ENVIRONOMICS

Research article

https://doi.org/10.70731/0ts30009

Socio-Political-Economic Co-evolution and Sustainable Development: Breaking the Impossible Trinity through Sino-Belarusian Comparative Analysis

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Received 22 March 2026

Revised 9 May 2026

Accepted 4 June 2026

Published 30 June 2026

Abstract: This study extends the Impossible Trinity framework to sustainable development governance and integrates co-evolution theory with comparative political economy to examine the interactive mechanisms between socio-political institutions and eco-economic systems. Using panel data from China and Belarus (1990–2022), we employ the coupling coordination degree model, fixed-effects regression, and mediating effect model to quantify co-evolution trajectories and driving forces. Empirical results reveal distinct co-evolution patterns: China has established a three-dimensional driven high-quality synergy model (coupling coordination degree = 0.82 in 2022), while Belarus has developed a dual-track adaptive favorable synergy model (D = 0.67 in 2022). Government governance efficiency (β=0.213, p<0.01), political stability (β=0.185, p<0.01), and geopolitical openness (β=0.157, p<0.01) emerge as core drivers, with technological innovation and industrial structure upgrading exerting partial mediating effects (21.1% and 18.3% respectively). Both countries face the Impossible Trinity constraints of equity, efficiency, and fiscal sustainability. We propose a three-tier governance framework (basic-equity, competitive-efficiency, regulatory-fiscal balance) and an international cooperation paradigm of "institutional complementarity, technology sharing, and risk sharing" under the Belt and Road Initiative. This research provides replicable solutions for developing countries and geopolitically constrained nations pursuing sustainable development.

Keywords: Sustainable development; Co-evolution; Socio-political institutions; Eco-economic synergy; Impossible trinity; Sino-Belarusian comparison; Belt and road initiative

ISSN 2760-6686 (Online)

Introduction

Research background

The global implementation of the UN Sustainable Development Goals (SDGs) is increasingly challenged by overlapping tensions: trade-offs between development rights and environmental responsibilities, fragmentation of global governance amid geopolitical conflicts, and the inherent contradiction between efficiency, equity, and fiscal sustainability. As the core institutional carrier of resource allocation and policy coordination, socio-political systems fundamentally shape national sustainable development pathways.

China, the world's largest developing country, has achieved simultaneous progress in economic growth, poverty reduction, and environmental improvement through top-level design of the "Dual Carbon" goals and market-driven green transformation. Belarus, a landlocked Eastern European economy with Soviet-era industrial foundations, faces 90% dependence on Russian energy imports and Western sanctions, yet has maintained stable sustainable development through a gradual circular economy transition. These two countries represent distinct institutional contexts (party-led collective governance vs. strong presidential system) and development trajectories (high-growth

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transformation vs. low-growth stability), making them ideal cases for comparative analysis.

Literature review

Existing research on sustainable development has three critical limitations. Analytical perspectives remain largely fragmented, with most studies focusing exclusively on either eco-economic performance evaluation or circular economy technology applications while neglecting the bidirectional co-evolution mechanism between socio-political institutions and eco-economic systems. Cross-country comparative studies also remain superficial, rarely probing how institutional differences including political regimes, governance models and welfare systems shape divergent co-evolution paths, and thus failing to reasonably explain the gap between China's rapid transformation and Belarus's steady adaptation. Furthermore, empirical support remains insufficient, as qualitative descriptions and single-indicator comparisons dominate existing research, lacking quantitative models to measure co-evolution levels and verify driving factors, while the enabling effect of Sino-Belarusian Belt and Road cooperation on co-evolution also remains understudied.

Research questions and contributions

This study addresses three core research questions to fill these gaps. It first explores the stage characteristics and fundamental differences in socio-political-eco-economic co-evolution between China and Belarus, then examines how key socio-political variables drive co-evolution and what mediating roles technological innovation and industrial upgrading play in this process, and finally investigates how institutional innovation and international cooperation can break the Impossible Trinity constraints of sustainable development.

This research makes three key theoretical contributions. It extends the Impossible Trinity framework from monetary economics to sustainable development governance and constructs a three-tier dynamic balance mechanism, develops an integrated analytical framework of "three-dimensional driving – dual-cycle synergy – stage evolution" for socio-political-eco-economic co-evolution, and enriches the diversity of sustainable development paradigms by comparing centralized governance and strong presidential governance systems. In practical terms, this study quantifies co-evolution levels and identifies core constraints for China and Belarus to propose targeted optimization paths, and summarizes a replicable international cooperation model under the Belt and Road Initiative, providing references for developing countries and geopolitically constrained nations pursuing sustainable development.

Research design

We adopt a mixed-methods approach combining quantitative analysis and qualitative case studies to ensure the scientificity and rigor of the research. Panel data from 1990 to 2022 are sourced from authoritative databases including the World Bank WDI, UN SDG Database, National Bureau of Statistics of China, and National Statistical Committee of Belarus. We use the entropy-weighted coupling coordination degree model to measure co-evolution levels, fixed-effects regression to test direct drivers, and a three-step mediating effect model to examine transmission mechanisms. The reliability of conclusions is verified through multiple robustness checks including variable substitution, model re-specification, outlier exclusion and instrumental variable estimation, and two micro cases—Zhejiang's "Ten Million Project" and Minsk Circular Economy Park—are analyzed to validate the macro-level conclusions.

Theoretical Framework and Research Hypotheses

Core concepts

Socio-political-eco-economic co-evolution refers to the dynamic process of mutual adaptation, interactive feedback, and continuous optimization between socio-political systems encompassing institutional arrangements, governance capacity, and geopolitical context, and eco-economic systems involving economic growth, environmental quality, and social equity. At its core, this process operates through a sequential logic of institutional adaptation, technological innovation, and interest coordination, with each dimension reinforcing and shaping the others over time. Complementing this concept, the Sustainable Development Impossible Trinity captures the inherent constraint that equity defined as social fairness and distributive justice, efficiency encompassing both economic growth and environmental governance effectiveness, and fiscal sustainability measured by government revenue-expenditure balance cannot be simultaneously maximized under static institutional arrangements. This fundamental tension necessitates a shift from static trade-offs between competing goals to dynamic hierarchical governance structures that can reconcile these objectives without sacrificing any core dimension of sustainable development.

Theoretical foundations

Co-evolution theory

Co-evolution theory, originating from evolutionary biology and later extended to the field of institutional economics, provides the foundational lens for analyzing the dynamic interactions between socio-political and eco-economic systems. The theory emphasizes that systems do not evolve in isolation but rather interact through a cyclical process of variation, selection, and retention. In the context of sustainable development, variation takes the form of institutional innovations such as new environmental policies or technological breakthroughs in renewable energy. Selection occurs through market competition and policy guidance, which determine which innovations are adopted and scaled up across sectors and regions. Retention involves the institutionalization of successful practices and the diffusion of proven technologies, creating path dependencies that shape future de-

velopment trajectories. Applied to this study, this framework suggests that socio-political systems steer eco-economic transformation through targeted policy supply and strategic resource allocation, while eco-economic performance in turn feeds back to institutional legitimacy by improving livelihoods and maintaining social stability, forming a self-reinforcing dual-cycle feedback loop.

Comparative political economy

Comparative political economy further enriches the analysis by highlighting how political regimes and governance models shape interest coordination mechanisms and policy preferences. Different institutional architectures generate distinct incentive structures for policymakers, firms, and citizens, leading to divergent sustainable development paths. For instance, China's centralized five-year plan system enables the mobilization of large-scale resources across regions and sectors to advance long-term green projects that require sustained investment and cross-jurisdictional coordination. In contrast, Belarus's strong presidential system prioritizes social stability and geopolitical balance in the transition process, leading to a more gradual approach to green transformation that minimizes potential social disruption. These institutional differences help explain the fundamental divergence in the pace and direction of sustainable development between the two countries, providing a critical context for interpreting their respective co-evolution trajectories.

Extended impossible trinity framework

The core theoretical innovation of this study lies in extending the classic Mundell-Fleming Impossible Trinity framework from monetary economics to the field of sustainable development governance. In its original form, the framework states that countries cannot simultaneously maintain a fixed exchange rate, free capital movement, and an independent monetary policy. Adapted to sustainable development, this logic reveals a similar trilemma: equity requires increased public expenditure on livelihood security and ecological compensation to ensure distributive justice; efficiency demands unlocking market vitality and investing in technological innovation to enhance economic and environmental performance; and fiscal sustainability imposes inherent limits on the scale of public spending to avoid unsustainable debt levels. Static trade-offs between these three goals inevitably lead to suboptimal outcomes, as prioritizing one goal necessarily comes at the expense of the others. To resolve this trilemma, this study proposes a three-tier hierarchical governance framework where the basic layer guarantees bottom-line equity by ensuring subsistence dignity and basic public services, the competitive layer enhances efficiency by unleashing market forces and promoting innovation, and the regulatory layer maintains fiscal balance through dynamic redistribution mechanisms such as taxation and carbon trading.

Integrated analytical framework

Building on these complementary theoretical foundations, this study constructs an integrated analytical framework that links driving mechanisms, interaction processes, and evolutionary stages to systematically examine socio-political-eco-economic co-evolution. The framework first identifies three key driving mechanisms through which socio-political systems influence co-evolution outcomes: institutional supply through the formulation of green policies and improvement of property right protection, resource allocation via fiscal investment and credit preferences, and interest coordination by encouraging social participation and establishing risk-sharing mechanisms. These driving forces shape the interaction processes between the two systems, where eco-economic systems achieve green transformation through industrial structure upgrading, pollution control, and energy substitution, while their performance outcomes in turn feed back to refine socio-political institutions and adjust policy priorities. Finally, the framework divides co-evolution into four distinct stages based on the coupling coordination degree (D) between the two systems: the disharmony stage where D is less than 0.4 and tensions between systems are acute, the transitional stage where D ranges from 0.4 to 0.6 and systems begin to adapt to each other, the favorable synergy stage where D is between 0.6 and 0.8 and positive interactions emerge, and the high-quality synergy stage where D reaches 0.8 or above and systems achieve deep integration and mutual reinforcement(See **Figure 1**).

Research hypotheses

Based on the theoretical framework and integrated analysis presented above, this study proposes five testable hypotheses regarding the drivers and mechanisms of socio-political-eco-economic co-evolution. First, government governance efficiency, as a key determinant of policy formulation and implementation effectiveness, is expected to have a significant positive effect on co-evolution outcomes. Second, political stability provides the necessary institutional environment for long-term planning and investment in green transition, so higher levels of political stability should be associated with better co-evolution performance. Third, geopolitical openness facilitates access to international markets, technology, and capital, which are critical for advancing sustainable development, leading to the hypothesis that greater geopolitical openness enhances co-evolution. Fourth, social welfare levels exert a conditional positive effect: moderate welfare provision helps balance transition costs and maintain social stability, while excessive welfare spending creates fiscal burdens and weakens incentives for innovation, resulting in a nonlinear relationship between social welfare and co-evolution. Finally, technological innovation and industrial structure upgrading are expected to mediate the relationship between core socio-political drivers and co-evolution outcomes, as effective institutions drive technological progress and structural transformation, which in turn improve eco-economic performance.

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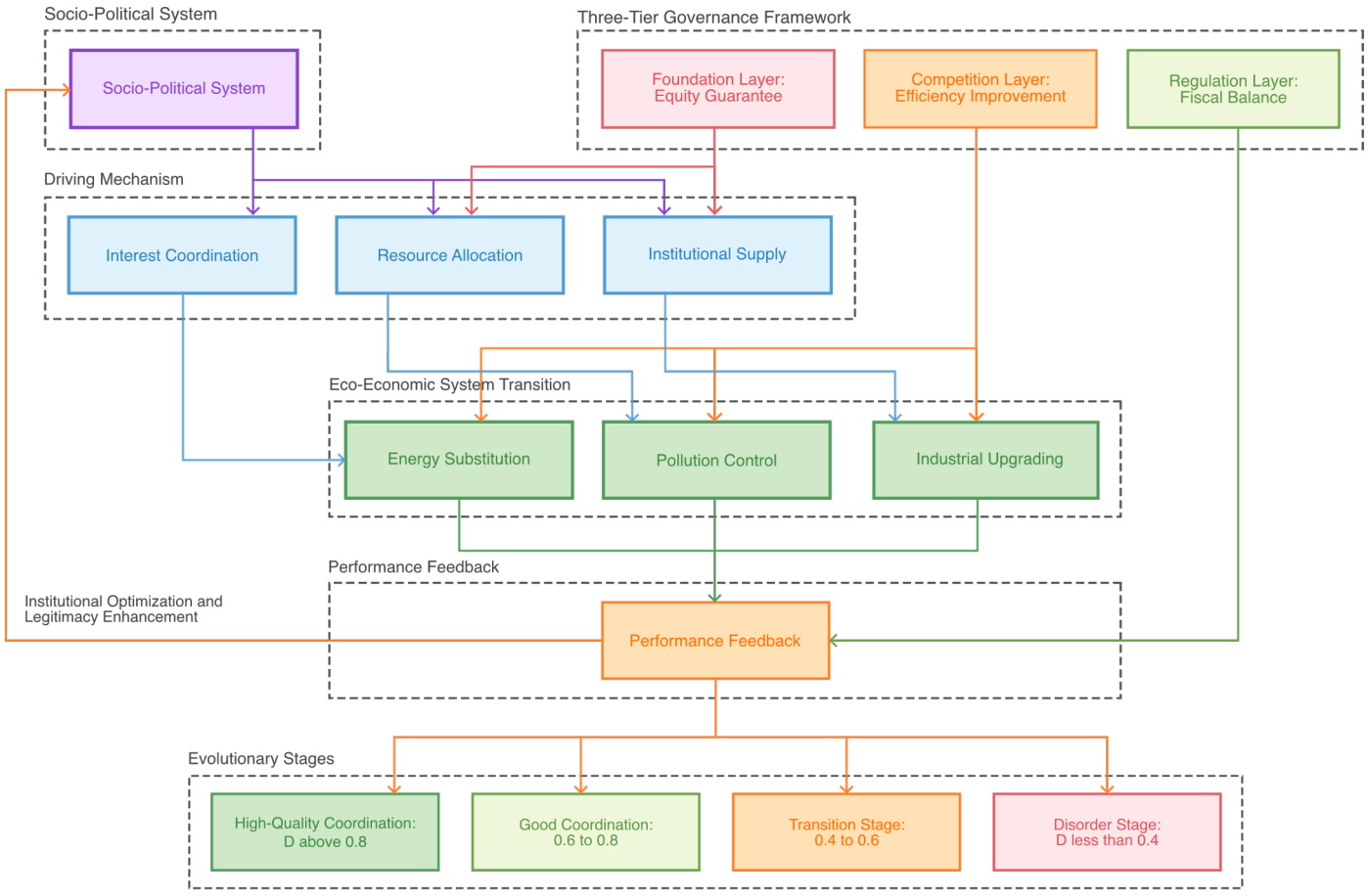

Figure 1 | Three-tiered governance framework and co-evolution mechanism for sustainable development

Research Design

Variable measurement

Dependent variable: Coupling coordination degree (D)

We construct an evaluation index system for socio-political and eco-economic subsystems (**Table 1**). The entropy weight method is used to calculate indicator weights, avoiding subjective bias. The coupling coordination degree is computed as:

$$C = \sqrt{\frac{U_1 U_2}{(U_1 + U_2)^2}}, \quad D = \sqrt{C} \times T, \quad T = 0.5U_1 + 0.5U_2$$

where U_1 and U_2 are the comprehensive indices of the socio-political and eco-economic subsystems, respectively.

Core explanatory variables

Political stability: Measured by the World Bank Worldwide Governance Indicators (WGI) "Political Stability and Absence of Violence/Terrorism" index.

Governance efficiency: Measured by the WGI "Government Effectiveness" index.

Geopolitical openness: Measured by the ratio of total foreign trade to GDP.

Social welfare: Measured by the ratio of social security expenditure to GDP.

Mediating variables

Technological innovation: R&D expenditure as a share of GDP.

Industrial structure upgrading: Tertiary industry value added as a share of GDP.

Control variables

Per capita GDP, population density, urbanization rate, and energy intensity.

Empirical models

Baseline fixed-effects model

$$D_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 G_{it} + \beta_3 Geo_{it} + \beta_4 W_{it} + \gamma X_{it} + \mu_i + \varepsilon_{it}$$

where D_{it} is the coupling coordination degree of country i in year t; P_{it}, G_{it}, Geo_{it}, W_{it} are core explanatory variables; X_{it} is the vector of control variables; μ_i is the individual fixed effect; ε_{it} is the random error term.

Table 1 | Evaluation Index System for Co-evolution

Subsystem	Primary Indicators	Secondary Indicators	Indicator Type	Weight (China)	Weight (Belarus)
Socio-political System	Political Stability	Regime continuity, social order	Positive	0.22	0.35
	Governance Efficiency	Policy implementation capacity, environmental governance effectiveness	Positive	0.31	0.24
	Geopolitical Openness	Trade dependence, FDI inflow	Positive	0.25	0.22
	Social Welfare	Gini coefficient, social security expenditure ratio	Positive	0.22	0.19
Eco-economic System	Economic Development	Per capita GDP, green GDP share	Positive	0.28	0.26
	Environmental Quality	Carbon emissions per unit GDP, forest coverage	Positive/Negative	0.32	0.34
	Industrial Structure	Tertiary industry share, green industry output ratio	Positive	0.21	0.20
	Social Equity	Urban-rural income ratio, poverty rate	Negative	0.19	0.20

Data sources: World Bank WDI, UN SDG Database, national statistical yearbooks (1990–2022)

Table 2 | Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Coupling Coordination Degree (D)	0.58	0.18	0.31	0.82
Political Stability	0.62	0.15	0.32	0.85
Governance Efficiency	0.57	0.17	0.28	0.81
Geopolitical Openness	0.72	0.21	0.35	1.12
Social Welfare	0.18	0.05	0.09	0.26
Technological Innovation	0.015	0.008	0.005	0.028
Industrial Upgrading	0.52	0.09	0.31	0.65

Data sources: Author's calculations based on WDI and national statistics

Mediating effect model

We use a three-step regression framework to test the mediating roles of technological innovation ($Tech_{it}$) and industrial upgrading (Ind_{it}):

Baseline regression (same as above)

Mediator regression: $Med_{it} = \alpha_0 + \alpha_1 Core_{it} + \gamma X_{it} + \mu_i + \varepsilon_{it}$

Total effect regression: $D_{it} = \beta'_0 + \beta'_1 Core_{it} + \beta'_2 Med_{it} + \gamma X_{it} + \mu_i + \varepsilon_{it}$

Partial mediation is confirmed if β_1, α_1, β'_2 and are all significant and $\beta_1 < \beta'_1$.

Robustness checks

Core variable substitution: Replace governance efficiency with environmental expenditure share; replace trade dependence with FDI dependence.

Model re-specification: Random-effects model and pooled OLS regression.

Outlier exclusion: Remove Belarus's 1990–1995 data (distorted by Soviet collapse).

Endogeneity mitigation: Use one-period lagged core explanatory variables as instrumental variables.

Empirical Results and Analysis

Descriptive statistics

Table 2 presents descriptive statistics for the full sample (66 observations, 1990–2022). The mean coupling coordination degree is 0.58, ranging from 0.31 (China, 1990) to 0.82 (China, 2022), indicating significant disparities in co-evolution performance between the two countries. All variables exhibit reasonable fluctuation ranges, with no severe multicollinearity (VIF < 3).

Co-evolution trajectories and stage analysis

Figure 2 shows the evolution of coupling coordination degrees for China and Belarus (1990–2022). Both countries exhibit upward trends, but China's growth rate (3.2% annually) is more than twice that of Belarus (1.5% annually).

China's three-stage accelerated evolution

1990–2000: Disharmony → Transitional Stage: Institutional exploration phase characterized by market-oriented reforms and initial environmental policy integration. Economic take-off was accompanied by insufficient environmental investment (D rose from 0.31 to 0.49).

2001–2010: Transitional → Favorable Synergy Stage: WTO accession enhanced geopolitical openness, and green industries began to emerge. Market empowerment and policy guidance drove D to 0.60 by 2010.

2011–2022: Favorable → High-quality Synergy Stage: Led by the Dual Carbon goals and sharing economy empowerment, China achieved large-scale poverty reduction and environmental improvement. D reached 0.82 in 2022, entering the high-quality synergy stage.

Table 3 | Baseline Fixed-Effects Regression Results

Variables	Coefficient	Std. Err.	t-statistic	p-value
Governance Efficiency	0.213*	0.032	6.656	0.000
Political Stability	0.185*	0.029	6.379	0.000
Geopolitical Openness	0.157*	0.025	6.280	0.000
Social Welfare	0.098*	0.023	4.261	0.000
Per capita GDP	0.087\\	0.036	2.417	0.019
Industrial Upgrading	0.124\\	0.051	2.431	0.018
Population Density	0.032	0.028	1.143	0.257
Urbanization Rate	0.025	0.022	1.136	0.260
Constant	-0.124\\	0.052	-2.385	0.020
Observations	66			
R-squared	0.923			
Individual Fixed Effects	Yes			

*\Note: *\p<0.01, *p<0.05, p<0.1*

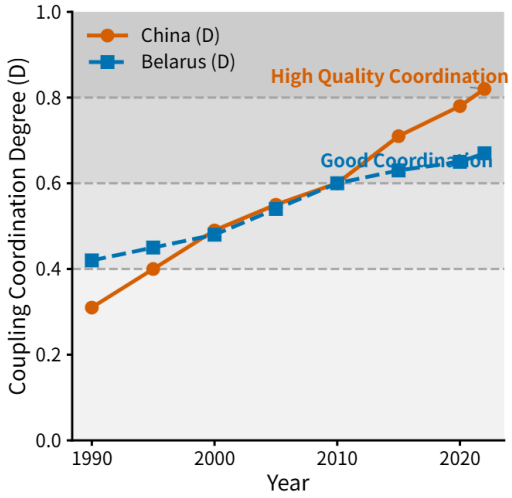

Figure 2 | Evolution trend of the coupling and coordination degree of the socio-political and eco-economic systems of China and Belarus

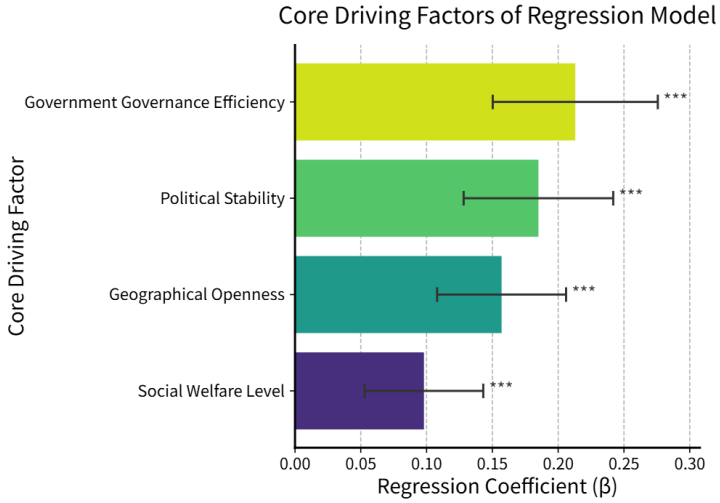

Figure 3 | Comparison of regression coefficients of core driving factors

Belarus's three-stage steady evolution

1990–2000: Fluctuating Transitional Stage: Transition agony phase marked by political instability and economic decline following the Soviet collapse. D fluctuated between 0.42 and 0.48.

2001–2010: Transitional → Early Favorable Synergy Stage: Energy security was secured through the Union State with Russia, and circular economy policies were implemented. D rose to 0.60 by 2010.

2011–2022: Early → Mid Favorable Synergy Stage: Deepened cooperation with China mitigated Western sanctions, but insufficient R&D investment limited transformation. D reached 0.67 in 2022, remaining in the favorable synergy stage.

Baseline regression results

Table 3 presents the fixed-effects regression results. All core explanatory variables have significant positive effects at the 1% level, supporting Hypotheses 1–4. Governance efficiency has the strongest driving force (β=0.213), confirming that efficient policy implementation is the cornerstone of co-evolution. Geopolitical openness (β=0.157) validates the logic of openness-facilitated synergy, explaining Belarus's slower progress amid Western sanctions. Social welfare (β=0.098) has a moderate positive effect, consistent with the theoretical expectation that moderate welfare balances transition costs.

Among control variables, industrial upgrading (β=0.124, p<0.05) and per capita GDP (β=0.087, p<0.05) also have significant positive effects, indicating that economic development and structural transformation enhance co-evolution(See **Figure 3**).

Mediating effect results

Table 4 reports the mediating effect test results with governance efficiency as the core explanatory variable. Technological innovation and industrial upgrading both exert partial mediating effects, accounting for 21.1% and 18.3% of the total effect respectively, supporting Hypothesis 5. This

Table 4 | Mediating Effect Test Results

Dependent Variable	Governance Efficiency Coefficient	Mediator Coefficient	Direct Effect	Mediating Effect Share
Coupling Coordination (Step 1)	0.213*	-	-	-
Technological Innovation (Step 2)	0.187*	-	-	-
Coupling Coordination (Step 3)	0.168*	0.241*	0.168	21.1%
Industrial Upgrading (Step 2)	0.152*	-	-	-
Coupling Coordination (Step 3)	0.174*	0.257*	0.174	18.3%

*\Note: *p<0.01. Control variables and fixed effects are included in all regressions.*

Table 5 | Comparison of Sino-Belarusian Sustainable Development Models

Dimension	China: Three-Dimensional Driven Model	Belarus: Dual-Track Adaptive Model
Institutional Foundation	Party-led collective governance; state-market-society coordination	Strong presidential system; state dominance + geopolitical balance
Core Logic	Institutional flexibility + market vitality + social participation	Political stability + gradual transformation + geopolitical adaptation
Key Drivers	Governance efficiency, technological innovation	Political stability, external cooperation
Main Constraints	Regional imbalance, fiscal pressure on local governments	Energy dependence, technological bottlenecks, geopolitical seclusion
2022 Coupling Coordination	0.82 (High-quality Synergy)	0.67 (Favorable Synergy)
Annual Growth Rate (1990–2022)	3.2%	1.5%
Key Performance	Carbon intensity reduced by 88.1%; 800 million people lifted out of poverty	Energy intensity reduced by 42%; industrial waste recycling rate 68%
Risk Preference	Moderate risk-taking (local pilot programs)	Risk aversion (stability prioritization)

indicates that governance efficiency drives co-evolution through two channels: directly improving policy implementation, and indirectly stimulating technological breakthroughs and industrial advancement (See **Figure 4**).

Robustness checks

All four robustness tests confirm the reliability of the baseline results:

Core variable substitution: Coefficients remain significant at the 1% level, with values close to the baseline (0.208 for environmental expenditure share).

Model re-specification: Random-effects and pooled OLS results are consistent with fixed-effects estimates.

Outlier exclusion: Removing Belarus's 1990–1995 data does not change the significance or magnitude of core coefficients.

Endogeneity mitigation: Instrumental variable regression results show that core variables remain significant, with coefficients slightly higher than the baseline (0.227 for governance efficiency), indicating that reverse causality does not bias the results.

Comparative Analysis of Sino-Belarusian Sustainable Development Models

Table 5 systematically compares the two countries' sustainable development models across institutional foundations, practical paths, and performance outcomes.

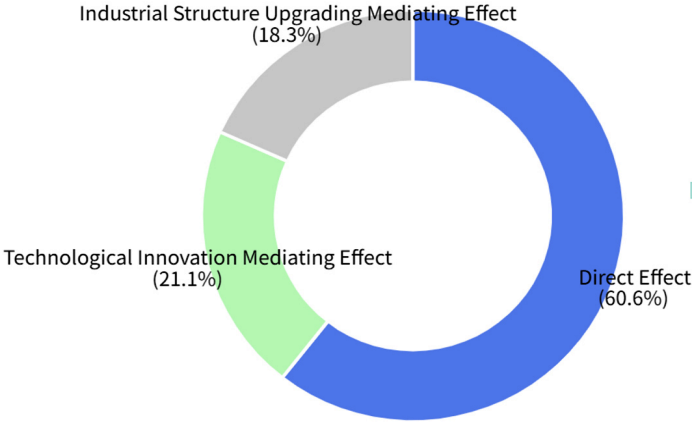

Figure 4 | Decomposition diagram of the mediating effect of government governance efficiency on co-evolution

Institutional origins of model divergence

Political regime differences: China's centralized governance enables long-term strategic planning and cross-regional resource mobilization, while Belarus's presidential system prioritizes policy continuity and social stability.

Geopolitical context differences: China's open geopolitical position as the Belt and Road initiator facilitates global technology and capital flows, while Belarus's position as a Russia-EU buffer zone limits its international cooperation space.

Welfare system differences: China's moderate welfare model balances equity and fiscal sustainability, while Be-

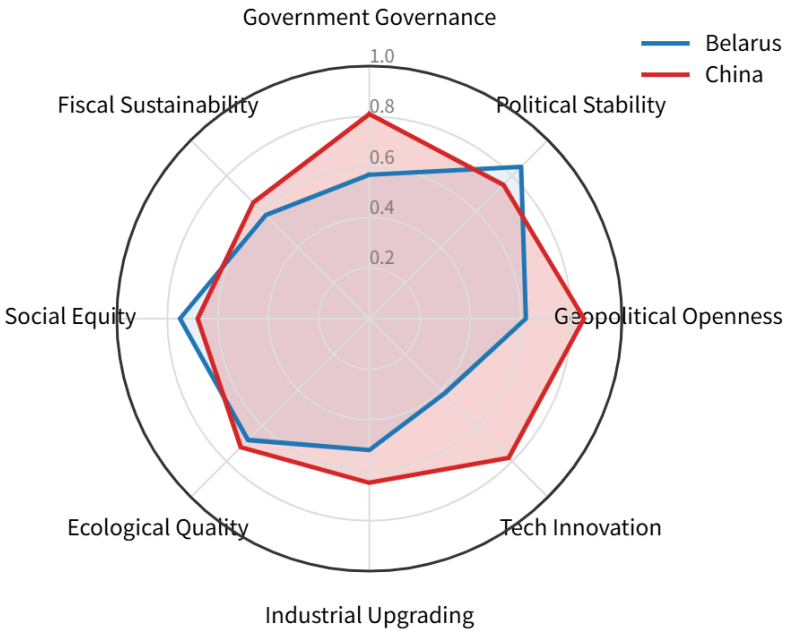

Figure 5 | Radar chart comparing the sustainable development models of China and Belarus from multiple dimensions

larus's Soviet-era high-welfare system increases fiscal pressures but maintains social stability.

Practical Path Differences

China: Adopts a top-down + bottom-up approach, combining national strategic guidance with local innovation and market participation. The Dual Carbon goals are integrated into local government performance assessments, and green finance markets are developed to mobilize private capital.

Belarus: Adopts a top-down gradual approach, focusing on circular economy transformation in traditional industries to avoid large-scale unemployment. International cooperation is primarily with Russia and China to secure energy supply and green investment.(See **Figure 5**)

Dilemmas and Optimization Paths

Shared dilemmas: The impossible trinity constraints

Both countries face the core challenge of balancing equity, efficiency, and fiscal sustainability inherent in the Sustainable Development Impossible Trinity. The trade-off between efficiency and equity manifests differently across the two contexts: China contends with pronounced regional and urban-rural disparities in green development, where eastern provinces have achieved significantly higher levels of eco-economic synergy than western regions, while rural areas lag behind urban centers in access to environmental governance resources and green infrastructure. For Belarus, the tension arises from the potential displacement of workers in energy-intensive traditional industries, which account for 35% of national economic output, as green transition progresses, creating a conflict between structural transformation and employment stability. Both nations also confront mounting fiscal sustainability pressures: China has seen rising local government debt levels driven by massive investment in green infrastructure, with green bonds accounting for a growing share of local government special-purpose bonds and raising concerns about debt sustainability in some central and western provinces. Belarus faces even more severe fiscal constraints, as its high social welfare spending and green subsidy commitments have kept the fiscal deficit ratio at 3–4% for an extended period, while Western sanctions have depleted foreign exchange reserves and limited its ability to finance large-scale green technology imports. Externally, both countries operate within a challenging geopolitical environment that constrains sustainable development progress: China faces growing green trade barriers including the European Union's Carbon Border Adjustment Mechanism (CBAM) and U.S. technology restrictions that hinder the export of its new energy products, while Belarus has been largely excluded from Western green technology markets and remains 90% dependent on Russian energy imports, creating a structural lock-in that slows renewable energy development.

Distinct dilemmas

Beyond these shared challenges, each country faces unique dilemmas rooted in their respective institutional contexts and development stages. China's primary challenge lies in addressing quality deficiencies that have emerged alongside its rapid co-evolution progress, including inconsistent implementation of environmental policies at the lo-

cal level, where some governments have engaged in perfunctory environmental inspections and symbolic green reporting to meet central mandates. The country also suffers from immature green market mechanisms, with fragmented green finance standards, insufficient liquidity in the carbon trading market, and persistent price premiums for green products that limit public acceptance. Additionally, social participation in environmental governance remains largely superficial, with most public engagement confined to basic behavioral changes rather than meaningful involvement in policy formulation and corporate environmental supervision. In contrast, Belarus's core challenge is overcoming openness deficits within its steady co-evolution model. The country's heavy reliance on Russian energy has created a persistent energy structure lock-in that is difficult to break due to technological, capital, and infrastructure constraints. Its isolation from Western technology markets has also stifled innovation momentum, with R&D investment as a share of GDP lagging far behind international benchmarks and leaving the mediating role of technological innovation underdeveloped. Furthermore, Belarus's strong presidential system, while ensuring policy continuity and social stability, has resulted in relatively inflexible institutional arrangements that limit the participation of market actors and civil society in sustainable development governance, causing policy adjustments to lag behind evolving eco-economic conditions.

General optimization framework: Three-tier hierarchical governance

To break the Impossible Trinity constraints that limit sustainable development progress in both countries, this study proposes a three-tier hierarchical governance framework that enables dynamic balance between equity, efficiency, and fiscal sustainability rather than static trade-offs. At the basic layer, the primary objective is to guarantee bottom-line equity by focusing investment on livelihood security, ecological compensation mechanisms, and inclusive green infrastructure, ensuring that the benefits of sustainable development are shared across all segments of society and that vulnerable populations are protected from the negative impacts of green transition. The competitive layer is designed to enhance development efficiency by unleashing market vitality and technological innovation, with policy interventions centered on improving green market mechanisms, strengthening research and development capabilities, and advancing industrial structure upgrading to drive eco-economic transformation through market forces. The regulatory layer serves as the critical balancing mechanism that maintains fiscal sustainability, using instruments such as carbon taxation, green bond issuance, and performance-based assessment systems to dynamically redistribute fiscal resources between the basic and competitive layers, ensuring that public spending remains within sustainable limits while supporting both equity and efficiency objectives.

Country-specific optimization paths

China: From high-speed to high-quality synergy

For China, the optimization path should focus on transitioning from the current high-speed co-evolution trajectory to a more sustainable high-quality synergy model, with targeted interventions across all three tiers of the governance framework. At the basic layer, the government should establish a horizontal ecological compensation transfer payment system that requires economically developed eastern provinces to provide financial support to central and western regions for green infrastructure construction and ecological protection, helping to narrow regional development gaps. Targeted subsidies for green products such as new energy vehicles and energy-efficient home appliances should also be expanded to reduce price premiums and improve access for low-income households, enhancing the equity of green transition. At the competitive layer, efforts should be directed at unifying national green finance standards, expanding the coverage and improving the liquidity of the carbon trading market, and increasing R&D investment in key areas including renewable energy, carbon capture and storage, and digital environmental governance technologies to fully leverage the mediating role of technological innovation. The integration of digital and green economies should also be accelerated, using big data and artificial intelligence to optimize pollution control systems and promote the sharing economy as a means of reducing energy consumption. At the regulatory layer, fiscal and taxation system reform should prioritize the introduction of a national carbon tax and strengthened environmental protection taxes, with revenues earmarked exclusively for ecological protection and green transition initiatives to alleviate fiscal pressures. Long-term special green bonds should be issued to finance large-scale green infrastructure projects, and public-private partnership models should be expanded to share investment risks and reduce local government debt burdens. Finally, the local government performance appraisal system should be comprehensively revised to incorporate indicators of green development quality, ecological product value, and public environmental participation, eliminating the residual GDP-oriented governance mindset and symbolic environmentalism.

Belarus: From steady adaptation to open synergy

For Belarus, the strategic priority is to evolve from its current steady adaptation model toward a more dynamic open synergy model that addresses its core constraints of geopolitical isolation and technological backwardness. At the basic layer, the social welfare system should be reformed from the current universal subsidy approach to a more targeted support system that focuses on providing employment training for workers in transitioning green industries and energy subsidies for low-income households, reducing overall fiscal burdens while maintaining social stability. Belarus should also draw on the experience of China's "Ten Million Project" to promote rural green development, investing in rural living environment remediation and green agricultural infrastructure to improve both social equity and environ-

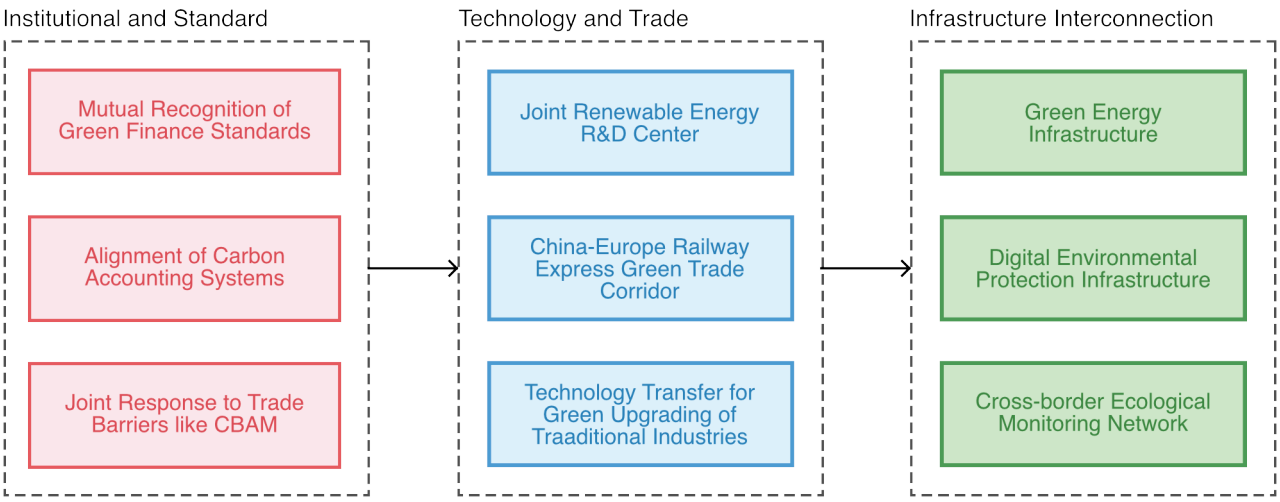

Figure 6 | Three-tiered paradigm of China-Belarus "Belt and Road" green cooperation

mental quality in rural areas. At the competitive layer, deepening green cooperation with China under the Belt and Road Initiative should be the central focus, with joint renewable energy R&D centers established based on the China-Belarus Industrial Park to introduce Chinese technology and capital and increase the share of renewable energy in the national energy mix. Traditional pillar industries including machinery manufacturing and chemicals should be systematically upgraded using advanced circular economy technologies, and the business environment should be optimized to attract green investment from both China and Russia, unlocking market-driven development momentum. At the regulatory layer, institutional innovation should prioritize the establishment of a tripartite consultation mechanism involving government, enterprises, and civil society, allowing broader participation in sustainable development policy-making and enhancing institutional flexibility. Green sovereign bonds should be issued to secure international financing for green projects, and efforts should be made to promote mutual recognition of green product and environmental technology standards with China and Russia, breaking down market barriers created by Western sanctions and enhancing Belarus's geopolitical openness.

Sino-belarusian synergistic cooperation priorities

Based on the empirical findings that geopolitical openness and technological cooperation are core drivers of socio-political-eco-economic co-evolution, China and Belarus should focus their bilateral cooperation on three interconnected areas to create synergistic effects that address their respective development challenges. The first priority is to build a comprehensive green technology sharing platform, jointly establishing R&D centers for circular economy technologies, renewable energy systems, and digital environmental governance solutions, while sharing experience in life-cycle environmental assessment and sustainable construction practices to complement Belarus's technological shortcomings and leverage China's technological advantages. The second area of focus is facilitating green trade and investment, expanding bilateral trade in green goods including Chinese new energy vehicles and Belarusian organic agricultural products via the China-Europe Railway Express, and promoting smart customs systems and digital trade infrastructure to reduce transaction costs and enhance the efficiency of cross-border economic cooperation. The third priority is strengthening institutional complementarity and policy coordination, working together to harmonize green finance standards and carbon accounting methodologies, and developing joint strategies to address global green trade barriers such as the EU CBAM, creating a more favorable institutional environment for sustainable development cooperation between the two countries (**Figure 6**).

Micro-Case Validation

Case 1: Zhejiang's "Ten Million Project" (China)

Initiated in 2003, Zhejiang's "Ten Million Project" has comprehensively transformed rural living environments and fostered a vibrant eco-friendly industrial system across the province, pushing its socio-political-eco-economic coupling coordination degree to 0.89 in 2022, the highest level in China. At the institutional supply level, the provincial government incorporated rural environmental governance into the mandatory performance assessment framework for local officials, with cumulative fiscal investment exceeding 300 billion yuan dedicated to rural infrastructure upgrading and ecological remediation. This top-down institutional design catalyzed a bottom-up tripartite stakeholder interaction pattern featuring government guidance, enterprise participation, and farmer leadership, elevating public environmental participation rate to 78%. The project delivered substantial and mutually reinforcing performance outcomes: the harmless treatment rate of rural household waste jumped from

28% in 2003 to 100% in 2022, and eco-tourism revenue accounted for 35% of total rural economic output by the end of the study period. This micro-level practice provides strong empirical support for the macro conclusion that high governance efficiency and the integrated three-dimensional driving force of state, market, and society are the cornerstones of achieving high-quality co-evolution.

Case 2: Minsk circular economy park (Belarus)

Established in 2010 as the core implementation platform for Belarus's national circular economy strategy, the Minsk Circular Economy Park currently hosts 42 operating enterprises, including 8 Sino-Belarusian joint ventures that serve as key carriers of cross-border technological cooperation. In terms of institutional supply, a special presidential decree granted the park preferential policies including a 10-year corporate income tax holiday and subsidized energy supply, while a directly presidential-led administrative committee streamlined approval procedures and ensured long-term policy continuity free from political fluctuations. A dual-track stakeholder interaction model of government dominance, China-Russia collaboration, and local adaptation has taken shape in the park: Chinese enterprises provide advanced digital environmental governance technologies, Russian partners guarantee stable and low-cost energy supply, and local enterprises implement technological transformation while prioritizing job retention to avoid large-scale unemployment. By 2022, the park's industrial solid waste recycling rate had risen from 45% at its inception to 82%, energy intensity per unit industrial output had decreased by 58%, and a total of 12,000 local jobs had been created. This case empirically confirms that political stability and targeted geopolitical cooperation are the primary drivers of steady co-evolution for nations facing external sanctions and resource dependence constraints.

Conclusion

This study systematically examines the socio-political-eco-economic co-evolution patterns in China and Belarus over the period 1990–2022, revealing that China has achieved high-quality synergy through a three-dimensional driven model while Belarus has attained favorable synergy via a dual-track adaptive model, with 2022 coupling coordination degrees of 0.82 and 0.67 respectively. Empirical analysis confirms that government governance efficiency, political stability, and geopolitical openness serve as the core drivers of co-evolution, with technological innovation and industrial structure upgrading exerting partial mediating effects accounting for 21.1% and 18.3% of the total effect respectively. Both countries face the fundamental constraints of the Sustainable Development Impossible Trinity, with China primarily challenged by development quality deficiencies and regional equity gaps and Belarus confronting bottlenecks in geopolitical openness and technological innovation capacity. The proposed three-tier hierarchical governance framework encompassing basic-layer equity guarantees, competitive-layer efficiency enhancement, and regulatory-layer fiscal balance provides a viable solution to break these trilemma constraints, while Sino-Belarusian cooperation under the Belt and Road Initiative demonstrates the effectiveness of the "institutional complementarity, technology sharing, and risk sharing" international cooperation paradigm. These findings carry significant global policy implications: developing countries can draw on the institution-led and market-empowered model to balance poverty alleviation and environmental protection while strengthening governance capacity to avoid the resource curse and middle-income trap; geopolitically constrained nations should prioritize political stability while gradually expanding regional cooperation and leveraging international partnerships to overcome technological and resource limitations; and global governance systems must respect the diversity of national development models, reject green hegemony, and strengthen multilateral cooperation through platforms such as the Belt and Road Initiative to build a more inclusive and shared global green governance architecture. Future research can be extended in multiple directions, including conducting micro-level studies using questionnaire surveys to analyze the behavioral mechanisms of enterprises and the public, introducing digital economy and social organization variables to enrich mediating effect pathways, employing difference-in-differences models to assess the impact of sudden shocks such as the COVID-19 pandemic and international sanctions on co-evolution dynamics, and extending the analytical framework to other Belt and Road participating countries to test the universality of the proposed theoretical model.

Funding. This work was supported by the State Research Program of the Republic of Belarus (Project title: Development of recommendations for optimizing the sustainable development model taking into account socio-political factors based on the experience of Belarus and China, State registration No. 20242000, registered on December 18, 2024).

Declarations. The authors include the Editor-in-Chief and editorial board members of this journal. A strict recusal policy was applied with independent peer review, and no preferential treatment was provided.

Conflicts of Interest. All authors declare no conflicts of interest related to this study. No commercial, financial, personal, or non-financial relationships exist that could be construed as potentially influencing the objectivity of this work.

Data Availability. All data supporting the findings of this study are publicly available from the authoritative international databases and national statistical agencies cited in the manuscript.

Author Contributions: Yuhao Gu: Conceptualization, methodology, data curation for China, formal analysis, writing original draft, revision and correspondence; Siarhei Lukin: Data collection of

Belarus, literature review, comparative institutional analysis, manuscript language polishing, discussion supplement.

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