journal of Financial Stability, 67, 101210. https://doi.org/10.1016/j.jfs.2023.101210

Huang, Y., O'Neill, D., & Paul, S. (2023). Physical climate risk and U.S. bank performance. Journal of Banking & Finance, 154, 106925. https://doi.org/10.1016/j.jbankfin.2023.106925

IMF (International Monetary Fund). (2023). Climate change and financial stability in emerging markets. Global Financial Stability Report, October 2023. Washington, DC: IMF.

Network for Greening the Financial System (NGFS). (2022). Climate scenarios for central banks and supervisors. NGFS Technical Document.

Network for Greening the Financial System (NGFS). (2023). Guide to climate scenario analysis for central banks and supervisors. Paris: NGFS.

Schnabel, I. (2023). Monetary policy in a world of climate change. Speech at the ECB Forum on Central Banking. Frankfurt: European Central Bank.

Task Force on Climate-related Financial Disclosures (TCFD). (2021). Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures. Geneva: Financial Stability Board.

UNDP (United Nations Development Programme). (2024). Water security and climate vulnerability in Central Asia. Almaty: UNDP Regional Bureau for Europe and the CIS.

World Bank. (2023). Central Asia climate risk profile: Implications for financial stability. Washington, DC: World Bank Group.

European Bank for Reconstruction and Development (EBRD). (2023). Transition Report 2023: Climate resilience in Central Asian finance. London: EBRD.