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# Non-Linear Impact of Global FDI and Chinese OFDI on Green Growth in Belt and Road Economies: A Comparative Panel Data Analysis*

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The environmental implications of foreign direct investment (FDI) have been extensively debated, yet, comparative evidence on how global FDI (GFDI) and China's outward FDI (COFDI) distinctly shape green growth (GG), particularly within the strategically significant Belt and Road Initiative (BRI) economies, remains notably scarce. Therefore, this paper provides a comparative non-linear analysis of the impact of GFDI and COFDI on green growth (GG) in 103 BRI countries, using data from 2000 to 2022. Employing the Feasible Generalized Least Squares (FGLS) technique, we find that both GFDI and COFDI exert complex, non-linear, and significant U-shaped and N-shaped influences on GG. The robustness of these non-linear impacts is verified using the System-GMM method and by excluding observations associated with global shocks, including the 2008 financial crisis (2007–2009) and the COVID-19 pandemic (2019–2021). Additionally, cross-model comparison reveals that the marginal linear and non-linear effects of GFDI and COFDI on GG differ significantly across the selected BRI nations. Furthermore, mechanism analysis demonstrates that renewable energy (REN) and structural change (STCH) partially mediate the relationship within specific ranges of GFDI and COFDI values, where both the direct and indirect effects are nonzero. Based on these empirical non-linear findings, we discuss relevant policy recommendations.

*Keywords*: Green Growth, Global Foreign Direct Investment, Chinese Outward Foreign Investment, Belt and Road Initiative, Environmental Kuznets Curve.

*JEL Classification:* F21, F15, Q56

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# I. Introduction

The People's Republic of China initiated the Belt and Road Initiative (BRI) in 2013 to enhance global connectivity and foster economic cooperation across Asia, Africa, and Europe (Kong et al., 2021). This initiative aims to create a more integrated global economy by improving infrastructure, stimulating trade, and reducing poverty (Li et al., 2022). While the BRI has yielded significant economic benefits (Iqbal et al., 2023), its environmental implications have sparked serious questions and concerns over time. This paper examines the contribution of Global Foreign Direct Investments (GFDI) and China's Outward Foreign Direct Investment (COFDI) to Green Growth (GG) in BRI economies. The volume of GFDI and COFDI in BRI economies during the past two decades makes it an interesting case for this study.

Generally, there are two theories about the relationship between GG and FDI: "Pollution Haven" and "Pollution Halo" hypotheses. The "Pollution Haven" hypothesis argues that FDI can lead to environmental degradation through resource exploitation, deforestation, and pollution, driven by lax environmental regulations in host countries. Conversely, the "Pollution Halo" hypothesis posits that FDI can promote environmental sustainability by introducing clean technologies and supporting green projects (Sharif et al., 2022; Amin et al., 2025). Empirical findings suggest that China's OFDI has mainly taken the "Pollution Halo" approach, facilitating the adoption of renewable energy and reducing $CO_2$ emissions in host countries (Ali and Wang 2024). Official statistics show that $CO_2$ emissions in BRI countries have declined from 4.72% (before 2013) to 1.05% (after 2013), which indicates the effectiveness of China's green investment strategies (Li et al., 2024).

Nevertheless, other scholars qualify this optimistic picture, maintaining that the impact of Chinese OFDI is mediated by two critical factors: the nature of the investment approach (green versus conventional) and the sectoral composition of the targeted industries in the host countries. (Chen et al., 2024; Choi and Li, 2024). Yuan and Yin (2023), for example, find that green foreign direct investment contributes to $CO_2$ abatement in the vicinity of targeted enterprises. Their study, however, centers on the importance of the green approach to these investments rather than on their country of origin. In a study of 27 African countries, Chen et al. (2024) find a negative relationship between Chinese foreign direct investment and green growth, attributing this effect to investments concentrated in pollution-intensive sectors such as construction and natural resource extraction. Overall, studies have reached varying conclusions about the impact of foreign investment on green growth, depending on researchers' approaches and the factors they consider.

This paper studies the effect of both Global FDI and China's Outward Foreign Direct Investment (COFDI) on Green Growth (GG) in selected BRI economies while considering the mediating role of Renewable Energy (REN) and Structural Change (STCH) in the process. Several studies have empirically investigated the link between FDI and aspects of green growth across different economies. For instance, Zhao et al. (2025), Soto and Martinez-Cobras (2025), and Wang et al. (2023) have studied the effect of FDI on Green Total Factor Productivity (GTFP) across different panels, which focus narrowly on producing outputs while considering environmental impact. Soto (2024), Saqib et al. (2024), and Ofori et al. (2023) have investigated the impact of FDI on inclusive green growth in different regions. Özkan et al. (2024) and Ketchoua et al. (2024) have analyzed the effect of FDI on green growth in BRICS and OECD economies, respectively. Despite these advancements in the field, there remains a gap in the academic literature regarding the investigation of the non-linear impacts of GFDI and COFDI on GG in BRI economies, particularly when considering the mediating roles of REN and STCH.

By addressing this gap, this study makes four primary contributions to the literature on foreign investment and sustainable development, with a specific focus on BRI economies. First, while prior research has examined the effect of FDI on green growth in other regional contexts, BRI economies are institutionally and structurally distinct. Unlike regions previously studied, BRI countries are characterized by weaker environmental regulations, rapid industrialization, and a unique dual investment landscape in which state-coordinated Chinese OFDI coexists with traditional market-driven GFDI. These distinct conditions create divergent pathways for green development that have not been comparatively examined, making this context a meaningful and necessary setting for investigation. Second, we introduce a novel empirical approach to testing the EKC hypothesis in the context of the GFDI–GG and COFDI–GG relationships. By incorporating squared and cubic terms of both GFDI and COFDI into our analytical models, we explicitly test for non-linear, specifically U-shaped and N-shaped relationships between these investment flows and GG, moving beyond simple linear assumptions. Third, this study investigates the mediating roles of REN and STCH in the non-linear impact of GFDI and COFDI on GG across the selected nations. We analyze whether REN and STCH attenuate or enhance the impact of both GFDI and COFDI on GG. Finally, by performing cross-model comparison and sign effect analyses of the direct and indirect non-linear impacts of GFDI and COFDI, we show that the linear and non-linear impacts of GFDI and COFDI on GG are heterogeneous, and that the mediating roles of REN and STCH vary according to the level and nature of GFDI and COFDI. This integrated modeling approach enables a direct comparative assessment of the marginal effects and interactions of GFDI and COFDI, offering clearer insights into their relative roles in promoting or hindering green growth in BRI countries.

The rest of the study is structured as follows: Section II provides a literature review; Section III presents the data and methodology; Section IV discusses the empirical findings; and finally, Section V offers a conclusion and policy recommendations.

## II. Literature Review

The relationship between FDI and GG, and FDI's impact on sustainable development in both developed and emerging economies, has been the subject of extensive academic research. For instance, Li et al. (2022) conclude that FDI in renewable energy removes financial and technical barriers to green growth and, therefore, enables a transition from fossil fuels to more sustainable energy sources in host countries. This aligns with the pollution-halo hypothesis, which suggests that FDI promotes sustainable development by transferring cleaner technologies and practices from developed to less-industrialised economies. Ma et al. (2025), similarly, explain that FDI significantly promotes green innovation development through mechanisms such as R&D investment and the spillover of advanced, environmentally friendly technologies and practices from developed multinational companies to local firms in host countries, which can ultimately lead to sustainable development. Wani et al. (2024) similarly find a positive relationship between green energy, green technology, foreign investment, and green growth in G7 countries and conclude that increased FDI leads to green economic growth as long as green resources are already in use in a country. Likewise, Iqbal et al. (2023) advocate for advancements in information and communication technology (ICT), as their findings indicate a positive association between ICT and FDI and between FDI and green economic growth. Tariq et al. (2022), on the other hand, although they agree on FDI's positive role in promoting green economic growth, they warn about certain challenges, including resource leakage. The "Resource Leakage Phenomenon" occurs when developed countries shift dirty industries through FDI to less-industrialised economies, thereby reducing greenhouse gas emissions in their own territories.

However, other studies find that FDI's impact varies across regions and even countries; rather, it depends on the regional and domestic circumstances of the FDI recipients. Özkan et al. (2024) find that FDI's impact on green growth in BRICS countries (Brazil, Russia, India, China, and South Africa) depends mainly on host-country characteristics, such as economic structure, institutional quality, and energy mix. Similarly, Su et al. (2022) demonstrate that FDI's impact varies considerably depending on a host country's specific characteristics, including technological advancement and environmental policy, thus requiring targeted policies to achieve desired green growth outcomes. Caetano et al. (2022) argue that FDI can hinder green growth in countries reliant on fossil fuels, as foreign investment requires increased consumption of fossil fuels. Likewise, She and Mabrouk (2023) show that reliance on natural resources and dependence on FDI inflows can hinder green growth in BRICS nations, while other studies indicate that green energy initiatives could counter this effect (Ofori et al., 2023; Acheampong, 2023). Therefore, some scholars aptly suggest reallocating FDI toward energy infrastructure to reduce environmental impacts, while others recommend targeting countries with strict environmental policies to enhance green technology innovation (Zhang et al., 2023; Zhao et al., 2025). Furthermore, Dai et al. (2025) show that FDI can lead to reduced air pollution and promote green growth through improved Green Total Factor Productivity (GTFP), while confirming that outcomes vary across regions due to regional disparities. Regional and country-level differences are significant in determining the impact of foreign investment on green growth, according to several other studies.

In addition to the growing body of literature on GFDI, numerous studies have examined the environmental implications of China's OFDI, particularly in facilitating the transition from fossil fuels to renewable energy in developing economies. China's OFDI, especially within countries participating in the BRI, has generally been associated with improvements in GG, although its effects remain contingent upon country-specific conditions. Several studies highlight the positive role of China's OFDI in promoting green development outcomes. For instance, Guo and Wang (2023), Pan et al. (2024), and Li et al. (2024) find that China's OFDI contributes significantly to green total factor productivity, green transition, technology transfer, and the development of green infrastructure in host countries. Similarly, Wu et al. (2020) demonstrate that China’s OFDI has a stronger positive impact on GTFP in BRI countries when institutional frameworks are robust. The role of environmental regulation and host-country characteristics has also been emphasized. Cai et al. (2023) show that China’s OFDI promotes green technology transfer more effectively in lower-income BRI countries with stricter environmental policies. Likewise, Long et al. (2023) find that firms achieve greater improvements in environmental performance when investing in developed host countries characterized by stringent environmental regulations and specific cultural traits, such as long-term orientation and masculinity. Moreover, Gao and Li (2023) provide evidence that China’s OFDI enhances the overall environmental performance of BRI countries. Their results indicate that OFDI contributes to climate change mitigation and improves wastewater treatment capacity, although its impact on air quality remains statistically insignificant. These findings suggest that while OFDI plays a constructive role in promoting sustainable development, further efforts are needed to enhance its environmental impact. Furthermore, Yang and Zheng (2021) show that China’s OFDI exerts a non-linear impact on environmental pollution in the home country, conditional on the level of financial development. Specifically, the pollution-reducing effect of OFDI becomes progressively stronger as financial development surpasses successive threshold levels.

Despite this generally positive evidence, a number of studies qualify these findings by identifying conditional and, in some cases, adverse effects. Kong et al. (2024), for instance, uncover a threshold effect whereby OFDI's impact on green total factor productivity turns negative as environmental regulations become excessively stringent. Crucially, they attribute this reversal not to declining efficiency, but to diminished green technology capability—suggesting that overly rigid regulatory environments may inadvertently hinder the very technological diffusion that OFDI is meant to facilitate. In a related but distinct line of inquiry, Cai et al. (2025) examine the domestic environmental consequences of China's OFDI, reporting a significant negative spatial spillover effect on sulfur dioxide ($SO_2$) emissions within China itself. Their findings indicate that OFDI reduces emissions not only in the home region but also in neighbouring areas with similar economic development levels, operating through scale, composition, and technique effects—thus complicating the narrative by showing that the environmental benefits of OFDI may also accrue to the investing country.

Despite the extensive literature examining the impact of GFDI and COFDI on environmental sustainability, several important gaps remain. First, most existing studies focus either on aggregate FDI or on China's OFDI in isolation, without explicitly distinguishing between different types of FDI, such as global FDI (GFDI) and country-specific outward investment (COFDI), within a unified analytical framework. Second, while prior research acknowledges that the effects of FDI are heterogeneous and context-dependent, most empirical studies rely on linear models, which may fail to capture the complex, potentially non-linear dynamics underlying the FDI–GG nexus. Although a few studies identify threshold or conditional effects, systematic evidence on higher-order nonlinearities, such as U-shaped and N-shaped relationships, remains limited. Third, the comparative analysis of how different forms of FDI influence GG through distinct mechanisms (e.g., REN and STCH) is largely underexplored. Therefore, this study contributes to the literature by jointly examining the non-linear impact of GFDI and COFDI on GG using flexible functional forms and advanced techniques, providing deeper insights into the shape, turning points, and intensity of these relationships. By doing so, it not only refines the understanding of the FDI–GG and COFDI–GG relationships but also offers more nuanced policy implications for promoting sustainable development across diverse economic contexts.

## III. Data, Model Specification, and Estimation Methodology

### *1. Data*

Our empirical analysis is based on a panel of 103 BRI-region economies over the period 2000–2022. Table 1 provides additional details about variable acronyms, descriptions, and data sources. The procedure of variable selection in this study is as follows:

**Dependent variable:** This study adopts Green Growth (GG) as its primary dependent variable. Following the definition proposed by Wu et al. (2020), Li et al. (2024), Cai et al. (2024), green growth refers to "growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards." In line with the OECD framework (2011, 2025), GG is operationalized as production-based $CO_2$ productivity, defined as real GDP per unit of $CO_2$ emitted (measured in USD per kilogram). This indicator has been widely employed in prior empirical research, including recent studies by Wani et al. (2024), Özkan et al. (2024), and Ketchoua et al. (2024).

**Core Independent variable:** This study employs two core independent variables: Global Foreign Direct Investment (GFDI) and China's Outward Foreign Direct Investment (COFDI). These variables are central to the analysis, given the BRI's emphasis on fostering sustainable infrastructure development through international investment. i) China's OFDI (COFDI): This variable measures China's outward foreign direct investment flows into the selected BRI economies, expressed in millions of US dollars. The use of COFDI as a key explanatory variable is well-established in the literature and follows the approach of recent studies (Guo and Wang, 2023; Pan et al., 2024; Li et al., 2024; Wu et al., 2020). ii) Global FDI (GFDI): This variable captures the total inflows of global foreign direct investment into the selected BRI economies, net of Chinese OFDI, expressed in millions of US dollars. Specifically, GFDI is constructed by subtracting COFDI from total global FDI inflows, thereby isolating non-Chinese foreign investment flows into the host economies. To ensure consistency with the dependent variable GG, which is measured as production-based $CO_2$ productivity (real GDP per unit of $CO_2$ emitted, in USD per kilogram), both GFDI and COFDI are converted from nominal to real values. Following standard practice in the literature, all nominal GFDI and COFDI data, originally reported in current US dollars, have been deflated to constant 2017 US dollars using the US GDP deflator before the net calculation. This transformation ensures that all monetary variables in the model reflect real purchasing power and are directly comparable with the real GDP component embedded in the green growth measure.

**Control variables:** i) Gross domestic product (GDP) per capita (measured in constant 2015 US$) is used in this study due to its significant relevance in green growth (Singh et al., 2025). ii) Digitalization (DIGIT) is the percentage of the population using the internet (Zhang, 2024; Sun et al., 2025). iii) Urbanization (URB), measured in terms of urban population percentage of total population, has been extensively utilized by Raihan et al. (2022) and Quaas and Smulders (2018). iv) Trade Openness (TO) is the sum of imports and exports divided by GDP (Baffour Gyau et al., 2026). v) Regulatory quality (REQ) index captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development, is sourced from WDI (Liu and Zhang, 2024; Costantiello and Leogrande, 2024).

Table 1. Variable Descriptions and Data Sources

| Variables | Status | Descriptions | Sources |
|---|---|---|---|
| GG | Dependent variable | Production-based $CO_2$ productivity is calculated as real GDP generated per unit of $CO_2$ emitted (USD/kg). | OECD |
| GFDI | Independent variables | Global foreign direct investment inflows, excluding Chinese OFDI (Constant 2017 million US$) | UNCTAD |
| COFDI | | China's outward foreign direct investment flows (Constant 2017 million US$) | Statistical Bulletin of China's Outward Foreign Direct Investment |
| GDP | Control variables | Real GDP per capita (constant 2015 US$) | WDI |
| URB | | Urban population (% of total population) | WDI |
| DIGIT | | Individuals using the Internet (% of population) | WDI |
| TO | | Trade (% of GDP) | WDI |
| REQ | | Regulatory Quality: Percentile Rank | WDI |
| REN | Mediating Variables | Renewable energy consumption (% of total final energy consumption) | WDI |
| STCH | | Industry (including construction), value added (current US$) | WDI |

**Mediating variables:** i) Renewable energy (REN): This variable captures the share of renewable energy in the total energy supply of each economy, expressed as a percentage. Renewable energy plays a critical role in promoting sustainable development, reducing greenhouse gas emissions, and enhancing energy security. Its inclusion as a key explanatory variable is well-documented in the literature (Liao et al., 2025; Zeng et al., 2024). ii) Structural Change (STCH): This variable is measured as the value added by industry (including construction) as a percentage of GDP. It serves as a proxy for structural change in the economy, reflecting the shift in economic activity toward or away from the industrial sector. This measurement follows established approaches in the literature (Ali and Ghaly, 2026; Artan et al., 2024).

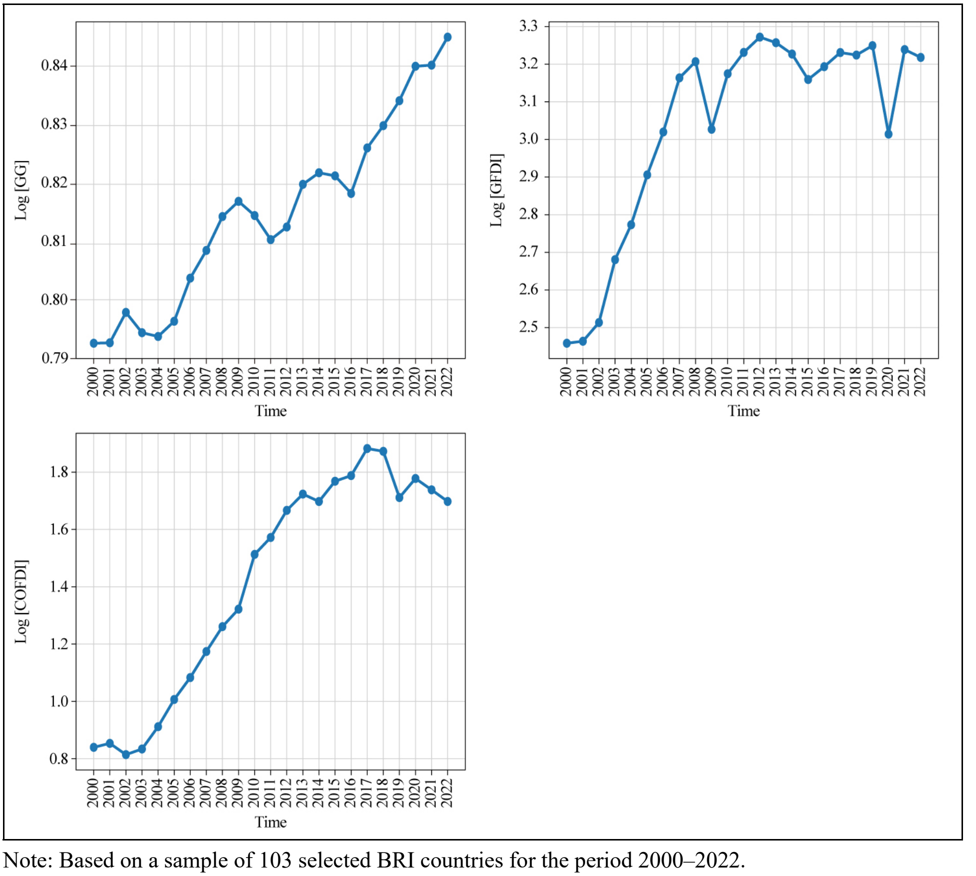
Table 2 shows descriptive statistics and correlation coefficients for the selected variables; URB has a lower standard deviation, while GFDI has a higher one. A higher standard deviation indicates greater variability in the data, and vice versa. Similarly, our data set does not exhibit multicollinearity, as almost all of the Variance Inflation Factor (VIF) values are less than 5.

Table 2. Descriptive Statistics, Variance Inflation Factor and Correlation Coefficients

| Variable | GG | GFDI | COFDI | URB | TO | DIGIT | REQ | GDP | REN | STCH |
|---|---|---|---|---|---|---|---|---|---|---|
| Panel A: Descriptive statistics | | | | | | | | | | |
| Obs. | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 |
| Mean | 0.815 | 3.039 | 1.413 | 1.726 | 1.901 | 1.298 | 1.571 | 3.608 | 1.214 | 10.093 |
| Std. Dev. | 0.244 | 0.866 | 0.771 | 0.194 | 0.213 | 0.568 | 0.369 | 0.602 | 0.596 | 0.732 |
| Min | 0.193 | –0.072 | 0.304 | 1.158 | 1.212 | 0 | 0 | 2.044 | 0 | 8.127 |
| Max | 1.727 | 5.484 | 4.071 | 2.004 | 2.642 | 2.004 | 2.241 | 5.126 | 1.985 | 11.862 |
| VIF | | 2.879 | 2.658 | 2.368 | 1.814 | 1.8 | 1.639 | 1.633 | 1.235 | 2.364 |
| Panel B: Correlation coefficient | | | | | | | | | | |
| GG | 1.000 | | | | | | | | | |
| GFDI | –0.181 | 1.000 | | | | | | | | |
| COFDI | –0.024 | 0.195 | 1.000 | | | | | | | |
| URB | –0.456 | 0.413 | 0.021 | 1.000 | | | | | | |
| TO | –0.254 | 0.181 | 0.048 | 0.346 | 1.000 | | | | | |
| DIGIT | –0.306 | 0.444 | 0.324 | 0.570 | 0.294 | 1.000 | | | | |
| REQ | –0.039 | 0.368 | –0.019 | 0.353 | 0.321 | 0.442 | 1.000 | | | |
| GDP | –0.369 | 0.467 | 0.138 | 0.754 | 0.440 | 0.764 | 0.507 | 1.000 | | |
| REN | 0.647 | –0.288 | –0.040 | –0.576 | –0.282 | –0.330 | –0.081 | –0.540 | 1.000 | |
| STCH | –0.277 | 0.570 | 0.184 | 0.405 | –0.100 | 0.463 | 0.158 | 0.524 | –0.406 | 1.000 |

Figure 1 illustrates the annual trends in logged green growth ($LogGG$), logged global FDI ($LogGFDI$), and logged China's OFDI ($LogCOFDI$) across BRI economies over the study period. All three variables exhibit a steady and largely parallel upward trajectory, indicating consistent long-term growth. Notably, $LogGFDI$ shows pronounced declines during the 2008 global financial crisis and the COVID-19 pandemic. To account for these exogenous shocks, we conduct a sensitivity analysis in the subsequent stage by excluding observations from the two crisis periods and re-estimating the main model. This approach allows us to assess the robustness of our findings and determine whether these extraordinary events drive the results. The synchronized movement across the three series suggests strong long-run co-movement or correlation, pointing to potential interdependencies among green growth, global FDI, and China's outward foreign direct investment within the BRI context.

Figure 1. Annual Trends of the Average LogGG, LogGFDI, and LogCOFDI



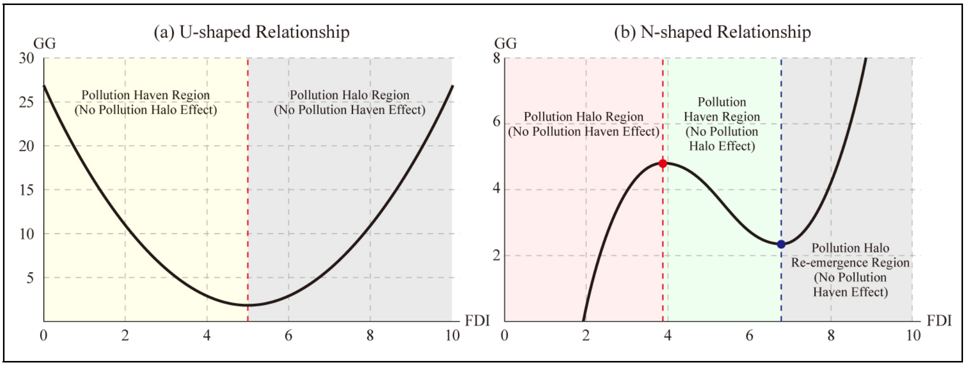

Note: Based on a sample of 103 selected BRI countries for the period 2000–2022.

## *2. Theoretical Framework and Econometric Models*

This study is rooted in the pollution halo and pollution haven hypotheses, along with the Environmental Kuznets Curve (EKC) theory. The EKC hypothesis posits an inverted-U-shaped relationship between economic growth and environmental degradation, suggesting that initial economic expansion is associated with increased environmental harm (Grossman and Krueger, 1991; Copeland and Taylor, 1994; Al-mulali and Foon Tang, 2013). This non-linear linkage between economic performance and environmental quality evolves across different developmental stages (Selden and Song, 1994). While numerous studies affirm the EKC hypothesis, they also reveal that environmental degradation can arise from FDI until it reaches an optimal level. For instance, Destek and Okumus (2019) and Bekun et al. (2024) employed second -generation panel data analyses on newly industrialized countries, demonstrating that FDI exhibits a U-shaped relationship with ecological footprints and $CO_2$ emissions. Similarly, investigations by Sapkota and Bastola (2017) and Ketchoua et al. (2024) in Latin America and OECD nations, respectively, corroborate the EKC framework. Furthermore, research by Shahbaz et al. (2018) and Doytch and Uctum (2019) also concludes that the relationship between FDI and environmental quality follows an inverted U-shape.

As illustrated in Figure 2 and extending the logic of the U-shaped relationship, this study proposes an N-shaped relationship between the two FDI sources, GFDI and COFDI, and green growth. In this N-shaped trajectory, Pollution Halo and Pollution Haven effects alternate across sequential investment stages rather than co-occurring randomly. Theoretically, this alternation is driven by shifting firm-host country dynamics over time. In the first stage, both GFDI and COFDI improve green growth. This initial positive effect reflects a Pollution Halo dynamic: foreign firms, including those from China, bring advanced, cleaner technologies, superior environmental management practices, and green production methods that enhance host countries' environmental performance (Padhan and Bhat, 2024; Su et al., 2022; Dai et al., 2025; Cai et al., 2024). In the second stage, as FDI stock accumulates, the relationship turns negative. This reversal occurs because rapid industrial expansion, congestion effects, and increased energy demand may outpace regulatory capacity, leading to environmental degradation, a delayed Pollution Haven effect (Chiappini and Gerard, 2025). Host countries may temporarily lower environmental standards to remain competitive as industrial agglomeration intensifies. In the third stage, the relationship becomes positive again. This re-emergence of green growth improvements reflects a second Pollution Halo phase, driven by regulatory learning, technological spillovers from maturing FDI, and host countries' increased bargaining power to enforce stricter environmental standards on foreign investors (Zhang and Jin, 2025; Padhan and Bhat, 2024). Thus, the N-shaped trajectory, positive-to-negative and negative-to-positive, captures an endogenous cycle of technology transfer, regulatory adjustment, and adaptive environmental governance across the investment lifecycle. Our empirical results confirm this theoretical expectation: both GFDI and COFDI exhibit N-shaped relationships with green growth, initially improving environmental outcomes, then degrading them, and finally improving them again beyond a threshold.

Figure 2. Visualization of U-shaped and N-shaped EKC relationships between FDI and Green Growth




Building on these theoretical bases, this study develops the following hypotheses:

H1: In the linear specification, the marginal effect of GFDI on GG is significantly different from the marginal effect of COFDI.

H2: In the non-linear specification, the marginal effects of GFDI and COFDI on GG, conditional on their respective investment levels, are significantly different from each other.

H4: The impact of GFDI and COFDI on GG is partially and significantly transmitted through the mediating channels of REN and STCH, across both linear and non-linear model specifications.

To test these research hypotheses, we design the following econometric models to investigate the linear and non-linear impact of GFDI and COFDI on GG, respectively:

Linear impact of GFDI on GG:

$$GG_{it} = f(GFDI_{it}\ \underbrace{,URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{1}$$

Non-linear impact of GFDI on GG:

$$GG_{it} = f(GFDI_{it},\ GFDI_{it}^{2}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{2}$$

$$GG_{it} = f(GFDI_{it}, GFDI_{it}^{2}, GFDI_{it}^{3}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{3}$$

Linear impact of COFDI on GG:

$$GG_{it} = f(COFDI_{it}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{4}$$

Non-linear impact of COFDI on GG:

$$GG_{it} = f(COFDI_{it},\ COFDI_{it}^{2}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{5}$$

$$GG_{it} = f(COFDI_{it}, COFDI_{it}^{2}, COFDI_{it}^{3}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \tag{6}$$

Combined non-linear effects of GFDI and COFDI on GG:

$$\begin{aligned} GG_{it} = f(&GFDI_{it}, GFDI_{it}^{2}, GFDI_{it}^{3}, COFDI_{it}, COFDI_{it}^{2}, \\ &COFDI_{it}^{3}, \underbrace{URB_{it}, TO_{it}, DIGIT_{it}, REQ_{it}, GDP_{it}}_{C_{it}}) \end{aligned} \tag{7}$$

where in Equations (1)–(7), Green Growth (GG), Global Foreign Direct Investment inflows excluding Chinese OFDI (GFDI), China's Outward Foreign Direct Investment (COFDI), Urbanization (URB), Trade Openness (TO), Digitalization (DIGIT), Regulatory Quality (REQ), and Gross Domestic Product (GDP). To ensure greater consistency in the results and to mitigate data volatility, all variables undergo a logarithmic transformation. Specifically, the transformation $Log(Z + 1)$ is applied, where Z represents the original variable values to be transformed, and the constant 1 is added to account for undefined log values when the original

variable equals zero. Accordingly, Models (1)–(7) are re-specified in log-linear and log-nonlinear forms, as presented in Equations (8) through (14).
Log form linear impact of GFDI on GG:

$$LogGG_{it} = \alpha_0 + \alpha_1 LogGFDI_{it} + \sum_{k=2}^{n} \alpha_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \quad (8)$$

Log form non-linear impact of GFDI on GG:

$$\begin{aligned} LogGG_{it} = \beta_0 + \beta_1 LogGFDI_{it} + \beta_2 [LogGFDI_{it}]^2 \\ + \sum_{k=3}^{n} \beta_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (9)$$

$$\begin{aligned} LogGG_{it} = \mu_0 + \mu_1 LogGFDI_{it} + \mu_2 [LogGFDI_{it}]^2 + \mu_3 [LogGFDI_{it}]^3 \\ + \sum_{k=4}^{n} \mu_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (10)$$

Log form linear impact of COFDI on GG:

$$LogGG_{it} = \delta_0 + \delta_1 LogCOFDI_{it} + \sum_{k=2}^{n} \delta_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \quad (11)$$

Log form non-linear impact of COFDI on GG:

$$\begin{aligned} LogGG_{it} = \eta_0 + \eta_1 LogCOFDI_{it} + \eta_2 [LogCOFDI_{it}]^2 \\ + \sum_{k=3}^{n} \eta_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (12)$$

$$\begin{aligned} LogGG_{it} = \theta_0 + \theta_1 LogCOFDI_{it} + \theta_2 [LogCOFDI]^2 + \theta_3 [LogCOFDI]^3 \\ + \sum_{k=4}^{n} \theta_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (13)$$

Log form combined non-linear impact of GFDI and COFDI on GG:

$$\begin{aligned} LogGG_{it} = \vartheta_0 + \vartheta_1 LogGFDI_{it} + \vartheta_2 [LogGFDI]^2 + \vartheta_3 [LogGFDI]^3 \\ + \vartheta_4 LogCOFDI_{it} + \vartheta_5 [LogCOFDI]^2 + \vartheta_6 [LogCOFDI]^3 \\ + \sum_{k=7}^{n} \vartheta_k \, LogC_{kit} + \rho_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (14)$$

where in Equations (7)–(14), $\alpha_0, \beta_0, \mu_0, \delta_0, \eta_0, \theta_0$, and $\vartheta_0$ show the intercept terms, the subscripts "$i$ $and$ $t$" stand for countries ($i$=1, 2, …, 103) and the time series ($t$=2000, 2001, …, 2022). $\alpha_1$, $\beta_1$, $\mu_1$, $\delta_1$, $\eta_1$, $\theta_1$, $\theta_2$, $\vartheta_1$ and $\vartheta_4$ signify the linear impacts of GFDI and COFDI on GG, while $\beta_2$, $\mu_2$, $\mu_3$, $\eta_2$, $\theta_2, \theta_3$, $\vartheta_2$, $\vartheta_3$, $\vartheta_5$ and $\vartheta_6$ denote the non-linear effects of GFDI and COFDI on GG, respectively. $\alpha_k$, $\beta_k$, $\mu_k$, $\delta_k$, $\eta_k$, $\theta_k$ and $\vartheta_k$ demonstrate the coefficients for all control variables in each equation. Finally, $\varepsilon_{it}$ refers to stochastic error terms.

### *3. Estimation Techniques*

To account for the data's underlying structure and the nature of the variables, this study employs a range of econometric techniques. First, cross-sectional dependence is examined using the Pesaran (2015, 2021) CD test and the CDw test with power enhancement proposed by Fan et al. (2015). The results, presented in Table A1, indicate that the null hypothesis of cross-sectional independence is rejected, as the p-values are equal to or less than the 0.01 significance level. Conversely, p-values exceeding 0.10 suggest failure to reject the null hypothesis, confirming the absence of cross-sectional dependence. Next, the slope homogeneity test developed by Pesaran and Yamagata (2008) is applied to determine whether the coefficients are homogeneous or heterogeneous across cross-sectional units. The results in Table A2 show that both the $\Delta$ and adjusted $\Delta$ tests reject the null hypothesis of slope homogeneity, indicating significant heterogeneity. Given the presence of cross-sectional dependence and slope heterogeneity, the second stage of the analysis proceeds with panel unit root testing. To examine the stationarity properties of the variables, the Cross-sectional Augmented IPS (CIPS) test, proposed by Pesaran (2007), is employed. As reported in Table A3, the null hypothesis of a unit root is rejected at the level for some variables; however, GG, TO, and REN become stationary only after first differencing. These mixed results, in which certain variables are stationary at the level, others at first differences, and some at both, necessitate further investigation into long-run relationships. Accordingly, the panel co-integration tests of Pedroni (2004) are conducted to explore the potential for a long-run equilibrium relationship—the results, detailed in Table A4 for Equations (8)–(14), provide evidence of a statistically significant long-run association between GG and the key independent variables.

Building on these preliminary diagnostic findings, the baseline model is estimated using Feasible Generalized Least Squares (FGLS), as advanced by Parks

(1967) and Beck and Katz (1995). The FGLS estimator is particularly suitable for panel data settings as it accounts for cross-sectional dependence and heteroskedasticity, yielding reliable estimates especially when the time dimension (T) is small or equal to the cross-sectional dimension (N) (Hoechle, 2007; Reed and Ye, 2011). To verify the robustness of the baseline results and assess potential endogeneity, we re-estimate the model using the System-GMM technique. This method is specifically designed for estimating dynamic panel regression models and has gained widespread adoption in applied econometric research (Phillips and Han, 2019). Its ability to account for endogeneity, unobserved heterogeneity, and a lagged dependent variable makes it particularly well-suited for analyzing dynamic relationships in panel data settings (Hammar and Djebbouri, 2026; Ullah et al., 2018). In addition, we conduct an event analysis that excludes observations corresponding to the 2008 global financial crisis and the COVID-19 pandemic period. This sensitivity check enables us to determine whether the baseline results are robust to the exclusion of these major exogenous shocks.

## IV. Empirical Results and Discussions

### *1. Baseline Analysis Results*

After confirming cross-sectional dependence (Table A1), slope heterogeneity (Table A2), stationarity properties of the variables at level and first difference (Table A3), and cointegration among GG, GFDI, and COFDI (Table A4), we estimate Equations (8) through (14) using the Feasible Generalized Least Squares (FGLS) technique. This approach allows us to examine the linear and non-linear effects of GFDI and COFDI on green growth (GG). The results are presented in Table 3. Specifically, Equation (8) captures the linear effect of GFDI on GG, while Equations (9) and (10) capture its non-linear effects. Similarly, Equation (11) captures the linear effect of COFDI on GG, and Equations (12) and (13) capture its non-linear effects. Finally, Equation (14) estimates the combined non-linear effects of both GFDI and COFDI on GG.

Based on Equation (8), the coefficient of GFDI is negative and statistically significant. This indicates that, in the baseline linear specification, an increase in GFDI inflows reduces GG in BRI economies. Economically, this suggests that at the early stage of GFDI inflows, multinational firms may engage in pollution-intensive production or resource-extractive activities in host economies with relatively weaker environmental regulations. As a result, GFDI initially increases environmental pressure and reduces the capacity of these economies to achieve sustainable or green growth. Additionally, based on Equation (9), the squared term of GFDI is introduced to capture a potential non-linear relationship. The results show that the coefficient for GFDI remains negative, while that for $GFDI^2$ is positive and statistically significant. This indicates a U-shaped relationship between GFDI and GG in BRI economies. In the early stage, increases in GFDI reduce GG, but after a certain threshold level of investment, the effect becomes positive. This suggests that once GFDI reaches a higher level, the benefits from technology spillovers, advanced management practices, and environmentally friendly production techniques begin to outweigh the initial environmental costs. Moreover, Equation (10) adds a cubic term further to explore the dynamic relationship between GFDI and GG. The results show that the coefficients of the linear, squared, and cubic terms are all statistically significant, indicating a more complex non-linear relationship between GFDI and GG. This implies that the environmental impact of GFDI changes across different levels of investment. The results of Equation (10) follow a standard N-shaped EKC, indicating that at lower levels, GFDI promotes GG through initial clean technology spillovers. At intermediate levels, GFDI harms GG as pollution-intensive activities dominate. At higher levels, GFDI again promotes GG as stringent regulations and advanced innovation effects take over.

In contrast, based on Equation (11), COFDI is introduced into the model. The coefficient of COFDI is positive and statistically significant, indicating that COFDI contributes positively to GG in BRI economies. This finding suggests that COFDI may facilitate infrastructure development, technological upgrading, and investment in renewable energy projects, thereby supporting environmentally sustainable development in host economies. Consequently, according to Equation (12), the squared term of COFDI is included to examine potential non-linear effects. The results show that the coefficient of COFDI becomes negative while the coefficient of $COFDI^2$ is positive and statistically significant. This indicates a non-linear relationship between COFDI and GG. The negative coefficient of the linear term suggests that, beyond a certain level, COFDI may initially generate environmental pressure, possibly due to large-scale infrastructure construction or energy-intensive projects. Furthermore, based on Equation (13), the cubic term of COFDI is included, and the results show that all linear, squared, and cubic terms are statistically significant. This confirms that the relationship between COFDI and GG is highly non-linear. The results imply that the environmental impact of COFDI varies depending on the scale of investment and the sectors in which it is directed. The results of Equation (13) follow

Table 3. Baseline Results Using FGLS

| Variables | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | GG | GG | GG | GG | GG | GG | GG |
| GFDI | –0.002** | –0.025*** | 0.104*** | | | | 0.086*** |
| | (0.001) | (0.003) | (0.005) | | | | (0.007) |
| GFDI$^2$ | | 0.004*** | –0.060*** | | | | –0.051*** |
| | | (0.001) | (0.002) | | | | (0.003) |
| GFDI$^3$ | | | 0.009*** | | | | 0.007*** |
| | | | (0.000) | | | | (0.000) |
| COFDI | | | | 0.012*** | –0.036*** | 0.095*** | 0.086*** |
| | | | | (0.001) | (0.004) | (0.013) | (0.012) |
| COFDI$^2$ | | | | | 0.014*** | –0.070*** | –0.065*** |
| | | | | | (0.001) | (0.007) | (0.007) |
| COFDI$^3$ | | | | | | 0.016*** | 0.014*** |
| | | | | | | (0.001) | (0.001) |
| URB | –0.495*** | –0.492*** | –0.491*** | –0.486*** | –0.486*** | –0.487*** | –0.478*** |
| | (0.005) | (0.005) | (0.012) | (0.006) | (0.007) | (0.008) | (0.008) |
| TO | –0.156*** | –0.159*** | –0.161*** | –0.152*** | –0.166*** | –0.171*** | –0.175*** |
| | (0.004) | (0.004) | (0.005) | (0.005) | (0.006) | (0.006) | (0.006) |
| DIGIT | –0.044*** | –0.041*** | –0.038*** | –0.052*** | –0.051*** | –0.048*** | –0.039*** |
| | (0.002) | (0.003) | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) |
| REQ | 0.137*** | 0.139*** | 0.135*** | 0.142*** | 0.143*** | 0.141*** | 0.135*** |
| | (0.003) | (0.002) | (0.003) | (0.002) | (0.002) | (0.005) | (0.005) |
| GDP | –0.015*** | –0.021*** | –0.019*** | –0.019*** | –0.016*** | –0.017*** | –0.023*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.005) |
| _cons | 1.867*** | 1.907*** | 1.856*** | 1.837*** | 1.883*** | 1.844*** | 1.850*** |
| | (0.011) | (0.011) | (0.011) | (0.008) | (0.012) | (0.014) | (0.015) |
| Country FE | √ | √ | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ | √ | √ |
| Wald Test | 26713.33 | 156924.55 | 15690.44 | 32290.38 | 19149.59 | 19053.96 | 32351.70 |
| Prob. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 | 2369 |

Note: Standard errors in parentheses, and * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

a standard N-shaped EKC, indicating that at lower levels, COFDI may enhance GG through technological spillovers and infrastructure improvements, while at moderate levels, concentration in pollution-intensive sectors may undermine environmental sustainability. However, at higher levels, COFDI may restore its positive impact on GG through clean technology diffusion and improved regulatory compliance.

Finally, Equation (14), which combines the linear and non-linear terms of GFDI and COFDI into a single regression model, provides additional confirmation of the non-linear relationship between GFDI–GG and COFDI–GG, with coefficients that remain statistically significant and consistent with the previous specifications. Overall, the results suggest that both global FDI and Chinese outward FDI influence green growth in Belt and Road economies through non-linear mechanisms, in which the environmental effects of foreign investment depend on investment scale, technological spillovers, and host-country regulatory environments.

The linear findings suggest that GFDI harms environmental outcomes (Equation 8), aligning with the pollution haven hypothesis, while COFDI contributes to environmental sustainability (Equation 11), aligning with the pollution halo hypothesis in BRI countries. This implies that the environmental impact of FDI is not uniform, but rather contingent on the nature and quality of investment — whether it channels pollution-intensive or eco-friendly activities into host economies, consistent with Su et al. (2022) and Cai et al. (2023). However, the presence of U-shaped and N-shaped relationships undermines the validity of the linear findings, highlighting the limitations of linear models in capturing the complex, threshold-dependent dynamics of FDI and GG.

### *2. Cross-Model Comparison Analysis*

To formally assess heterogeneity between GFDI and COFDI, a cross-model comparison is conducted using the seemingly unrelated regression (Suest) framework, as presented in Table 4. The results for the linear specification Equation (8) versus Equation (11) indicate that the null hypothesis of equal coefficients between GFDI and COFDI is rejected at the 5% significance level ($\chi^2 = 4.03, p = 0.0447$). Economically, this implies that the two types of FDI have statistically different linear effects on GG in BRI economies, indicating that a 1% increase in GFDI leads to a 0.002% decrease in GG. In contrast, a 1% increase in COFDI is associated with a 0.012% increase in GG. This finding suggests that foreign investments are not homogeneous in their environmental consequences. In particular, the divergence likely reflects differences in investment motives, sectoral allocation, and embedded technologies. While GFDI may be more associated with cost-seeking and potentially pollution-intensive activities in developing economies, COFDI, especially under the BRI, may be more aligned with infrastructure development and increasingly with green and energy-related investments. Thus, even at a basic linear level, the source of foreign investment plays a critical role in shaping environmental outcomes. These findings support the proposed research hypothesis H1.

Table 4. Model Comparison Analysis Results

| Model Type | Eqs. | ME of GFDI: $\frac{\partial LogGG}{\partial LogGFDI}$ | ME of COFDI: $\frac{\partial LogGG}{\partial LogGFDI}$ | Hypotheses | WT ($\chi^2$) (P-V) |
|---|---|---|---|---|---|
| L | (8) vs (11) | $\alpha_1$ | $\delta_1$ | H1: $\left(\frac{\partial LogGG}{\partial LogGFDI}\right) - \left(\frac{\partial LogGG}{\partial LogCOFDI}\right) \neq 0$ | 4.030** (0.044) |
| Q | (9) vs (12) | $\beta_1 + 2\beta_2 Log\overline{GFDI}_{it}$ | $\eta_1 + 2\eta_2 Log\overline{COFDI}_{it}$ | H2: $\left(\frac{\partial LogGG}{\partial LogGFDI}\right) - \left(\frac{\partial LogGG}{\partial LogCOFDI}\right) \neq 0$ | 8.540** (0.014) |
| C | (10) vs (13) | $\mu_1 + 2\mu_2 Log\overline{GFDI}_{it} + 3\mu_3[Log\overline{GFDI}_{it}]^2$ | $\theta_1 + 2\theta_2 Log\overline{COFDI}_{it} + 3\theta_3[Log\overline{COFDI}_{it}]^2$ | H3: $\left(\frac{\partial LogGG}{\partial LogGFDI}\right) - \left(\frac{\partial LogGG}{\partial LogCOFDI}\right) \neq 0$ | 15.170*** (0.001) |

Note: L denotes the linear model, Q denotes the quadratic model, and C denotes the cubic model. ME represents the marginal effect, derived from the first derivative of the corresponding equations. $H_0$ denotes the null hypothesis, which assumes that the marginal effects of GFDI and COFDI are equal. WT refers to the Wald test statistic, and P-V indicates the corresponding p-value of the test.

For the quadratic specification Equation (9) vs. Equation (12), the Wald test strongly rejects the null hypothesis of equality of coefficients ($\chi^2$ = 8.54, p = 0.0140), indicating that the U-shaped relationships differ significantly between GFDI and COFDI. This result has deeper economic implications, as it demonstrates that not only the magnitude but also the non-linear adjustment process of GG differs across the two types of FDI. The turning points, calculated as $-\frac{\beta_1}{2\beta_1} = 3.125$ for $LogGFDI$ and $-\frac{\eta_1}{2\eta_1} = 1.285$ for $LogCOFDI$, corresponding to approximately \$1,333.52 million and \$19.28 million in constant 2017 US dollars, respectively.[1] In the case of GFDI, the initial negative environmental impact may be more pronounced, requiring a higher threshold before positive effects such as technology spillovers and efficiency gains emerge. In contrast, COFDI may reach this turning point earlier or follow a different curvature due to its strategic orientation toward infrastructure, energy cooperation, and technology transfer within BRI economies. This implies that the transition from environmental degradation to improvement occurs differently depending on the source of investment, highlighting structural heterogeneity in how foreign capital interacts with host-country development pathways. These findings support our proposed research hypothesis H2.

The observed U-shaped relationships between GFDI and GG and between COFDI and GG indicate a scale effect driven by increased production and economic activity, as previously analyzed by Sinha and Shahbaz (2018), Adebayo et al. (2022), and Bekun et al. (2024). In the second stage, the increase in GFDI and COFDI promotes GG, driven by reductions in environmental pollution and greenhouse gas emissions resulting from technological transfers and the transition to clean energy sources. This increase in the amount of GG confirms the composition and technical impacts of FDI in BRI economies, as reported in the studies by Balsalobre-Lorente et al. (2022), Gyamfi et al. (2021), Soto (2024), Destek and Okumus (2019), and Dam and Sarkodie (2023).

The results for the cubic specification Equation (10) versus Equation (13) provide even stronger evidence of heterogeneity, with the null hypothesis rejected at the 1% level ($\chi^2 = 15.17, p = 0.0017$). This confirms that the estimated N-shaped relationships between GFDI and GG, and between COFDI and GG, are significantly different from one another. Economically, this suggests that the dynamic, multi-stage effects of foreign investment, capturing initial improvements, subsequent declines, and eventual recoveries, vary substantially between GFDI and COFDI flows. For GFDI, the N-shaped pattern reveals that GG begins to improve up to approximately GFDI≈$15.14 million, but this positive effect reverses when GFDI is between $15.14 and $1836.54 million, where environmental pressures from industrial expansion may outweigh early gains. A renewed positive impact emerges

[1] The turning points for the quadratic specifications are obtained by differentiating Equations (9) and (12) with respect to *LogGFDI* and *LogCOFDI*, respectively, setting the first derivatives to zero, and solving for the logged variables. The coefficient estimates required for these calculations are drawn from Table 3.

only as investments mature beyond the $1836.54 million threshold. In contrast, Chinese OFDI exhibits a much narrower window of decline: green growth improves up to $11.86 million, declines between $11.86 million and $69.58 million, and recovers thereafter.[2] This narrower, tighter turning range may reflect the policy-driven, infrastructure-focused nature of COFDI under the BRI, which is more readily aligned with green development goals even at moderate scales. Finally, based on the N-shaped GFDI-GG and COFDI-GG relationships, and given that the linear and cubic forms of GFDI and COFDI have positive signs and their quadratic forms have negative signs, it seems that both the pollution haven and the pollution halo phenomena can occur in BRI countries at different stages. These results are in line with the findings of the studies by Shahbaz et al. (2018), Halliru et al. (2021), and Bekun et al. (2024). These findings further support the proposed research hypothesis H2.

### *3. Robustness Checks*

To further validate the robustness of the baseline results obtained from the FGLS technique in Table 3 and to address potential endogeneity concerns, we employed System-GMM. This method's ability to account for endogeneity, unobserved heterogeneity, and the presence of a lagged dependent variable makes it particularly well-suited for analyzing dynamic relationships in panel data settings (Hammar and Djebbouri, 2026; Ullah et al., 2018).

Table 5 presents the System-GMM estimates alongside the baseline FGLS results. Across all specifications, the signs and significance levels of the linear, quadratic, and cubic terms for both GFDI and COFDI remain consistent between the two estimators. The Hansen test statistics fail to reject the validity of the instruments, and the Arellano-Bond test indicates no second-order serial correlation. The consistency of the non-linear U- and N-shaped patterns for GFDI and COFDI across both estimators suggests that endogeneity does not materially bias our baseline FGLS findings. Additionally, to further ensure the reliability of our baseline

[2] The turning points for the cubic specifications are obtained by differentiating Equations (10) and (13) with respect to *LogGFDI* and *LogCOFDI*, respectively, setting the first derivatives to zero, and solving for the logged variables. The coefficient estimates required for these calculations are drawn from Table 3.

findings and to assess whether the results are driven by extreme observations associated with global economic shocks, we re-estimated Equation (8)–Equation (14) after excluding observations from the 2008 global financial crisis (2007–2009) and the COVID-19 pandemic (2019–2021). The results of this robustness exercise, reported in Panels A and B of Table 6, remain quantitatively consistent with the baseline

Table 5. Robustness Checks and Endogeneity Analysis Using System GMM

| Variables | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | GG | GG | GG | GG | GG | GG | GG |
| L.GG | $0.951^{***}$ | $0.952^{***}$ | $0.951^{***}$ | $0.953^{***}$ | $0.952^{***}$ | $0.953^{***}$ | $0.952^{***}$ |
| | (0.017) | (0.017) | (0.018) | (0.018) | (0.017) | (0.017) | (0.017) |
| GFDI | -0.002 | -0.025 | $0.114^{***}$ | | | | $0.093^{**}$ |
| | (0.007) | (0.020) | (0.033) | | | | (0.036) |
| $GFDI^2$ | | 0.004 | $-0.065^{***}$ | | | | $-0.054^{***}$ |
| | | (0.004) | (0.016) | | | | (0.017) |
| $GFDI^3$ | | | $0.010^{***}$ | | | | $0.008^{***}$ |
| | | | (0.002) | | | | (0.003) |
| COFDI | | | | $0.013^{*}$ | $-0.045^{**}$ | 0.122 | 0.104 |
| | | | | (0.007) | (0.019) | (0.103) | (0.099) |
| $COFDI^2$ | | | | | $0.017^{***}$ | -0.089 | -0.076 |
| | | | | | (0.006) | (0.064) | (0.061) |
| $COFDI^3$ | | | | | | $0.019^{*}$ | 0.016 |
| | | | | | | (0.011) | (0.010) |
| _cons | $1.870^{***}$ | $1.901^{***}$ | $1.862^{***}$ | $1.838^{***}$ | $1.892^{***}$ | $1.840^{***}$ | $1.833^{***}$ |
| | (0.066) | (0.040) | (0.046) | (0.053) | (0.062) | (0.088) | (0.072) |
| Controls | √ | √ | √ | √ | √ | √ | √ |
| Country FE | √ | √ | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ | √ | √ |
| Diagnostics | | | | | | | |
| Hansen Test | 88.20 | 87.82 | 87.30 | 87.88 | 87.43 | 87.63 | 88.13 |
| | [0.248] | [0.257] | [0.270] | [0.256] | [0.267] | [0.262] | [0.250] |
| AR(1) | -4.64 | -4.64 | -4.63 | -4.64 | -4.65 | -4.65 | -4.64 |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| AR(2) | 1.27 | 1.26 | 1.30 | 1.28 | 1.24 | 1.20 | 1.22 |
| | [0.203] | [0.208] | [0.194] | [0.200] | [0.213] | [0.229] | [0.222] |
| *N* | 2266 | 2266 | 2266 | 2266 | 2266 | 2266 | 2266 |

Note: Standard errors in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$, and control variables include URB, TO, DIGIT, REQ, and GDP. The diagnostics test p-values are in [].

Table 6. Robustness Checks Excluding 2008 Financial Crisis and COVID-19 Period

| Variables | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | GG | GG | GG | GG | GG | GG | GG |
| **Panel A: Robustness checks excluding the 2008 financial crisis observations from the dataset.** | | | | | | | |
| GFDI | -0.003** | -0.030*** | 0.128*** | | | | 0.110*** |
| | (0.001) | (0.005) | (0.011) | | | | (0.007) |
| $GFDI^2$ | | 0.006*** | -0.072*** | | | | -0.061*** |
| | | (0.001) | (0.004) | | | | (0.003) |
| $GFDI^3$ | | | 0.011*** | | | | 0.009*** |
| | | | (0.001) | | | | (0.000) |
| COFDI | | | | 0.013*** | -0.029*** | 0.101*** | 0.051*** |
| | | | | (0.002) | (0.006) | (0.016) | (0.018) |
| $COFDI^2$ | | | | | 0.012*** | -0.073*** | -0.040*** |
| | | | | | (0.002) | (0.009) | (0.011) |
| $COFDI^3$ | | | | | | 0.016*** | 0.009*** |
| | | | | | | (0.002) | (0.002) |
| _cons | 1.838*** | 1.887*** | 1.844*** | 1.811*** | 1.851*** | 1.844*** | 1.864*** |
| | (0.015) | (0.018) | (0.019) | (0.015) | (0.018) | (0.014) | (0.019) |
| Controls | √ | √ | √ | √ | √ | √ | √ |
| Country FE | √ | √ | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ | √ | √ |
| Wald Test | 8096.59 | 6799.82 | 10231.65 | 7980.47 | 7185.17 | 19605.11 | 25288.44 |
| Prob. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 2060 | 2060 | 2060 | 2060 | 2060 | 2060 | 2060 |
| **Panel B: Robustness checks excluding the COVID-19 observations from the dataset.** | | | | | | | |
| GFDI | -0.001 | -0.007 | 0.108*** | | | | 0.092*** |
| | (0.001) | (0.005) | (0.007) | | | | (0.008) |
| $GFDI^2$ | | 0.001 | -0.060*** | | | | -0.052*** |
| | | (0.001) | (0.003) | | | | (0.004) |
| $GFDI^3$ | | | 0.009*** | | | | 0.007*** |
| | | | (0.000) | | | | (0.001) |
| COFDI | | | | 0.017*** | -0.035*** | 0.059*** | 0.043** |
| | | | | (0.001) | (0.006) | (0.017) | (0.017) |
| $COFDI^2$ | | | | | 0.015*** | -0.045*** | -0.031*** |
| | | | | | (0.002) | (0.010) | (0.010) |
| $COFDI^3$ | | | | | | 0.011*** | 0.008*** |
| | | | | | | (0.002) | (0.002) |
| _cons | 1.884*** | 1.901*** | 1.877*** | 1.854*** | 1.883*** | 1.855*** | 1.855*** |
| | (0.012) | (0.013) | (0.017) | (0.017) | (0.014) | (0.015) | (0.022) |

Table 6. continued

| Panel B: Robustness checks excluding the COVID-19 observations from the dataset. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Variables | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | GG | GG | GG | GG | GG | GG | GG |
| Controls | √ | √ | √ | √ | √ | √ | √ |
| Country FE | √ | √ | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ | √ | √ |
| Wald Test | 19371.11 | 23602.01 | 22917.38 | 16768.18 | 16735.10 | 10647.35 | 12934.23 |
| Prob. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 2060 | 2060 | 2060 | 2060 | 2060 | 2060 | 2060 |

Note: Standard errors in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$, and control variables include URB, TO, DIGIT, REQ, and GDP.

analysis. Specifically, the magnitude of the estimated coefficients for the linear, quadratic, and cubic terms of GFDI and COFDI exhibit only marginal changes, while the direction and statistical significance of the impact of GFDI and COFDI on GG remain unchanged. This indicates that our main findings are not unduly influenced by outlier observations or structural breaks associated with these exogenous shock periods. Consequently, the baseline results are robust to the exclusion of crisis-period observations, reinforcing the validity and reliability of our core conclusions.

### *4. Mediation Analysis*

According to the above analytical framework, the GFDI and COFDI have acted as significant drivers of GG in countries participating in the BRI initiative. Next, following studies by Li et al. (2022), Wu et al. (2020), Cai et al. (2023), and Zhang et al. (2023), we have considered a three-step mediation analysis using REN and STCH as mediator variables, which can significantly mediate the total impacts of GFDI and COFDI on GG. Considering Equation (10) as the baseline (first step), which includes GFDI, $GFDI^2$, and $GFDI^3$, we construct the second and third steps of the mediation analysis as Equations (15) and (16), respectively, illustrating the nonlinear mechanisms by which GFDI impacts GG in the selected nations.

Mechanism impacts of GFDI on GG through mediating factors (M = REN, and STCH):

$$LogM_{it} = \psi_0 + \psi_1 LogGFDI_{it} + \psi_2[LogGFDI_{it}]^2 + \psi_3[LogGFDI_{it}]^3 + \textstyle\sum_{k=4}^{n} \psi_k LogC_{kit} + \varepsilon_{it} \quad (15)$$

$$LogGG_{it} = \phi_0 + \phi_1 LogGFDI_{it} + \phi_2[LogGFDI_{it}]^2 + \phi_3[LogGFDI_{it}]^3 + \omega LogM_{it} + \textstyle\sum_{k=4}^{n} \phi_k LogC_{kit} + \varepsilon_{it} \quad (16)$$

by substituting Equation (15) instead of M into Equation (16), we can distinguish between the direct, indirect, and total effect of GFDI on GG in the form of Equation (17) as follows:

$$LogGG_{it} = \xi_0 + \xi_1 LogGFDI_{it} + \xi_2[LogGFDI_{it}]^2 + \xi_3[LogGFDI_{it}]^3 + \textstyle\sum_{k=4}^{n} \xi_k LogC_{kit} + \varepsilon_{it} \quad (17)$$

where $\xi_0 = \phi_0 + \omega\psi_0$, $\xi_1 = \phi_1 + \omega\psi_1$, $\xi_2 = \phi_2 + \omega\psi_2$, $\xi_3 = \phi_3 + \omega\psi_3$, and $\xi_k = \phi_k + \omega\psi_k$, which $\phi_1$, $\phi_2$, and $\phi_3$ calculate the direct effects, and $\omega\psi_1$, $\omega\psi_2$, and $\omega\psi_3$ the indirect effects of $LogGFDI$, $[LogGFDI_{it}]^2$, and $[LogGFDI_{it}]^3$ on $GG$, respectively.

Similarly, considering Equation (13) as the baseline (first step), which includes COFDI, $COFDI^2$, and $COFDI^3$, we construct the second and third steps of the mediation analysis as Equations (18) and (19), respectively, illustrating the nonlinear mechanisms by which COFDI impacts GG in the selected nations.

Mechanism impacts of COFDI on GG through STCH:

$$LogM_{it} = \gamma_0 + \gamma_1 LogCOFDI_{it} + \gamma_2[LogCOFDI_{it}]^2 + \gamma_3[LogCOFDI_{it}]^3 + \textstyle\sum_{k=4}^{n} \gamma_k LogC_{kit} + \varepsilon_{it} \quad (18)$$

$$LogGG_{it} = \lambda_0 + \lambda_1 LogCOFDI_{it} + \lambda_2[LogCOFDI_{it}]^2 + \lambda_3[LogCOFDI_{it}]^3 + \varphi LogM_{it} + \textstyle\sum_{k=4}^{n} \lambda_k LogC_{kit} + \varepsilon_{it} \quad (19)$$

by substituting Equation (18) instead of M into Equation (19), we can distinguish between direct, indirect, and total effects of COFDI on GG in the form of Equation (20) as follows:

$$LogGG_{it} = \zeta_0 + \zeta_1 LogGFDI_{it} + \zeta_2 [LogGFDI_{it}]^2 + \zeta_3 [LogGFDI_{it}]^3 + \sum_{k=4}^{n} \zeta_k LogC_{kit} + \varepsilon_{it} \quad (20)$$

where $\zeta_0 = \lambda_0 + \varphi\gamma_0$, $\zeta_1 = \lambda_1 + \varphi\gamma_1$, $\zeta_2 = \lambda_2 + \varphi\gamma_2$, $\zeta_3 = \lambda_3 + \varphi\gamma_3$, and $\zeta_k = \lambda_k + \varphi\gamma_k$, which $\lambda_1$, $\lambda_2$, and $\lambda_3$ calculate the direct effects, and $\varphi\gamma_1$, $\varphi\gamma_2$, and $\varphi\gamma_3$ the indirect effects of $LogCOFDI$, $[LogCOFDI_{it}]^2$, and $[LogCOFDI_{it}]^3$ on $GG$, respectively.

Table 7 reports the results of the three-step approach mediation effect test regarding the assumption that GFDI affects GG through REN and STCH. The results of Equation (10) in Column 1 of the Table 7show the total non-linear impact of GFDI on GG (same as the results of Equation (10) in Table 3). In contrast, the results of Equation (15) display the effects of GFDI on REN and STCH in Columns 2 and 4, respectively, indicating that the linear and quadratic terms of GFDI exert statistically insignificant effects on REN. In contrast, its cubic term significantly impacts the level of REN. In contrast, the linear, quadratic, and cubic terms of GFDI have statistically significant impacts on STCH. In line with these non-linear outcomes, the results of Equation (16) for both mediators reveal that the non-linear impact of GFDI on GG in Column 3 remains more stable and closer to the baseline results after considering REN as a mediator. In contrast, the non-linear effects of GFDI on GG in Column 5 are significantly reduced relative to the baseline results after accounting for the mediating role of STCH.

As our focus is non-linear analysis, we calculate the ranges and levels of GFDI where REN partially or fully mediates the total non-linear impact of GFDI on GG. To do so, we take the partial derivatives of Equations (15) and (16) with respect to GFDI and M to derive the impact of GFDI on M ($\frac{\partial LogM_{it}}{\partial LogGFDI_{it}}$), as well as the direct and indirect impacts of GFDI on GG ($\left(\frac{\partial \mathrm{LogGG_{it}}}{\partial \mathrm{LogGFDI_{it}}}\right)_{\mathrm{Direct}}$ and $\left(\frac{\partial \mathrm{LogGG_{it}}}{\partial \mathrm{LogGFDI_{it}}}\right)_{\mathrm{Indirect}}$), respectively (see Appendix B for the full derivation procedure). Then, by substituting the estimated coefficients from Table 7 (Columns 2 and 3) into the direct and indirect effect formulas and treating REN as the mediator, we explicitly derive the direct and indirect equations. Next, by setting $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0$ and solving for LogGFDI, we find that at the values of 1.186 and 3.183, the direct effect of GFDI on GG is zero, indicating that REN fully mediates the impact of GFDI on

GG; otherwise, REN partially mediates this impact. As $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Indirect} < 0$ for all values of GFDI, we conclude that REN negatively and partially mediates the non-linear impacts of GFDI on GG in the selected BRI nations, except at the points where the direct effect equals zero.

Similarly, by substituting the estimated coefficients from Table 7 (Columns 4 and 5) into the direct and indirect effect formulas and treating STCH as the mediator, we explicitly derive the direct and indirect equations. Next, by setting $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0$ and solving for $LogGFDI$, we find that at the values of

Table 7. Mediation Role of REN and STCH on the Impact of GFDI on GG.

| Variables | Baseline Results | Mediating Role of REN $GFDI \rightarrow REN \rightarrow GG$ | | Mediating Role of STCH $GFDI \rightarrow STCH \rightarrow GG$ | |
|---|---|---|---|---|---|
| | Eq. (10) | Eq. (15) | Eq. (16) | Eq. (15) | Eq. (16) |
| | (1) | (2) | (3) | (4) | (5) |
| | GG | REN | GG | STCH | GG |
| GFDI | 0.104*** | -0.014 | 0.102*** | -0.850*** | 0.036*** |
| | (0.005) | (0.017) | (0.007) | (0.045) | (0.008) |
| GFDI$^2$ | -0.060*** | 0.003 | -0.059*** | 0.410*** | -0.026*** |
| | (0.002) | (0.008) | (0.003) | (0.023) | (0.003) |
| GFDI$^3$ | 0.009*** | -0.002** | 0.009*** | -0.040*** | 0.005*** |
| | (0.000) | (0.001) | (0.000) | (0.003) | (0.000) |
| REN | | | 0.243*** | | |
| | | | (0.003) | | |
| STCH | | | | | -0.077*** |
| | | | | | (0.002) |
| _cons | 1.856*** | 4.329*** | 0.818*** | 10.517*** | 2.682*** |
| | (0.011) | (0.028) | (0.018) | (0.073) | (0.033) |
| Controls | √ | √ | √ | √ | √ |
| Country FE | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ |
| Wald Test | 15690.44 | 50166.62 | 32676.44 | 10847.94 | 12123.17 |
| Prob. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 2369 | 2369 | 2369 | 2369 | 2369 |

Note: Standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01, and control variables include URB, TO, DIGIT, REQ, and GDP.

0.955 and 2.511, the direct effect of GFDI on GG is zero, indicating that STCH fully mediates the impact of GFDI on GG; otherwise, STCH partially mediates this impact. As $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Indirect} > 0$ for all values of $LogGFDI$ less than 1.274 and greater than 5.559, we conclude that STCH positively and partially mediates the non-linear impacts of GFDI on GG, while in the range $1.274 < LogGFDI < 5.559$, STCH negatively and partially mediates the non-linear impact of GFDI on GG in the BRI nations.

Table 8 reports the results of the three-step mediation effect test for the impact of COFDI on GG via REN and STCH. The results of Equation (13) in Column 1 of the Table 8 show the total non-linear impact of COFDI on GG (same as the results of Equation (13) in Table 3). In contrast, the results of Equation (18) display the effects of COFDI on REN and STCH in Columns 2 and 4, respectively, indicating that the linear, quadratic, and cubic terms of COFDI exert statistically significant effects on both REN and STCH. In line with these non-linear outcomes, the results from Equation (19) for both mediators indicate that the non-linear impact of COFDI on GG in Columns 3 and 5 remains consistent with the baseline results after accounting for REN and STCH as mediators.

As our focus is on non-linear analysis, we calculate the ranges and levels of COFDI at which REN and STCH partially or fully mediate the total non-linear impact of COFDI on GG. To do so, we take the partial derivatives of Equations (18) and (19) with respect to COFDI and M to derive the impact of COFDI on M ($\frac{\partial LogM_{it}}{\partial LogCOFDI_{it}}$), as well as the direct and indirect impacts of COFDI on GG ($\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct}$ and $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect}$), respectively (see Appendix C for the full derivation procedure). Then, by substituting the estimated coefficients from Table 8 (Columns 2 and 3) into the direct and indirect effect formulas and treating REN as the mediator, we explicitly derive the direct and indirect equations. Next, by setting $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0$ and solving for $LogCOFDI$, we find that at the values of 0.954 and 1.868, the direct effect of COFDI on GG is zero, indicating that REN fully mediates the impact of COFDI on GG; otherwise, REN partially mediates this impact. As $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} < 0$ for all values of $LogCOFDI < 1.423$ or $LogCOFDI > 4.310$, we conclude that REN negatively and partially mediates the non-linear impacts of COFDI on GG in these ranges. In contrast, as $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} > 0$ for all $1.423 < LogCOFDI < 4.310$, we conclude that REN positively and partially mediates the impacts of COFDI on GG within this specific range.

Table 8. Mediation Role of REN and STCH on the Impact of COFDI on GG.

| Variables | Baseline Results | Mediating Role of REN $COFDI \rightarrow REN \rightarrow GG$ | | Mediating Role of STCH $COFDI \rightarrow STCH \rightarrow GG$ | |
|---|---|---|---|---|---|
| | Eq. (13) | Eq. (18) | Eq. (19) | Eq. (18) | Eq. (19) |
| | (1) | (2) | (3) | (4) | (5) |
| | GG | REN | GG | STCH | GG |
| COFDI | 0.095*** | 0.092*** | 0.091*** | 0.179*** | 0.102*** |
| | (0.013) | (0.016) | (0.010) | (0.028) | (0.014) |
| COFDI² | -0.070*** | -0.043*** | -0.072*** | -0.082*** | -0.071*** |
| | (0.007) | (0.009) | (0.006) | (0.017) | (0.008) |
| COFDI³ | 0.016*** | 0.005*** | 0.017*** | 0.018*** | 0.016*** |
| | (0.001) | (0.002) | (0.001) | (0.003) | (0.001) |
| REN | | | 0.239*** | | |
| | | | (0.003) | | |
| STCH | | | | | -0.055*** |
| | | | | | (0.003) |
| _cons | 1.844*** | 4.353*** | 0.791*** | 9.513*** | 2.366*** |
| | (0.014) | (0.021) | (0.017) | (0.042) | (0.028) |
| Controls | √ | √ | √ | √ | √ |
| Country FE | √ | √ | √ | √ | √ |
| Time FE | √ | √ | √ | √ | √ |
| Wald Test | 19053.96 | 79528.55 | 26038.64 | 62080.84 | 28921.75 |
| Prob. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 2369 | 2369 | 2369 | 2369 | 2369 |

Note: Standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01, and control variables include URB, TO, DIGIT, REQ, and GDP.

Similarly, by substituting the estimated coefficients from Table 8 (Columns 4 and 5) into the direct and indirect effect formulas and treating STCH as the mediator, we explicitly derive the direct and indirect equations. Next, by setting $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0$ and solving for $LogCOFDI$, we find that at the values of 1.228 and 1.730, the direct effect of COFDI on GG is zero, indicating that STCH fully mediates the impact of COFDI on GG; otherwise, STCH partially mediates this impact. As $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} < 0$ for all values of $LogCOFDI$, we conclude that STCH negatively and partially mediates the non-linear impacts of COFDI on GG in the selected BRI economies.

Table 9 summarizes the mediating roles of REN and STCH on the impact of GFDI and COFDI on GG. For GFDI, REN consistently acts as a negative mediator across all investment levels, while STCH exhibits a nonlinear mediation pattern—positive mediation at low ($LogGFDI < 1.274$) or high ($LogGFDI > 5.559$) levels, but negative mediation at intermediate levels. For COFDI, REN shows a similar nonlinear mediation pattern, positively mediating at low ($LogCOFDI < 1.423$) or high ($LogCOFDI > 4.310$) levels, and negatively mediating at intermediate levels. In contrast, STCH consistently serves as a negative mediator of COFDI across all values, indicating that structural changes induced by Chinese outward FDI uniformly hinder green growth in Belt and Road economies.

Table 9. Summary of the Mediation role of REN and STCH on the Impact of GFDI and COFDI on GG

| FDI Type | Mediators | Indirect effect sign | Positive mediation | Negative mediation |
|---|---|---|---|---|
| GFDI | REN | − | None | All GFDI values |
| GFDI | STCH | ± | $LogGFDI < 1.274$ $or\ LogGFDI > 5.559$ | $1.274 < LogGFDI < 5.559$ |
| COFD | REN | ± | $LogCOFDI < 1.423$ $or\ LogCOFDI > 4.310$ | $1.423 < LogCOFDI < 4.310$ |
| COFD | STCH | − | None | All COFDI values |

Nonetheless, our results reveal distinct mediation patterns for REN and STCH in the relationship between FDI and green growth. The negative mediation of STCH for both GFDI and COFDI, albeit with different patterns, can be attributed to several interrelated economic factors. Foreign investments often concentrate on high-return sectors such as extractive industries and heavy manufacturing, which can lead to environmental degradation and resource misallocation. In other words, FDI may prioritize economic growth over sustainability, leading to disruption of local ecosystems and increased environmental pollution. The market dynamics created by this situation may also encourage local businesses to prioritize short-term profitability over long-term sustainability. BRI countries frequently have weaker regulatory frameworks for environmental protection, enabling both GFDI and COFDI to exploit lax environmental standards and thereby perpetuate harmful practices. Furthermore, economic dependence on FDI in these countries may skew local policies toward attracting investment without adequate due diligence into environmental protections. Finally, insufficient technological transfer associated with sustainable practices limits the capacity for green development, as the rate of FDI inflows may substantially exceed the rate at which firms transition to green technologies. All these factors collectively contribute to the negative mediating effect of STCH on the relationship between the two types of FDI and GG in BRI economies.

The contrasting non-linear mediation analyses further illuminate the conditional nature of these relationships. The positive mediation of REN at low and high levels of COFDI suggests that COFDI may contribute to REN expansion during initial and mature investment phases. However, a direct tension emerges: while COFDI is often portrayed as more environmentally constructive than GFDI, our results show that STCH consistently and negatively mediates COFDI’s effect on green growth, a pattern not observed for GFDI, where STCH mediation is positive at low and high levels. This contradiction indicates that COFDI-induced structural change may not be inherently green, and any claim of COFDI’s environmental superiority must be qualified by its adverse STCH pathway.

These findings align with a substantial body of existing literature highlighting the complex association between FDI and sustainable development. While some studies affirm a positive relationship between GFDI and green economic growth, many others indicate that this association is highly context-dependent (Antweiler et al., 1998; Cole and Elliott, 2003; Cai et al., 2023). Specifically, the positive impact of FDI on GG often depends on the host country’s economic characteristics, institutional frameworks, and capacity for sustainable industrial development. For example, host countries can support local firms in reorganizing their structures and enhancing workforce capacity to effectively harness the knowledge spillover effects of FDI and adopt new green technologies (Alfaro et al., 2004; Gyamfi et al., 2021; Balsalobre-Lorente et al., 2022). However, this requirement can be challenging in developing countries due to inefficient financial markets and lax macro policies toward environmental protection. Studies further suggest that in the absence of the right conditions, STCH driven by GFDI and COFDI may lead to undesirable outcomes such as increased environmental degradation and resource misallocation. Thus, while GFDI and COFDI have the potential to promote GG, the mediation patterns observed in this study, particularly the nonlinear mediation of REN and STCH, illustrate that the type and stage of structural transformation and renewable energy integration critically determine whether these outcomes align with or diverge from sustainability goals.

## V. Conclusion and Policy Recommendations

### *1. Main Conclusion*

This paper provides a comprehensive comparative analysis of the effects of GFDI and COFDI on GG across 103 BRI countries from 2000 to 2022. By employing a robust econometric framework that includes Feasible Generalized Least Squares (FGLS) for baseline estimation, System-GMM for robustness, and the exclusion of global shock periods, this study advances understanding of how distinct sources of foreign capital influence sustainable development in one of the world's most strategically significant economic corridors.

Our findings reveal several key insights. First, both GFDI and COFDI exhibit complex, non-linear relationships with GG, characterized by significant U- and N-shaped patterns. These nonlinearities indicate that the relationship between FDI (both global and Chinese) and GG is inherently non-monotonic, evolving progressively with the level of investment accumulation, a pattern that underscores the shifting balance between developmental gains and environmental costs. Second, cross-model comparisons indicate that the marginal effects of GFDI and COFDI on GG differ significantly, underscoring the importance of disaggregating FDI by source when formulating policy. Third, mechanism analysis demonstrates that REN and STCH serve as partial mediators in these relationships, with their mediating roles varying across specific ranges of GFDI and COFDI values. Notably, while REN exhibits a nonlinear mediation pattern for COFDI and STCH exhibits a nonlinear pattern for GFDI, STCH consistently acts as a negative mediator for COFDI across all levels, and REN consistently acts as a negative mediator for GFDI. These nuanced mediation patterns highlight the conditional nature of how foreign investment translates into sustainable outcomes. Overall, this study demonstrates that the relationship between FDI and GG in BRI economies is neither linear nor uniform across investment sources. By uncovering the non-linear pathways and heterogeneous mediation mechanisms through which GFDI and COFDI influence GG, we contribute to a more nuanced understanding of the FDI–environment nexus. These findings underscore the need for context-sensitive, stage-dependent, and source-differentiated policy interventions to harness the full potential of foreign investment for sustainable development in the BRI region.

### *2. Policy Recommendation*

Based on these findings, we propose three policy recommendations for BRI economies. First, given the significantly different marginal effects of GFDI and COFDI on GG, policymakers should adopt source-differentiated FDI strategies, implementing conditional investment frameworks for GFDI that mandate technology transfer and renewable energy integration, while establishing bilateral green investment corridors with China that promote sustainability standards and exercise heightened environmental scrutiny during intermediate investment levels where COFDI's mediation turns negative. Second, recognizing the U-shaped and N-shaped non-linear relationships, governments should establish threshold-based regulatory triggers that automatically activate enhanced environmental safeguards, mandatory sustainability reporting, and accelerated permitting for renewable energy projects once FDI stocks approach the identified inflection points, enabling proactive governance that addresses the negative phases of the non-linear trajectory before environmental degradation occurs. Third, to counter the consistently negative mediating role of structural change, particularly for COFDI, policymakers should launch a coordinated Structural Change Mitigation Program. This program should mandate environmental impact assessments that explicitly account for long-term structural transformation effects, while also allocating a portion of FDI-related revenues to a Green Structural Adjustment Fund dedicated to worker retraining and clean technology adoption. Furthermore, it should institutionalize participatory planning processes that grant local communities formal decision-making authority over major investment projects likely to induce significant structural change. Collectively, these source-differentiated, threshold-based, and mitigation-oriented interventions offer a pragmatic pathway for harnessing the full potential of foreign investment for sustainable development in the BRI region.

### *3. Limitation*

Based on the findings of this study, we acknowledge several limitations that offer fruitful avenues for future research. First, while our analysis captures the non-linear impacts of GFDI and COFDI on GG, the specific thresholds at which the U-shaped and N-shaped patterns transition remain sample-specific and may vary across different institutional, geographic, and developmental contexts within BRI economies. Future research should employ country-specific or sub-regional analyses to identify heterogeneous threshold effects and the underlying factors driving these inflection points. Second, although our mediation analysis reveals the distinct roles of renewable energy and structural change, the consistently negative mediation of structural change for COFDI and of renewable energy for GFDI warrants deeper investigation into the micro-level mechanisms such as firm-level technology adoption, sectoral composition shifts, and policy implementation quality that shape these pathways; future studies utilizing firm-level or sectoral data could uncover the granular processes through which foreign investment translates into environmental outcomes. Third, despite the robustness of our econometric approach, the potential for reverse causality and unobserved confounding remains inherent to panel data analysis, particularly given the dynamic nature of FDI–environment relationships; future research could extend our findings by employing quasi-experimental methods, instrumental variable approaches, or dynamic structural equation modeling to establish causal pathways further while building upon the non-linear and mediation patterns we have identified. Addressing these limitations would complement and enrich this study's contributions, advancing understanding of how foreign investment can be better harnessed for sustainable development in the BRI region and beyond.

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# APPENDIX A

Table A1. Cross-sectional Dependency (CSD) Test Results

| Variables | CD | CDw+ |
|---|---|---|
| GG | 33.170*** | 13960.790*** |
| | (0.000) | (0.000) |
| GG | 33.170*** | 13960.790*** |
| | (0.000) | (0.000) |
| GFDI | 92.280*** | 7964.650*** |
| | (0.000) | (0.000) |
| COFDI | 124.880*** | 9484.000*** |
| | (0.000) | (0.000) |
| URB | 192.300*** | 20908.760*** |
| | (0.000) | (0.000) |
| TO | 38.890*** | 10635.930*** |
| | (0.000) | (0.000) |
| DIGIT | 320.480*** | 23227.550*** |
| | (0.000) | (0.000) |
| REQ | 5.040*** | 8272.770*** |
| | (0.000) | (0.000) |
| GDP | 285.660*** | 21486.990*** |
| | (0.000) | (0.000) |
| REN | 3.730*** | 12385.860*** |
| | (0.000) | (0.000) |
| STCH | 270.210*** | 20394.860*** |
| | (0.000) | (0.000) |

Note: This table reports the cross-sectional dependency test statistics for the full set of variables under investigation. Corresponding p-values are provided in parentheses.

Table A2. Slope Heterogeneity (SH) Test Results

| Statistics | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
|---|---|---|---|---|---|---|---|
| Δ | 31.998*** | 27.795*** | 23.995*** | 32.068*** | 27.668*** | 23.806*** | 15.567*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Adj. Δ | 39.623*** | 35.626*** | 31.916*** | 39.709*** | 35.463*** | 31.665*** | 23.609*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |

Note: This table reports the slope Heterogeneity test statistics for the estimated models specified in Equations (8) to (14). Corresponding p-values are provided in parentheses.

Table A3. CIPS Panel Unit Root Test Result

| Variables | Level | 1st Difference | Results |
|---|---|---|---|
| GG | –1.988 | –4.479*** | I(1) |
| GFDI | –3.135*** | –5.333*** | I(0) & I(1) |
| COFDI | –3.758*** | –5.691*** | I(0) & I(1) |
| URB | –0.841 | –1.169 | - |
| TO | –1.704 | –4.070*** | I(1) |
| DIGIT | –2.369*** | –3.949*** | I(0) & I(1) |
| REQ | –2.029* | –5.202*** | I(0) & I(1) |
| GDP | –2.332*** | –3.673*** | I(0) & I(1) |
| REN | –1.465 | –4.078*** | I(1) |
| STCH | –2.235*** | –3.656*** | I(0) & I(1) |

Note: This table reports the CIPS unit root test statistics for the full set of variables under investigation. The sign "–", means not applicable.

Table A4. Pedroni Cointegration Test Result

| Tests | Eq. (8) | Eq. (9) | Eq. (10) | Eq. (11) | Eq. (12) | Eq. (13) | Eq. (14) |
|---|---|---|---|---|---|---|---|
| Modified Phillips –Perron t | 10.010*** (0.000) | 9.474*** (0.000) | 10.088*** (0.000) | 10.337*** (0.000) | 10.869*** (0.000) | 11.302*** (0.000) | 13.983*** (0.000) |
| Modified Phillips –Perron t | –6.018*** (0.000) | –5.080*** (0.000) | –3.760*** (0.004) | –5.211*** (0.004) | –3.339*** (0.000) | –1.511* (0.000) | 6.255** (0.011) |
| Augmented Dickey –Fuller t | –5.838*** (0.000) | –4.613*** (0.000) | –3.462*** (0.007) | –5.235*** (0.007) | –2.665*** (0.000) | –0.264 (0.000) | 4.906* (0.024) |

Note: This table reports Pedroni's co-integration test statistics for the estimated models specified in Equations (8) to (14). Corresponding p-values are provided in parentheses.

# Appendix B

Mediating role of REN and STCH on the impact of GFDI on GG:
By taking partial derivative of Equation (15) with respect to GFDI, and that of Equation (16) with respect to GFDI and M, we can derive the impact of GFDI on M, and the direct and indirect impact of GFDI on GG as follows, respectively:
Impact of GFDI on M:

$$\frac{\partial LogM_{it}}{\partial LogGFDI_{it}} = \psi_1 + 2\psi_2 LogGFDI_{it} + 3\psi_3[LogGFDI_{it}]^2$$

Direct impact of GFDI on GG:

$$\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = \phi_1 + 2\phi_2 LogGFDI_{it} + 3\phi_3[LogGFDI_{it}]^2$$

Impact of M on GG:

$$\frac{\partial LogGG_{it}}{\partial LogM_{it}} = \omega$$

Indirect impact of GFDI on GG:

$$\begin{aligned}\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Indirect} &= \left(\frac{\partial LogGG_{it}}{\partial LogM_{it}}\right)\left(\frac{\partial LogM_{it}}{\partial LogGFDI_{it}}\right) \\ &= \omega(\psi_1 + 2\psi_2 LogGFDI_{it} + 3\psi_3[LogGFDI_{it}]^2)\end{aligned}$$

Now, by replacing the estimated coefficients presented in Table 6 (Columns 2 and 3) into the direct and indirect effects formulas, we have (in this stage, M will be replaced with REN):

$$\frac{\partial LogREN_{it}}{\partial LogGFDI_{it}} = -0.014 + 0.006LogGFDI - 0.006[LogGFDI]^2$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0.102 - 0.118LogGFDI_{it} + 0.027[LogGFDI_{it}]^2$$

$$\frac{\partial LogGG_{it}}{\partial REN_{it}} = 0.243$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Indirect} = 0.243(-0.014 + 0.006LogGFDI - 0.006[LogGFDI]^2)$$

By setting $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0$, and solving it for LogGFDI, we can find that at 1.186 and 3.183 points the direct effect of GFDI on GG will be 0, indicating that REN fully mediates the impact of GFDI on GG, otherwise REN partially mediates the impact of GFDI on GG.

Similarly, by replacing the estimated coefficients presented in Table 6 (Columns 4 and 5) into the direct and indirect effects formulas, we have (in this stage M will be replaced with STCH):

$$\frac{\partial LogSTCH_{it}}{\partial LogGFDI_{it}} = -0.85 + 0.82LogGFDI - 0.12[LogGFDI_{it}]^2$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0.036 - 0.052LogGFDI + 0.015[LogGFDI_{it}]^2$$

$$\frac{\partial LogGG_{it}}{\partial STCH_{it}} = -0.077$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Indirect} = -0.077(-0.85 + 0.82LogGFDI - 0.12[LogGFDI_{it}]^2)$$

By setting $\left(\frac{\partial LogGG_{it}}{\partial LogGFDI_{it}}\right)_{Direct} = 0$, and solving it for LogGFDI, we can find that at 0.955 and 2.511 points the direct effect of GFDI on GG will be 0, indicating that STCH fully mediates the impact of GFDI on GG, otherwise STCH partially mediates the impact of GFDI on GG.

# Appendix C

Mediating role of REN and STCH on the impact of COFDI on GG:
By taking partial derivative of Equation (18) with respect to COFDI, and that of Equation (19) with respect to COFDI and M, we can derive the impact of COFDI on M, and the direct and indirect impact of COFDI on GG as follows, respectively:
Impact of COFDI on M:

$$\frac{\partial LogM_{it}}{\partial LogCOFDI_{it}} = \gamma_1 + 2\gamma_2 LogCOFDI_{it} + 3\gamma_3[LogCOFDI_{it}]^2$$

Direct impact of COFDI on GG:

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = \lambda_1 + 2\lambda_2 LogCOFDI_{it} + 3\lambda_3[LogCOFDI_{it}]^2$$

Impact of M on GG:

$$\frac{\partial LogGG_{it}}{\partial LogM_{it}} = \varphi$$

Indirect impact of COFDI on GG:

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} = \left(\frac{\partial LogGG_{it}}{\partial LogM_{it}}\right)\left(\frac{\partial LogM_{it}}{\partial LogCOFDI_{it}}\right)$$
$$= \varphi(\gamma_1 + 2\gamma_2 LogCOFDI_{it} + 3\gamma_3[LogCOFDI_{it}]^2)$$

Now, by replacing the estimated coefficients presented in Table 7 (Columns 2 and 3) into the direct and indirect effects formulas, we have (in this stage, M will be replaced with REN):

$$\frac{\partial LogREN_{it}}{\partial LogCOFDI_{it}} = 0.092 - 0.086 LogCOFDI + 0.015[LogCOFDI]^2$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0.091 - 0.144 LogCOFDI + 0.051[LogCOFDI]^2$$

$$\frac{\partial LogGG_{it}}{\partial REN_{it}} = 0.239$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} = 0.239(0.092 - 0.086LogCOFDI + 0.015[LogCOFDI]^2)$$

By setting $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0$, and solving it for *LogCOFDI*, we can find that at 0.954 and 1.868 points the direct effect of COFDI on GG will be 0, indicating that REN fully mediates the impact of COFDI on GG, otherwise REN partially mediates the impact of COFDI on GG.

Similarly, by replacing the estimated coefficients presented in Table 7 (Columns 4 and 5) into the direct and indirect effects formulas, we have (in this stage, M will be replaced with STCH):

$$\frac{\partial LogSTCH_{it}}{\partial LogCOFDI_{it}} = 0.179 - 0.164LogCOFDI + 0.053[LogCOFDI]^2$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0.102 - 0.142LogCOFDI + 0.048[LogCOFDI]^2$$

$$\frac{\partial LogGG_{it}}{\partial STCH_{it}} = -0.055$$

$$\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Indirect} = -0.055(0.179 - 0.164LogCOFDI + 0.053[LogCOFDI]^2)$$

By setting $\left(\frac{\partial LogGG_{it}}{\partial LogCOFDI_{it}}\right)_{Direct} = 0$, and solving it for *LogCOFDI*, we can find that at 1.228 and 1.730 points the direct effect of COFDI on GG will be 0, indicating that STCH fully mediates the impact of COFDI on GG, otherwise STCH partially mediates the impact of COFDI on GG.