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Climate Transition Risk and Financial Development in a Resource-Dependent Economy: Evidence from Kazakhstan

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Abstract

Climate transition risks are increasingly relevant to financial development, particularly in resource-dependent economies. However, the existing literature has largely examined how financial development affects environmental outcomes, while the reverse relationship remains comparatively understudied. This study investigates whether carbon emissions and renewable energy consumption influence financial development in Kazakhstan over 1996–2024, controlling for economic growth, inflation, and foreign direct investment. Financial development is measured by domestic credit to the private sector provided by banks (% of GDP). Using the Autoregressive Distributed Lag (ARDL) bounds testing approach and accounting for structural breaks, the study examines short-run and long-run dynamics. The results confirm a long-run equilibrium relationship among the variables, but none of the individual long-run coefficients is statistically significant. This finding does not imply that climate-transition factors are economically irrelevant; rather, it suggests that their effects have not yet translated into persistent, statistically identifiable changes in aggregate bank-based financial development. In the short run, economic growth has a positive effect, while inflation has a negative effect, with renewable energy consumption and foreign direct investment showing lagged effects. The study contributes new evidence on the climate–finance nexus from a resource-dependent transition economy and highlights the evolving, but still limited, transmission of climate-transition dynamics through Kazakhstan's banking system.

Keywords: financial development; climate transition risk; carbon emissions; renewable energy; ARDL; Kazakhstan

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1. Introduction

Climate change has emerged as one of the most significant challenges facing contemporary economies, reshaping the interaction between environmental sustainability, economic development, and financial systems. Rising global temperatures, increasing

greenhouse gas emissions, and the growing frequency of climate-related shocks have intensified international efforts to accelerate decarbonization and achieve carbon-neutrality targets. Consequently, climate-related factors are no longer viewed solely as environmental concerns. They have increasingly acquired financial relevance because changes in environmental regulation, energy systems, technological trajectories, and market preferences can affect investment decisions, credit allocation, asset valuations, and the broader stability of financial systems. As governments implement increasingly ambitious climate policies and financial institutions face growing pressure to incorporate environmental considerations into decision-making, understanding how climate-transition dynamics interact with financial development has become an important research priority.

Within this context, climate transition has become an increasingly important dimension of the climate–finance nexus. The transition toward a low-carbon economy involves structural adjustments associated with environmental regulation, carbon pricing, technological innovation, renewable-energy deployment, and changing market preferences. These adjustments can create both risks and opportunities for financial systems. Carbon-intensive sectors may face increasing regulatory and financing pressures as economies decarbonize, while renewable-energy investments, green technologies, and sustainable infrastructure can create new opportunities for capital allocation and financial intermediation. The extent to which these environmental and energy-transition developments are reflected in financial systems, however, is likely to depend on the structure of the economy, the maturity of financial institutions, and the institutional environment in which the transition takes place.

The existing finance–environment literature has predominantly examined the relationship in the opposite direction. A large body of empirical research investigates whether financial development affects carbon emissions, environmental degradation, or renewable-energy outcomes. Some studies argue that financial development increases environmental pressure by facilitating production, consumption, energy use, and carbon-intensive investment, whereas others suggest that more developed financial systems can support environmental improvements through technological innovation, renewable-energy investment, and sustainable financing mechanisms (Zafar et al. 2019; Kirikkaleli and Adebayo 2021; Bilgili et al. 2025; Apeaning and Labaran 2025). This literature has therefore generated important insights into the environmental consequences of financial development, but the evidence remains heterogeneous across countries, income groups, institutional settings, and energy structures.

The growing literature on renewable energy reinforces the importance of examining the interaction between environmental transition and financial systems. Existing studies generally document a beneficial role for renewable energy in reducing carbon emissions and improving environmental sustainability (Khan et al. 2020; Sheraz et al. 2022b; Habiba et al. 2023; Rehan et al. 2026). At the same time, recent evidence indicates that the effectiveness of renewable-energy deployment depends on financial development, institutional quality, and technological innovation (Apeaning and Labaran 2025; Shanyazov et al. 2026). Parallel developments in sustainable finance have also increased attention to climate-related financial risks, carbon exposure, ESG integration, and the ability of financial institutions to adapt to structural changes associated with decarbonization (Yahya and Lee 2026; Zhassan et al. 2026).

Despite these developments, an important asymmetry remains in the literature. The dominant analytical framework considers financial development as an explanatory factor and examines its consequences for environmental outcomes. Comparatively less attention has been paid to the reverse direction, namely whether environmental conditions and energy-transition dynamics themselves are reflected in financial development. This distinction is important because financial systems do not operate independently of structural

changes in the real economy. Changes in carbon-intensive economic activity, renewable-energy deployment, investment patterns, and transition-related policies may affect the demand for credit, the allocation of financial resources, and the development of financial intermediation. Examining this reverse relationship therefore provides a complementary perspective on the finance–environment nexus rather than simply replicating the established literature.

A second gap concerns the limited evidence from resource-dependent and emerging economies. Much of the existing literature is based on developed economies or broad cross-country panels, where financial institutions, capital markets, regulatory systems, and sustainable-finance frameworks may differ substantially from those in resource-dependent transition economies. The extent to which environmental and energy-transition dynamics influence financial development may therefore depend on the economic structure and institutional maturity of the country under consideration. Country-specific evidence is consequently important for understanding whether relationships identified in more financially developed economies are also observable in economies where fossil fuels continue to play a central role in production, exports, fiscal revenues, and investment.

This issue is particularly relevant to Kazakhstan. The country possesses abundant fossil-fuel resources and remains substantially dependent on oil, gas, and mining activities, which play an important role in economic activity, export revenues, and fiscal stability. At the same time, Kazakhstan has adopted ambitious decarbonization and carbon-neutrality objectives and has sought to expand renewable energy and sustainable infrastructure. This creates a structural tension between continued dependence on carbon-intensive economic activity and the gradual transition toward a lower-carbon energy system. Recent Kazakhstan-focused studies have examined renewable-energy potential (Taizhanova et al. 2026), carbon-neutrality pathways (Khuanysh et al. 2026), climate governance (Martus et al. 2026), ESG implementation (Zhassan et al. 2026), regional environmental performance (Satanbekov et al. 2026), and sustainable economic growth under energy transition (Ülger Danacı 2026). These studies provide important evidence on individual dimensions of Kazakhstan's transition, but they do not directly address whether environmental and energy-transition indicators are reflected in the development of domestic private-sector credit.

The Kazakhstan-specific literature also illustrates why the direction of analysis matters. Satanbekov et al. (2026), for example, examine the relationship between bank lending and regional carbon emissions, thereby considering financial development as a factor associated with environmental outcomes. By contrast, the present study asks whether carbon emissions and renewable-energy consumption are associated with changes in financial development itself. Similarly, studies of Kazakhstan's renewable-energy potential, carbon-neutrality transition, climate governance, and ESG implementation provide important contextual evidence, but they do not directly test whether aggregate environmental-transition dynamics generate identifiable long-run or short-run effects on bank-based financial development. The present study therefore complements rather than duplicates this emerging Kazakhstan-focused literature.

Against this background, this study investigates whether carbon emissions and renewable-energy consumption are associated with financial development in Kazakhstan over the period 1996–2024. Financial development is represented by domestic credit to the private sector provided by banks as a percentage of GDP, while carbon emissions, renewable-energy consumption, GDP per capita, inflation, and foreign direct investment (FDI) are included as explanatory variables. The study deliberately reverses the dominant direction of analysis in the finance–environment literature by treating financial development as the dependent variable. The objective is not to interpret carbon emissions or renewable-energy consumption as direct measures of bank-level climate-transition risk,

but rather to examine whether broad environmental and energy-transition dynamics are reflected in aggregate bank-based financial intermediation.

Methodologically, the study employs the Autoregressive Distributed Lag (ARDL) framework to distinguish between short-run dynamics and long-run relationships while accommodating variables with different orders of integration. The analysis also incorporates structural breaks identified through the Bai–Perron procedure, allowing the estimated relationships to account for endogenous regime shifts during a period of substantial economic and institutional transformation in Kazakhstan. This combination is particularly relevant for a country whose economic and financial structure has evolved considerably over nearly three decades.

The study contributes to the literature in four principal respects. First, it extends the finance–environment literature by reversing the conventional analytical direction and examining whether environmental and energy-transition indicators are associated with financial development rather than treating financial development solely as a determinant of environmental outcomes. Second, it provides country-specific evidence for Kazakhstan, a resource-dependent transition economy whose financial system operates alongside persistent fossil-fuel dependence and an emerging low-carbon transition. Third, it distinguishes between short-run and long-run dynamics through the ARDL framework while explicitly accounting for structural shifts in the underlying economic environment. Fourth, it contributes to the interpretation of sustainable-finance development in an emerging economy by examining whether aggregate environmental-transition dynamics have yet become sufficiently embedded in domestic bank-based financial intermediation to generate statistically identifiable effects.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical and empirical literature and develops the research hypotheses. Section 3 presents the data, variables, and methodology. Section 4 reports the empirical findings. Section 5 discusses the results in relation to previous studies and Kazakhstan's economic and institutional context. Finally, Section 6 presents the conclusions, policy implications, limitations, and directions for future research.

2. Literature Review and Hypothesis Development

The relationship between financial development, environmental sustainability, renewable energy transition, and climate-related risks has become an increasingly important area of research within environmental economics, energy economics, and sustainable finance. Traditionally, financial development has been viewed as an important driver of economic growth because deeper financial systems improve capital allocation, mobilize savings, facilitate investment, and reduce financing constraints. However, the environmental consequences of financial development are not unambiguous. Financial deepening may support environmentally harmful activities by expanding credit to energy-intensive production and consumption, but it may also facilitate investment in renewable energy, clean technologies, and environmentally sustainable infrastructure. Consequently, the finance–environment nexus depends not only on the scale of financial development but also on the composition of financial flows, institutional quality, technological capabilities, and the structure of the energy system.

Most importantly for the present study, the dominant direction of causality examined in the existing literature runs from financial development toward environmental outcomes. Considerably less attention has been devoted to the reverse possibility that environmental pressures and climate-transition dynamics may themselves influence financial development. This distinction is particularly relevant as climate policies increasingly affect investment incentives, sectoral profitability, asset valuations, and financing conditions. The present

study therefore builds on the existing finance–environment literature while shifting the analytical perspective toward the potential influence of environmental and energy-transition variables on bank-based financial development.

2.1. Financial Development and Environmental Outcomes: From a Direct to a Conditional Relationship

An influential strand of the literature argues that financial development can intensify environmental degradation by facilitating economic expansion and increasing access to capital for carbon-intensive activities. Al-Mulali and Sab (2012) show that financial development contributes significantly to economic expansion, while such expansion may also be accompanied by higher carbon emissions. Using a large cross-country sample, Jiang and Ma (2019) similarly find that financial development increases carbon emissions, particularly in emerging and developing economies. Their findings suggest that greater availability of credit can stimulate production, consumption, and investment activities whose energy requirements remain substantially dependent on fossil fuels.

Evidence from individual country groups provides further support for this argument. Wang et al. (2020) find that financial development and economic growth increase carbon emissions across N-11 countries, whereas renewable energy consumption and technological innovation mitigate environmental degradation. Qayyum et al. (2021) report similar evidence for India, showing that financial development increases carbon emissions while renewable energy utilization and technological innovation reduce environmental pressure in both the short and long run. Raihan and Voumik (2022) likewise demonstrate that financial development, urbanization, and economic growth increase carbon emissions, whereas renewable energy consumption has a significant mitigating effect.

The consistency of these findings, however, should not be interpreted as evidence of a universally detrimental role for financial development. Evidence from developing and emerging economies indicates that the environmental consequences of financial deepening depend substantially on what financial resources are used to finance. Habiba and Cao (2022), for example, find that both financial market development and financial institution development contribute to higher carbon emissions in Sub-Saharan Africa. Sheraz et al. (2022b) similarly report that financial development increases environmental degradation across Belt and Road Initiative countries, while Habiba et al. (2023) emphasize that financial development becomes more environmentally beneficial when combined with renewable energy expansion and green technological innovation.

Other studies provide evidence pointing in the opposite direction. Kirikkaleli and Adebayo (2021) find that financial development can improve environmental sustainability under appropriate institutional and technological conditions. Awosusi et al. (2022), using a quantile-based analysis for Uruguay, show that financial development reduces consumption-based carbon emissions across most quantiles. These findings are important because they challenge the assumption that financial development has an inherently negative environmental effect. Instead, they suggest that the environmental consequences of financial development are conditional on the institutional and technological environment in which financial intermediation operates.

Darweesh et al. (2023), through a systematic review of the literature, further emphasize the fragmented and sometimes contradictory nature of the empirical evidence. Taken together, the existing findings indicate that financial development should not be considered environmentally harmful or beneficial in isolation. Rather, its effects depend on the energy structure of the economy, the allocation of credit, technological capabilities, institutional quality, and the extent to which financial systems incorporate environmental considerations. This conditionality is particularly relevant to resource-dependent economies, where financial intermediation may remain closely connected to fossil-fuel-intensive economic activity.

This literature also reveals an important asymmetry in the direction of empirical inquiry. Although a substantial body of research examines how financial development affects environmental outcomes, substantially fewer studies investigate whether environmental and climate-transition dynamics influence financial development itself. As financial institutions increasingly face changing regulatory requirements, carbon-related exposures, and evolving investment opportunities, this reverse relationship represents an important but comparatively underexplored dimension of the finance–environment nexus.

The theoretical relationship between carbon emissions and financial development is ambiguous. On the one hand, higher carbon emissions may reflect greater industrial production, energy consumption, and investment activity, which can increase demand for financial services and private-sector credit. On the other hand, in an economy increasingly exposed to climate-transition policies, carbon-intensive activities may face higher regulatory and financing costs, weaker investment prospects, and greater transition-related risks. The empirical literature also provides mixed evidence regarding the broader finance–environment relationship (Jiang and Ma 2019; Kirikkaleli and Adebayo 2021; Darweesh et al. 2023).

For a resource-dependent economy such as Kazakhstan, the relationship is particularly context-specific because carbon-intensive economic activity remains closely connected to production, investment, exports, and fiscal revenues, while climate-transition policies are gradually increasing pressure for decarbonization. The net effect on domestic financial development is therefore an empirical question.

H1. *Carbon emissions significantly influence financial development in Kazakhstan.*

2.2. Renewable Energy, Financial Development, and the Financing of the Energy Transition

Renewable energy constitutes another central component of the relationship between environmental transition and financial development. A broad body of research demonstrates that renewable energy consumption contributes to reducing environmental degradation. Khan et al. (2020), using evidence from 192 countries, find that renewable energy consumption significantly reduces carbon emissions. Similar environmental benefits are reported by Wang et al. (2020), Qayyum et al. (2021), Habiba and Cao (2022), Sheraz et al. (2022b), Habiba et al. (2023), and Rehan et al. (2026).

Nevertheless, establishing that renewable energy improves environmental quality does not automatically establish that renewable energy expansion generates greater financial development. The two relationships involve different transmission mechanisms. Renewable energy expansion may create financing demand for infrastructure, technology, and investment, thereby stimulating financial intermediation. At the same time, if renewable-energy projects are financed primarily through public resources, international development institutions, or specialized financing mechanisms, their expansion may have only a limited effect on domestic private-sector credit.

The literature increasingly supports the importance of institutional and financial conditions in determining the economic effects of renewable energy. Xu et al. (2023) show that the long-run environmental effects of renewable energy are influenced by globalization and institutional quality. Sheraz et al. (2022a) similarly demonstrate that institutional quality strengthens the environmental benefits associated with renewable energy adoption across Belt and Road Initiative countries. These findings imply that renewable energy does not operate independently of the institutional environment; rather, the effectiveness and broader economic consequences of the energy transition depend on the capacity of financial and institutional systems to support it.

The interaction between financial development and renewable energy is particularly relevant to the present research question. Chiu and Zhang (2023) find that financial

development moderates the relationship between renewable energy consumption and carbon emissions in OECD countries, while Anton (2026) shows that financial development strengthens the relationship between climate vulnerability and renewable energy consumption. Shanyazov et al. (2026) further find that financial development promotes renewable-energy investment in resource-rich developing economies by reducing financing costs and improving risk-sharing mechanisms. Lin and Okoye (2023) likewise report that financial development contributes to renewable energy generation, although the magnitude of the effect is relatively modest in high-income countries.

These findings suggest a potentially important feedback mechanism. A developing renewable-energy sector can create new investment opportunities and financing requirements, while a sufficiently developed financial system can facilitate the mobilization of capital required for the energy transition. However, the strength of this feedback is likely to vary according to the maturity of domestic financial markets, the structure of project financing, and the extent of government or multilateral involvement. Thus, renewable energy expansion may have a positive, negative, or statistically weak relationship with aggregate bank-based financial development depending on the institutional and financing context.

In Kazakhstan, renewable energy remains relatively modest within the broader energy system, while financing may involve public support and international development institutions. Consequently, renewable-energy expansion may not necessarily translate proportionately into domestic private-sector credit. The empirical relationship therefore warrants direct testing.

H2. *Renewable energy consumption significantly influences financial development in Kazakhstan.*

2.3. Climate Transition Risk and Financial Intermediation

The growing literature on climate-related financial risk provides a broader theoretical basis for examining whether environmental-transition dynamics can influence financial systems. Climate transition risk arises from the structural adjustments associated with moving toward a low-carbon economy, including regulatory changes, carbon pricing, technological transformation, changing market preferences, and the reallocation of investment away from carbon-intensive activities. These developments can affect firms' profitability, asset valuations, financing conditions, and ultimately the behavior of financial intermediaries.

Recent evidence indicates that climate-related considerations are increasingly relevant to financial-sector behavior. Zhu et al. (2026), for example, distinguish between physical climate risks and transition risks and find that both reduce the carbon footprint of bank lending, with transition risks exerting a particularly strong effect. Their findings suggest that climate policies and decarbonization pressures can alter the allocation of financial resources. This provides an important conceptual foundation for considering the possibility that environmental-transition variables may influence financial development rather than merely being influenced by it.

Evidence from carbon markets reinforces this argument. Kenges (2026) finds that carbon-intensive firms in Kazakhstan experienced significant valuation discounts following the introduction of the Kazakhstan Emissions Trading System (KazETS). This result indicates that carbon exposure can become financially relevant when regulatory and market mechanisms begin to price transition-related risks. Yahya and Lee (2026) further demonstrate that institutional characteristics of central banks influence financial-sector carbon emissions, highlighting the role of financial governance in shaping climate-related financial outcomes.

At the same time, the existence of climate-transition risk at the global or firm level does not necessarily imply that such risks will immediately appear in aggregate indicators of domestic financial development. The transmission from climate policy and environmental pressures to bank credit depends on whether financial institutions identify, price, and in-

corporate such risks into lending and investment decisions. Where climate-risk assessment and ESG integration remain relatively limited, aggregate environmental indicators may have only weak or delayed effects on domestic financial intermediation.

This distinction is particularly important for interpreting country-level evidence. The present study does not directly measure bank-level transition risk, carbon-pricing exposure, stranded assets, or climate-related loan-portfolio risk. Instead, carbon emissions and renewable energy consumption are used as aggregate indicators of environmental intensity and energy-transition dynamics. Accordingly, the expected relationship should be understood as an empirical association between aggregate transition-related conditions and bank-based financial development rather than as a direct measure of banks' micro-prudential climate-risk exposure.

2.4. Macroeconomic Determinants of Financial Development

The relationship between climate-transition variables and financial development should also be considered within the broader macroeconomic environment. Economic growth, inflation, and foreign direct investment may influence domestic credit independently of environmental-transition dynamics and therefore represent important conditioning factors in the empirical specification.

Economic growth is generally expected to support financial development by increasing investment, income, demand for financial services, and the scale of economic transactions. Higher income levels can strengthen firms' and households' demand for credit while increasing the resources available for financial intermediation. Nevertheless, the strength of this relationship may depend on the structure of economic growth and the development of financial institutions. In resource-dependent economies, economic expansion may be concentrated in capital-intensive sectors with financing structures that do not necessarily translate proportionately into broader private-sector credit. The supply-leading evidence reported by Syzdykova et al. (2021) for transition economies further indicates the importance of financial development in the broader growth process. Nevertheless, this evidence does not establish that economic growth necessarily produces proportional changes in domestic financial intermediation.

Accordingly, the study expects economic growth to be positively associated with financial development.

H3. *Economic growth positively affects financial development in Kazakhstan.*

Inflation may exert the opposite effect. Persistent inflation can increase uncertainty, shorten planning horizons, distort real returns, and weaken the efficiency of financial intermediation. Inflation can also discourage long-term lending and investment by reducing the predictability of real returns and distorting the allocation of financial resources. These mechanisms provide a basis for expecting a negative relationship between inflation and financial development, although the empirical magnitude of this relationship may depend on monetary institutions and macroeconomic stability.

H4. *Inflation negatively affects financial development in Kazakhstan.*

Foreign direct investment can also influence financial development by introducing capital, technology, managerial capabilities, and new financing opportunities. However, its effect is not necessarily unambiguously positive. FDI may strengthen domestic financial development when it generates linkages with domestic firms and financial institutions, but its effects may be more limited when investment is concentrated in capital-intensive extractive sectors with financing structures that operate largely outside domestic private credit

markets. This consideration is particularly relevant to Kazakhstan because a substantial share of investment activity is connected to resource-intensive sectors.

The environmental consequences of FDI are similarly mixed. Arzova and Sahin (2023) find that FDI reduces both carbon emissions and renewable energy supply in emerging economies, while Ahmad et al. (2026) report that FDI reduces carbon emissions in Sub-Saharan Africa. By contrast, Bhat and Ikram (2025) find that FDI increases carbon emissions in Asia-Pacific and Oceanian countries, particularly when combined with financial development. These contrasting findings reinforce the importance of country-specific institutional and sectoral characteristics.

Nevertheless, based on the broader theoretical expectation that FDI can enhance capital formation and financial integration, the study formulates the following hypothesis:

H5. *Foreign direct investment positively affects financial development in Kazakhstan.*

2.5. Institutional Quality, ESG Integration, and the Kazakhstan Context

Institutional quality is particularly important for understanding whether environmental pressures are transmitted into financial decision-making. Sheraz et al. (2022a) show that institutional quality can suppress the negative environmental externalities associated with financial development while strengthening the benefits of renewable energy. Lin and Okoye (2023) similarly emphasize the importance of governance in supporting renewable energy generation and reducing greenhouse gas emissions. Nizamdinova et al. (2026) further demonstrate that environmental management accounting can improve ESG performance and environmental outcomes among Kazakhstani firms.

The Kazakhstan-specific literature provides evidence of an economy undergoing a gradual but incomplete environmental and institutional transition. Taizhanova et al. (2026) emphasize Kazakhstan's substantial renewable-energy potential, particularly in wind and solar resources, while identifying financing and infrastructure constraints. Stergiou (2026) argues that continued dependence on fossil-fuel rents constrains the country's green transition. Ülger Danacı (2026) similarly finds that fossil-fuel consumption negatively affects sustainable economic growth, whereas renewable energy has not yet generated significant economic effects, partly reflecting its relatively limited deployment.

Other studies highlight the institutional dimensions of this transition. Khuanysh et al. (2026) identify important risks and opportunities associated with Kazakhstan's movement toward carbon neutrality, while Martus et al. (2026) show that climate strategies remain strongly influenced by state priorities within the fossil-fuel sector. Akhmedyarova et al. (2026) further demonstrate the macroeconomic relevance of energy-transition policies through a DSGE framework incorporating both green and fossil energy. Shin et al. (2026) identify substantial regional differences in sustainable development outcomes, illustrating the heterogeneous nature of the country's transition process.

Importantly, the emerging Kazakhstan literature also provides evidence concerning the relationship between environmental conditions and finance. Satanbekov et al. (2026) find that greater access to bank lending contributes to lower regional carbon emissions, suggesting that financial development can support energy efficiency and green infrastructure. This finding is consistent with the broader literature emphasizing the potential environmental benefits of financial development. However, it does not address the reverse question of whether environmental-transition dynamics influence aggregate financial development.

The development of ESG practices provides an additional institutional dimension. Zhassan et al. (2026) identify substantial gaps in ESG implementation within Kazakhstan's banking sector and indicate that climate-risk assessment practices remain at an early stage. This institutional context is important because the financial transmission of climate-transition pressures depends on the extent to which banks incorporate environmental

information into credit assessment, risk management, and capital allocation. Where such mechanisms are still evolving, changes in aggregate carbon emissions or renewable energy consumption may not yet produce statistically identifiable long-run changes in domestic private-sector credit.

The financing structure of the energy transition may reinforce this separation. If large renewable-energy and decarbonization projects rely substantially on public support, sovereign financing, or international development institutions, an increase in renewable-energy investment need not generate a proportional increase in domestic private-sector bank credit. Consequently, renewable-energy expansion can occur alongside relatively limited changes in the aggregate domestic credit indicator used to measure bank-based financial development. This institutional possibility is particularly relevant in a resource-dependent economy in which the state and international institutions may play an important role in financing strategic energy-transition projects.

2.6. Research Gap and Contribution to the Literature

The preceding literature reveals three interconnected gaps. First, the dominant empirical literature examines financial development as a determinant of carbon emissions, renewable energy, or environmental quality. Although this literature has established that financial development can have both environmentally harmful and beneficial effects, considerably less attention has been paid to the reverse relationship in which environmental and energy-transition dynamics influence financial development.

Second, the climate-transition literature increasingly recognizes that changes in environmental regulation, carbon exposure, and energy structures can influence financial-sector behavior, yet much of the empirical evidence focuses on firm-level financial risk, bank lending emissions, or developed-country financial systems. Comparatively limited evidence exists on whether aggregate indicators of environmental transition are reflected in bank-based financial development in resource-dependent emerging economies.

Third, the Kazakhstan-focused literature remains fragmented across renewable energy, carbon neutrality, climate governance, carbon markets, ESG implementation, regional environmental performance, and macroeconomic energy-transition issues. These studies establish the importance of Kazakhstan's energy and institutional transformation, but they do not directly examine whether carbon emissions and renewable energy consumption are associated with the long-run development of domestic private-sector credit.

The present study addresses these gaps by reversing the conventional analytical perspective. Rather than asking whether financial development affects environmental outcomes, it examines whether carbon emissions and renewable energy consumption are associated with financial development in Kazakhstan. Financial development is measured by domestic credit to the private sector provided by banks as a percentage of GDP, thereby focusing specifically on bank-based financial intermediation rather than the financial system as a whole. Carbon emissions and renewable energy consumption are treated as aggregate indicators of environmental intensity and energy-transition dynamics, while GDP per capita, inflation, and FDI are incorporated as relevant macroeconomic determinants.

The focus on Kazakhstan is substantively important because the country combines substantial fossil-fuel dependence with ambitious decarbonization objectives and an emerging renewable-energy sector. This combination provides a particularly relevant setting for examining whether environmental-transition dynamics have become sufficiently integrated into domestic financial intermediation to generate identifiable long-run relationships. The study therefore contributes not only to the climate-finance literature but also to the emerging literature on financial development in resource-dependent transition economies.

3. Methodology

3.1. Data and Variables

This study investigates the role of climate transition factors in shaping financial development in Kazakhstan over the period 1996–2024. Annual time-series data were compiled from two publicly accessible and official sources. Renewable energy consumption (% of total final energy consumption) was obtained from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, while the remaining variables were obtained from the World Bank's World Development Indicators (WDI). Both sources provide publicly available statistical data and internationally comparable macroeconomic, financial, and environmental indicators. The analysis uses the original annual observations and does not involve interpolation or artificial temporal disaggregation.

The annual frequency of the dataset is retained rather than generating interpolated quarterly observations. Although temporal disaggregation methods such as Denton and Chow–Lin can be useful when reliable high-frequency benchmark indicators are available, converting the 29 annual observations into a larger number of interpolated observations would not increase the underlying informational content of the original annual series. Such an approach could increase the nominal number of observations without proportionately increasing the information available for econometric identification. The analysis therefore retains the original annual frequency to preserve transparency regarding the actual information content of the dataset.

Financial development is represented by domestic credit to the private sector by banks as a percentage of GDP (CREDIT), which serves as the dependent variable. This indicator is widely used in the financial development literature to capture the depth of bank-based financial intermediation and is particularly relevant for examining whether environmental and energy-transition dynamics are associated with changes in private-sector credit allocation. Nevertheless, it represents only one dimension of financial development. It does not capture developments in capital markets, stock-market capitalization, institutional equity financing, or emerging forms of sustainable finance, such as green bonds. Consequently, the estimated relationships should be interpreted specifically as relationships between climate-transition indicators and bank-based financial development rather than as evidence concerning the financial system as a whole. Future research could extend the analysis by incorporating multiple financial-development indicators as data availability improves.

To capture climate transition dynamics, carbon dioxide emissions per capita (CO_2) and renewable energy consumption as a percentage of total final energy consumption (REN) are included as the main explanatory variables. Carbon emissions reflect the environmental intensity of economic activities and potential climate-related transition risks, while renewable energy consumption represents progress toward a cleaner and more sustainable energy structure.

In addition, three macroeconomic control variables are incorporated into the model. GDP per capita (GDPPC) is included to capture the effect of economic development on financial deepening. Inflation (INF) is employed to account for macroeconomic stability, as persistent inflation may affect credit allocation and financial intermediation. Foreign direct investment (FDI) is included because external capital inflows may contribute to financial sector development through technology transfer, capital accumulation, and increased financial activity.

Following standard practice in the finance–environment literature, the natural logarithms of CREDIT, CO_2 emissions, and GDP per capita are used in the empirical analysis. The logarithmic transformation helps reduce potential heteroscedasticity, smooth fluctuations in the data, and allows the estimated coefficients to be interpreted as elasticities where applicable. The empirical model therefore utilizes the variables summarized in Table 1.

Table 1. Definition and Measurement of Variables.

Variable	Symbol	Measurement	Role in the Model
Financial Development	CREDIT	Domestic credit to private sector by banks (% of GDP)	Dependent variable
Carbon Emissions	lnCO2	Carbon dioxide emissions per capita (t CO_2e per capita)	Main explanatory variable
Renewable Energy Consumption	REN	Renewable energy consumption (% of total final energy consumption)	Main explanatory variable
GDP per Capita	GDPPC	GDP per capita (constant 2015 USD)	Control variable
Inflation	INF	Inflation, consumer prices (annual %)	Control variable
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	Control variable

3.2. Model Specification

The theoretical foundation of this study is based on the emerging climate-finance literature, which argues that environmental performance, decarbonization efforts, and energy transition processes increasingly influence financial systems and financial intermediation. Unlike the conventional approach that examines the impact of financial development on environmental outcomes, this study reverses the direction of analysis by investigating how environmental and climate-related factors affect financial development. The functional relationship can be expressed as follows:

$$CREDIT_t = f(CO_{2t}, REN_t, GDPpc_t, INF_t, FDI_t)$$

The estimable long-run model is specified as:

$$lnCREDIT_t = \beta_0 + \beta_1 lnCO_{2t} + \beta_2 REN_t + \beta_3 lnGDPpc_t + \beta_4 INF_t + \beta_5 FDI_t + \varepsilon_t$$

where

β_0 denotes the intercept term,

$\beta_1 - \beta_5$ represent the long-run parameters,

ε_t is the stochastic error term.

Given Kazakhstan's exposure to several major economic and financial shocks during the study period, structural breaks may influence the stability of the estimated relationships. Therefore, multiple structural break tests are performed and the identified break dates are incorporated into the empirical model as dummy variables.

The extended model can thus be written as:

$$lnCREDIT_t = \beta_0 + \beta_1 lnCO_{2t} + \beta_2 REN_t + \beta_3 lnGDPpc_t + \beta_4 INF_t + \beta_5 FDI_t + \beta_6 Dummy2010_t + \beta_7 Dummy2018_t + \varepsilon_t$$

where:

$$Dummy2010 = \begin{Bmatrix} 1, \ 2010 \ and \ afterwards \\ 0, \ otherwise \end{Bmatrix}$$

$$Dummy2018 = \begin{Bmatrix} 1,\ 2018\ and\ afterwards \\ 0,\ otherwise \end{Bmatrix}$$

The inclusion of these structural break dummies allows the model to account for major changes in Kazakhstan's economic and financial environment and helps avoid biased coefficient estimates.

3.3. Unit Root and Structural Break Analysis

Prior to estimating the long-run relationship, the time-series properties of the variables are examined using the Augmented Dickey–Fuller (ADF) and Phillips-Perron (PP) unit root tests. Testing for stationarity is essential because regressions involving non-stationary variables may produce spurious results and misleading statistical inference. The ADF test is represented by the following equation:

$$\Delta Y_t = \alpha + \beta_t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

where Δ denotes the first difference operator and p represents the optimal lag length.

Since Kazakhstan is a resource-dependent economy that has experienced multiple external shocks, including fluctuations in global oil prices, the 2008 global financial crisis, exchange rate adjustments, and structural policy reforms, the possibility of structural breaks must also be considered. Ignoring structural changes may distort the integration properties of variables and affect subsequent cointegration analysis.

Therefore, the Bai and Perron (2003) multiple structural breakpoint test is applied to identify endogenous break dates within the sample period. The identified break dates are subsequently incorporated into the ARDL model through dummy variables.

3.4. ARDL Bounds Testing Approach

Following the unit root and structural break analyses, the Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran et al. (2001) is employed to examine both the long-run and short-run relationships among the variables.

The ARDL methodology offers several advantages. First, it can be applied when variables are integrated of order I(0), I(1), or a combination of both. Second, it performs efficiently in small samples, making it particularly suitable for the present study, which uses annual data for Kazakhstan. Third, the ARDL framework simultaneously estimates short-run dynamics and long-run equilibrium relationships.

The unrestricted error-correction representation of the ARDL model can be written as:

$$\begin{aligned} \Delta lnCREDIT_t = \alpha_0 \quad & + \sum_{i=1}^{p} \alpha_i \Delta lnCREDIT_{t-i} + \sum_{i=0}^{q} \beta_i \Delta lnCO_{2t-i} + \sum_{i=0}^{r} \delta_i \Delta REN_{t-i} + \sum_{i=0}^{s} \phi_i \Delta lnGDPpc_{t-i} + \sum_{i=0}^{m} \lambda_i \Delta INF_{t-i} \\ & + \sum_{i=0}^{n} \psi_i \Delta FDI_{t-i} + \omega_1 lnCREDIT_{t-1} + \omega_2 lnCO_{2t-1} + \omega_3 REN_{t-1} + \omega_4 lnGDPpc_{t-1} + \omega_5 INF_{t-1} + \omega_6 FDI_{t-1} \\ & + \omega_7 Dummy_{2010} + \omega_8 Dummy_{2018} + \varepsilon_t \end{aligned}$$

To determine whether a long-run relationship exists among the variables, the ARDL bounds test is conducted.

The null hypothesis of no cointegration is:

$$H_0 : \omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = \omega_6 = 0$$

The alternative hypothesis is:

$$H_1 : \omega_1 \neq 0, \omega_2 \neq 0,\ \omega_3 \neq 0, \omega_4 \neq 0, \omega_5 \neq 0, \omega_6 \neq 0$$

If the calculated F-statistic exceeds the upper critical bound, the null hypothesis is rejected and a long-run equilibrium relationship is confirmed.

It is important to clarify that the study does not directly measure bank-level climate transition risk. Instead, carbon dioxide emissions per capita and renewable energy consumption are used as aggregate indicators of environmental intensity and energy-transition dynamics. These indicators capture broad changes in the environmental and energy structure of the economy that may be relevant to the financial implications of climate transition; however, they do not directly measure specific microprudential or regulatory exposures, such as carbon-pricing risk, stranded-asset exposure, climate-related loan portfolio risk, or bank-level regulatory requirements.

Accordingly, the empirical results should be interpreted as evidence on the relationship between aggregate environmental-transition indicators and financial development rather than as a direct measure of banks' exposure to climate transition risk. More granular measures of transition risk would provide a valuable avenue for future research, particularly as bank-level ESG and climate-risk data become increasingly available for Kazakhstan.

3.5. Error Correction Model (ECM)

Once cointegration is established, the short-run dynamics are estimated using the Error Correction Model (ECM), which captures the speed at which deviations from long-run equilibrium are corrected.

The ECM specification is expressed as:

$$\Delta lnCREDIT_t = a_0 + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \lambda ECT_{t-1} + \varepsilon_t$$

ECT_{t-1} is the lagged error correction term,

λ measures the speed of adjustment toward long-run equilibrium,

ΔX represents the differenced explanatory variables.

A negative and statistically significant error correction coefficient indicates that short-run disequilibria converge toward the long-run equilibrium path, confirming the stability of the estimated relationship.

3.6. Diagnostic and Stability Tests

To ensure the reliability and robustness of the empirical findings, several post-estimation diagnostic tests are conducted.

Model specification is evaluated using the Ramsey RESET test. The Breusch-Pagan-Godfrey test is employed to detect heteroscedasticity, while the Breusch-Godfrey Serial Correlation LM test is used to examine residual autocorrelation. The normality of residuals is assessed through the Jarque–Bera test.

Finally, the stability of the estimated coefficients is examined using the CUSUM and CUSUMSQ tests. If the cumulative sums remain within the 5% critical boundaries, the model is considered structurally stable over the sample period. The stability tests provide additional evidence regarding the robustness and reliability of the estimated ARDL coefficients and the associated policy implications.

Overall, this empirical framework enables a comprehensive assessment of how carbon emissions, renewable energy transition, and macroeconomic conditions influence financial development in Kazakhstan within both short-run and long-run contexts.

4. Results

Table 2 presents the descriptive statistics of the variables used in the analysis. The results indicate substantial variation in financial development, inflation, and foreign direct

investment over the sample period, reflecting the structural transformations experienced by Kazakhstan's economy during the transition toward a market-oriented and globally integrated economic system. In particular, the relatively high volatility of inflation suggests the presence of recurrent macroeconomic shocks, exchange-rate adjustments, and commodity price fluctuations, which have historically influenced credit allocation and financial sector dynamics.

Table 2. Descriptive Statistics.

	LNCREDIT	LNCO2	REN	LNGDPPC	INF	FDI
Mean	3.133150	2.454829	1.851724	8.936230	10.03987	6.453421
Median	3.238325	2.494488	1.900000	9.071619	7.579999	5.405185
Maximum	4.076493	2.755392	2.800000	9.382004	39.18254	13.01286
Minimum	1.632625	2.125491	1.100000	8.184059	5.195684	0.196995
Std.Dev.	0.664077	0.190254	0.431460	0.395114	6.628563	4.008202
Skewness	−1.017117	−0.338232	0.138546	−0.752029	3.133505	0.314469
Kurtosis	3.290779	2.147945	2.353448	2.116140	14.00713	1.839224
Jarque–Bera	5.102382	1.430186	0.597896	3.677436	193.8557	2.106083
Probability	0.077989	0.489147	0.741598	0.159021	0.000000	0.348875
Sum	90.86135	71.19004	53.70000	259.1507	291.1561	187.1492
SumSq.Dev.	12.34797	1.013501	5.212414	4.371231	1230.260	449.8391

The descriptive statistics further reveal that carbon emissions remained relatively stable compared to financial and macroeconomic indicators. This pattern is consistent with Kazakhstan's long-standing dependence on fossil fuel-based production and energy-intensive industries, where environmental pressures have persisted despite increasing commitments to decarbonization and climate transition policies. By contrast, renewable energy consumption exhibits limited variation and remains at relatively low levels throughout the sample period, indicating that the transition toward a cleaner energy structure is still at an early stage.

The observed fluctuations in foreign direct investment are also noteworthy. Given Kazakhstan's strong reliance on natural resource exports and external capital inflows, variations in FDI likely reflect changing global commodity market conditions and investor perceptions regarding economic and political stability. Overall, the descriptive evidence portrays Kazakhstan as a resource-dependent economy characterized by evolving financial development, persistent carbon intensity, emerging renewable energy adoption, and considerable exposure to macroeconomic and external shocks. These features provide a relevant context for examining how climate transition factors and environmental sustainability interact with financial development.

Table 3 reports the correlation matrix among the study variables. Financial development (LNCREDIT) is positively correlated with carbon emissions (LNCO2) and real GDP per capita (LNGDPPC), suggesting that credit expansion in Kazakhstan has historically coincided with economic growth and carbon-intensive economic activities. Renewable energy consumption (REN) exhibits a negative correlation with both financial development and carbon emissions, providing preliminary evidence that a greater share of renewable energy may be associated with lower environmental pressure. Inflation (INF) is negatively correlated with financial development and income, indicating that macroeconomic instability may constrain credit growth. Importantly, the highest correlation coefficient (0.8219) remains below the conventional threshold of 0.90, suggesting that multicollinearity is unlikely to pose a serious concern in the subsequent ARDL estimations.

Table 3. Correlation matrix.

	LNCREDIT	LNCO2	REN	LNGDPPC	INF	FDI
LNCREDIT	1	0.8219	−0.1981	0.7307	−0.4466	0.1376
LNCO2	0.8219	1	−0.5297	0.7704	−0.2077	−0.1431
REN	−0.1981	−0.5297	1	−0.1284	−0.0643	−0.0146
LNGDPPC	0.7307	0.7704	−0.1284	1	−0.3714	−0.4262
INF	−0.4466	−0.2077	−0.0643	−0.3714	1	0.0552
FDI	0.1376	−0.1431	−0.0146	−0.4262	0.0552	1

Table 4 presents the results of the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests. The findings indicate a mixed order of integration among the variables. Specifically, LNCO2, REN, and FDI are found to be non-stationary at levels but become stationary after first differencing, implying that these variables are integrated of order one, I(1). Similarly, the PP results suggest that lnGDPPC and lnCREDIT achieve stationarity after first differencing.

Table 4. ADF and PP Unit Root Test Results.

Variables	ADF		PP	
	t-Statistic	Prob.	t-Statistic	Prob.
$lnCREDIT$	−3.420155	0.0191	0.510394	0.8196
$\Delta lnCREDIT$			−1.940589	0.0514
$lnCO_2$	−1.277496	0.6256	−1.361495	0.5864
$\Delta lnCO_2$	−4.887864	0.0005	−4.889119	0.0005
REN	−1.642757	0.4483	−1.642757	0.4483
ΔREN	−3.741852	0.0093	−4.541185	0.0013
$lnGDPPC$	−3.209643	0.0300	−2.721134	0.0831
$\Delta lnGDPPC$			−6.283846	0.0000
INF	−2.672808	0.0927	−11.32921	0.0000
ΔINF	−6.030819	0.0000		
FDI	−2.794773	0.0718	−2.802674	0.0707
ΔFDI	−5.537067	0.0001	−11.84141	0.0000

In contrast, inflation (INF) appears stationary at level according to the PP test, while the ADF results indicate stationarity after first differencing. Such minor differences between ADF and PP outcomes are not uncommon, as the two tests differ in their treatment of serial correlation and heteroskedasticity. Nevertheless, both tests consistently confirm the absence of any variable integrated beyond the first order.

Overall, the unit root results reveal that the variables are integrated at a combination of I(0) and I(1) levels, while none is I(2). This finding satisfies the key precondition for applying the ARDL bounds testing methodology proposed by Pesaran et al. (2001). Therefore, the ARDL framework is considered appropriate for investigating the long-run and short-run relationships between financial development, carbon emissions, renewable energy consumption, economic growth, inflation, and foreign direct investment in Kazakhstan.

Following the unit root analysis, the study did not proceed directly to the ARDL bounds testing approach. Given Kazakhstan's resource-dependent economic structure and its exposure to major external shocks, overlooking potential structural changes could lead to biased estimates of long-run relationships and weaken the reliability of subsequent cointegration results. Therefore, before examining the existence of a long-run equilibrium relationship among the variables, it was necessary to investigate whether the sample period was characterized by significant structural shifts that might have altered the underlying economic dynamics.

To this end, the Bai and Perron (2003) multiple structural break test was conducted. The results reported in Table 5 reveal the presence of two statistically significant structural breaks. The sequential F-statistics for the tests of no break against one break (69.70) and one break against two breaks (28.14) exceed their respective critical values at the 5% significance level, confirming the existence of multiple structural shifts in the sample period. The sequential procedure identifies break dates in 2010 and 2018, while the repartition method confirms 2018 and suggests an earlier break around 2008. Overall, the evidence consistently indicates that the study period experienced substantial regime changes affecting the dynamics among financial development, carbon emissions, renewable energy consumption, and macroeconomic variables.

Table 5. Multiple breakpoint tests (Bai–Perron tests).

Break Test	F-Statistic	Scaled F-Statistic	Critical Value **
0 vs. 1 *	11.61667	69.70003	18.97
1 vs. 2 *	4.690752	28.14451	20.89
* Significant at the 0.05 level.			
** Bai and Perron (2003) critical values.			
Break dates:			
	Sequential	Repartition	
1	2010	2008	
2	2018	2018	

The first break is closely associated with the aftermath of the 2008–2009 global financial crisis, which significantly affected Kazakhstan's banking sector, credit markets, and capital inflows. The second break in 2018 coincides with a period of accelerating energy transition policies, increased renewable energy investments, and stronger commitments toward environmental sustainability and climate-related reforms. These developments are likely to have altered the interactions between financial development and environmental indicators within the Kazakh economy.

To account for these structural changes and ensure robust parameter estimation, dummy variables representing the identified break years (D2010 and D2018) were incorporated into the ARDL specification. Controlling for these regime shifts reduces the risk of omitted structural effects and enhances the reliability of both short-run and long-run coefficient estimates. Having established the presence of structural breaks and confirmed that none of the variables are integrated beyond the first order, the ARDL bounds testing framework emerges as an appropriate econometric approach for investigating the long-run equilibrium relationship among the variables.

Following the integration and structural-break analyses, alternative ARDL specifications were evaluated using the Akaike Information Criterion (AIC). Figure 1 presents the top 20 competing ARDL models ranked according to their AIC values. The model selection results indicate that the ARDL(2,1,2,2,2,2,2,2) specification yields the lowest AIC value among the candidate models and was therefore selected as the baseline specification. The AIC-based selection procedure provides a systematic basis for balancing model fit against the number of estimated parameters and helps avoid unnecessarily complex lag structures.

Nevertheless, given the relatively small number of annual observations, the AIC-selected specification should not be interpreted as being free from small-sample limitations. In particular, the inclusion of multiple lagged terms together with structural-break dummies may reduce the effective degrees of freedom and, consequently, the statistical power of individual coefficient tests. This consideration is particularly relevant when interpreting

the estimated long-run coefficients. Accordingly, the long-run estimates are interpreted cautiously, and the sensitivity of the main findings to the baseline specification is assessed through additional robustness checks.

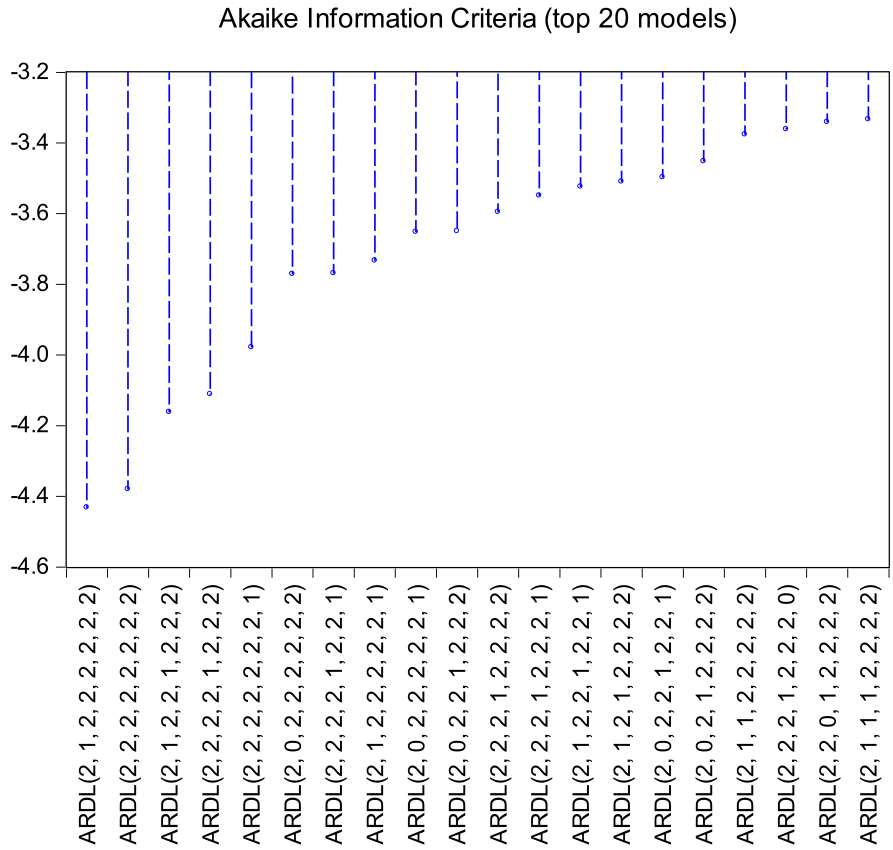

Figure 1. Selection of the ARDL Model.

The two structural-break dummies identified by the Bai–Perron procedure are retained in the baseline model because the estimated break dates indicate statistically significant regime shifts during the sample period. Their inclusion is intended to control for discrete changes in the underlying economic environment and to reduce the risk of omitted structural effects, rather than to unnecessarily increase model complexity. The selected ARDL specification is subsequently used for the bounds test, long-run estimation, and error-correction analysis.

Following the selection of the optimal ARDL specification, the existence of a long-run equilibrium relationship among the variables was examined using the ARDL bounds testing approach. The results reported in Table 6 provide strong evidence of cointegration. Specifically, the calculated F-statistic (21.4887) substantially exceeds the upper critical bound (I1) at all conventional significance levels. At the 1% significance level, the upper bound critical value is 4.26, which is considerably lower than the estimated F-statistic.

The bounds testing results provide evidence against the null hypothesis of no long-run relationship among the variables included in the model. Specifically, the calculated F-statistic exceeds the relevant upper-bound critical value, indicating the presence of a long-run cointegrating relationship among financial development, carbon emissions, renewable energy consumption, economic growth, inflation, and foreign direct investment, conditional on the structural-break controls included in the specification.

Importantly, the existence of cointegration should be distinguished from the statistical significance of individual long-run coefficients. The bounds test assesses whether the variables are jointly characterized by a long-run equilibrium relationship, whereas the

estimated long-run coefficients indicate the conditional long-run association between financial development and each individual explanatory variable. Therefore, the absence of statistically significant individual coefficients for the climate-transition variables does not contradict the evidence of cointegration. Rather, the results suggest that the variables are jointly linked over the long run, while the data do not provide sufficient statistical evidence to identify statistically significant individual long-run effects of carbon emissions or renewable energy consumption on financial development.

Table 6. ARDL Bounds Test Results.

Test Statistic	Value	k
F-statistic	21.48868	7
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.03	3.13
5%	2.32	3.5
2.5%	2.6	3.84
1%	2.96	4.26

From an economic perspective, the existence of cointegration is particularly meaningful in the context of Kazakhstan. As a resource-dependent economy undergoing a gradual transition toward a more sustainable growth model, changes in carbon emissions, renewable energy consumption, and macroeconomic conditions are closely intertwined with developments in the financial sector. The strong cointegration evidence suggests that environmental and economic factors are not isolated determinants of financial development; rather, they form part of a common long-run adjustment process. Consequently, policies aimed at managing climate transition risks, promoting renewable energy adoption, and maintaining macroeconomic stability are likely to have persistent implications for the development of Kazakhstan's banking and credit markets.

Having confirmed the existence of a long-run equilibrium relationship, the next step is to estimate the long-run coefficients and examine the short-run adjustment dynamics through the error correction mechanism.

Tables 7 and 8 report the long-run and short-run ARDL estimates for the determinants of financial development in Kazakhstan. The long-run results indicate that none of the explanatory variables exerts a statistically significant individual effect on domestic credit to the private sector at conventional significance levels. Although carbon emissions, renewable energy consumption, inflation, and foreign direct investment display negative coefficients, while GDP per capita exhibits a positive coefficient, these estimated signs should not be interpreted as evidence of stable structural effects or long-run elasticities in the absence of statistical significance. Rather, the results indicate that the available data do not provide sufficient statistical evidence to identify persistent individual long-run effects of these variables on bank-based financial development in Kazakhstan over the sample period.

Several economic and institutional factors may help explain the absence of statistically identifiable long-run effects. First, Kazakhstan's financial system operates within a resource-dependent economic structure in which fossil-fuel extraction and hydrocarbon-related activities remain important components of economic activity and investment. In such an environment, aggregate carbon emissions may primarily reflect the scale and composition of economic activity rather than a climate-related financial risk that is systematically incorporated into domestic credit allocation. Second, the integration of ESG considerations and climate-risk assessment into banking practices remains at an evolving stage. Consequently, aggregate environmental indicators may not yet be sufficiently embedded in banks' credit-allocation and risk-management decisions to generate a statistically

identifiable long-run relationship. This interpretation is consistent with the institutional context discussed in the literature, while it should nevertheless be regarded as a plausible economic explanation rather than as a directly tested causal mechanism, given the aggregate nature of the indicators employed in the present study.

Table 7. ARDL Long-Run Estimation Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO2	−2.028123	3.990451	−0.508244	0.6380
REN	−1.633943	2.200541	−0.742519	0.4990
LNGDPPC	3.563500	2.116014	1.684063	0.1675
INF	−0.130466	0.174244	−0.748754	0.4956
FDI	−0.269031	0.465128	−0.578402	0.5940
D2018	0.317166	0.978776	0.324044	0.7621
D2010	−4.054306	4.873018	−0.831991	0.4522
C	−16.392323	8.382766	−1.955479	0.1222

Table 8. ARDL Short-Run Estimation Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNCREDIT(−1))	−0.667267	0.199307	−3.347933	0.0286
D(LNCO2)	0.187476	0.212393	0.882685	0.4273
D(REN)	0.011313	0.051806	0.218367	0.8378
D(REN(−1))	0.162194	0.056031	2.894739	0.0444
D(LNGDPPC)	4.189388	1.198961	3.494182	0.0250
D(LNGDPPC(−1))	1.387098	0.530779	2.613326	0.0592
D(INF)	−0.011134	0.003204	−3.475504	0.0255
D(INF)	0.005329	0.004157	1.281808	0.2692
D(FDI)	−0.001994	0.005953	−0.334856	0.7546
D(FDI(−1))	0.020302	0.004171	4.867554	0.0082
D(D2018)	−0.009838	0.062883	−0.156453	0.8833
D(D2018(−1))	−0.348541	0.065617	−5.311773	0.0060
D(D2010)	−0.500140	0.117611	−4.252508	0.0131
D(D2010(−1))	−0.186996	0.086564	−2.160218	0.0969
CointEq(−1)	−0.152600	0.043780	−3.484331	0.0057

With respect to the main variables of interest, both carbon emissions and renewable energy consumption have negative estimated coefficients in the long-run specification. However, neither coefficient is statistically significant at conventional levels. Therefore, the results do not provide sufficient evidence to conclude that higher carbon emissions or greater renewable energy consumption systematically affect domestic credit to the private sector in the long run. This finding should not be interpreted as evidence that climate-transition factors are economically irrelevant to financial development. Rather, it indicates that their individual long-run effects cannot be identified with sufficient statistical precision within the present aggregate-data framework.

The widespread statistical insignificance of the long-run coefficients should also be considered in light of the relatively small annual sample and the dynamic structure of the estimated model, including lagged terms and structural-break controls. These features may reduce the statistical power available to identify individual long-run effects with precision, even when the variables are jointly embedded in a long-run equilibrium relationship. Accordingly, the interpretation of the long-run estimates remains deliberately cautious, and the signs and magnitudes of statistically insignificant coefficients are not treated as evidence of stable structural relationships.

Among the control variables, GDP per capita exhibits a positive long-run coefficient, which is consistent in direction with the possibility that higher income levels may be associated with greater financial deepening. Nevertheless, its lack of statistical significance prevents this interpretation from being established as a stable long-run relationship within the estimated model. Inflation and foreign direct investment both display negative long-run coefficients, but neither reaches conventional levels of statistical significance. Similarly, the structural-break dummies are not statistically significant in the long-run specification, suggesting that the identified regime shifts do not provide sufficient evidence of a persistent alteration in the conditional long-run relationship among the variables.

Overall, the long-run results should therefore be interpreted as evidence of limited statistical identification of individual effects rather than as evidence of their economic absence. The distinction is particularly important given the finite-sample characteristics of the study. The limited number of annual observations and the dynamic specification may affect the precision of individual coefficient estimates. Consequently, the absence of statistical significance should be understood as indicating that the available data do not permit these individual long-run effects to be estimated with sufficient precision, rather than as demonstrating that the underlying economic mechanisms are necessarily absent.

The short-run dynamics, however, reveal a more informative picture. Carbon emissions do not have a statistically significant short-run effect on financial development, indicating that short-term fluctuations in environmental pressure are not immediately transmitted to domestic credit markets. In contrast, renewable energy consumption exerts a positive and statistically significant lagged effect, suggesting that increases in renewable energy utilization contribute to financial development after a short adjustment period. This finding implies that renewable energy-related investments may stimulate financing activities and credit demand in the short run.

Economic growth emerges as one of the most important short-run determinants of financial development. The positive and statistically significant coefficients indicate that increases in income levels contribute directly to the expansion of private sector credit. This result reflects the close relationship between economic activity and financial intermediation in Kazakhstan, where periods of stronger economic performance are generally accompanied by higher lending activity.

Inflation displays a statistically significant negative short-run effect, indicating that macroeconomic instability adversely affects financial development. Rising inflation may increase uncertainty, reduce real returns, and discourage both lenders and borrowers, thereby constraining credit expansion. This result highlights the importance of maintaining price stability for the effective functioning of the financial system.

Foreign direct investment exhibits mixed short-run effects. While the contemporaneous coefficient is statistically insignificant, the lagged coefficient is positive and significant, suggesting that the beneficial effects of foreign capital inflows on financial development materialize with a time delay. This finding implies that foreign investment may initially enter specific sectors before generating broader financing needs that support domestic credit expansion.

The structural break variables associated with 2010 and 2018 are statistically significant in the short run and carry negative coefficients, indicating that major economic and institutional changes during these periods temporarily reduced financial development. These findings confirm the relevance of incorporating structural breaks into the empirical framework and support the earlier evidence obtained from the Bai–Perron test.

Finally, the error-correction term is negative and statistically significant, confirming the existence of a long-run equilibrium relationship among the variables. The negative sign indicates that deviations from the long-run equilibrium are gradually

corrected over time, with approximately 15% of short-run disequilibria being eliminated within one period. This adjustment mechanism suggests that although short-run shocks may temporarily affect financial development, the system tends to converge back toward its long-run equilibrium path.

The diagnostic tests reported in Table 9 confirm the adequacy of the estimated ARDL model. The results indicate no evidence of model misspecification, heteroskedasticity, serial correlation, or non-normality. Therefore, the estimated coefficients can be considered statistically reliable for inference and policy interpretation.

Table 9. Post-estimation Results.

Ramsey RESET Test			
F-statistic: 0.188102		*p*-value: 0.6938	
Heteroskedasticity Test: Breusch–Pagan–Godfrey			
F-statistic: 0.762642		*p*-value: 0.7033	
Serial Correlation LM			
F-statistic: 7.249922		*p*-value: 0.1212	
Normality			
Skewness: −0.227363	Kurtosis: 3.372603	Jarque–Bera: 0.388809	*p*-value: 0.823325

Figure 2 presents the CUSUM and CUSUMSQ stability tests for the estimated ARDL model. The results show that both the CUSUM and CUSUMSQ statistics remain within the 5% critical bounds throughout the sample period. Therefore, the null hypothesis of parameter stability cannot be rejected. These findings indicate that the estimated coefficients are structurally stable and that the model does not suffer from significant parameter instability despite the structural shifts identified in 2010 and 2018. Accordingly, these diagnostic and stability results provide complementary evidence supporting the adequacy and parameter stability of the estimated ARDL specification. However, they do not eliminate the finite-sample limitations of the analysis, which are taken into account when interpreting the long-run and short-run estimates.

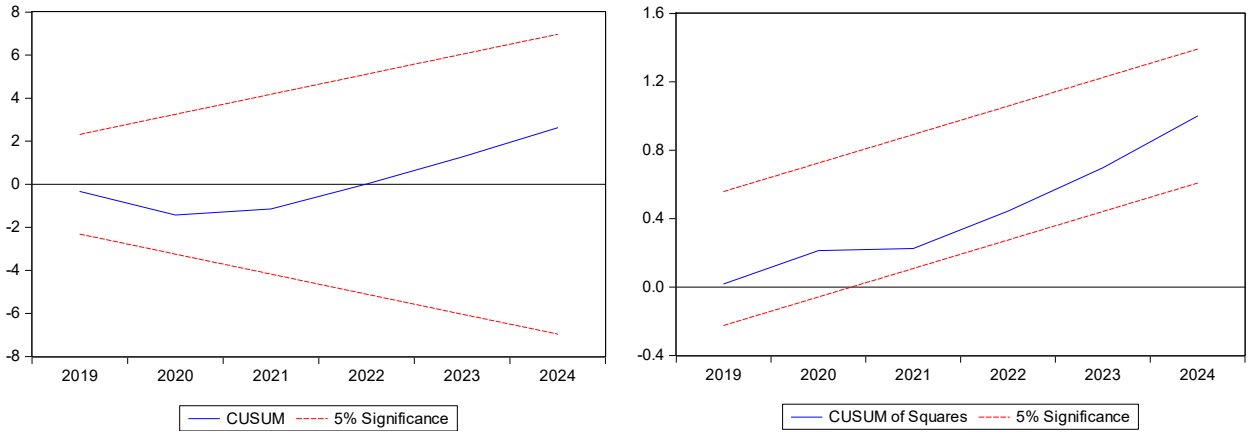

Figure 2. CUSUM and CUSUMSQ Graphs.

5. Discussion

The primary objective of this study was to examine whether climate transition-related factors, particularly carbon emissions and renewable energy consumption, influence financial development in Kazakhstan. The findings provide a nuanced picture of the climate-

finance nexus in a resource-dependent economy undergoing gradual energy transition, where institutional and financing structures may shape how aggregate environmental developments are transmitted into domestic financial intermediation. While the ARDL bounds test confirmed the existence of a long-run relationship among the variables, the long-run coefficients indicate that neither carbon emissions nor renewable energy consumption exert a statistically significant effect on financial development. By contrast, several variables exhibit significant short-run effects, suggesting that the interaction between environmental transition dynamics and financial intermediation in Kazakhstan is primarily manifested through short-term adjustments rather than structural long-run transformations.

One of the most notable findings is the absence of a statistically significant long-run relationship between carbon emissions and domestic credit to the private sector. This result differs from a substantial part of the existing literature that identifies strong linkages between environmental performance and financial sector development. For example, Zafar et al. (2019) report that financial development and carbon emissions are closely interconnected across both developed and emerging economies, while Bilgili et al. (2025) find that financial sector dynamics can influence environmental outcomes over longer time horizons. Similarly, Yahya and Lee (2026) argue that financial institutions increasingly internalize carbon-related considerations through governance and regulatory mechanisms.

The insignificant long-run effect observed in Kazakhstan may reflect the country's distinctive economic and institutional structure. Kazakhstan remains heavily dependent on fossil fuel extraction and hydrocarbon exports, which continue to constitute major sources of government revenues, foreign exchange earnings, and investment activity (Stergiou 2026; Ülger Danacı 2026). Under such conditions, carbon emissions may still be perceived primarily as a by-product of aggregate economic activity rather than as a financial risk that systematically influences credit allocation within the domestic banking sector. Although climate-related risks have become increasingly important in global financial markets, their transmission into domestic financial intermediation may remain limited where climate-risk assessment and ESG considerations are still evolving within banking practices. This interpretation is broadly consistent with Zhassan et al. (2026), who identify substantial gaps in ESG implementation and indicate that climate-risk assessment practices within Kazakhstan's banking sector remain at an early stage. In such an institutional setting, aggregate changes in carbon emissions may not yet translate systematically into changes in bank-based credit allocation. However, this should be regarded as a plausible institutional explanation rather than a directly tested causal mechanism, because the present analysis relies on aggregate environmental indicators and does not directly observe banks' internal climate-risk assessment, credit-scoring, or underwriting practices.

The results also indicate that renewable energy consumption does not exert a statistically significant long-run influence on financial development. This finding contrasts with studies suggesting that renewable energy deployment can stimulate financial deepening through increased investment opportunities and the expansion of green financing mechanisms (Lin and Okoye 2023; Shanyazov et al. 2026). It also differs from evidence showing that renewable energy contributes significantly to environmental sustainability and economic transformation (Khan et al. 2020; Rehan et al. 2026). This divergence may reflect the specific stage and institutional structure of Kazakhstan's energy transition. Although the country possesses considerable renewable energy potential, particularly in wind and solar resources (Taizhanova et al. 2026), renewable energy still represents a relatively modest share of the overall energy mix. Consequently, renewable-energy investment may not yet be sufficiently large or broadly integrated into domestic financial intermediation to generate substantial spillover effects on aggregate bank-based financial development.

The financing structure of renewable-energy and decarbonization projects provides an additional institutional explanation. Where large-scale transition projects rely substantially on public support mechanisms, sovereign financing, or international development institutions, their expansion may not translate proportionately into domestic private-sector bank credit. Thus, renewable-energy investment can increase without generating a corresponding increase in the domestic credit-to-private-sector indicator used in this study. The statistically insignificant long-run coefficient may therefore reflect a limited transmission of renewable-energy expansion through the specific bank-credit channel captured by the CREDIT measure, rather than the financial irrelevance of renewable energy more broadly. This interpretation is particularly important because the present study measures financial development through domestic private-sector credit and does not capture alternative financing channels such as public, sovereign, development-institution, or broader sustainable-finance mechanisms. Nevertheless, this explanation should be interpreted as a plausible institutional mechanism rather than as a directly tested causal channel, given the aggregate nature of the data and the relatively small annual sample.

Another important result concerns the role of economic growth. Although GDP per capita does not exhibit a significant long-run impact, it demonstrates a positive and statistically significant short-run effect on financial development. This finding is consistent with traditional financial development theory, which argues that economic expansion increases demand for financial services, credit allocation, and investment financing. In Kazakhstan's context, periods of economic growth are often associated with rising commodity prices, increased investment activity, and improved business confidence, all of which stimulate credit demand. The short-run significance therefore suggests that financial development remains closely linked to cyclical economic conditions rather than structural environmental factors.

The inflation variable exhibits a significant negative short-run effect on financial development. This finding aligns with conventional macroeconomic theory, according to which inflation creates uncertainty, weakens financial intermediation, and reduces the efficiency of credit markets. Elevated inflation may increase borrowing costs, reduce real returns on financial assets, and discourage long-term lending activities. Given Kazakhstan's historical exposure to exchange-rate volatility, external commodity price shocks, and inflationary pressures, the negative short-run relationship appears economically plausible. The result further suggests that macroeconomic stability remains a prerequisite for sustained financial sector development.

The findings regarding foreign direct investment are particularly interesting. While FDI does not exert a significant contemporaneous effect, its lagged value positively influences financial development. This delayed impact is consistent with the notion that foreign investments require time to be absorbed into the domestic economy before generating measurable effects on financial intermediation. New investments often stimulate demand for banking services, supplier financing, infrastructure development, and corporate borrowing over subsequent periods rather than immediately after entry.

This result partially complements the broader literature emphasizing the importance of international capital flows in shaping economic and environmental outcomes. Although previous studies report mixed environmental effects of FDI (Arzova and Sahin 2023; Ahmad et al. 2026; Bhat and Ikram 2025), the present findings suggest that foreign capital contributes positively to financial sector activity in Kazakhstan through indirect and delayed transmission channels. Considering the country's long-standing reliance on foreign investment in energy, mining, and infrastructure sectors, such a lagged effect appears consistent with Kazakhstan's development model.

An additional finding worth noting is the significance of the structural break variables in the short run. The identified breakpoints correspond to periods associated with major

economic and institutional changes in Kazakhstan. The significance of these dummy variables confirms that financial development has been influenced by discrete structural events rather than evolving solely through gradual economic adjustments. This outcome supports the decision to account for structural breaks within the ARDL framework and highlights the importance of considering Kazakhstan's exposure to external shocks, commodity market fluctuations, and policy transitions when examining financial sector dynamics.

Perhaps the most important econometric result is the significance and negative sign of the error-correction term. The coefficient confirms the existence of a stable adjustment mechanism through which short-run disequilibria gradually converge toward long-run equilibrium. In practical terms, this suggests that although environmental and macroeconomic shocks may temporarily affect financial development, the system retains an inherent tendency to return to its long-run path. This finding strengthens the robustness of the estimated ARDL model and supports the validity of the identified long-run relationship.

Taken together, the findings suggest that the climate-finance nexus in Kazakhstan remains at a relatively early stage of development. Unlike evidence from more advanced financial systems where climate risks, carbon exposure, and renewable energy investments increasingly shape financial sector behavior (Yahya and Lee 2026; Zhu et al. 2026), Kazakhstan's financial development continues to be driven primarily by macroeconomic conditions and investment dynamics. Carbon emissions and renewable energy transition appear to have limited direct influence on financial intermediation in the long run, reflecting the country's continued dependence on fossil-fuel-based growth and the still-emerging role of sustainable finance mechanisms.

At the same time, the results should not be interpreted as evidence that climate transition factors are irrelevant for Kazakhstan's financial sector. Rather, they suggest that the financial implications of decarbonization and renewable energy deployment have not yet become sufficiently large to alter aggregate credit dynamics. As climate regulations strengthen, ESG standards become more widespread, and renewable energy investments expand, the relationship between environmental transition and financial development may evolve considerably. Consequently, the findings should be viewed as reflecting the current stage of Kazakhstan's transition process rather than a permanent feature of the economy.

6. Conclusions

This study examined the effects of carbon emissions, renewable energy consumption, economic growth, inflation, and foreign direct investment on financial development in Kazakhstan over the period 1996–2024. Motivated by the growing importance of climate transition risks and sustainable finance, the study adopted an alternative perspective to the dominant literature by treating financial development, measured by domestic credit to the private sector, as the dependent variable. Using the ARDL bounds testing approach and accounting for structural breaks in the Kazakh economy, the analysis examined both the short-run and long-run dynamics linking environmental and macroeconomic factors to financial development.

The empirical findings provide several important insights. First, the ARDL bounds test confirms the existence of a long-run equilibrium relationship among the variables considered jointly in the model. However, the individual long-run estimates indicate that carbon emissions, renewable energy consumption, GDP per capita, inflation, and foreign direct investment do not have statistically significant long-run effects on domestic credit to the private sector. Accordingly, the estimated coefficients should not be interpreted as evidence of stable structural effects or long-run elasticities. Rather, the results indicate that the available aggregate data do not provide sufficient statistical evidence to identify the per-

sistent individual long-run effects of these variables on bank-based financial development in Kazakhstan.

Second, the short-run results reveal a more pronounced role for macroeconomic and environmental dynamics. Economic growth has a positive short-run effect on financial development, indicating that stronger economic activity is associated with increased credit demand and financial intermediation. Inflation exerts a negative short-run effect, highlighting the importance of macroeconomic stability for financial-sector development. Foreign direct investment exhibits a positive lagged effect, suggesting that external capital inflows may require time to be transmitted through investment, production, and financing channels. Renewable energy consumption also exhibits a delayed positive short-run effect, indicating that the financial implications of energy-transition dynamics may emerge gradually rather than immediately.

Overall, the findings suggest that climate-transition factors have not yet become statistically identifiable as individual long-run determinants of aggregate bank-based financial development in Kazakhstan, despite the existence of a joint long-run equilibrium relationship among the variables. This outcome should be interpreted in the context of Kazakhstan's resource-dependent economic structure, the relatively gradual development of renewable energy, and the evolving integration of ESG and climate-risk considerations within the financial sector. The findings therefore point to a transition process in which environmental and financial dynamics may not yet be fully connected through the domestic private-credit channel captured by the present study.

6.1. Policy and Regulatory Implications

The findings have several implications for policymakers, financial regulators, and financial institutions. Importantly, because the climate variables are not statistically significant in the long run, the policy implications should be understood as forward-looking institutional recommendations rather than responses to an established causal effect on financial development.

First, financial regulators could continue strengthening the integration of climate-related and ESG considerations into banking supervision and risk-management frameworks. Proportionate guidance on climate-risk identification, disclosure, sectoral exposure monitoring, and internal risk assessment could help financial institutions progressively incorporate transition-related considerations into lending decisions. Such measures would be particularly relevant for banks with substantial exposure to carbon-intensive sectors.

Second, the development of green and sustainable finance frameworks could help strengthen the connection between Kazakhstan's energy-transition objectives and domestic financial intermediation. Clearer standards for green lending, sustainable-finance instruments, and climate-related disclosure could improve the identification and financing of environmentally oriented investment opportunities. Given the financing structure of large-scale renewable-energy and decarbonization projects, greater coordination among domestic banks, public financing mechanisms, and international development institutions could also help mobilize private capital toward transition-related investment.

Third, climate-transition considerations could be incorporated more systematically into financial-sector risk assessment. Scenario analysis and climate-related stress-testing frameworks may assist regulators and financial institutions in evaluating potential exposures to changes in carbon-pricing policies, energy-transition policies, and the profitability of carbon-intensive sectors. Such approaches would provide a forward-looking complement to conventional macroeconomic risk assessment, particularly given the importance of hydrocarbon-related activities in Kazakhstan's economy.

Fourth, stronger coordination among financial, energy, and environmental authorities would be beneficial for aligning sustainable-finance development with the country's broader energy-transition objectives. Policies supporting renewable-energy deployment should be complemented by financing mechanisms capable of connecting transition investment with domestic financial markets. This coordination could help ensure that the expansion of renewable energy generates broader financial-sector opportunities rather than remaining concentrated within public or external financing channels.

From an academic perspective, the findings also highlight the importance of moving beyond aggregate indicators when examining the climate–finance nexus in Kazakhstan. The absence of statistically significant long-run effects should not be interpreted as evidence that climate-transition risks are absent from financial institutions. Rather, it underscores the need for future research using more granular bank-level information on sectoral credit exposure, financed emissions, ESG practices, climate-risk assessments, and sustainable-finance portfolios. Such evidence would make it possible to examine more directly the mechanisms through which climate-transition risks may influence financial intermediation.

6.2. Limitations and Directions for Future Research

Despite its contributions, this study has several limitations. First, the analysis focuses on a single country, which limits the generalizability of the findings to other resource-dependent and transition economies. Second, financial development is represented by domestic credit to the private sector, capturing only one dimension of financial development and not capital-market development, green bonds, sustainable-finance instruments, or other forms of financial intermediation. Third, data limitations prevent the inclusion of more direct measures of bank-level climate-transition risk, ESG performance, climate-related financial regulation, and sector-specific credit exposure.

A further limitation concerns the relatively short annual sample available for Kazakhstan. The 1996–2024 period provides 29 annual observations, which may constrain the statistical power of individual coefficient tests, particularly given the dynamic specification and structural-break controls. The findings should therefore be interpreted cautiously and primarily as country-specific evidence. Moreover, while the ARDL framework is appropriate for examining short-run and long-run relationships within the integration structure of the data, it does not fully capture potential nonlinearities or asymmetric responses.

Future research could address these limitations by using longer and, where reliable data permit, higher-frequency datasets and broader cross-country samples covering Central Asian and other resource-dependent economies. Further studies could incorporate broader measures of financial development and more granular bank-level climate-financial indicators to examine how transition risks are incorporated into credit allocation and risk management. Alternative econometric approaches, including nonlinear and asymmetric models, could also be considered. In addition, DOLS and FMOLS could be employed as alternative cointegration estimators, while bootstrap-based ARDL inference could provide finite-sample critical values and assess the sensitivity of bounds-test results, subject to the underlying methodological requirements of these approaches. These methods represent potential directions for future research rather than additional estimators implemented in the present study.

6.3. Concluding Remarks

In conclusion, this study contributes to the emerging climate–finance literature by providing country-specific evidence from Kazakhstan, a resource-rich economy undergoing a gradual energy transition. The results indicate that carbon emissions and renewable energy consumption do not have statistically identifiable individual long-run effects on

aggregate bank-based financial development over the sample period, while short-run dynamics reveal more pronounced roles for renewable energy consumption and broader macroeconomic conditions. These findings suggest that the climate–finance transmission mechanism in Kazakhstan remains at an evolving stage and may not yet be fully reflected in aggregate domestic private-sector credit.

As Kazakhstan advances its decarbonization agenda and sustainable-finance framework, strengthening the institutional capacity of the financial sector to identify, disclose, and manage climate-transition risks will become increasingly important. At the same time, continued improvements in climate-financial data availability will be essential for determining whether the relationships identified in this study evolve as the country's energy transition and sustainable-finance architecture mature.

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