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Mineral resources, Fintech, Innovative human capital, and CO2 emissions: Missing evidence from the Mineral rich Asian countries

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Abstract

This paper examines the intricate relationship between innovative human capital, mineral resources, fintech, and CO2 emissions across mineral-rich Asian countries, highlighting the pressing need for sustainable development. Through a comprehensive literature review and empirical analysis using the Generalized Method of Moments-Panel Vector Autoregression (GMM-PVAR) model, the study underscores the persistent nature of CO2 emissions and the critical role of human capital and fintech in mitigating environmental degradation. It reveals a positive correlation between the abundance of mineral resources and CO2 emissions, suggesting a dire need for sustainable resource management. Moreover, the study demonstrates the significant negative impact of fintech on CO2 emissions, offering new pathways for green finance and sustainable economic practices. By analysing data from 2003 to 2019 across selected countries, this paper contributes to the understanding of how innovative human capital and technological advancements in finance can lead to a reduction in CO2 emissions. It concludes with policy implications that advocate for the integration of sustainability into economic planning, the promotion of green skills and education, and the harnessing of fintech for environmental sustainability. This study not only provides valuable insights for policymakers in Belt and Road Initiative countries but also lays the groundwork for a more sustainable and environmentally conscious global economy.

Keywords: Innovative human capital, Mineral resources, financial technology (Fintech), CO2 emissions, Sustainable development.

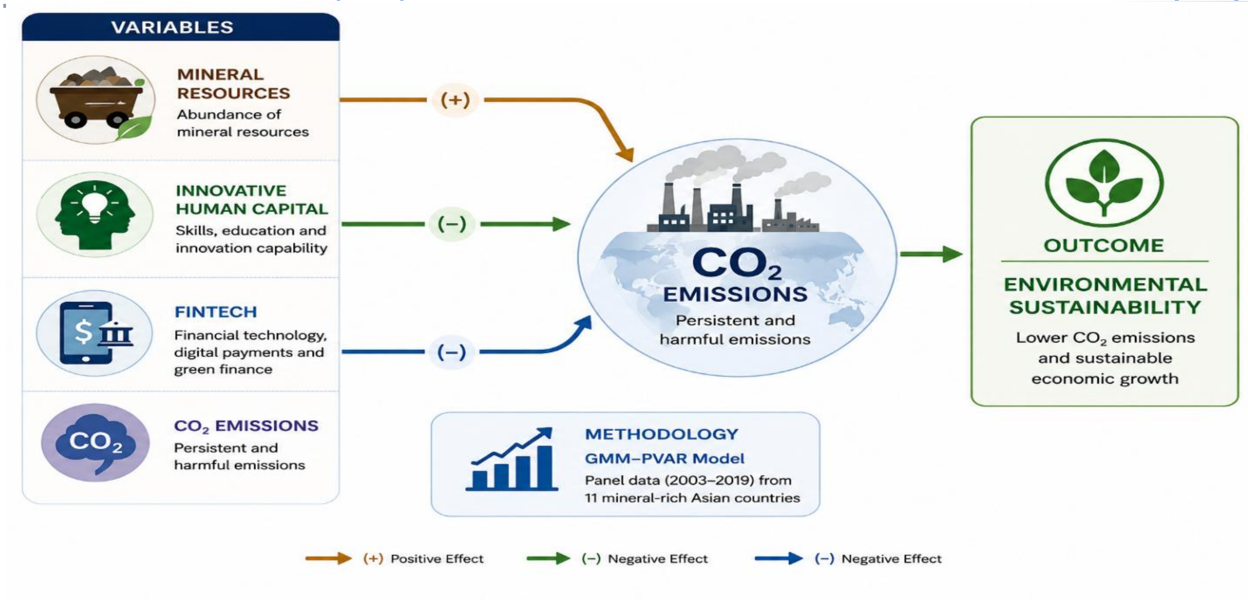

Figure 1.
Graphical Abstract

INTRODUCTION

Every social and economic system should have as its primary goal the improvement of people's standard of living. In addition to economic output and consumption, the development of social infrastructure, and institutional frameworks, environmental conditions are a factor that determines the well-being of humans. Due to increased pollution emissions, increased consumption of energy resources and electricity, and the formation of unused and non-recyclable toxic waste, the majority of mineral-rich Asian countries have been experiencing a systemic socio-environmental and economic crisis as well as a decline in competitiveness in recent years. This has been the case because of the accumulation of toxic waste that is not recyclable. It is necessary to take into consideration all of the relevant economic, social, and environmental factors to prevent development scenarios that could be classified as catastrophic and to ensure that there will be sustained improvements in living standards.

Environmental sustainability One of the prime themes on which there is a primary emphasis is the responsible and efficient utilization of mineral resources. Baz et al. (2021) state that economic growth leads to an increase in energy demand, primarily derived from non-renewable sources like natural gas, oil, and other fossil fuels. Carbon dioxide (CO2) contributes to the generation of harmful emissions, and the consumption of resources in mining and agriculture causes the ecosystem to be in a state of distress during the early stages of development. We fail to consider the environmental sustainability of the consumption scenario. Various sources suggest that these actions lead to simultaneous increases in income and CO2 emissions. Chen et al., 2020). On the other hand, human activities primarily contribute to environmental degradation and climate fluctuations. Isiksal et al. (2022) claim that the demand for food, energy, infrastructure, water, and clean air leads to an increase in emissions and exerts pressure on the environment, thereby causing environmental degradation.

Previous research suggests that human capital is the most likely factor that could save the earth by ensuring the identification of a high-quality environment (Ahmad et al., 2022; Zhu et al., 2021; Arefieva et al., 2021). The fact that human capital is the most likely factor supports this belief. According to Zen et al. (2014), education has resulted in an increase in the number of recycling operations carried out by both individuals and businesses. As a result, we will focus on the mineral-rich Asian countries, including Russia, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, India, China, Indonesia, Japan, and North Korea, and how their human capital and mineral resources affect emissions.

Innovative human capital outperforms all other types of human capital when it comes to the development of new technologies for manufacturing that are less harmful to the environment. Academics have paid relatively little attention to the relationship that exists between artistic human capital, environmentally responsible growth, and ecological sustainability. One of the most popular topics of discussion among researchers is the relationship that exists between the quantity of human capital, economic growth, and environmental quality (Ahmed et al., 2020). They frequently look at levels of education in order to quantify human capital, but they fail to take into account variations in the quality of human capital among individuals. On the other hand, the quality of human capital may have a greater impact on green growth and environmental sustainability. There is a possibility that the quality dimensions of human capital can provide a more satisfactory explanation for growth (Prasetyo & Kistanti, 2020). In academic circles, the measurement of human capital, and more specifically, innovative human capital, has always been a contentious topic of discussion. For a considerable amount of time, researchers have found that college graduates are a good proxy for creative human capital (Mellander & Florida, 2021). Despite its widespread use, this measurement method poses several potential issues, such as the following: The first problem is that this approach does not take into account the fact that individuals who have completed tertiary education are of varying degrees of quality; after all, their educational accomplishments are merely a reflection of the differences in their levels of human capital (Tienet al., 2021). Second, the common practice of counting college students among higher education recipients significantly expands the pool of available creative human capital. In conclusion, while most bachelor's degree holders find employment in scientific or technical fields, it's crucial to acknowledge that not all college graduates possess innovative human capital.

The purpose of this study is to address these deficiencies and investigate the impact of innovative human capital on CO2 emissions in North Korea, Uzbekistan, India, China, Indonesia, and Turkmenistan, as well as Kazakhstan, Tajikistan, Uzbekistan, the Kyrgyz Republic, and China. It is absolutely necessary for these countries to exercise strict control over carbon dioxide emissions and effectively implement green development. This paper aimed to address the previously discussed issues by focusing on measuring innovative human capital in the context of science and technology personnel. As a result, the new measure of innovative human capital is more likely to reflect its capacity to stimulate innovation, which in turn can increase energy efficiency and production while simultaneously reducing environmental degradation. In addition, this will reduce the likelihood of erroneous findings and misleading policies, both of which could be the consequence of employing flawed metrics for human capital. According to Ponce et al. (2021), in Latin American countries, for example, human capital (as measured by education) is positively associated with emissions. According to our perspective, the shortcomings of earlier methods of measuring human capital can be the cause of such unexpected results. Education-based measures, which primarily aim to raise awareness about the importance of environmental sustainability, are less relevant to environmental sustainability than our measure, which directly promotes innovation and technological advancement. As a result, our measure is more relevant to environmental sustainability. Regarding issues pertaining to the environment and the utilization of natural resources, there are contrasting points of view. On the other hand, environmental degradation is a direct consequence of the growing demand for the extraction and utilization of natural resources. Income inequality, rapid urbanization, and associated industrialization patterns fuel this demand. 2. Similarly, countries that are abundant in resources can reduce their reliance on fossil fuels by reducing the amount of fossil fuels they import. 3) As an additional point of interest, the current study asserts that human activities such as mining and deforestation are the primary contributors to the presence of pollutants in the air, soil, and water. In this way, the ongoing research on sustainable development and natural resources has reached a point where it is no longer possible to proceed. For instance, some empirical studies challenge the previously presented arguments that natural resources bear responsibility for the rising levels of pollution in the environment. The inadequacy of the previously mentioned studies necessitates further investigation to reach a logical conclusion about the relationship between natural resources and environmental degradation.

Despite the abundance of literature on the ways in which financial development affects energy transition and the adoption of renewable energy, there have been relatively few studies that have investigated the effects of financial technology (fntech) (Shahbaz et al., 2021; Abdullalam & Sajid, 2023). As a result of the innovative methods that fintech has the potential to bring to economies, the possibility of cleaner energy that is both more affordable and more easily accessible came into existence. In their study, Li et al. (2023) discovered that fntech plays an important part in the energy transition. When it comes to developing green finance and sustainable investment, experts in the field have brought attention to the potentially game-changing possibilities that advancements in financial technology could bring about. Fintech helps allocate capital more effectively towards green initiatives, promotes sustainable business practices, and provides support for renewable energy sources (Macchiavello & Siri, 2022). Digital platforms and data analytics enable this. There is a great deal of mystery surrounding the intersection of pollution and technical advancements in the financial sector. There is a deficiency in the data that would enable us to arrive at definitive conclusions regarding the impact that green energy imports, fintech, and foreign direct investment have on pollution in the countries that we have chosen as our sample.

HYPOTHESIS DEVELOPMENT

Innovative Human Capital and CO2 Emissions

The study of the relationship between human capital and environmental quality is attracting the attention of an increasing number of academics (Abaidullah, 2024). In order to provide an explanation for the impact that human capital has on the environment, there is an increasing amount of research that makes use of the traditional education-based proxy (Yao et al., 2020; Jan & Rizwan, 2023; Sukmaningrum, 2022; Khokhar et al., 2024). As part of their investigation into the relationship between human capital and environmental concerns, researchers have utilized both panel and individual country-level data. Fang et al. (2022) demonstrated, from a panel perspective, that educated individuals prefer the consumption of clean energy over the consumption of dirty energy by using data from twenty economies that are members of the OECD. They discover that higher levels of human capital, as measured by college degrees, have a negative effect on carbon dioxide emissions. More specifically, they discover that an additional year of college is associated with a decrease in emissions that ranges from 50.1% to 65.8%. Alvarado et al. (2021) found that human capital contributed to a reduction in the consumption of non-renewable energy in 27 OECD countries between the years 1980 and 2015. However, economic development did not have this effect. Lin et al. (2021) conducted an empirical study on the relationships between energy, physical capital, and human capital in a broader region that includes the countries that are members of the OECD, the North American Free Trade Agreement (NAFTA), the BRIC nations, East European or East Asian countries, and the EU15. Researchers have determined that the relationships between human capital and energy consumption are interchangeable. According to Xu and Li (2020), economic development has an effect on emissions that is dependent on human capital. Once we reach a certain point, we will see a decrease in CO2 emissions, a rise in environmental consciousness, and an increase in the adoption of environmentally friendly technology. Hao et al. (2021) found that investments in human capital have the potential to reduce carbon dioxide emissions, focusing on the G7 nations from 1991 to 2017.

Khan et al. (2020) found that the utilization of renewable energy in the countries that make up the G7 summit, based on collected data from 1995 to 2017, has the potential to increase. According to Khan et al. (2020), the degree of fiscal decentralization means that improvements to human capital have the potential to amplify the inverse correlation that exists between the CO2 emissions of G7 countries.

Additionally, several studies conducted in African countries have demonstrated that human capital plays a constructive role in fostering the utilization of renewable energy sources. Wen et al. (2022) revealed that moving on to studies that are specific to a country and human capital can lower CO2 emissions in Pakistan. The EKC model conducts an empirical investigation into the effects of renewable energy and economic growth on emissions. Ganda (2021) conducted research in Pakistan to investigate the relationship between human capital and emissions, finding that human capital can reduce emissions without hindering economic proliferation.

The researchers found that human capital promotes sustainable urbanization by decreasing environmental degradation and substituting as a moderator (Zia et al., 2021). The study discovered the impact of urbanization, mineral resources, and human capital on China's environmental excellence. Similarly, Dai et al. (2022) explained the connection that exists between technological innovation and pollution in China's major cities. Xin and Lyu successfully demonstrated the EKC model, which illustrates the impact of technological advancement on pollution through human capital accumulation. It is crucial to emphasize that excessive accumulation of human capital could exacerbate the situation.

The study by Du et al. (2022) utilized two models, specifically ARDL, CUP-FM, and CUP-BC, and examined the impact of human capital on environmental quality in two samples, namely China and G7 countries. Academic journals have published a significant amount of research on the growth-environment nexus. They found that human capital provides long-term protection, while mineral resources exacerbate environmental problems. Khan's (2020) research also revealed an inverse relationship between human capital and emissions.

At the beginning of the 1990s, academics devoted a significant amount of time and effort to investigating the connections that exist between environmental sustainability, human capital, mineral resources, and economic growth. The findings of these studies provided evidence that both supported and disproved the hypothesis that a clean environment is helpful to economic development. Reviewing the most recent research will allow us to shed light on these connections and their most important conclusions. Economically sustainable, this will enable us to provide these nations with actionable advice and policies that will assist them in becoming more environmentally and economically sustainable.

Mineral Resources And Co2 Emission

Mineral resources, even though they may seem to be a panacea for the long-term well-being of the economy, actually have consequences for the atmosphere (Hassan et al., 2023). The study found that China's rapid development led to an increase in both mineral resource consumption and pollution discharges between 1978 and 2018. Despite Turkey's confirmation of QARDL and EKC, a different study (Aydin & Turan, 2020) found a positive and significant impact of the gross domestic product on the ecological footprint of the BRICS economies between 1995 and 2014. Adedoyin et al. (2020), who investigated the impact of coal rent and GDP on carbon emissions in the BRICS states, confirmed that mineral resources reduced the ecological footprint in all ten NICs and N11 countries between the years 1990 and 2016. Climate change and its threat to human health continue to dominate global agendas and policy conversations. The concept of sustainability integrates considerations from the economy, society, and the natural environment. We have observed a significant shift in the relative importance of environmental factors for human existence. When compared to the other two pillars of sustainable development, the environmental pillar stands out because of the correlation that exists between the deterioration of biological standards and the phenomenon of global warming. Several questions remain unanswered, including those concerning climate change, sustainable development, the role of per capita income, and the availability of natural resources. A fresh perspective has emerged in the ongoing conversation about people's incomes and environmental degradation. There is a lack of clarity regarding environmental sustainability and the impacts of climate change; however, the majority of these studies use carbon dioxide emissions as a substitute for actual environmental degradation. Even though carbon dioxide emissions caused by humans are the primary contributor to global warming, there are a number of other factors that also play a role in the phenomenon (Yoro & Daramola, 2020). These include increasing urbanization, population size and income levels, energy resources, lifestyle choices, technological advancements, and current policies regarding the atmosphere.

Fintech And CO2 Emissions

The popularity of innovative approaches to environmental issues has led to an increase in people becoming aware of the urgency of the need to reduce carbon dioxide emissions and combat climate change. Recently, people have recognized financial technology as a potentially valuable tool that can promote sustainable behavior and aid in lowering carbon dioxide emissions. The purpose of the literature review is to provide a comprehensive summary of current knowledge regarding the relationship between fintech and CO2 emissions, with a specific focus on how this field is enhancing environmental sustainability. Various studies have showcased the revolutionary impact of financial technology (fintech) and its potential to promote environmentally responsible financial practices. (Chueca Vergara & Ferruz Agudo, 2021).

Schulz and Feist (2021) assert that fintech-driven finance outperforms traditional forms of financing in terms of effectiveness and transparency, thereby channeling more funds into projects that are resilient to climate change, green infrastructure, and renewable energy. Evidence suggests that the use of blockchain technology and digital finance platforms has simplified investment procedures, making it easier for businesses and individuals to access funding for green projects. A team of representatives from various Asian economies disclosed the information. This will lead to lower carbon dioxide emissions and improved sustainable development.

Boden et al. (2020) conducted a previous study that suggests the availability of mobile payment options and their convenience may encourage consumers to purchase environmentally friendly products and services, thereby reducing the demand for products with a high carbon footprint. Research on mobile payment systems for fintech has demonstrated that these systems influence consumer behavior in a way that benefits the environment. Implementing large-scale mobile payment systems will attract a number of customers by promoting greater environmental friendliness in various industries, such as retail and transport, which are known to negatively impact the environment. Energy efficiency plays a crucial role in reducing carbon dioxide emissions. However, FinTech has made a significant impact on optimizing power consumption.

Through utilizing applications based on fntech, smart grids can observe energy consumption patterns and adjust the distribution of power in real-time. This leads to more efficient energy use and consequent emission reductions in China, according to Yang et al. (2021) and Ding et al. (2022). Fintech has the potential to facilitate energy trading and equip individuals with the necessary devices to generate and trade renewable energy (Rehman et al., 2021). Zhang and Liu (2022) assert that the digital infrastructure supporting fintech platforms in Chinese cities may involve energy consumption and associated carbon emissions, encompassing data centers and cloud computing, among other aspects of digital infrastructure. Investigations into how fntech affects CO2 release revealed that it could stimulate eco-friendly buying behaviors, sustainable finance management, and power savings.

Financial technology has the potential to contribute to a reduction in carbon dioxide emissions. The streamlining of financial operations and the provision of innovative payment solutions increase environmental sustainability. Addressing current issues and promoting green technologies in digital infrastructure are crucial for maximizing the benefits of fintech while simultaneously minimizing its environmental impact.

SPECIFICATION OF MODEL

The primary objective of the model is to conduct panel analysis. Equation (1) represents the basic functional structure of the model:

$$CO_2 = f(HC + MNR + FNT + HC * FNT + MNR * FNT \quad (1)$$

Equation (2) demonstrates that log-linear data exhibit greater efficiency and consistency compared to linear data. This was initially discovered. Below is an illustration of the function expressed in log-linear form.

$$CO_{2it} = \alpha_i + \gamma_t + \beta_1 lnHC_{it} + \beta_2 lnMNR_{it} + \beta_3 lnFNT_{it} + +\beta_4 \ln{(HC * FNT)_{it}} + \beta_5 \ln{(MNR * FNT)_{it}} \quad (2)$$

The variables and the proxies are shown in the table 1 below. The data of twenty mineral rich countries from 2003 to 2019 are used for the analysis purpose.

Table 1.
Variable Description

Variable	Definition	Source
CO2	Total emissions of carbon dioxide	World Bank
MNR	Natural resources percentage of GNI	World Bank
Fintech	The digital inclusive finance index, developed by the digital finance research center at Peking University, is a measure of the level of digital finance development in specific countries. The progress of digital finance in Asian countries abundant in minerals is demonstrated by this indicator, which is quantified using PKU-DFIC (log).	Institute of Digital Finance, PKU (2019)
Human capital	Index	Penn world

ANALYSIS

Slope homogeneity (SLH) test

Following the completion of the CSD evaluation, the next step is to examine the cross-sectional slope homogeneity (SLH). The problem of heterogeneity is of the utmost significance because the countries that make up the Belt and Road Initiative (BRI) have different demographic and economic structures. Any changes that are made to the slope parameters could potentially have an impact on the reliability of panel estimators. With that in mind, the SLH method was utilized in this research project (Khoza-Shangase & Kalenga et al.,2024). We employ the test that was developed by Schulz and Feist (2021). This test is suitable for situations where the values of N and T are getting closer to infinity. It is founded on the modified statistic $\tilde{S}$ that was developed by Swamy (1970).

$$\bar{O} = (N)^{\frac{1}{2}}(2C)^{-\frac{1}{2}}(\frac{1}{N}S - k)......................(3)$$

$$\bar{O}_{adj} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}(\frac{1}{N}S - k)................(4)$$

In Equations (3) and (4) $\bar{O}$ the test consists asymptotically normal and standard distribution, where $\tilde{S}$ is the Swamy statistic, k the explanatory indicators, $\bar{O}_{adj}$represents the bias-adjusted

from the slope homogeneity test

When SLH and CSD are present, the traditional unit root tests, such as Choi, Pesaran and Shin, Fisher-ADF, Levin-Lin-Chu, and Im, perform less well than they should. In the application of the second-generation unit root test of cross-sectionally augmented Dickey-Fuller (CADF)-cross-section Im-Pesaran (CIPS) that is presented in this paper, the stationary properties of the variables that are being investigated are taken into consideration (Azam et al., 2021). Presented here is the equation for the test:

$$\Delta CAD_{it} = \theta_i + \theta_i X_{it-1} + \theta_i \widehat{CAD}_{it-1} + \sum_{I=0}^{q} \theta_{il} \widehat{CAD}_{it-1} + \sum_{I=0}^{q} \theta_{il} \Delta CAD_{it-1} + \varepsilon_{it}........(5)$$

According to Equation (5), the averages of the cross-sections are represented by the symbols ΔCAD_{it} and $\widehat{CAD}_{it-1}$ respectively. Equation (6) illustrates how the research makes use of CIPS statistics, which are as follows:

$$CIPS = \frac{1}{N}\sum_{i=1}^{n} CDF_i............(6)$$

1.1. GMM–PVAR technique

Once we confirmed that the GMM-PVAR model had successfully passed the CSD, SLH, stationarity, and cointegration tests, we opted to utilize it. The PVAR method with fixed effects was originally developed by Dogan et al. (2022), and later adopted by Djeunankan and Tekam (2022). The PVAR model expanded upon this methodology. During our research, we have introduced the PVAR model, outlined as follows:

$$Y_{i,t} = \left(X_n - \sum_{I=1}^{q} A_i\right)N_i + \sum_{I=0}^{q} A_i Y_{i,t-1} + BY_{i,t} + C\omega_{i,t} + \mu_{i,t}..........(7)$$

When considering Equation (8), the endogenous factor yi t with time t is represented by the symbol −1. Additionally, X_n is an identity matrix with dimensions of n × n, and the homogeneity parameters are denoted by the letters A, B, and C. In the context of v = 1,..., T, the term $\omega_{i,t}$ denotes a vector that is composed of variables that are entirely external. The final representation of the individual error that is anticipated to be independent and exhibit favorable behavior is denoted by the symbol $\mu_{i,t}$.

In order to lessen the impact of fixed effects, there are two different approaches. We make use of the first difference, which is the forward orthogonal conversion, in order to circumvent the problem introduced by the fixed effect. Nevertheless, if we employ the GMM method, it is possible that we will be able to bypass these procedures. Specifically, the parameters could be utilized as instrumental variables (lagged regressors) in the GMM estimation if the conversion matrix between modified variables and lagged covariates was preserved. This would allow for the parameters to be used in the estimation process. In the same way that Djeunankan and Tekam, (2022) determined the initial variation in the GMM estimate to be, Dogan et al. (2022) did the same thing.

$$\Delta Y_{i,t} = +\sum_{I=0}^{q} A_i \Delta Y_{i,t-1} + B\Delta Y_{i,t} + C\Delta\omega_{i,t} + \Delta\mu_{i,t}........(8)$$

Transforming the econometric model 2 as of equation 8

$\Delta CO_{2it} = \alpha + \sum j = 1p\phi j\Delta CO2i, t-j + \sum k = 1q(\beta 1k\ln(HC)i, t-k + \beta 2k\ln(MNR)i, t-k + \beta 3k\ln(FNT)i, t-k + \beta 4k\ln(HC \times FNT)i, t-k + \beta 5k\ln(MNR \times FNT)i, t-k) + \epsilon it$ ……………………………………(9)

Equation (9), where "Δ" represents the forward orthogonal conversion or first difference, is a mathematical expression. Within the framework of our model, the delayed endogenous factors are HC, MNR, and FNT. In addition, we made use of the forward orthogonal conversion method, which was recommended by Ge and Sadhu (2024). It was recommended by the research that three metrics from the MMSC be utilized. These metrics are the MMSC, the Bayesian information criterion (MMSC-BIC), and the Hannan-Quinn information criterion to be specific. In light of the findings of earlier studies conducted by MMSC-BIC (Dogan et al., 2022), we were able to ascertain that the lag length throughout our investigation was equal to one for each of the frameworks.

Pre-estimation Test

At a significance level of 5%, the White Heteroscedasticity test is able to successfully reject the null hypothesis. The p-value for this test ranges from 0.0000 to 0.0020. As a result, it recommends making use of estimates based on random effects and reveals that heteroscedasticity is a problem with the aggregate pooled model. The Bresuch Pagan LM test is utilized in order to make a decision between the pooled OLS and Random effects estimations. The pooled OLS method does not generate an autocorrelation-free BLUE estimator when the cross-sections specific term is zero. This indicates that the method failed to produce the estimator. The purpose of the test is to ascertain this particular aspect. LM uses a Chi-square distribution with one degree of freedom when tested under the assumption that the null hypothesis is true. Our conclusion is that the cross-section individual effects are present when the calculated value is greater than the tabulated chi-square. This leads us to reject the null hypothesis and come to this conclusion. As a consequence of this, the random effects model is the methodology that is recommended. The Hausman specification test is utilized in order to make a comparison between the fixed effect estimator μ1 and the random effect estimator μ2 (Baltagi, 2023). Additionally, the results of the Arrelano-Bond Test indicated that autocorrelation was not present in the observations. It appeared that the GMM and fixed effect models provided the most accurate estimates for the aggregate model. For the purpose of determining the cross-sectional dependence of the model, the Pearson test is utilized. According to the findings, there is a dependence that involves cross-sectional analysis. In order to address the cross-sectional dependence, the analysis involves the utilization of robust and clustering options.

Table 2.
Various Test To Determine The Most Appropriate Panel Data Estimates

Statistics	Prob>chi2 Prob>z
Breusch and pagan test/ autocorrelation test	0.0000
White Heteroscedasticity test	0.0000***
Hausman test	0.0001**
Arrelano-Bond Test	0.361
Pesaran	0.0000

Table 3.
Summary Statistics

Variable	**Mean**	**Std.Dev.**	**Min**	**Max**

CO_2	0.721	0.381	.227	1.364
HC	0.595	0.823	0.227	5.329
MNR	2.177	1.128	0.339	8.134
FNT	0.192	2.233	0.03	2.014

There are two major problems with panel data estimation: CSD and SLH. These problems are the cause of results that are unreliable and inconsistent. It is common practice to arrive at CSD when using macroeconomic indicators. When it comes to CSD, the typical culprits are the multinational economic relations that exist between countries. As a consequence of this, the policies that are implemented in one country have an effect on the economies of countries that are adjacent to it. Panel B displays the results of the SLH test, which further demonstrates that the panel data is heterogeneous with regard to its composition. Taking this into consideration, it can be deduced that the coefficients of the model are also heterogeneous, and the slope varies from economy to economy. Furthermore, Ali et al. (2022) provide evidence that the social and economic structures of one nation cannot have an impact that is comparable to that of the other nation. In order to determine whether or not panels contain CSD and SLH, tests were developed by Ali et al. (2023). These tests are what we use to determine whether or not they are present in our panel. Based on the findings presented in Panel A of Table 3, it can be concluded that our model does, in fact, incorporate CSD. The fact that the p-value for each parameter is lower than 0.001 indicates that we are able to reject the null hypothesis that there is no CSD. This is an important fact to take into consideration. The conclusion that can be drawn from this finding is that every single panel country is susceptible to the economic shocks that are caused by any one variable. cointegration techniques to the panel data is required because of the presence of CSD and heterogeneity. Therefore, it is necessary to apply these techniques.

Table 4.
CSD Test

Variable CSD Results	T-statistics (p-value)
CO_2	7.219***(0.000)
HC	6.281***(0.000)
MNR	7.089***(0.000)
FNT	8.761***(0.000)
HC*FNT	12.201***(0.000)
MNR*FNT	9.918***(0.000)

A heterogeneous distribution of the panel data is demonstrated in Table 5, Through the utilization of CO_2 as dependent variables in both models, the SLH test is able to confirm that the slopes are distinct from one another, thereby rejecting the null hypothesis that there is no difference between them. The application of the second-generation unit root and second-generation.

Table 5.
SLH Test

SLH Results

Statistics	CO2
Delta Tilde	9.431***(0.000)
Delta Tilde (adjusted)	10.001***(0.000)

Once it has been determined that the panel of economies comprises a CSD, nonstationary, and SLH, the estimation of long-run and short-run correlations, which constitute the fundamental components of the empirical method, can commence.

Table 6.
Unit Root Cointegration Test Results

Variable	CIPS	CADF	Integration Order
CO2	-3.299***	-3.201***	I (1)
HC	-3.371***	-4.300***	I (1)
MNR	-4.177***	-3.019***	I (1)
FNT	-6.771***	-4.223***	I (1)
HC*FNT	-3.311***	-2.901***	I (1)
MNR*FNT	-5.518***	-4.312***	I (1)

Table 7.
Westerlund Cointegration Results

Statistics	CO2		
	Value	Z-value	p-value
Gt	-4.284	-6.372***	0.000
Ga	-7.272	-4.193***	0.000
Pt	-11.047	-3.893***	0.000
Pa	-14.283	-4.849***	0.000

How Pearson correlation coefficients measure relationships' strength among the predictor variables in this study has been demonstrated in Table 6. It has been projected in Table 1 that there is no value higher than 0.80 for the correlation coefficients among the independent variables. The 0.8 is the standard value to show the extent of correlation utilized to identify the presence of multicollinearity, as affirmed by . The correlation matrix between any variable has projected no signs of multicollinearity. For every variable, Pearson's correlation matrix was incorporated by us to identify more than 80% collinearity.

Table 8.
Correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)
CO2	1.000					
HC	-0.124**	1.000				
MNR	0.215*	-0.602*	1.000			
FNT	-0.173**	0.201**	-0.037	1.000		
HC*FNT	-0.278*	0.210**	0.127	-0.468*	1.000	
MNR*FNT	-0.321**	0.311*	0.121	-0.290**	-0.290**	1.000

In order to increase our understanding of the dynamic relationship that exists between CO2 emissions and a number of important variables, This study makes use of the GMM-PVAR model, which is a relatively complicated statistical instrument. It is an outstanding choice for our investigation into the effects of historical CO2 emissions, human capital, mineral resource abundance, and advancements in financial technology (fintech). Because GMM-PVAR is so adept at manufacturing time-series data that involves multiple variables, With the GMM-PVAR method, it is possible to conduct an in-depth investigation into the factors' contributions to CO2 emissions. The method accomplishes this by identifying and eliminating potential biases and capturing the intricate relationship between these variables. This method seeks to provide actionable insights for reducing environmental impact by implementing strategic interventions in education, resource management, and the adoption of technology aimed at reducing environmental impact. This lays the groundwork for a more nuanced analysis. Table 9 displays the results.

Table 9.
Regression Result

	CO2	
$CO2_{t-1}$	0.2172** (-3.10)	0.1772** (-2.59)
HC	-0.184**	-0.284***
	(-1.75)	(-2.75)
MNR		0.459**
		(-2.44)
FNT	-0.1072***	-0.1536**
	(-3.90)	(-3.47)
HC*FNT		-0.737***
		(-3.170)
MNR*FNT		-1.304**
		(-2.74)

The fact that the coefficient values for CO2 emissions (CO2_(t-1)) that are one period behind is 0.2172 and 0.1772, both statistically significant, shows how persistent carbon dioxide emissions are. These conclusions demonstrate intrinsic inertia within ecological systems; where emission levels have been considerable historically they will also be so prospectively.As a result of the consequence of these coefficients, it is evident that policies aimed at reducing CO2 emissions cannot afford to be reactive; rather, they must be proactive, taking into consideration both the current and the future levels of emissions. The fact that these emissions will have an effect on the environment for a considerable amount of time in the future brings to light the significance of taking immediate and ongoing action to reduce CO2 emissions.

Meanwhile, the coefficients of Human Capital (HC) present an odd finding: they are negative for CO2 emissions (-0.184 and -0.284 respectively). This is contrary to the initial assumption that higher levels of HC would lead to increased energy use and thus more emissions. It may be that what is being captured here instead reflects how much knowledge and skills people have, which enables them to come up with new ideas that use fewer resources or work better and are also able to meet human needs equitable way possible. As shown by the example where societies could only take full advantage of technologies if all persons were educated and skilled enough; these results indicate a need for investment in education if we want our society not only grow economically but be environmentally.

There is a link between carbon dioxide release and mineral resources according to the correlation coefficient; (r=0.459) this means that greater CO2 releases are accompanied by more abundant mineral reserves. The mining and processing of minerals are very energy-intensive operations which result in considerable amounts of CO2 being emitted into the atmosphere. It may be assumed that these processes consume large amounts of energy. It is therefore necessary to review the methods used in extracting resources with immediate effect and start employing renewable sources of power as well as eco-friendly mining techniques if we are to minimize our environmental footprint.Furthermore, it emphasizes the importance of distinguishing economic growth from environmental degradation, which is an essential component of an economic model that is responsible for sustainability growth. The very positive effect that

Fintech (FNT) has on this metric (-0.1072 and -0.1536) demonstrates that advancements in financial technology contribute to a reduction in CO_2 emissions through their influence. It is possible that this is due to the fact that fintech inspires the utilization of environmentally friendly technologies, assists with the execution of more effective financial transactions, and enables a more effective allocation of resources toward environmentally responsible projects.

Despite the significant negative impact fintech has the potential to play a significant role in the environmental sector. This is because fintech deals innovative solutions that have the potential to lead to more sustainable economic practices and lower CO_2 emissions. Last but not least, the interaction terms MNRFNT and HCFNT, which have coefficients of -0.737 and -1.304 correspondingly, demonstrate that fintech significantly moderates the associations between human capital, mineral resource abundance, and CO_2 emissions. When everything is taken into consideration, these interconnections indicate that fintech has the potential to lessen the environmental impact of abundant mineral resources while simultaneously enhancing the positive influence that human capital has on sustainability and reducing emissions of carbon dioxide. This is demonstrated by the fact that the coefficients for these terms are negative.

Financial technology (fintech) is probably in making human resource innovation more sustainable and less bad effect toward the environment due to mineral extraction. This is recommended from findings that also show how fintech could possibly transform efforts towards environmental sustainability globally. The most effective way to reduce carbon emissions might therefore involve combining technical progress with eco-friendly practices on developing people's skills as well as managing natural resources.

CONCLUSION

We applied the Generalized Method of Moments-Panel Vector Autoregression (GMM-PVAR) model to study CO_2 emissions in Belt and Road Initiative (BRI) countries, revealing that these emissions are long-lasting and require proactive strategies. This highlights the importance of incorporating sustainability into economic planning and policymaking. Human capital's role in environmental factors is also significant, as it has a mixed effect on CO_2 emissions (Khan, 2020). By reimagining it as a resource that promotes environmentally friendly practices and technologies, human capital can ensure its long-term viability. To prepare the workforce for the green economy and develop innovative ways to reduce emissions, there needs to be a shift in focus towards sustainability-oriented training and education. The increasing release of carbon dioxide into our atmosphere underscores the necessity for us to implement sustainable management systems for our abundant minerals in BRI countries. Mining should employ energy efficiency measures, clean technologies, and renewable energy sources to minimize the negative impacts of extracting natural resources, thereby ensuring their future robustness as well as the sustainability of these economies over time.

Digital finance can reduce the environmental impact of financial operations and encourage widespread use of eco-friendly technology and procedures. Fintech has a significant negative effect on CO_2 emissions, but it can revolutionize sustainable development by making green finance more accessible, financial transactions more efficient, and sustainable investments more easily allocated. The interaction effects between mineral resource abundance and fintech, as well as between human capital and fintech, reveal the synergistic potential of these factors to improve environmental consequences. Fintech reduces CO_2 emissions, boosts human capital's positive impact on sustainability, and lessens the negative effects of resource abundance. To sum up, this research offers an important understanding of the variables impacting CO_2 emissions in BRI countries and establishes the foundation for a more environmentally friendly future through the integration of technology, sustainable behaviors, and education. For BRI states to meet their environmental goals and fully use the Belt and Road Initiative's potential to advance global sustainability, they must implement these tactics.

POLICY IMPLICATIONS

Research that uses the GMM-PVAR model to examine CO_2 emissions among the nations included in the Belt and Road Initiative (BRI) provides leaders with a strategy. It mandates that they take immediate action and concentrate on specific issues related to the SDGs. The study also highlights the reality that CO_2 emissions continue to rise over time. As a result, it recommends developing long-term environmental regulations that will aid in achieving the climate change objective, which is the thirteenth aim of sustainable development. These strategies could involve the establishment of extremely aggressive objectives aimed at lowering greenhouse gas emissions, the development of renewable energy sources, and the creation of sustainable urban transport plans to carry out these policies. By incorporating environmental education and green skills into national curricula and vocational training programs, BRI countries can cultivate a workforce capable of driving and sustaining green innovation. Education and training have the ability to contribute to the attainment of SDG 4 (Quality Education) with a focus on sustainability, thanks to the multifaceted role of human capital in affecting CO2 emissions. Goals 7 (renewable and affordable energy), 9 (industry, innovation, and infrastructure), and 12 (responsible consumption and production) are just a few of the Sustainable Development Goals (SDGs) that this method helps attain. It also promotes a more sustainable social ethic. Implementing more sustainable extraction and processing practices is crucial for advancing SDG 15 (Life on Land) and SDG 14 (Life Below Water), and this shift is critical for BRI countries to make. Moreover, a paradigm shift in resource organization policies is required due to the positive correlation between mineral resource abundance and CO2 emissions. Reduce the negative effects of resource abundance on the environment by promoting circular economy principles, increasing efficiency, and decreasing environmental degradation. Such regulations would result in sustainable use of land and water resources, as well as a reduction in carbon dioxide emissions, would be the results of such regulations. The study's discovery of fintech's substantial negative impact on CO2 emissions opens up a new path for environmental policy, which intersects with SDG 17 (Partnerships for the Goals). We can encourage green investment by promoting innovative financial technologies. The promotion of fintech solution development and adoption can accelerate investments in environmentally friendly infrastructure.

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