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Research methods in economics to evaluate the role of energy efficiency and financial inclusion in achieving China's carbon neutrality target

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ABSTRACT

In the recent literature, energy efficiency got the attention of scholars due to its discouraging impact on CO_2 emissions, which is considered the most prevalent greenhouse gas that human activities produce. Data reports that China is the leading CO_2 emitting country across the globe, and still the environmental degradation is in progress. Thus, the current paper empirically investigates the impact of energy efficiency (ENEF), financial inclusion (FD), GDP, export diversification (EXD), and human capital index (HCI) on the environmental degradation of China over the period from 1988 to 2018. This study uses various time-series tests to empirically investigate the determinant of CO_2 emissions, including normality tests, unit root tests, and combined cointegration tests. Besides, the long-run coefficients are analyzed via the fully modified ordinary least square (FMOLS), dynamic OLS (DOLS), and the Canonical Cointegrating Regression (CCR) estimators. The empirical findings reveal that all the variables are cointegrated in the long run. However, the coefficient estimate shows that ENEF and HCI significantly promote environmental sustainability. While GDP, FD, and EXD significantly promote environmental degradation by enhancing the CO_2 level in the atmosphere. This study recommends practical policy implications based on the empirical findings: energy-efficient products and energy sources could be promoted.

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1. Introduction

Environmental degradation and global warming are the most destructive issues of the 21st century, because of which the International Energy Agency (IEA) and United Nations Intergovernmental Panel on Climate Change (IPCC) consider energy efficiency as an effective strategy associated with emissions (Grant et al., 2016). Evidence shows that human activities produce carbon dioxide (CO_2) emission, which is a

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major greenhouse gas (GHG) and detrimental for environmental quality by rising global warming and climate change (Sarwar et al., 2019). The level of CO_2 emissions is reported increasing since the industrial revolution, and still, it is in the increasing trend globally. Besides, industrialization is considered the major factor that increases the CO2 emission level and promotes environmental degradation and global warming by consuming the traditional fossil fuel energy and electricity (Fernando & Hor, 2017). Every country across the globe consistently promotes industrial growth in order to achieve or maintain higher economic growth. Additionally, these countries used their available sources, including natural resources, energy sources, and human capital, which inherently raises economic growth (Rahim et al., 2021). Besides, financial development and export diversification are those factors contributing to economic growth.

Empirical evidence has shown a mixed effect of energy efficiency on environmental regulations. The traditional concept projected that efficiency comes at an additional cost that the firms face. For instance, environmental regulations, including emission trading schemes, push the firms to reduce pollution-intensive products consumption and production, which could not be favorable to improve efficiency or productivity (Gray, 1987). However, as per the Porter hypothesis, environmental regulations do not certainly impede efficiency improvement (Porter & Van der Linde, 1995). Whereas strict and well-designed policies can speed up technological innovation, which helps to offset the compliance cost partially or fully.

Besides, financial inclusion (FD) is the access of business firms and individuals or households to a range of financial products and services in an affordable, responsible, and sustainable manner (World Bank, 2018). As a result of higher access to wide-ranging financial products and services, including transactions, payments, savings, insurance, credit, remittances flows, among others, speed up economic activities and economic growth. This immense financial inclusivity rate helps reduce income inequality. Hence, it is assumed that financial inclusion plays a substantial role in the economic stability of the country (Sahay et al., 2015). Thus, the FD's role in higher economic growth achievement cannot be suspected. Additionally, as FD contributes to higher economic growth, it could also play an influential role in environmental quality (Qin et al., 2021). The degree of FD could be assumed in the higher gross fixed capital enhancement, which increases the energy demand in the region and simultaneously enhances the CO_2 emission level.

Although the under-discussion variables play an influential role in achieving higher economic growth, these factors also contribute to either environmental sustainability or environmental degradation, depending upon the nature of the influence. The earlier literature already identified the impact of these variables. However, these findings are either mixed or contradictory. For instance, higher economic growth promotes environmental degradation by enhancing the CO_2 emission level due to a surge in economic activities (Akram et al., 2020). These economic activities further increase the energy demand and lead to environmental degradation (Banday & Aneja, 2020). However, achieving a higher level of income leads the economy to transition and adopt renewable and energy-efficient sources, which contribute to environmental sustainability (Malik et al., 2020). This is termed the environmental Kuznets curve hypothesis. Similarly, the diverse findings of financial development reveal that financial development provides a pathway to households and industrialists by delivering financial products and services, promoting economic activities, and increasing the fossil fuel energy demand, thus affecting the region's environmental quality (Odugbesan & Adebayo, 2020). On the other hand, a developed financial system promotes environmentally friendly technologies and promotes green finance that reduces fossil fuel energy demand and enhances environmental quality by minimizing non-renewable energy consumption (Godil et al., 2020). Similarly, the diverse outcomes of export diversification reveal that export diversification significantly promotes energy-intensive products that enhance CO2 emissions levels and lead to environmental degradation (Mania, 2020). However, a contradiction has been observed as the other group of scholars support export product diversification that enhances energy-efficient energy sources and less energy-intensive products via the advancing technological sector (Shahzad et al., 2021; Wang et al., 2020). Technological progress enhances environmentally friendly energy sources consumption and reduces hazardous emissions, which further promote environmental sustainability. Extensive literature supports the stance that human capital promotes environmental sustainability (Sheraz et al., 2021; Hao et al., 2021). Higher education and skills lead to adopting innovative measures that significantly reduce fossil fuel consumption and reduce CO_2 emissions in the environment.

In the case of China, which is an emerging economy and rapidly moving towards economic stability, the environmental conditions are still not well and up to the global standards that target to limit CO_2 emissions reduction below 1.5 °C. As the largest energy consumer and carbon-emitting country in the world since 2007, China remained under huge international and domestic pressure to minimize energy consumption and reduce emissions (Liu et al., 2020). However, China has taken rapid environmental-economic measures consistently addressing energy-saving emissions. Still, the consequences of these policy measures to come in the future. Therefore, investigating the energy efficiency in the presence of other economic and non-economic factors for reducing CO_2 emission is the need of an hour, which could be helpful to attain economic development at a lower environmental cost.

Based on the prior discussion, it is mentioned by different international organizations that China is an emerging developing economy and could be a developed economy in the future. Still, it remained the leading energy consumer and CO_2 emitter in the world. This got the attention of scholars and policy-makers to provide policies that efficiently promote economic growth without harming environmental sustainability. In this regard, energy efficiency could be used for efficient economic-environmental sustainability. The current study focused on China's economic, energy, and environmental conditions and aimed to identify the influence of energy efficiency on environmental degradation. Besides, higher economic growth, financial inclusion, and export diversification are developmental economic factors that facilitate economic activities. At the same time, these factors could also influence environmental quality. Therefore, the second objective of this study is to empirically analyze the influence of economic growth, financial development, and export diversification on environmental quality. Moreover, human capital is an influential factor that could provide higher growth achievement based on higher education, skills, and economic behavior. Hence, the study's final objective is to investigate human capital's influence on environmental sustainability empirically. These objectives could be achieved by utilizing advanced time-series approaches on the data throughout the 1988-2018 period.

1.1. An overview

As the world's largest energy consumer and emitter the world, China's carbon emission data is found in an increasing trend. With no practical environmental regulations, the CO_2 emissions in China followed rapid growth from 1988 till 2014, as shown in Figure 1. However, initiating the environmental and pollution control measures lead China to reduce CO_2 emissions since 2015. Similarly, the trend line of the economic growth (GDP) reveals the steady and higher economic growth in each preceding year, as shown in Figure 2. It is noticed that after 2001, the steady growth followed an upward direction revealing that the GDP of China is increasing faster than the previous years.

Following the trend of economic growth, the financial development index and human capital index are found following the growing trend, as shown in Figure 3. However, the human capital index is more rapidly increasing than the financial development index. Since the economy is growing upward, the education level and skills level are also growing. However, the financial development is also reported increasing but at a slower pace than the financial development. The financial digitalization and advancement of the financial sector provide more opportunities to the general public to be financially included in the system along with the reduction of in gender disparity in financial inclusion (Kulkarni & Ghosh, 2021). However, the financial development is still not up to the required level due to steady or constant growth over time.

Figure 4 presents the export diversification of China over the selected time period for the study. The data shows steady growth from 1988 to 2004. However, fluctuations have been observed in the export diversification of China. These fluctuations mainly occurred due to the global shocks, including the global financial crises of 2007-08 and the lowest index value in 2009. However, after 2010, China starts recovering but still did not achieve the highest index value as of 2003 and 2004.

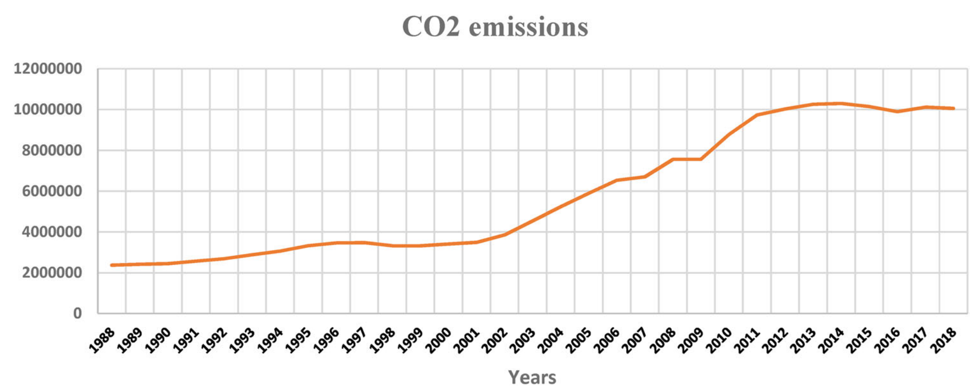

Figure 1. Carbon dioxide emission in China.
Source: World Bank (2022)

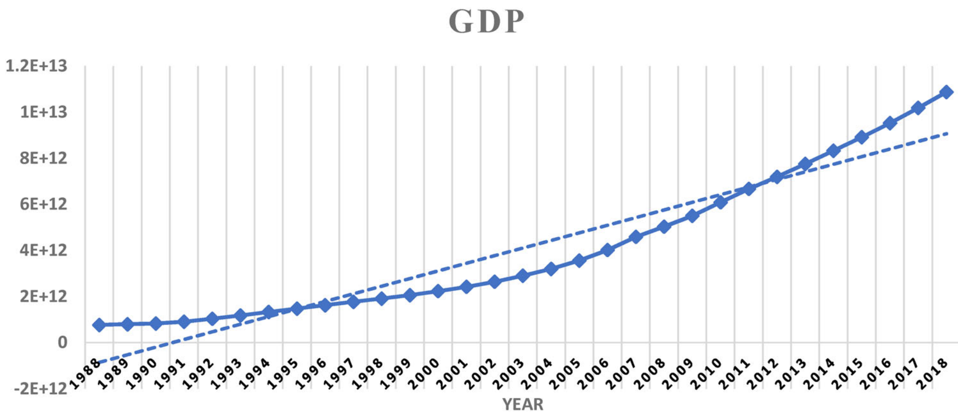

Figure 2. Gross Domestic Product of China (constant 2010 US$).
Source: World Bank (2022)

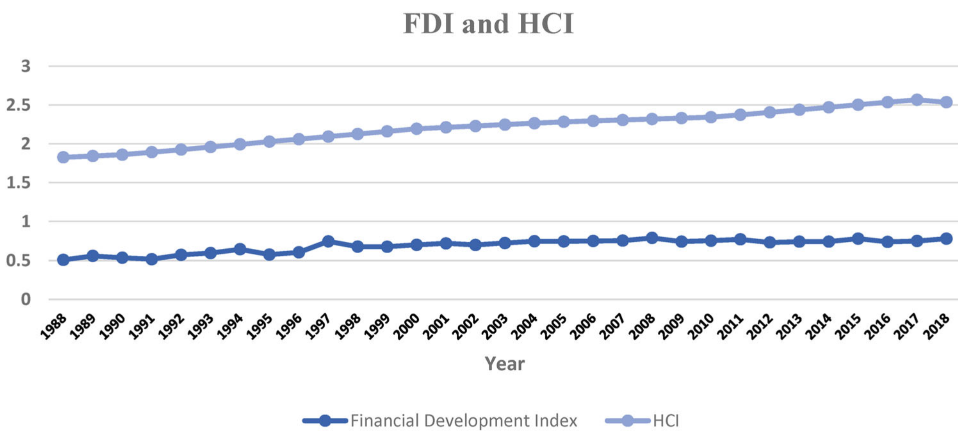

Figure 3. Financial Development Index and Human Capital Index in China.
Source: IMF (2022)

Figure 4. Export diversification Index.
Source: FRED (2022)

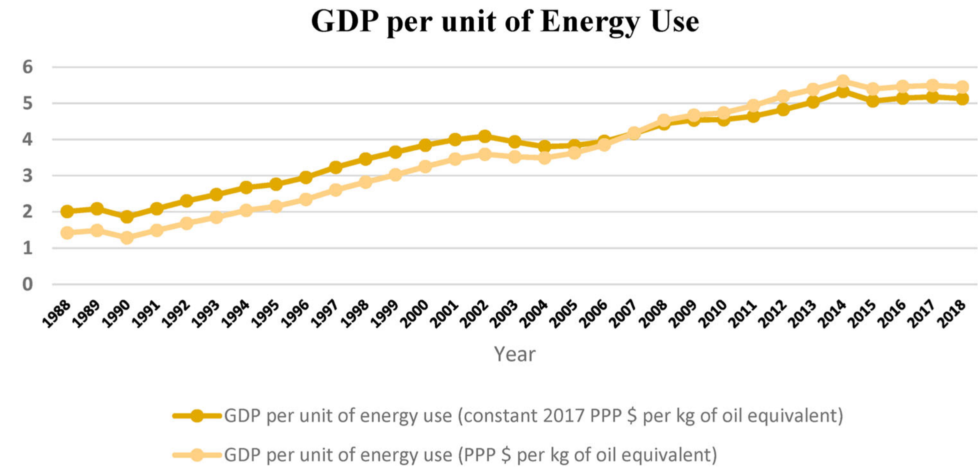

Figure 5. China's GDP per unit of energy use.
Source: World Bank (2022)

It is noted that the GDP and the CO_2 emission in China followed an increasing trend. Similarly, the increase in the aggregate income level increases the energy demand for China, as shown in Figure 5. Since 1990, China follows an increasing trend in energy consumption. However, after 2001-02 the energy demand decreases, and it is possibly due to the policies that restricted the coal, oil, and gas industries. Besides, after imposing the environmental regulation, China has been observed to lower energy demand due to increased energy efficiency.

China's attempts to enhance energy efficiency are critical to the global climate and energy systems since China is the world's biggest energy user. China is responsible for about 22 percent of world energy usage and 29 percent of total emissions (i.e. CO_2) from fossil fuel burning in 2018. China's efforts in adopting compulsory energy efficiency measures over the last few years have elevated it to the global leadership position in energy efficiency. The under-discussion economy has made enormous progress in terms of energy efficiency technology. Even without efficiency gains realized since 2010, the country would have consumed 25 percent extra energy in 2018. China's economic growth, from energy-intensive sectors, primarily heavy industries, to the service sector, resulted in structural reforms that also contributed to the reduction of energy consumption. Substantial increases in energy efficiency technology may be credited to internationally recognized energy efficiencies programs such as digital power labeling and strengthening of the required TOP 10,000 plan in the manufacturing industry. These are critical initiatives that contribute to China's energy efficiency policy coverage being much greater than the world average, as can be seen in Figure 6.

The rest of the study is organized as following: Section-2 provides relevant literature review; Section-3 proposed the relevant methodology used in the study; Section-4 provides the estimated empirical results and their discussion; Section-5 provides the conclusion of the study and policy implications.

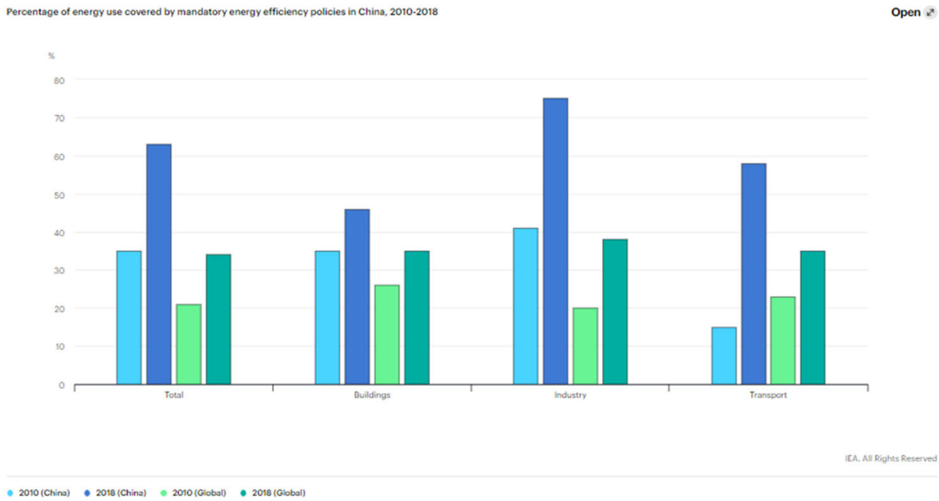

Figure 6. Comparison of China and Global Energy Efficiency, 2010–2018.
Source: IEA (2021)[1]

2. Literature review

The modern world focused on attaining low or zero carbon emission in the mid of 21st century. Thus, many strategies have been made and adopted to achieve the target. Concerning these strategies, energy efficiency has become the most influential factor in reducing CO_2 emission and attain environmental sustainability. Following the trend of attaining a low carbon economy, China also initiates strategies to achieve emissions neutral environment and attain sustainable development goals (SDGs). Concerning the effect of energy efficiency, the scholars have provided extensive literature that empirically investigates the behavior or role of energy efficiency on CO_2 emissions. Such studies include the recent studies of Mahapatra and Irfan (2021), Razzaq et al. (2021), Akram et al. (2020), Akdag and Yıldırım (2020), and Fernando and Hor (2017), Zaid et al. (2014).

Specifically, Fernando and Hor (2017) examined Malaysian manufacturing firms and reported that the energy management practices in the Malaysian industrial sector are still at the initial level. Thus, the lack of reasonable environmentally friendly policies is responsible for CO_2 emissions in the industrial sector. However, energy efficiency and energy audit could be the two critical factors that help reduce CO_2 emissions in the region. Besides, the study argued that energy efficiency is associated with energy awareness, commitments, and knowledge. Mahapatra and Irfan (2021) investigated the asymmetric impact of energy efficiency on the CO2 emissions of developed and developing countries from 1990 to 2017. The study uses the non-linear panel autoregressive distributed lags (NARDL) model and concludes heterogeneous effects. The long-run positive shocks in energy efficiency reduce CO_2 emissions, while the short-run negative shocks enhance the CO_2 emissions level in both developed and developing countries. For 66 developing economies, Akram et al. (2020) analyzed data from 1990-2014 and found that the EKC hypothesis is valid for the study region.

Besides, the study concludes that energy efficiency negatively influences CO_2 emissions in the region.

Following the same 1990-2017 period, Razzaq et al. (2021) analyzed carbon emissions and energy efficiency in municipal solid waste recycling in the United States. Using the novel bootstrapping autoregressive distributed lag model, the results asserted that energy efficiency enhances economic growth and significantly reduces CO_2 emissions. However, it is noted that the long-run impact is dominant than the short-run influences with the significant long-run equilibrium convergence. Akdag and Yı ldı rı m (2020) studied the influence of energy efficiency on greenhouse ga emissions in29 European economies over the 1995-2016 period. The results are obtained by using the FMOLS, and the DOLS approached and asserted that the long-run relationship exists between energy efficiency and GHG. Also, the empirical findings reveal that increase in energy efficiency significantly reduces GHG emissions in the region. Besides, Zaid et al. (2014) conducted a study for the Malaysian building sector and revealed that the surge in the pollution emission is mainly due to the absence of energy efficiency legislation.

Literature also provides relevant studies exploring the energy efficiency and emission nexus. The most recent study of He et al. (2021) investigated the role of research and development (R&D) induced energy efficiency on China's industrial sector CO_2 emissions. The results reveal that under the optimized scenario, the R&D intensity's annual growth rate significantly reduces the energy intensity, encouraging environmental sustainability. Concerning emission trading policy, Zhang et al. (2020a) examined seven emission trading pilots between 2014 and 2016 via employing the data envelopment analysis (DEA) approach. The study concludes that carbon trading policy implementation increases economic dividend produced by the gross industrial output value whereas significantly decreases the industrial CO_2 emission in all the study regions. Similarly, Liu et al. (2020) investigated carbon emission trading pilots in China while considering efficiency, innovation, and structural environmental regulation. The study found that carbine emission trading policies accelerate significant adjustments in the energy and industrial structure. Besides, the study argued that industrial structure significantly improves total factor energy efficiency, while enhancement in the technological innovation has diverse energy efficiency outcomes. In the same line, Zhang et al. (2020b) and Zhang et al. (2019) investigated energy efficiency and the CO_2 emission reduction for Beijing (China) and illustrates that the energy and electricity efficiency significantly reduces production-based CO_2 emissions in the region.

Concerning China, the literature extensively provides evidence regarding the carbon neutrality target. For instance, Dinga and Wen (2022) asserted that China could achieve carbon neutrality target only by promoting the alternative energy sources and renewable energy consumption. In the same line, Ahmad et al. (2018), Qin et al. (2021a), and Qin et al. (2021b) also provides evidence that financial inclusion, human capital, financial development, and renewable energy are the prominent factors of achieving carbon neutrality target. However, the scholars are more biased towards improvement in renewable energy generation, environmental-related policy instruments, environmental related taxes, technological innovation (Shahzad et al., 2021;

Ma et al., 2021; Khan et al., 2020; Hasanov et al., 2021), investment in new energy industry and industrial pollution prevention (Luan et al., 2022), and green development efficiency (Cai et al., 2022). Since the CO_2 emissions are one of the leading issues of human health (Wei et al., 2022). Therefore, the aforementioned techniques could be used as a remedial major for environmental recovery and attaining carbon neutrality targets.

Financial development plays an essential role in determining economic growth and environmental quality. In this concern, various studies have been done analyzing the role of financial development in environmental degradation. Specifically, Odugbesan and Adebayo (2020) examined the symmetric and asymmetric impacts of financial development and foreign direct investment (FDI) on CO_2 emissions in Nigeria throughout the 1981-2016 period. Using linear and the non-linear ARDL approach, the study found that the CO_2 emission is associated the positive shocks in financial development in the long run. However, both the positive and negative shocks in financial development are associated with CO_2 emissions. Godil et al. (2020) examined quarterly data from $1995Q_1$ to $2018Q_4$ and employed a quantile ARDL approach to identify the non-linear influences of financial development institutional quality and ICT on the CO_2 emissions of Pakistan. The estimated results reveal that whether the emissions are high low in the country, financial development and ICT significantly reduces CO_2 emissions in the country. In contrast, Qin et al. (2021) reveal while investigating the emerging seven economies throughout the 2004-2016 period that enhancement in the financial activities leads to increase CO_2 emissions.

Concerning China's financial development and environmental conditions, Guo and Hu (2020) investigated time series data over the 1997-2016 period by using the time series ARDL approach. The study found that financial development weakly influences CO_2 emission reduction in both the short and long run. However, the magnitude of the long-run financial development impact is found greater than the short-run impact on CO_2 emission reduction. The most recent study of Koondhar et al. (2021) revisited agricultural financial development and the carbon emission and renewables consumption China between 1998-2018. The study utilizes the ARDL method and concludes that agricultural financial development significantly encourages CO_2 emission reduction. However, renewable energy is found in a negative association with the CO_2 emission in China. For the same country, Shen et al. (2021) examined 30 provinces over the period 1995-2017 via employing CS-ARDL and reveals consistent findings to the earlier studies that financial development significantly increases CO_2 emission in the region. Besides, Shahzad et al. (2017), Longe et al. (2020), Koshta et al. (2021), and Zhang (2011) also investigated the non-linear influences of financial development for various regions and the time period and conclude diverse outcomes with respect to the case study region(s).

Moreover, the economic-environmental relationship has been well studied in the literature. However, the scholars provided diverse outcomes concerning economic growth or income and environmental quality. In this regard, Malik et al. (2020) investigated economic growth, oil prices, and FDI in the case of Pakistan throughout 1971-2014. Employing linear and non-linear ARDL approaches, the study found that the EKC hypothesis is valid for Pakistan, whereas economic growth and FDI helps

CO_2 emissions increase. The recent study of Safi et al. (2021) investigated financial instability and consumption-based CO_2 emissions in the emerging seven economies throughout 1995-2018. The results reveal the validity of the long-run relationship between the variables. Also, the findings indicate that financial instability and exports significantly reduce consumption-based CO_2 emissions, whereas imports enhance the CO_2 emission level. Concerning the influence of energy consumption and economic growth on the CO_2 emission in BRICS economies, Banday and Aneja (2020) analyzed the 1990-2017 period by utilizing the causality estimators and reports the unidirectional causality running from GDP to CO_2 emissions. However, the feedback hypothesis has been observed between renewable energy consumption and CO_2 emission. The recent study of Nathaniel et al. (2019) asserted that financial development and economic growth not only degrades environmental quality in the short run, but further it in the long-run. Where the economic growth itself is driven by higher energy consumption and information and communication technology (Sharma et al., 2021).

Similarly, export product diversification is an essential economic growth factor that also determines environmental quality. In this regard, the study of Mania (2020) analyzed 1995-2013 data for 98 developed and developing nations by employing the GMM and PMG estimators. The results examined revealed that the EKC hypothesis is valid for the region. Also, export diversification is found as a catalyst of environmental degradation by enhancing the CO_2 emission level in the selected panel. On the contrary, Wang et al. (2020) investigated G-7 economies over the 1990-2017 period and reveal that export diversification increase CO_2 emission levels in the region. However, the enhancement of environmental innovation significantly reduces the negative impact of export diversification on environmental quality. The CO_2 emissions are mainly recognized by the demand and consumption of fossil fuel energy. Therefore, Shahzad et al. (2021) analyzed energy demand in the ten newly industrialized economies from 1971 to 2014 using DOLS, FMOLS, GMM, and FGLS estimators. The estimated results reveal that export diversification, extensive and intensive margins significantly reduce energy demand. However, economic growth, natural resources, and urbanization are found positively associated with CO_2 emissions in the region. Bashir et al. (2020) investigated 29 OECD economies over the 1990-2015 period using panel quantile regression and GMM approaches. The study found that export diversification decreases energy intensity and helps promote energy efficiency. However, the intensive margin and extensive margins are reported to reduce CO_2 emission in the OECD economies. Apart from the general trading policies, Wang et al. (2022) reveals that carbon trading leads China towards environmental sustainability and promote green environment.

Additionally, the essential role that human capital plays in determining economic growth and environmental quality could not be ignored. As education and skills are crucial for sustainable development thus, it could also influence the environment. In this concern, extensive literature is available the empirically analyzed the role of human capital in environmental quality. Including, the study of Sheraz et al. (2021) investigated financial development, human capital, and economic growth in relation to CO_2 emissions of the G20 economies. Using the fixed effect OLS approach, the study found that human capital and financial development significantly reduces CO_2

emissions in the region, whereas the GDP significantly promotes environmental degradation by enhancing the atmospheric CO_2 emission level. Similarly, Hao et al. (2021) used the CS-ARDL approach and revealed that human capital, environmental taxes, and renewables' consumption significantly reduces CO_2 emissions in the G-7 economies throughout 1990-2017.

In contrast, the study of Sarkodie et al. (2020) investigated the role of human capital, environmental sustainability, and renewable energy in China's CO_2 emissions throughout the 1961-2016 period by using the ARDL approach. The study's empirical findings reveal that human capital and fossil fuel energy consumption are the major contributors to climate change. Further, the study of Khan et al. (2021) argued that fiscal decentralization improves environmental quality only by enhancing the human capital and institutional quality. Besides, Mahmood et al. (2019) and Bano et al. (2018) also provide consistent results supporting the priory mentioned studies demonstrating the negative association of human capital and CO_2 emission. In contrast, Haini (2021) analyzed ASEAN countries and found that human capital significantly promotes environmental degradation by enhancing the CO2 emission level in the region throughout 1996-2019. The literature summary is given in Table 1.

3. Methodology and model specification

3.1. Theoretical framework

The theoretical notion of how energy efficiency, financial development, economic growth, export diversification, and human capital influence environmental quality are presented in this section. Concerning energy efficiency, which is the main independent variable of the study, several studies exhibit the positive role of energy efficiency on attaining environmental sustainability; specifically, scholars and authors argued that energy efficiency promotes the use of less energy-intensive products and enhance energy saving, which significantly reduces the CO_2 emission level in the atmosphere and promote environmental sustainability (Mahapatra & Irfan, 2021; Razzaq et al., 2021; Akram et al., 2020). However, a country that targets higher economic growth also achieves a low carbon economy by enhancing the R&D budget and investment in the energy efficiency sector (He et al., 2021). An increase in the R&D budget helps reduce CO2 emissions by improving energy-efficient products and reducing demand for fossil fuel energy consumption, which inherently promotes environmental sustainability. Generally, the influence of energy efficiency is assumed positive on the CO_2 emission as: $\beta_1 = \frac{\partial CO_{2,t}}{\partial ENEF_t} < 0$.

In continuation, financial development is considered the key indicator that determines both economic growth and environmental quality. The development of the financial sector promotes financial activities, including financial products and services such as transactions, investments, and credits, among others (Qin et al., 2021). These financial products and services further enhance economic activities such as production and expansion of the industrial sector, which require more energy obtained from traditional fossil fuels. Thus, an increase in energy demands significantly enhances the CO_2 emission level in the region. Thus, financial development could be detrimental to environmental sustainability (Guo & Hu, 2020; Koondhar et al., 2021; Shen

Table 1. Literature summary.

Author	Title	Findings
Dou and Li (2022)	Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from B.R.I.C.S. countries	Energy efficiency and financial inclusion promote emissions.
Qin et al. (2021a)	Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output	Financial inclusion reduces the emission level.
Fernando and Hor (2017)	Impacts of energy management practices on energy efficiency and carbon emissions reduction: a survey of Malaysian manufacturing firms.	Energy efficiency reduces carbon emissions.
Mahapatra and Irfan (2021)	Asymmetric impacts of energy efficiency on carbon emissions: A comparative analysis between developed and developing economies.	Energy efficiency decreases emission.
Razzaq et al. (2021)	Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency using a novel bootstrapping autoregressive distributed lag.	Energy efficiency promote environmental sustainability
Akdag and Yıldırım (2020)	Toward a sustainable mitigation approach of energy efficiency to greenhouse gas emissions in the European countries.	Energy efficiency degrade carbon emissions
Akram et al. (2020)	Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: Evidence from developing countries.	EKC is valid.
He et al. (2021)	Exploring the path of carbon emissions reduction in China's industrial sector through energy efficiency enhancement induced by R&D investment.	R&D intensity enhances environmental quality.
Nathaniel et al. (2019)	Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded	Economic growth and financial development degrade environment.
Wang et al. (2022)	Can China's carbon trading policy help achieve Carbon Neutrality? A study of policy effects from the Five-sphere Integrated Plan perspective	Carbon trading reduce emissions.
Sharma et al. (2022)	Revisiting conventional and green finance spillover in post-COVID world: Evidence from robust econometric models	Investors transform funds to green finance after Covid-19.
Sharma et al. (2021a)	Nexus between energy consumption, information and communications technology, and economic growth: an enquiry into emerging Asian countries.	Energy use and ICT enhances economic growth.
Sharma et al. (2021b)	Revisiting the sustainable versus conventional investment dilemma in COVID-19 times	Medium and long-run causal nexus exist between conventional and sustainable investments.
Dinga and Wen (2022).	China's green deal: Can China's cement industry achieve carbon neutral emissions by 2060?	Alternative energy resources, materials, and renewable energy helps achieve carbon neutrality.
Guo and Hu (2020)	The Impact of Financial Development on Carbon Emission: Evidence from China.	Financial development weakly affects emissions.
Sheraz et al. (2021)	Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from G20 countries.	Financial development, human capital declines the emissions level.
Sarkodie et al. (2020)	Mitigating degradation and emissions in China: the role of environmental sustainability, human capital and renewable energy.	Human capital increases the emissions level.

Source: Authors' own Calculations.

et al., 2021). Based on the previous empirical support, the influence of financial development on the CO_2 is assumed as positive, represented as: $\beta_2 = \frac{\partial CO_{2,t}}{\partial FD_t} > 0$.

GDP measures the health of the economy. Where industrialization acts as a catalyst for promoting economic growth. Similarly, higher economic growth tends to maintain economic stability by enhancing economic activities such as trade and foreign direct investments. These economic activities lead to the existence of new industries and expand the existing industrial sector, which creates higher energy demand. However, the energy demand in the short run is fulfilled by utilizing traditional fossil fuel energy, which in turn harms the environmental quality. Thus, it is concluded that economic growth could contribute to environmental degradation by enhancing the CO_2 emission level (Malik et al., 2020; Safi et al., 2021). Hence, the influence of economic growth on the CO_2 emission could be assumed positive as: $\beta_3 = \frac{\partial CO_{2,t}}{\partial GDP_t} > 0$.

Concerning export diversification, there are two kinds of influences that the literature provided. 1. On the one hand, some scholars argued that export diversification enhances the CO_2 emission level by enhancing the production of more energy-intensive products, increasing CO_2 emission in the region, and causes environmental degradation (Wang et al., 2020; Shahzad et al., 2021). 2. While on the other hand, scholars provide evidence that export diversification promotes energy-efficient and environmentally friendly products, which minimizes the fossil fuel energy demand and promote environmental sustainability (Mania, 2020; Bashir et al., 2020). Generally, these two kinds of influences are presented as: $\beta_4 = \frac{\partial CO_{2,t}}{\partial EXD_t} > 0$ or $\beta_4 = \frac{\partial CO_{2,t}}{\partial EXD_t} < 0$.

Moreover, human capital is also considered an efficient environmental indicator. Scholars argued that the higher level of education and skills development leads to adopt environmentally friendly resources of energy and promote energy-saving behavior, which consequently reduces the CO_2 emission level and enhances environmental degradation (Sheraz et al., 2021; Hao et al., 2021; Sarkodie et al., 2020). Generally, the positive influence of the human capital on environmental quality is presented as: $\beta_5 = \frac{\partial CO_{2,t}}{\partial HC_t} < 0$.

3.2. Model specification

Based on the theoretical conception and discussion in the literature review, the current study considered carbon dioxide (CO_2) emission as a proxy for environmental degradation. However, the earlier discussion intended to use five exogenous variables because of their considerable influence on environmental degradation. These exogenous variables include the gross domestic product (GDP), which is a measure of the economy's health that covers various components of the country, including investment, consumption, government expenditures, net exports, among others (Khan et al., 2020). Similarly, financial development remains an important indicator for economic growth by enhancing economic activities via stimulating the costs incurred in the financial system. The said two variables, i.e. GDP and financial development, are taken as the main exogenous variables, which are intended to be analyzed separately regarding the environment. In this regard, the current study constructed two models aiming at what-if analysis. Besides, three exogenous variables, including energy efficiency, human capital, and export diversification, are considered. Recently, economies across the globe have been concerned about the environmental degradation that leads them to adopt environmentally friendly and energy-efficient energy sources to reduce CO_2 emissions. Thus, energy efficiency could be a substantial tool to reduce CO_2 emissions while analyzing the country's environmental degradation. At the same time, export diversification and human capital could play an environmental remedial measure if used efficiently. Export diversification could be an important indicator if environmentally friendly and energy-efficient technologies are adopted. The said three variables, i.e. energy efficiency, human capital index, and export diversification, are included in the models investigating environmental degradation. Generally, the two constructed models are given below as Model-1 and Model-2:

Model-1.

$$CO_{2,t} = f(GDP_t, ENEF_t,\ HCI_t,\ EXD_t)$$

In Model-1, GDP and energy efficiency are taken as the main exogenous variable throughout the time series.

Model-2.

$$CO_{2,t} = f(FD_t, ENEF_t,\ HCI_t,\ EXD_t)$$

In Model-2 financial development and energy efficiency are taken as the main exogenous variables. In both the models, CO_2 represents carbon dioxide emission, GDP indicates gross domestic product, ENEF reveals the energy efficiency, and GDP per unit of energy use at constant 2017 PPP dollars per kilogram of oil equivalent is taken as a proxy for energy efficiency. Additionally, the HCI indicated the human capital index, and the EXD represents export diversification. The time-series data for the discussed variable have been taken from various sources for China, covering the 31 years from 1988 to 2018. The variables' descriptions and data sources are provided in Table 2. The said discussed models are modified into the regression equations and presented as Eq. (1) and Eq. (2) below:

$$CO_{2,t} = \alpha_0 + \beta_1 GDP_t + \beta_2 ENEF_t + \beta_3 HCI_t + \beta_4 EXD_t + \varepsilon_t \tag{1}$$

Table 2. Variables description and data sources.

Variable	Description	Data source
CO_2	Carbon Emissions measured in Kt	https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
GDP	Constant 2010 US dollars	https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
ENEF	GDP per unit of energy use at constant 2017 PPP dollars per kilogram of oil equivalent	https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
FD	Financial Development Index (FDI)	https://data.imf.org/
EXD	Exports diversification	https://data.imf.org/
HCI	Human Capital Index (extracted from Penn World Table 9.0)	https://fred.stlouisfed.org/release?rid=285

Source: Authors' own Calculations.

$$CO_{2,t} = \alpha_0 + \beta_1 FD_t + \beta_2 ENEF_t + \beta_3 HCI_t + \beta_4 EXD_t + \varepsilon_t \quad (2)$$

Where α_0 in both, the equations present the intercept and the β_1, β_2, β_3 and β_4 are the slope coefficients in both the models, representing the magnitude of the influence of each variable under consideration. Moreover, 't' in the subscript indicates the time series of the variables' data.

3.3. Estimation strategy

After specifying the regression models, the current study uses various estimation approaches based on the distribution and characteristics of data. The estimation approaches include various econometric techniques such as normality of the data, unit root test, and the cointegration test. Besides, the current study used three long-run estimation techniques, i.e. fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS), and the canonical cointegration regression (CCR) estimator and the robust regression to confirm the findings of earlier estimators. All the estimating strategies are specifically explained herewith.

3.3.1. Normality test

Examining the normality of data is an essential step to adopt an efficient long-run estimator of the data. Regarding the normality of the data, the current study utilized the Jarque-Bera normality test proposed by Jarque and Bera (1987), which considers skewness and excess kurtosis as zero as the null hypothesis in a binomial distribution. Generally, the final form of the Jarque and Bera (1987) normality test is presented as Eq. (3) below:

$$JB = \frac{N}{6}\left(S^2 + 4^{-1}(K-3)^2\right) \quad (3)$$

3.3.2. Unit root test

After estimating the normality distribution of the data, we further examined the presence of the unit root in the data. Analyzing time-series data, the presence of a unit root(s) can cause unpredictable estimates. In this regard, we utilized three unit root tests, namely the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979), Phillips-perron unit root test proposed by Phillips and Perron (1988), and the Dickey-Fuller Generalized Least Square (DF-GLS) test which is the modified form of Dickey-Fuller t-test and proposed by Elliott et al. (1992). Concerning ADF, this test is efficient as it can be used with serial correlation, and because of more power, it controls more complex models than the simple Dickey-Fuller test. Generally, the inclusive form of the Dickey-Fuller test is given as Eq. (4) below:

$$y_t = \gamma + \theta t + \mu y_{t-1} + e_t \quad (4)$$

Notably, the prior Eq. (4) could be estimated by the ordinary least square (OLS) as provided in Eq. (5) below:

$$\Delta y_t = (\mu - 1)y_{t-1} + \gamma + \theta t + e_t \tag{5}$$

The ADF test has two versions, i.e. the one with the intercept and the other with the trend. The said test holds the presence of the unit root as the null hypothesis. Concerning Phillips and Perron (1988) unit root test, the general form is provided as Eq. (6) below:

$$PP_{r1}^{r2} = \sqrt{\frac{\hat{\gamma}_{0,T}}{\lambda_T^2}} \frac{\hat{\beta}_{r1,r2}}{S.E(\hat{\beta}_{r1,r2})} - \frac{1}{2}\left(\lambda_T^2 - \hat{\gamma}_{0,T}\right) \frac{1}{\hat{\lambda}_T} \frac{T.S.E(\hat{\beta}_{r1,r2})}{S.T} \tag{6}$$

The said test has been made robust to serial correlation by operating the heteroscedasticity of the Newey and West (1986) and autocorrelation consistent covariance estimator matrix (Escobari et al., 2017). Regarding the DF-GLS, which exhibit good power and small distortion in the finite samples with dependent errors are provided in general form as Eq. (7) below:

$$\Delta y_t^{\mu} = \alpha_0 y_{t-1}^{\mu} + \sum_{j=1}^{P} \alpha_j \Delta y_{t-j}^{\mu} + e \tag{7}$$

The general form of the DF-GLS does not consider the intercept here because the GLS already demeaned the data under the local alternative, i.e. constant (C). However, in the detrended case, the statistic the same except for considering the term DF-GLS as GF-GLS^{T}, where the y_t^{μ} is replaced by the y_t^{T} (Elliott et al., 1992).

All the priory mentioned unit root test exhibits the null hypothesis as the presence of the unit root in data or the non-stationarity of the data. The coefficients or the probability value if exceeds the critical values. The null hypothesis could be rejected and exhibits that the data is stationary, which allows us to analyze the long-run cointegration relationship among the variables under consideration.

3.3.2. Bayer-Hanck combined cointegration test

After examining stationarity in the data, we further investigate the cointegration relationship between the variables under consideration. In this regard, we utilize the cointegration approaches include Engle and Granger (1987), Johansen (1991), Banerjee et al. (1998), and Boswijk (1994). However, these cointegration tests may provide uncertain empirical estimates based on their explanatory power properties (Shahbaz et al., 2018). Thus, to tackle the issue of ambiguous results and increase the cointegration analysis power, Bayer and Hanck (2009) proposed a new approach of cointegration recognized as the combined cointegration approach, which considers all the pre-mentioned cointegration tests combined and provides more reliable and conclusive estimates via Fisher F-statistics (Shahbaz et al., 2018). In order to apply the Bayer-Hanck combined cointegration test, the integration order could essentially be unique, i.e. I(1). Notably, the estimated F-statistics if surpass the critical values, the null hypothesis of no cointegration may be rejected. The general Fisher's formula for the Bayer-Hanck cointegration is provided as Eq. (8) and (9) below:

$$EG - J = -2\left[\ln(P_{EG}) + \ln(P_J)\right] \tag{8}$$

$$EG - J - Ba - Bo = -2\left[\ln(P_{EG}) + \ln(P_J) + \ln(P_{Ba}) + \ln(P_{Bo})\right] \tag{9}$$

In the above equations, P_{EG}, P_j, P_{Ba} *and* P_{Bo} are the probability (p) values for the earlier mentioned cointegration tests, i.e. Engle and Granger (1987), Johansen (1991), Banerjee et al. (1998), and Boswijk (1994), respectively. The formulation mentioned above of Fisher's statistics signifies whether the cointegration between the variables under consideration exists.

3.3.4. Regression estimation and diagnostic tests

The cointegration analysis allows the current study to empirically investigate the impact of financial development, GDP, energy efficiency, export diversification, and human capital index on the CO_2 emissions in China. In this regard, efficient estimators are required that provide unbiased estimates. Thus, Following the study of Khan et al. (2019), the current study employed the dynamic ordinary least square (DOLS) proposed by Pedroni (2000) and fully modified ordinary least square (FMOLS) approaches which are the parametric (DOLS) and non-parametric (FMOLS), respectively: and reliable estimators by tackling the serial correlation and endogeneity issues. The DOLS approach is considered efficient by tackling the non-stationarity issue in the time series data. Generally, the FMOLS and the DOLS are provided as Eq. (10) and (11) below, respectively.

$$\hat{\emptyset} = \begin{bmatrix} \alpha \\ \hat{\beta} \end{bmatrix} = \left(\sum_{t=2}^{T} Z_t \acute{Z}_t\right)^{-1} \left(\sum_{t=2}^{T} Z_t y_t^{+} - T\begin{bmatrix} \hat{\theta}_{12}^{+} \\ 0 \end{bmatrix}\right) \tag{10}$$

Where $Z_t = \left(\acute{X}_t, \acute{D}_t\right)'$. However, for estimating FMOLS, the long-run covariance matrix is playing an essential role.

$$y_t = \acute{X}_t\beta + \acute{D}_{1t}\gamma_1 + \sum_{j=-q}^{r} \Delta\acute{X}_{t+j}\sigma + v_{1t} \tag{11}$$

Where the DOLS approach includes the cointegration regression augmentation with both leads and lags for $\Delta\acute{X}_t$ due to the orthogonal error term cointegration equation. As per assumption of the DOLS, addition of q lags and r leads of the differences regressors, the long-run correlation is absorbed between e_{1t} *and* e_{2t}.

Additionally, the current study utilizes the Canonical Cointegrating Regression (CCR) method proposed by Park (1992), which is a regression-based estimator. For feasible CCR analysis, Park et al. (2010) argued that the CCR estimator only plays the role of fixing the linear part of the regression. Thus, finding the exact lags and leads order is the critical issue of the estimator. The general form of the CCR estimator is provided as Eq. (12) given below:

$$y_t^* = \acute{\beta}_{pq} z_{pqt}^* + \mu_{pqt}^* \tag{12}$$

Where y_t^* and z_{pqt}^* are the stationary transformation of y_t and z_{pqt}, respectively. Besides, this study also considers the residual diagnostics estimates to examine the heteroskedasticity by Breusch-Pagan-Godfrey heteroscedasticity test proposed by Breusch and Pagan (1979) and Godfrey (1978).

And the correlation by Breusch-Godfrey serial correlation LM Test. Moreover, besides these estimators, the results of the said estimators have been confirmed by employing a robust regression estimator that overcomes the limitations of traditional parametric and non-parametric estimators. The estimated results are provided and discussed in the next section.

4. Results and discussion

4.1. Results interpretation

We begin our analysis section by providing the descriptive statistics and normality test estimations presented in Table 3. The descriptive statistics cover the mean, median, standard deviation, skewness, and kurtosis. However, the normality of the data is analyzed via employing the Jarque and Bera (1987) normality test by considering the combined skewness and kurtosis. Concerning descriptive estimates, the mean value of the CO_2 emission is reported as 6.70127 kt emissions, which nearly equal the median value accounted for 6.65709. The lower value of standard deviation has been reported, accounted for 0.23608 variations of each observation from the mean value. Besides, the probability value of the Jarque-Bera normality test is estimated as 0.19275, which is higher than the critical values of the Jarque-Bera normality. This leads us to accept the null hypothesis and conclude that the CO_2 emission data is normally distributed. Concerning the GDP, the mean and median values are reported approximately the same, i.e. 12.4748 and 12.4629, respectively. The standard deviation for the GDP is noted slightly greater than that of CO_2 emission, which reveals a 0.36768 deviation from the mean GDP value. The Jarque-Bera normality test provides an insignificant p-value, which cannot lead to rejection of the null hypothesis. Thus, the GDP data is normally distributed. Concerning the indices values of financial inclusion (FD) and energy efficiency (ENEF), the mean values are reported as 0.69093 and 0.55678, respectively. Whereas the median values are reported as slightly greater than their mean values, accounted for 0.73292 and 0.59492, respectively. Differences in the mean and median values show the tendency of the standard

Table 3. Descriptive statistics.

	CO_2	GDP	FD	ENEF	EXD	HCI
Mean	6.70127	12.4748	0.69093	0.55678	3.87413	2.21274
Median	6.65709	12.4629	0.73292	0.59492	3.92721	2.24617
Std. Dev.	0.23608	0.36768	0.08632	0.13915	0.62384	0.22036
Skewness	0.11464	−0.06550	−0.87088	−0.68739	−0.21252	−0.21639
Kurtosis	1.41994	1.74088	2.34399	2.24326	1.67143	2.00325
Jarque-Bera	3.29265	2.06993	4.47446	3.18098	2.51327	1.52521
Probability	0.19275	0.35523	0.10675	0.20382	0.28461	0.46644

Source: Authors' own Calculations.

deviation. The standard deviation values for both of these variables are 0.08632 and 0.13915, respectively. Where the standard deviation of FD is noted as the smallest of all the variables under consideration. The Jarque-Bera normality test provides evidence of the acceptance of the null hypothesis of the combined skewness and excess kurtosis being zero and concludes that FD and ENEF data is normally distributed. Besides, export diversification (EXD) and human capital index (HCI) exhibit the mean values of 3.87413 and 2.21274, while a slightly greater median value is 3.92721 and 2.24617, respectively. The standard deviation values are noted as 0.62384 and 0.22036 for EXD and HCI, respectively. Moreover, the EXD and HCI variables' data are normally distributed due to the variables' insignificant p-values. Hence, it is concluded that all the variables under consideration are normally distributed, which allows us to analyze the long-run estimates via regression analysis.

The Jarque-Bera normality test reveals the normal distribution of data. This further allows us to test for the presence of unit root in the data. In this regard, the result estimates of Dickey and Fuller (1979) ADF, Phillips and Perron (1988) unit root test, and the Elliott et al. (1992) DF-GLS are provided in Table 4. The results of the said tests have been obtained at both the leveled [I(0)] data and the first difference [I(1)] data. The estimated results of ADF, PP, and DF-GLS unit root tests on the I(0) show that the presence of the unit root due to insignificant outcomes, which are insufficient to reject the null hypothesis of the unit root presence. However, the findings of these tests reported highly significant results at I(1) at 1%, 5%, and 10% levels. These significant values of the ADF, PP, and DF-GLS unit root tests lead to rejecting the null hypothesis of the presence of unit root. Hence it is concluded that the data for CO_2, ENEF, EXD, FD, GDP, and HCI at I(1) has no unit root, and hence it is stationary.

Table 5 provides estimated results for the Bayer-Hanck (2009) combined cointegration test. The said test combined estimates Engle and Granger (1987) (EG), Johansen (1991) (J), Banerjee et al. (1998) (Ba), and Boswijk (1994) (Bo) cointegration tests. Also, the under-discussion test provides the combined estimates for Engle and Granger (1987) and Johansen's (1991) cointegration tests. The estimated results reveal that the combined EG-J and EG-J-Ba-Bo showed highly significant results at 1% level,

Table 4. Unit root tests.

	Level I(0))		
Variable(s)	ADF	PP	DF(GLS)
CO_2	−2.47	−1.87	−2.73
ENEF	−1.18	−1.10	−1.38
EXD	−1.63	−1.59	−1.49
FD	−1.06	−2.87	−0.99
GDP	−3.06	−1.45	−3.01
HCI	−2.03	−1.30	−1.74
First Difference I(1)			
ΔCO_2	−4.61***	−3.78**	−2.94*
ΔENEF	−4.54***	−4.48***	−4.69***
ΔEXD	−5.82***	−5.82***	−6.02***
ΔFD	−8.08***	−21.11***	−7.90***
ΔGDP	−4.83***	−4.87***	−4.821***
ΔHCI	−4.53***	−4.52***	−3.61**

Note: Significance is indicated by 10, 5, and 1% though *, **, and ***. ADF (Augmented Dickey-Fuller); PP (Phillips-Perron), and ERS-DF(GLS) (Elliott-Rothenberg-Stock Dickey Fuller-Generalised Least Square).
Source: Authors' own Calculations.

Table 5. Bayer-Hanck Cointegration (2009) analysis.

Models	Engle-Granger (EG)	Johansen (J)	Banerjee (Ba)	Boswijk (Bo)	EG-J	EG-J-Ba-Bo
Model-1	−18.421***	105.239***	−17.241***	122.08***	59.42***	118.40***
Model-2	19.422***	128.04***	−20.122***	660.99***	55.32***	165.84***

Note: Significance is indicated by 10, 5, and 1% though *, **, and ***.
Source: Authors' own Calculations.

Table 6. Empirical results and diagnostic tests.

	Model − 1			Model − 2		
	Coefficients			Coefficients		
Variable(s)	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
GDP	1.60***	1.56***	1.62**	–	–	–
EXD	0.23**	0.193**	0.25***	0.38**	0.29*	0.25***
FD	–	–	–	0.33**	0.40***	0.32***
ENEF	−0.21***	−0.27***	−0.21*	−0.56***	−0.40***	−0.57**
HCI	−0.407*	−0.28***	−0.44***	−0.23*	−0.412**	−0.23**
Constant	−1.208**	−1.911***	−1.044***	−1.521***	−1.171**	−1.492**
Diagnostic Tests						
Test				F − Statistic		p − value
Heteroskedasticity Test : Breusch − Pagan − Godfrey				1.707		0.178
Breusch − Godfrey Serial Correlation LM Test				1.782		0.193

*Note: Significance is indicated by 10, 5, and 1% though *, **, and ***.*
Source: Authors' own Calculations.

which reject the null hypothesis and conclude that the CO_2 emissions, ENEF, FD, GDP, EXD, and HCI are in the long-run cointegration. The cointegration relationship reveals that any policy concerning ENEF, FD, GDP, EXD, and HCI will significantly influence the CO_2 emissions in China. Thus, further investigation of the specific impact of these variables is necessary.

The validation of the long-run cointegration between the variables under consideration further allows this study to use an efficient estimator to identify each exogenous variable's impact on CO_2 emission. The estimated results of the FMOLS, DOLS and the CCR estimator for both Model-1 and Model-2 are provided in Table 6. The results of Model-1 provide significant estimates on all the three FMOLS, DOLS, and CCR estimators. Specifically, GDP and export diversification increase CO_2 emission, while ENEF and HCI reduce it. A one percent increase in the GDP causes an increase of 1.60, 1.56, and 1.60% via FMOLS, DOLS, and CCR, by 1% and 5% level of significance. The positive influence of GDP in the current study is consistent with the earlier findings of Safi et al. (2021), Malik et al. (2020), Banday and Aneja (2020). The economic growth in a country increases the per capita income, which in turn increase the demand level of both individual and the industrial sector. The increasing demand further leads to energy-intensive product consumption, which could be fulfilled by fossil fuel energy. Hence, the fossil fuel energy consumption increases CO_2 emission level, and promote environmental degradation. Concerning Model-2, FD and EXD positively affect the CO_2 emission while ENEF and HCI consistently reduce CO_2 emissions as in Model-1. Specifically, a one percent increase in FD leads to an increase in CO_2 emissions by 0.33, 0.40, and 0.32%, at 5%, 10%, and 1% significance level on the three estimators, respectively. The current findings are consistent with the earlier findings of Koondhar et al. (2021), Shen et al. (2021), and Longe et al. (2020). Developing the financial sector provides more credits and investment prospects that enhance economic activities and consequently increase the traditional fossil fuel demand. This increase in the energy demand extensively promotes emissions and degrades the environment.

Both the models report the negative influence of ENEF on CO_2 emissions. That is, a one percent increase in the ENEF reduces the CO_2 emissions by 21-27% in the presence of economic growth and 40-57% in the presence of financial development. The results are found statistically significant at 1%, 5%, and 10% levels. These findings are consistent to the findings of Mahapatra and Irfan (2021), Razzaq et al. (2021), Akram et al. (2020), Akdag and Yıldırım (2020) and Zaid et al. (2014). The smaller negative influence of ENEF in the presence of GDP is mainly due to the enhancement in economic activities that further increase fossil fuel energy consumption and enhances CO_2 emission level, which surpasses the negative influence of ENEF on CO_2 emissions. However, the magnitude of the ENEF is found relatively greater in the presence of FD, which does not cause energy demand extensively by providing restricted loans and investments. Hence, the influence of ENEF is higher in the presence of FD. Besides, the influence of EXD is found positive on the CO_2 emissions level in China. A one percent increase in the EXD leads to an increase in CO_2 emissions by 0.193-0.25% in the presence of GDP and 0.25-0.38% in the presence of FD. The results are found statistically significant at 1%, 5%, and 10% significance levels. Current findings are consistent with the findings of Mania (2020) and Wang et al. (2020), while contrary to the findings of Shahzad et al. (2021) and Bashir et al. (2020). The former studies reveal that EXD decreases energy demand which reduces CO_2 emissions in the region. However, the latter studies argued that an increase in the energy demand is promising after enhancing EXD, which harms the environmental quality by enhancing the CO_2 emissions. The same is the case for China; enhancement in the EXD could significantly promote environmental degradation.

Moreover, the estimated results reported that the HCI negatively affects the CO_2 emissions in China. Specifically, a one percent increase in the HCI significantly reduces the CO_2 emissions by 1.044-1.911% in the presence of economic growth and 1.171-1.521% in the presence of FD. These findings are found statistically significant at 1% and 5% levels. The estimated results are found inconsistent with the prior findings of Sheraz et al. (2021), Hao et al. (2021), Khan et al. (2021), and Mahmood et al. (2019). More education and higher skills level in an economy lead the households and the industrialists to utilize environmentally friendly and energy-efficient energy sources. Besides, these factors also contribute to the energy saving behavior of both households and industrialists. Thus, the higher the human capital development, the lower will be the CO_2 emissions in the country, which promotes environmental sustainability.

Additionally, the estimated results of Breusch and Pagan (1979) and Godfrey (1978) heteroscedasticity provide the p-value of 0.178, which is above the critical values and leads to accepting the null hypothesis of no heteroscedasticity. Also, the Breush-Godfrey serial correlation LM tests estimates reports the p-value as 0.193, which is above the critical values and insufficient for the rejection of the null hypothesis. Hence, no serial correlation is found for the variables under consideration.

In order to confirm the validity of the findings of FMOLS, DOLS, and CCR, we employed robust regression, and the estimated results are provided in Table 7. The

Table 7. Robust regression analysis.

Variable(s)	Model-1 Coefficients	Model-2 Coefficients
GDP	1.542***	–
EXD	0.51*	0.502***
FD	–	0.71**
ENEF	−0.255**	−0.35**
HCI	−0.36***	−0.172*
Constant	−1.292***	−1.047***

Note: Significance is indicated by 10, 5 and 1% though *, ** and ***.
Source: Authors' own Calculations.

examined results confirm the prior findings and reveal that GDP, FD, and EXD promote CO_2 emissions. However, the ENEF and HCI are found detrimental to CO_2 emissions and catalyst for environmental sustainability. The coefficients magnitude has been found slightly different. Still, the average impact and the influence remained the same as the findings of FMOLS, DOLS, and the CCR estimators.

4.2. Discussion

From the above empirical statistics, it is noted that all the variables are stationary at I(1). Also, the long-run equilibrium relationship is validated by the Bayer-Hanck (2009) combined cointegration test. Due to the regular distribution property of the data, current study utilizes parametric regression approaches including FMOLS, DOLS, and CCR to analyze whether the adopted variables influence CO_2 emissions in China. The examined results asserted that economic growth, financial development, and export diversification significantly enhances China's emission level. In other words, Since all the three variables are highly linked to the industrial sector. Enhancement in the production level or diversification of products leads to industrial expansion, where demand for energy rises. Whereas financial sectors provide support to the industrial sector in the shape of loan, investments, or financial transaction. Therefore, financial development is among the leading factor of environmental degradation (Nathaniel et al., 2019; Guo & Hu, 2020). In order to enhance the industrial productivity level, economies provide financial support in shape of subsidies to the industrial sector for the purpose of rising exports, products manufacturing, consumption. On the one hand, this contributes to the economic growth as a return, but also influences environmental quality by encouraging the CO_2 emissions level (Sheraz et al., 2021; Nathaniel et al., 2019). In order to reduce environmental hazards, measures such as energy efficiency and human capital improvement could be used as substantial policy measures. For instance, with the improved human capital and efficient use of energy, the use of traditional fossil fuel consumption reduces, which is not only cost effective, but also reduces the carbon emissions in the region (Mahapatra & Irfan, 2021; Razzaq et al., 2021; Sheraz et al., 2021).

5.1. Conclusion

The recent challenge countries face around the globe is emission reduction and attaining environmental sustainability. In this sense, economies initiated the adoption of energy-efficient products to reduce emissions while maintaining the production level. Nonetheless, China is the leading fossil fuel energy importer and the top CO_2 emitting country (Tian et al., 2022). Therefore, it is essential to investigate its environmental quality as China is rapidly moving towards the achievement of its economic goals while ignoring environmental sustainability. The current study investigated time series data for China covering the period from 1988 to 2018. Particularly, the study covers the most substantial economic, financial, and environmental variables. In addition, the study also uncovers the role of export diversification and human capital in environmental quality. The empirical findings synthesized that the long-run equilibrium relationship exist between the CO_2 emissions, energy efficiency, financial development, economic growth, export diversification, and human capital index. Whereas the long-run estimates reveal that economic growth, financial development, and export diversification are the leading causes of environmental degradation in China. For instance, the higher economic growth, and developed financial system encourages industrialists and investors to expand and invest more in the industrial sector, that further enhances the energy demand. As a result, the CO_2 emissions helps encourages climate change and global warming issues. Although these variables are strongly influential in environmental degradation. Yet, the empirical results provide evidence that energy efficiency and human capital could be used as tools to reduce CO_2 emissions and promote environmental sustainability in China. Apart from the economic growth, the energy efficiency is observed more influential on CO_2 emissions in the presence of developed financial system. Hence, appropriate policies are required that could help maintain economic growth while reduces environmental degradation in China.

5.2. Policy implications

Based on the empirical findings, the current study proposed energy efficiency is a pro-environmental strategy. Where the industrialists are more concerned in revenue generation, rather than environmental recovery. Therefore, policies concerning environmental efficiency needs proper attention from administration. For instance, energy-efficient products shall be promoted, and the industries using energy-efficient energy sources should be supported financially and morally. Not only energy efficiency, the human capital also plays a significant role in achieving environmental sustainability. In other words, higher education and skills could lead the industries to reduce fossil fuel consumption, promote energy-saving behavior, and adopt technologically advanced equipment that could provide the same or even more output while minimizing the energy usage. Therefore, the human capital needs further attention in terms of environmental education and skills that will help to achieve carbon neutrality in China. Though economic growth is found negatively associated with environmental sustainability, therefore the government must take a step by revising policies that could consider low carbon economic growth. That is, the higher economic growth could be used as a tool for environmental sustainability in terms of subsidizing the industrial sector for energy efficient and environmentally friendly energy resources consumption. Lastly, financial development and export diversification are the keys to economic growth but detrimental if their environmental influence remained ignored. Therefore, policies must be designed that promote green financial development by encouraging green investment, green bonds, green loans, and export diversification while using energy efficient resources.

5.3. Limitations and future recommendations

Although this study provides substantial empirical evidence regarding the carbon neutrality target achievement. Still, the study is limited in few dimensions. For instance, this study covers only China, which is the leading carbon emitting economy, yet the US, Russia, and the EU economies are also emitting higher level of emissions. Therefore, future studies could empirically analyze these economies either in time series or using the panel approaches. Additionally, this study examines the data for 31 years due the issue of data availability. However, the future researchers could extend this study by widening the time period. Moreover, the studies in future could also use novel and non-parametric empirical approaches such Quantile-on-Quantile regression, Method of moment Quantile regression, or even the ARDL for the short-run and long-run estimates.

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Note

1. For more details, visit: https://www.iea.org/articles/e4-country-profile-energy-efficiency-in-china

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