Etikonomi
Volume 25(1), 2026: 321 - 336
P-ISSN: 1412-8969; E-ISSN: 2461-0771
https://doi.org/10.15408/etk.v25i1.46766

Does Governance Quality Mediate the Relationship Between Green Innovation and Economic Performance in China?

Jawad Khan[1*], Lin Ying[2], Kashif Raza Shah[3], Alweena Hasan[4]
[1,2,3]School of Economics and Finance, Xi'an Jiaotong University, Xi'an, China
[4]Department of Economics, Institute of Management Sciences, Peshawar, Pakistan
E-mail: [1]jawad@stu.xjtu.edu.cn, [2]linying@xjtu.edu.cn,
[3]kashifeconomist6@gmail.com, [4]alweenahasan@gmail.com
[*)]Corresponding Author

JEL Classification:
O31
O44
Q55
Q56
C22

Received: 07 October 2025

Revised: 01 May 2026

Accepted: 03 May 2026

Available online: May 2026

Abstract

Research Originality: This study advances macro-level evidence by testing governance quality as an explicit mediation channel through which green innovation is translated into income gains, rather than treating institutions only as control variables.

Research Objectives: It examines the long-run effect of green technological innovation on GDP per capita and tests whether governance quality mediates this relationship after controlling for R&D expenditure, renewable energy, emissions, labor participation, and trade openness.

Research Method: Annual data for 1996–2024 are analyzed using a harmonized cointegration-based mediation framework, with FMOLS, CCR, robust least squares, and additional HAC/DOLS robustness checks.

Empirical Results: Green technological innovation and R&D expenditure show positive long-run associations with GDP per capita across the main estimators. Governance quality is positively related to GDP per capita and partially mediates the innovation-growth relationship. Renewable energy is generally supportive but less stable, while the carbon indicator reflects continued reliance on carbon-intensive production during the transition.

Implications: The findings suggest that stronger regulatory quality, implementation capacity, and institutional coordination can increase the economic returns from green innovation and support more balanced, high-quality growth.

Keywords:

eco-innovation; institutional mediation; sustainable growth; renewable transition; cointegration analysis

How to Cite:

Khan, J., Ying, L., Shah, K. R., & Hasan, A. (2026). Does Governance Quality Mediate the Relationship Between Green Innovation and Economic Performance in China?. *Etikonomi, 25*(1), 321 – 336. https://doi.org/10.15408/etk.v25i1.46766.

INTRODUCTION

China provides a critical case for examining whether green innovation can generate durable economic performance during structural transformation. Over the last three decades, the country has moved from low-income, manufacturing-led growth toward a more diversified model shaped by technological upgrading, services, digitalization, renewable energy expansion, and cleaner production. This transition has occurred alongside rapid urbanization, export competitiveness, rising energy demand, and environmental stress. As growth shifted from double-digit expansion to the "new normal" of slower but more quality-oriented development, the policy debate also changed. The main issue is no longer only how to expand output rapidly, but how to sustain productivity, competitiveness, resilience, and environmental viability at the same time (Zhou & Luo, 2018; Dong et al., 2018; Wang & Li, 2017). Green innovation is central to this debate because it connects industrial competitiveness with ecological adjustment. The literature generally defines green innovation as the creation, diffusion, or adoption of products, processes, and organizational practices that reduce environmental harm while improving efficiency and long-run performance (Antonioli et al., 2016; Mazzanti & Rizzo, 2017; Liu et al., 2024). In China, the concept is important because past growth relied heavily on fossil-fuel-intensive manufacturing, large-scale infrastructure, and resource-intensive urban expansion. These drivers increased income and production capacity, but they also generated air pollution, carbon emissions, and pressure on land, water, and energy systems. Green innovation, therefore, has a dual economic role: it must support upgrading and productivity while helping the economy become cleaner, more resource-efficient, and less carbon-intensive.

Research increasingly shows that green technological innovation can improve economic outcomes through productivity gains, energy efficiency, compliance efficiency, product differentiation, and knowledge spillovers (Cho & Sohn, 2018; Li et al., 2020; Liu et al., 2021; Wang et al., 2024a). R&D expenditure also matters because it reflects broader capability formation rather than narrow environmental effort. R&D strengthens absorptive capacity, supports industrial upgrading, and enables firms and regions to exploit cleaner technologies more effectively (Qi et al., 2021; Wu & Hu, 2020; Li et al., 2024). Renewable energy can complement this process by improving energy security and reducing dependence on fossil fuels, although its macroeconomic effects may be uneven because grid constraints, capital requirements, and legacy industrial structures can delay growth effects (Pahle et al., 2016; Wang et al., 2021). Recent firm-level evidence also shows that digital transformation can strengthen enterprise green innovation in China (Zhuo et al., 2024).

A similar innovation effort can produce different outcomes when governance quality differs. Governance shapes how research resources are allocated, how environmental regulations are enforced, how industrial policies are coordinated, and how quickly firms respond to policy signals. Stronger governance can make green investment more credible, predictable, and scalable. Weaker governance can dilute returns through inconsistent regulation, weak monitoring, implementation gaps, or rent-seeking. Recent studies

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

increasingly link environmental governance, low-carbon city policy, digital government, accountability pressure, and green finance with stronger green innovation outcomes, indicating that governance should be treated as an economic transmission mechanism rather than a passive background condition (Wang et al., 2024b; Li & Lou, 2024; Chen & Deng, 2024; Fu et al., 2024).

This institutional channel is important in China because the green transition is strongly policy-led. The state helps direct investment, set environmental targets, scale renewable manufacturing, support research, and guide technological upgrading. Whether these efforts produce durable economic returns depends not only on spending or innovation, but also on policy coherence, enforcement credibility, administrative capacity, and coordination across government levels. Governance, therefore, helps explain why environmental innovation may generate economic benefits in some settings but more modest results in others. Recent studies on green economy and new-quality productivity in China reinforce this argument by showing that green innovation yields stronger outcomes when it operates within a supportive regulatory and organizational environment (Li et al., 2024; Wang et al., 2024a; Ma et al., 2024).

Despite growing interest, three empirical gaps remain. First, many studies examine green patents, renewable energy, environmental regulation, R&D, or emissions separately, which limits understanding of the green transition as an integrated economic process. Second, governance quality is often treated as a contextual factor or control variable, while fewer studies test it directly as a mediating mechanism between green innovation and macroeconomic performance. Third, many stop before the post-2020 period, even though China's economic environment changed materially after the pandemic, amid renewed industrial policy activism and stronger decarbonization commitments. These gaps matter because China's green transition is not only technological; it is also an institutional and policy-coordination challenge.

Recent macroeconomic patterns illustrate the relevance of this question. GDP per capita increased from US$10,627 in 2020 to US$13,303 in 2024, while R&D expenditure rose from 2.36% to 2.58% of GDP. Trade openness recovered from 34.0% of GDP to 37.2% over the same period. At the same time, carbon dioxide emissions excluding land-use change increased from 8.48 to 9.32 tons per capita, while renewable energy's share remained broadly flat in the latest observations. These patterns suggest that stronger innovation effort and renewed income growth coexisted with unresolved emissions pressure. China has therefore become more research-intensive and economically stronger, but not yet decisively less carbon-burdened. This tension makes the governance channel analytically important, thereby rendering the issue theoretically relevant and policy-sensitive for China's current green transition.

This study addresses these gaps by examining whether green innovation improves economic performance in China and whether governance quality mediates that relationship. It integrates green technological innovation, R&D expenditure, renewable energy use, a carbon indicator, labor-force participation, and trade openness within a single long-run framework, while treating governance quality as an explicit mediating variable rather than a passive institutional backdrop. The study's contribution is its direct test of whether governance helps transmit the economic benefits of green innovation. The objectives are to estimate the long-run relationship between green innovation and GDP per capita, assess whether governance quality is positively associated with economic performance, and examine whether governance quality transmits part of the economic effect of green innovation.

METHODS

The study uses annual time-series data for China from 1996 to 2024. GDP per capita (current US$) is the dependent variable and proxy for economic performance. The explanatory variables are green technological innovation, R&D expenditure as a share of GDP, renewable energy consumption as a share of total final energy consumption, a carbon indicator, labor-force participation, and trade openness. Governance quality is specified as the mediator. It is measured as the average of six Worldwide Governance Indicators: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.

The study draws on three data sources. Environment-related technology indicators are taken from the OECD database. GDP per capita, R&D expenditure, renewable energy, CO2 emissions excluding LULUCF per capita, labor force, population, exports, imports, and GDP are drawn from the World Development Indicators. Governance data are taken from the Worldwide Governance Indicators. Labor-force participation is calculated as the labor force divided by the total population, while trade openness is calculated as exports plus imports divided by GDP. The empirical design separates descriptive coverage from the harmonized econometric sample. Macro indicators are described through 2024, where available, while the mediation estimations use the common sample in which the outcome, explanatory variables, and mediator are jointly observed. This prevents coefficients from being compared across samples of different lengths and maintains internal consistency of the mediation equations.

Table 1. Variables and Data Sources

Variable	Operationalization	Primary source
GDP per capita	Economic performance proxy, current US$	WDI
Green technological innovation	Environment-related technologies (% of all technologies)	OECD
R&D expenditure	Research and development expenditure (% of GDP)	WDI
Renewable energy	Renewable energy consumption (% of final consumption)	WDI
CO_2 indicator	CO_2 emissions excluding LULUCF per capita	WDI
Labor-force participation	Labor force / total population	WDI
Trade openness	(Exports + imports) / GDP	WDI
Governance quality	Composite index of six WGI dimensions	WGI

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

The estimating equations are written as follows. This equation calculates labor-force participation by expressing the total labor force as a percentage of the total population.

$$LAB_t = \left(\frac{Labor\ force_t}{Population_t}\right) \times 100 \quad (1)$$

This equation measures trade openness by expressing the sum of exports and imports as a percentage of GDP.

$$TRADE_t = \left(\frac{Exports_t + Imports_t}{GDP_t}\right) \times 100 \quad (2)$$

The baseline, mediator, mediated, and indirect-effect equations are specified as follows. This baseline equation estimates the direct long-run effect of green technological innovation and control variables on GDP per capita.

$$lnGDPPC_t = \alpha_0 + \alpha_1 GTI_t + \alpha_2 RD_t + \alpha_3 REN_t + \alpha_4 CO2_t + \alpha_5 LAB_t + \alpha_6 TRADE_t + \varepsilon_t \quad (3)$$

This mediator equation examines whether green technological innovation and related control variables influence governance quality.

$$Gov_t = \beta_0 + \beta_1 GTI_t + \beta_2 RD_t + \beta_3 REN_t + \beta_4 CO2_t + \beta_5 LAB_t + \beta_6 TRADE_t + \mu_t \quad (4)$$

This mediated equation estimates the effect of green innovation on GDP per capita, controlling for governance quality as a mediating variable.

$$lnGDPPC_t = \gamma_0 + \gamma_1 GTI_t + \gamma_2 RD_t + \gamma_3 REN_t + \gamma_4 CO2_t + \gamma_5 LAB_t + \gamma_6 TRADE_t + \gamma_7 Gov_t + v_t \quad (5)$$

This dynamic specification tests the robustness of the long-run relationship by including current, lagged, and lead changes in the explanatory variables.

$$lnGDPPC_t = \delta_0 + \delta' X_t + \sum_{j=-1}^{1} \psi_j \Delta X_{t-j} + u_t \quad (6)$$

Where

$$X_t = (GTI_t + RD_t + REN_t + CO2_t + LAB_t + TRADE_t + Gov_t)$$

This short-run growth equation examines how annual changes in green innovation, governance quality, and control variables affect changes in GDP per capita.

$$\Delta lnGDPPC_t = \eta_0 + \eta_1 \Delta GTI_t + \eta_2 \Delta RD_t + \eta_3 \Delta REN_t + \eta_4 \Delta CO2_t + \eta_5 \Delta LAB_t + \eta_6 \Delta TRADE_t + \eta_7 \Delta Gov_t + \varepsilon_t \quad (7)$$

The empirical logic is straightforward. The first equation estimates the total long-run effect of green innovation and related structural variables on GDP per capita. The second equation estimates whether the same variables significantly explain governance quality. The third equation re-estimates GDP per capita after adding governance quality. Mediation is supported when governance enters positively and significantly, and the coefficient on green innovation declines, while remaining economically meaningful. This setup is appropriate for the study because the research question is not merely whether innovation and income move together, but whether institutional quality helps transmit innovation into measurable growth outcomes.

DOI: https://doi.org/10.15408/etk.v25i1.46766

Before long-run coefficients are interpreted, the stochastic properties of the series must be checked. The Augmented Dickey–Fuller test is used to assess whether a series contains a unit root. In the harmonized sample, the variables are non-stationary in levels but stationary in first differences, implying integration of order one. The Johansen procedure is then used to determine whether a stable long-run equilibrium relationship exists among the variables. This is a necessary step because regressions on non-stationary series can otherwise be spurious, even when the fit appears strong. Once cointegration is established, long-run coefficients are estimated through Fully Modified Ordinary Least Squares, Canonical Cointegrating Regression, and Robust Least Squares. FMOLS and CCR are widely used in cointegrated systems because they correct for endogeneity and serial correlation that arise in integrated time-series settings. RLS is added as a robustness check to reduce sensitivity to leverage points and outliers. The use of three estimators is particularly useful here because the paper is interested in the stability of substantive conclusions across alternative long-run specifications, not only in single-model significance.

The variables are interpreted as follows. Green technological innovation is the study's most direct measure of environmental innovation because it captures the development of technologies related to the environment. R&D expenditure reflects a broader national innovation effort and the formation of innovation capabilities. Renewable energy represents the transition of the energy system toward cleaner sources. The carbon indicator is treated as an environmental-pressure variable; a positive coefficient does not imply that emissions are desirable, only that emissions may still co-move with production scale during an incomplete transition. Labor-force participation reflects labor availability relative to population, though not labor quality. Trade openness captures international integration, export learning, and the possibility of technology spillovers.

On that basis, the study expects four main patterns. Green technological innovation and R&D expenditure should be positively associated with GDP per capita. Governance quality should also be positively associated with GDP per capita. Governance quality is expected to mediate part of the effect of green innovation on economic performance. Renewable energy and trade openness are expected to support long-run growth, although their coefficients may be less stable because transition costs, external shocks, and structural adjustment can weaken short- to medium-run payoffs. As additional robustness checks, the study estimates a heteroskedasticity- and autocorrelation-consistent log-level model, a dynamic OLS (DOLS) model with one lead and one lag of the first-differenced regressors, and a short-run growth regression in first differences.

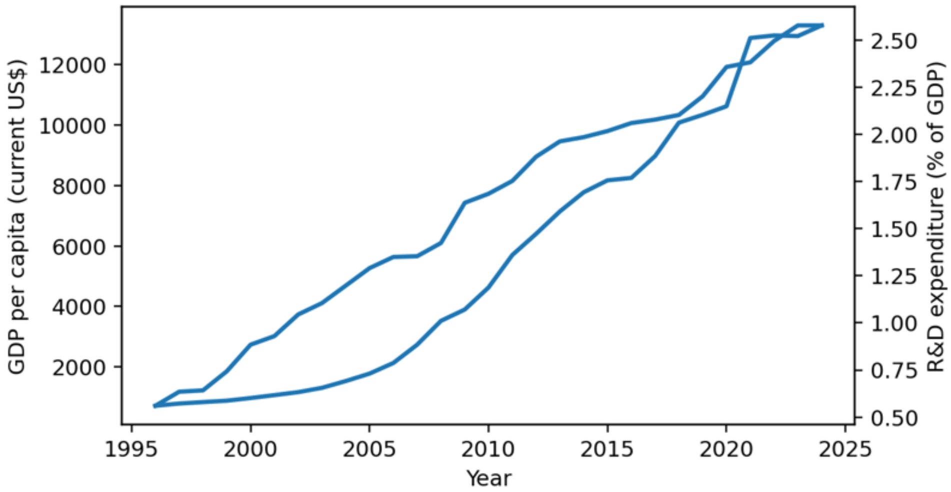
RESULTS AND DISCUSSION

Green technological innovation and R&D expenditure are positively associated with GDP per capita in the long run, and governance quality partially mediates this relationship. Renewable energy is generally growth-supportive, but its coefficient is less stable than those of the core innovation variables. The carbon indicator is positive but weak, suggesting that China's transition remains incomplete: cleaner innovation has

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

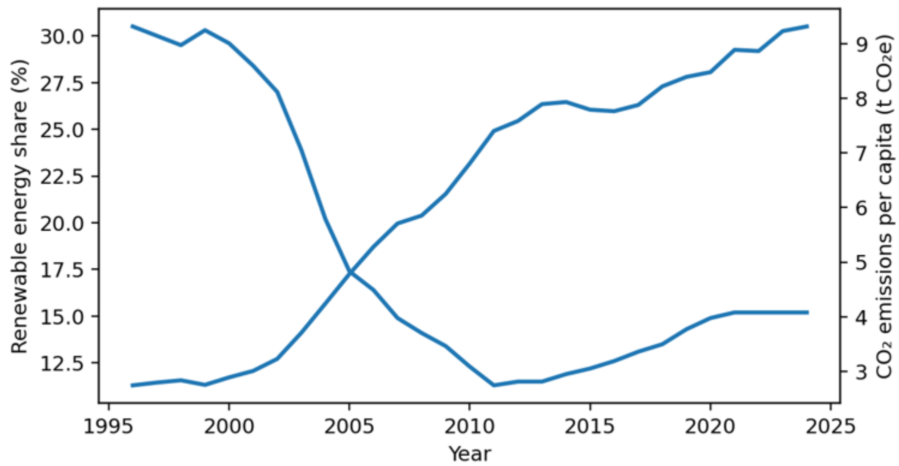
advanced, yet carbon-intensive production effects remain visible. Once governance is introduced into the long-run model, the direct coefficient on green innovation declines, while governance itself remains positive, consistent with partial mediation rather than a purely direct innovation effect.

Figure 1. GDP per capita and R&D expenditure in China, 1996–2024



Source: Author's calculations

Figure 2. Renewable energy consumption and CO_2 emissions per capita in China, 1996–2024

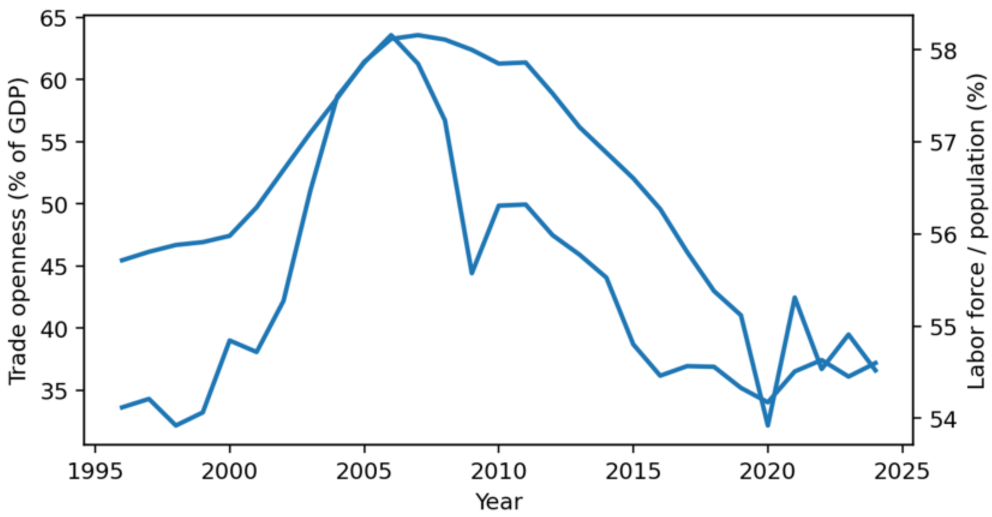


Source: Author's calculations

Descriptive evidence helps place those econometric results in context. Figure 1 shows that GDP per capita and R&D expenditure rose strongly from 1996 to 2024, especially after the late 2000s. GDP per capita increased from roughly US$713 in 1996 to US$13,303 in 2024, while R&D expenditure rose from 0.56% to 2.58% of GDP. The post-2020 period is particularly notable: GDP per capita increased by about one quarter between 2020 and 2024, while R&D intensity continued climbing despite macroeconomic disruption. This pattern reinforces the idea that China's growth model increasingly depends on formal research effort, industrial upgrading, and technology-based competitiveness rather than on low-cost factor expansion alone. Similar results are reported in studies that identify innovation effort as a major source of productivity growth and structural upgrading in China (Qi et al., 2021; Zhou & Luo, 2018; Liu & Waqas, 2024).

Figure 2 shows the environmental tension that runs through the analysis. Renewable energy's share declined from the relatively high levels observed in the late 1990s and then stabilized around the mid-teens in the latest available observations, while carbon dioxide emissions per capita rose from 2.74 tons in 1996 to 9.32 tons in 2024. In the narrower post-2020 window, emissions still increased by about 9.9%. This does not negate the role of green innovation; rather, it shows that innovation and decarbonization do not move in lockstep in a large industrial economy. Scale effects from production, urbanization, and electricity demand can offset gains from efficiency and cleaner energy deployment. Comparable tensions between industrial expansion and emissions outcomes are reported in recent work on China's green transition and environmental regulation (Ma et al., 2019; Wang et al., 2024c).

Figure 3. Trade openness and labor-force participation proxy in China, 1996–2024



Source: Author's calculations

Figure 3 adds an external-sector and labor-market perspective. Trade openness increased sharply during the export-led expansion of the early and mid-2000s, peaked above 60% of GDP, then moderated before recovering modestly after the pandemic shock. The labor-force participation proxy remained comparatively stable in the mid-50% range. These patterns suggest that China's current growth path cannot be explained by openness and labor supply alone. Trade still matters, but its effect is increasingly conditioned by technological content and institutional capacity. Labor availability remains important, but labor productivity, skills, and sectoral allocation now matter more than labor quantity alone. This reading is consistent with studies showing that openness raises growth more

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

strongly in contexts with stronger governance and absorptive capacity (Keho, 2017; Malefane & Odhiambo, 2019).

Table 2. Descriptive statistics for macro series, 1996–2024

Variable	Mean	Median	Max	Min	Std. dev.
GDP per capita (US$)	5,640.00	4,629.25	13,303.15	713.34	4,445.22
R&D expenditure (%)	1.62	1.68	2.58	0.56	0.63
Renewable energy (%)	18.12	15.20	30.50	11.30	6.96
CO_2 emissions per capita	6.16	6.81	9.32	2.74	2.35
Labor-force participation (%)	56.44	56.29	58.16	53.92	1.24
Trade openness (%)	43.18	38.70	63.57	32.17	9.58

Table 2 confirms the broad direction of change. GDP per capita shows the greatest dispersion, as expected given China's sustained income growth over the period. Renewable energy and trade openness also show substantial variation, reflecting both long-run structural change and cyclical episodes. R&D expenditure, by contrast, rises in a relatively steady upward direction, which is consistent with a deliberate strategic commitment rather than a temporary macro fluctuation. The long-run estimations reinforce the descriptive picture. In the baseline cointegration model, green technological innovation is positive and statistically significant across FMOLS, RLS, and CCR. R&D expenditure is also strongly positive and highly significant in all three estimators. Renewable energy is positive in FMOLS and CCR and weaker in RLS. By contrast, the labor-force variable is negative and significant, while trade openness is statistically weak in the baseline specification. The positive sign on green innovation and R&D is the central empirical result: it suggests that environmental technological effort and broader research capability are associated with higher GDP per capita in China over the long run.

The positive coefficient on green technological innovation is consistent with the view that cleaner technologies can improve resource efficiency, reduce compliance costs, generate new product niches, and support industrial modernization. This result broadly aligns with empirical work showing that green innovation supports economic upgrading when embedded in broader capability-building and market expansion (Antonioli et al., 2016; Li et al., 2020; Wang et al., 2024a). The strong role of R&D expenditure is also intuitive because research investment strengthens knowledge accumulation, absorptive capacity, and the ability to commercialize cleaner technologies. In an economy as large and technologically ambitious as China's, such investment is likely to matter more for long-run income than narrow short-term factor accumulation alone.

The renewable-energy result is more nuanced. Its coefficient is positive, but not uniformly strong across estimators. This suggests that cleaner energy supports economic performance, yet its macroeconomic payoff is conditional. Renewable deployment can improve security, reduce exposure to fossil fuels, and stimulate new industries, but it also requires grid adaptation, capital-intensive infrastructure, and institutional coordination. For that reason, the growth effect may emerge more slowly or less cleanly than the R&D

effect. Recent evidence from China also suggests that the benefits of renewable expansion depend strongly on complementary policies and industrial conditions (Pahle et al., 2016; Wang et al., 2021). The carbon indicator is positive but statistically weak. That does not imply that higher emissions are beneficial. Rather, it indicates that emissions still co-move with production scale in a rapidly industrializing and still partly carbon-intensive economy. In China's case, cleaner innovation often advances within an expanding industrial system rather than outside it. The coefficient, therefore, reflects transition incompleteness: environmental capability has risen, but carbon-intensive scale effects remain visible. Similar tensions have been documented in studies showing that energy-intensive development and carbon emissions persist alongside growth in emerging economies, even as greener technologies diffuse (Ma et al., 2019; Mikayilov et al., 2018).

The negative labor-force coefficient also requires careful interpretation. It should not be read as evidence that labor is economically harmful. Instead, it indicates that increases in labor-force participation alone, without corresponding gains in productivity, skills, or sectoral upgrading, are not sufficient to raise GDP per capita. In a development stage where high-value-added production matters more, labor quality and allocation matter more than labor quantity. This is consistent with research arguing that demographic scale supports growth only when human-capital formation, technological change, and institutional quality convert population into productive capability (Wijaya et al., 2021).

Trade openness is statistically weak in the baseline equation but becomes more positive once governance is added. That shift is important because it suggests that openness alone does not guarantee stronger economic performance; rather, its payoff depends on the institutional setting in which cross-border learning and competition take place. Governance can raise the growth return to openness by reducing transaction costs, making regulation more predictable, and supporting the absorption of technology. This helps explain why the governance channel is central to the study's argument.

Table 3. Long-run effects of green innovation on GDP per capita

Variable	FMOLS	RLS	CCR
Green technological innovation	108.031** (0.050)	260.735*** (0.007)	109.975** (0.040)
R&D expenditure	2677.495*** (0.005)	6789.313*** (0.001)	2692.466*** (0.015)
Renewable energy	195.476** (0.023)	257.468 (0.107)	195.821* (0.058)
CO_2 indicator	216.438 (0.699)	1058.851 (0.457)	122.378 (0.832)
Labour-force participation	-1344.502*** (0.000)	-223.236*** (0.007)	-1348.254*** (0.000)
Trade openness	-5.291 (0.645)	0.261 (0.992)	-6.153 (0.630)
R-squared	0.995	0.982	0.995

Note: Harmonized long-run estimates from the common-sample mediation framework. P-values are in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

The empirical results strengthen the argument that green technological innovation is an important driver of China's long-run economic performance. The positive and

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

significant coefficient of green technological innovation is consistent with prior studies showing that cleaner technologies contribute to productivity gains, cleaner production, cost efficiency, and knowledge spillovers. This finding supports Wang et al. (2024a), who show that green technology innovation improves green economic performance in China, and Li et al. (2020), who argue that sustainable production technologies enhance productivity and competitiveness. It also aligns with Liu et al. (2021), who emphasize that green innovation becomes more economically meaningful when it is linked with broader structural transformation. This study's results suggest that green innovation is not only an environmental response but also part of China's transition toward high-quality growth.

The strong positive effect of R&D expenditure further confirms that broader innovation capacity is central to economic performance. This result is consistent with Qi et al. (2021) and Wu and Hu (2020), who show that absorptive capacity, research effort, and institutional support improve the effectiveness of green technological development. It also supports Li et al. (2024), who connect green innovation with new-quality productivity. For China, this means that environmental innovation cannot be separated from the wider national innovation system. R&D expenditure strengthens the ability of firms, industries, and regions to absorb, adapt, and commercialize cleaner technologies, which explains its robust association with GDP per capita across the estimated models.

The renewable energy result is more conditional. Although renewable energy is generally expected to support sustainable growth, its coefficient is less stable across estimators. This finding is consistent with Pahle et al. (2016), who argue that renewable energy policies may involve short- to medium-term adjustment costs before their full economic benefits become visible. It also corresponds with Wang et al. (2021), who show that the growth effect of renewable energy in China depends on financial development and supporting institutional conditions. In the present study, the weaker stability of the renewable-energy coefficient suggests that renewable deployment alone may not immediately translate into higher income unless it is supported by grid capacity, investment coordination, industrial upgrading, and effective implementation.

The positive but statistically weak carbon coefficient also requires careful interpretation. It does not imply that higher emissions are desirable for economic performance. Rather, it reflects the continuing connection between production scale and carbon-intensive activity during an incomplete transition. This result is consistent with Ma et al. (2019), who show that China's emissions remain closely linked to energy consumption and industrial structure. It also aligns with Mikayilov et al. (2018), who find that growth and emissions may remain connected in developing and transition economies. The result, therefore, highlights a central policy challenge: China's innovation capacity has increased, but the economy has not yet fully decouple growth from carbon pressure.

The weak baseline effect of trade openness adds another important dimension. Previous studies suggest that openness can support growth through market access, competition, and technology transfer, but these benefits depend on domestic absorptive capacity and institutional quality (Keho, 2017; Malefane & Odhiambo, 2019). In this study, trade openness becomes more meaningful once governance is introduced,

DOI: https://doi.org/10.15408/etk.v25i1.46766

indicating that external integration generates stronger economic returns when supported by predictable rules, effective regulation, and policy coordination.

The governance mediation result is therefore the study's main contribution. Governance quality enters positively in the mediated model, while the coefficient of green technological innovation declines but remains meaningful. This pattern confirms partial mediation: green innovation affects GDP per capita directly, but part of its effect also operates through institutional quality. This result is consistent with studies linking low-carbon governance, digital government, accountability pressure, and green finance with stronger innovation outcomes in China (Wang et al., 2024b; Li & Lou, 2024; Chen & Deng, 2024; Fu et al., 2024). The study extends this literature by showing that governance quality not only supports green innovation but also helps convert it into economic performance. This means that green innovation becomes more productive when regulatory quality, implementation capacity, institutional coordination, and administrative credibility are stronger.

Table 4. Summary of governance mediation evidence

Indicator	Estimate	Interpretation
Governance in mediated FMOLS model	74.991* (0.063)	Governance quality is positively associated with GDP per capita.
Green innovation in mediated FMOLS model	96.418** (0.016)	Positive direct effect remains after adding governance.
R&D expenditure in mediated FMOLS model	2223.502** (0.036)	Research effort remains a strong long-run driver.
Governance → GDP per capita (SEM)	0.1362*** (0.011)	Governance has a positive mediated effect.
Green innovation → governance (SEM)	0.0662*** (0.015)	Green innovation significantly predicts the mediator.
R&D expenditure → governance (SEM)	0.0154* (0.080)	Research effort supports governance quality.

Table 5. Estimations Macro Sample

Variable	OLS-HAC lnGDP level	DOLS lnGDP level	Short-run HAC ΔlnGDP growth
R&D	0.586***	0.558**	-32.702*
Renewable energy	-0.034**	-0.034***	-1.362
CO_2 indicator	0.188***	0.193**	17.291***
Labour-force participation	-0.019	-0.037	1.966
Trade openness	-0.010***	-0.007***	-0.405
R^2	0.996	0.999	0.510

Note: HAC = heteroskedasticity- and autocorrelation-consistent standard errors; DOLS = dynamic ordinary least squares. The log-level models use lnGDP per capita as the dependent variable. The short-run model uses ΔlnGDP per capita × 100. *** p<0.01, ** p<0.05, * p<0.10.

As robustness checks, the study estimates three additional models using variables available annually through 2024: (i) a log-level OLS model with Newey–West HAC standard errors, (ii) a DOLS specification with one lead and one lag of the differenced regressors, and (iii) a short-run growth model estimated in first differences.

https://journal.uinjkt.ac.id/index.php/etikonomi
DOI: https://doi.org/10.15408/etk.v25i1.46766

The Engle–Granger residual test for the augmented log-level specification yields an ADF statistic of -4.682 ($p < 0.001$), consistent with cointegration. In the HAC log-level model, R&D remains positive and highly significant, renewable energy enters with a negative sign, CO_2 remains positive, labor-force participation is statistically weak, and trade openness is negative. The DOLS specification reproduces the same sign pattern, while the short-run differenced model shows that year-to-year GDP per capita growth is most clearly associated with contemporaneous changes in the carbon indicator.

These supplementary estimations do not overturn the paper's central argument. Instead, they show that the 1996–2024 macro sample preserves a strong association between innovation and income even when the specification shifts from levels to DOLS and then to a short-run differenced model. A parsimonious HAC model that retains only R&D, the carbon indicator, and trade openness also preserves the same general sign pattern, suggesting that the core result is not driven solely by the broader variable set.

CONCLUSION

This paper examined whether governance quality mediates the relationship between green innovation and economic performance in China. The results show that green technological innovation and R&D expenditure are positively associated with GDP per capita, while governance quality partially mediates this effect. Renewable energy is generally supportive, although its economic effect is less stable, and the carbon indicator suggests that China's transition remains incomplete rather than fully decoupled from emissions. The main contribution of the study is the evidence of partial mediation. After governance quality is included in the long-run model, the coefficient of green innovation declines but remains meaningful, while governance enters positively. This indicates that green innovation supports economic performance directly through productivity and structural upgrading, and indirectly through stronger regulatory quality, implementation capacity, and institutional coordination.

The policy implication is that China should continue expanding green technological innovation and R&D, but these efforts need to be supported by credible governance reforms. Cleaner energy, greener industry, and export-oriented upgrading are more likely to generate high-quality growth when policy implementation is consistent, regulation is predictable, and institutions can coordinate the transition effectively. Future research should extend the full mediation model once updated common data are available and examine whether the governance channel differs across sectors and provinces.

REFERENCES

Antonioli, D., Borghesi, S., & Mazzanti, M. (2016). Are Regional Systems Greening the Economy? Local Spillovers, Green Innovations and Firms' Economic Performances. *Economics of Innovation and New Technology, 25(7),* 692–713. https://doi.org/10.1080/10438599.2015.1127557.

Chen, L., & Deng, X. (2024). Executive Accountability Pressure and Green Innovation: Evidence from China. *Sustainability, 17(1),* 161. https://doi.org/10.3390/su17010161.

Cho, J. H., & Sohn, S. Y. (2018). A Novel Decomposition Analysis of Green Patent Applications for the Evaluation of R&D Efforts to Reduce CO2 Emissions From Fossil Fuel Energy Consumption. *Journal of Cleaner Production, 193,* 290–299. https://doi.org/10.1016/j.jclepro.2018.05.060.

Dong, C., Qi, Y., Dong, W., Lu, X., Liu, T., & Qian, S. (2018). Decomposing Driving Factors for Wind Curtailment Under Economic New Normal in China. *Applied Energy, 217,* 178–188. https://doi.org/10.1016/j.apenergy.2018.01.040.

Fu, Y., Wang, Z., & Wang, Y. (2024). Green Financial Policy for Fostering Green Technological Innovation: The Role of Financing Constraints, Science Expenditure, and Heightened Industrial Structure. *Sustainability, 16(20),* 9136. https://doi.org/10.3390/su16209136.

Keho, Y. (2017). The Impact of Trade Openness on Economic Growth: The Case of Cote D'Ivoire. *Cogent Economics & Finance, 5(1),* 1332820. https://doi.org/10.1080/23322039.2017.1332820.

Li, J., Feng, S., Luo, T., & Guan, Z. (2020). What Drives the Adoption of Sustainable Production Technology? Evidence from the Large Scale Farming Sector in East China. *Journal of Cleaner Production, 257,* 120611. https://doi.org/10.1016/j.jclepro.2020.120611.

Li, J., & Lou, W. (2024). Digital Government Construction and Provincial Green Innovation Efficiency: Empirical Analysis Based on Institutional Environment in China. *Sustainability, 16(22),* 10030. https://doi.org/10.3390/su162210030.

Li, J., Noorliza, K., & Zhang, X. (2024). Enhancing Environmental, Social, and Governance Performance through New Quality Productivity and Green Innovation. *Sustainability, 16(11),* 4843. https://doi.org/10.3390/su16114843

Liu, L., Zhao, Z., Su, B., Ng, T. S., Zhang, M., & Qi, L. (2021). Structural Breakpoints in the Relationship Between Outward Foreign Direct Investment and Green Innovation: An Empirical Study in China. *Energy Economics, 103,* 105578. https://doi.org/10.1016/j.eneco.2021.105578.

Liu, L., Zhu, G., & Yu, F. (2024). How Does CEO Tenure Affect Enterprises' Green Innovation? Evidence from Chinese Listed Firms from 2007 to 2021. *Journal of Cleaner Production, 454,* 142092. https://doi.org/10.1016/j.jclepro.2024.142092.

Liu, W., & Waqas, M. (2024). Green Innovation at the Crossroads of Financial Development, Resource Depletion, and Urbanization: Paving the Way to a Sustainable Future from the Perspective of an MM-QR Approach. *Sustainability, 16(16),* 7127. https://doi.org/10.3390/su16167127

Ma, X., Wang, C., Dong, B., Gu, G., Chen, R., Li, Y., Zou, H., Zhang, W., & Li, Q. (2019). Carbon Emissions from Energy Consumption in China: Its Measurement and Driving Factors. *Science of The Total Environment, 648,* 1411–1420. https://doi.org/10.1016/j.scitotenv.2018.08.183.

Ma, Y., Liu, P., & Chen, H. (2024). Corporate ESG Performance, Green Innovation, and Green New Quality Productivity: Evidence from China. *Sustainability, 16(22),* 9804. https://doi.org/10.3390/su16229804.

Malefane, M. R., & Odhiambo, N. M. (2019). Trade Openness and Economic Growth: Empirical Evidence from Lesotho. *Global Business Review, 22(5),* 1103–1119. https://doi.org/10.1177/0972150919830812.

Mazzanti, M., & Rizzo, U. (2017). Diversely Moving towards a Green Economy: Techno-Organisational Decarbonisation Trajectories and Environmental Policy In EU Sectors. *Technological Forecasting and Social Change, 115,* 111–116. https://doi.org/10.1016/j.techfore.2016.09.026.

Mikayilov, J. I., Galeotti, M., & Hasanov, F. J. (2018). The impact of economic growth on CO2 emissions in Azerbaijan. *Journal of Cleaner Production, 197,* 1558–1572. https://doi.org/10.1016/j.jclepro.2018.06.269

OECD. (2025). *Research and Development Expenditure (% of GDP) and Environment-Related Technology Indicators Database*. Paris: OECD Publishing.

Pahle, M., Pachauri, S., & Steinbacher, K. (2016). Can the Green Economy Deliver It All? Experiences of Renewable Energy Policies with Socio-Economic Objectives. *Applied Energy, 179,* 1331–1341. https://doi.org/10.1016/j.apenergy.2016.06.073.

Qi, G., Jia, Y., & Zou, H. (2021). Is Institutional Pressure the Mother of Green Innovation? Examining the Moderating Effect of Absorptive Capacity. *Journal of Cleaner Production, 278,* 123957. https://doi.org/10.1016/j.jclepro.2020.123957.

Wang, B., Wu, Z., & Wang, Y. (2024b). The Impact of Low-Carbon City Governance on Firm Green Innovation: An Enterprise Life Cycle Perspective. *Sustainability, 16(22),* 9737. https://doi.org/10.3390/su16229737.

Wang, C., Du, D., Liu, T., Zhu, Y., Yang, D., Huang, Y., & Meng, F. (2024a). Impact of Green Technology Innovation on Green Economy: Evidence from China. *Sustainability, 16(19),* 8557. https://doi.org/10.3390/su16198557.

Wang, C., Du, D., Liu, T., Li, X., Zhu, Y., Du, W., Xu, F., Yan, M., & Chen, J. (2024c). Environmental Regulations, Green Technological Innovation, and Green Economy: Evidence from China. *Sustainability, 16(13),* 5630. https://doi.org/10.3390/su16135630.

Wang, J., Zhang, S., & Zhang, Q. (2021). The Relationship of Renewable Energy Consumption to Financial Development and Economic Growth in China. *Renewable Energy, 170,* 897–904. https://doi.org/10.1016/j.renene.2021.02.038.

Wang, Q., & Li, R. (2017). Decline in China's Coal Consumption: An Evidence of Peak Coal or a Temporary Blip? *Energy Policy, 108,* 696–701. https://doi.org/10.1016/j.enpol.2017.06.041.

Wijaya, A., Kasuma, J., Tasenţe, T., & Caisar Darma, D. (2021). Labor Force and Economic Growth based on Demographic Pressures, Happiness, and Human Development. *Journal of Eastern European and Central Asian Research (JEECAR), 8(1),* 40–50. https://doi.org/10.15549/jeecar.v8i1.571.

Wu, H., & Hu, S. (2020). The Impact of Synergy Effect Between Government Subsidies and Slack Resources on Green Technology Innovation. *Journal of Cleaner Production, 274, 122682.* https://doi.org/10.1016/j.jclepro.2020.122682.

Zhou, G., & Luo, S. (2018). Higher Education Input, Technological Innovation, and Economic Growth in China. *Sustainability, 10(8),* 2615. https://doi.org/10.3390/su10082615.

Zhuo, R., Zhang, Y., Zheng, J., & Xie, H. (2024). Digitalization Transformation and Enterprise Green Innovation: Empirical Evidence from Chinese Listed Companies. *Frontiers in Environmental Science, 12,* 1361576. https://doi.org/10.3389/fenvs.2024.1361576.