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EDITED BY
Farrukh Shahzad,
Guangdong University of Petrochemical Technology, China

REVIEWED BY
Muhammad Sibt E. Ali,
Zhengzhou University, China
Ilyas Ahmad,
University of Education Lahore, Pakistan

*CORRESPONDENCE
Florian Marcel Nuţă,
floriann@univ-danubius.ro
Levente Dimen,
dimenlev@yahoo.com

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Relationship between FDI inflow, CO_2 emissions, renewable energy consumption, and population health quality in China

Ziwei Zhang[1], Florian Marcel Nuţă[2]*, Levente Dimen[3]*, Irfan Ullah[4], Si Xuanye[4], Yao Junchen[4], Zhou Yihan[4] and Chen Yi[4]

[1]School of Economics and Management, Binzhou University, Binzhou, China, [2]Faculty of Economics, Danubius University, Galaţi, Romania, [3]Faculty of Computer Science and Engineering, 1 Decembrie 1918 University of Alba Iulia, Alba Iulia, Romania, [4]Reading Academy, Nanjing University of Information Science and Technology, Nanjing, China

China has received significant foreign direct investment in the last few decades; the FDI inflow could affect the environment, income, and people's health. Therefore, this paper aims to investigate the relationship between FDI, renewable energy consumption, CO_2 emissions, and Population health quality in China for the period 1980–2020. We applied the VECM method for the data analysis for the short and long-run effects of the independent variables. In the short run, FDI and CO_2 emissions did not affect health quality in China; however, in the long run, FDI and CO_2 emissions improved life expectancy. Renewable energy has both run and long implications for the health quality in China. These results reflect that FDI creates more jobs in China and improves the overall income of Chinese citizens, contributing to more accessible healthcare services in the long run. Therefore, the government should provide incentives to increase the FDI inflow, which uses renewable energy in production. Furthermore, to mitigate the CO_2 emissions government should implement a carbon tax on the industries which has substantial CO_2 emissions in the country.

KEYWORDS

FDI inflow, CO_2 emissions, renewable energy consumption, health quality, China

1 Introduction

China gradually removed the trade restrictions and opened the economy to foreigners, and a significant amount of FDI inflow has been witnessed in last few decades. The inflow of foreign direct investment, considered to be a source of advanced technologies which leads to the technological diffusion. The foreign direct investment (FDI) provides job opportunities, makes the host country more productive and reduces unemployment. Trade liberalization and tax-reduction policy for foreign investment increase the FDI inflow in China (Li et al., 2021; Zhou and Latorre, 2021). China has focused on the FDI inflow for the last few decades to achieve its economic and social development goal. According to the Yearbook (2017) in China, 52.75% of the FDI is allocated to the secondary and manufacturing industries, while primary and tertiary industries account for 2.56% and 44.69%, respectively. Furthermore, the addition of capital stock in manufacturing industries is the main contributor to CO_2 emissions in the country. FDI in the secondary industry, i.e., Mining Industry, Construction Industry to the tertiary industry, i.e., Education Industry, Tourism, Environment, and Facilities Management, raises concerns about environmental protection and provides biases to the use exploitation of renewable energy. The relationship between FDI and CO_2 emissions are still controversial and uncertain, some

researcher such as Xie et al. (2020); Salahuddinet al., 2018; Salahodjaev and Isaeva (2022) and Farooq (2022) found a positive relationship between FDI and CO_2 emissions, while other researcher such as Zhang and Zhou (2016); Faheem et al. (2022); Gyamfi et al. (2022) and Shabir, Ali, Hashmi, and Bakhsh (2022) reported a negative relationship between FDI and CO_2 emissions.

Other types of foreign inflow, such as remittances also possible sources of CO_2 emissions in the country (Jafri et al., 2022). The remittances increase the household income, which means the household owns more capital and increases energy consumption from various perspectives. For example, with higher income, people may purchase cars, consume more electricity and fuel gases in their daily life and ultimately contribute to the increased consumption and thus increase CO_2 emissions. Furthermore, the portion of foreign remittances that save from consumption will be allocated to the financial sector, which could be further used as an investment and leads to CO_2 emissions. Furthermore, according to Yang et al. (2020) the existence of FDI will cause a "Pollution Haven" which can be explained by the fact that developed countries put heavily polluting enterprises into developing countries, leading to the increased amount of CO_2 emissions. In line with this hypothesis, developed countries participating in FDI typically disseminate technologies that contribute to increasing the release of carbon dioxide emissions (Khan et al., 2019). The increase in CO_2 emissions negatively affects human health and decreases life expectancy and health quality (Ullah et al., 2019; Shah et al., 2021; Mahalik et al., 2022). Mainly, a substantial pollutant element in the air causes respiratory diseases. The kids may affect more severely by air pollution due to low resistance and immune system (Matthew, 2015). Although low CO_2 emissions could improve human health, a healthy lifestyle, better healthcare conditions, and adequate amounts of nutritious food could also improve health quality (Claessens & Feyen, 2007).

FDI inflow may affect the population's health from different aspects; firstly, FDI inflow accompanying renewable may reduce CO_2 emission and improve the health quality. Secondly, the rise enables the purchasing power of the people, and they may have access to better healthcare facilities. Thirdly FDI inflow would enhance the level of medical services, including applying advanced medical apparatus and employing elite doctors (Immurana, 2020a). Conversely, FDI may negatively affect the population's health quality in some cases, such as more FDI inflows significantly increasing the probability of purchasing harmful products like tobacco (Mckee & Schwalbe, 2005). Besides, social equality is also the main concern with FDI inflow. Foreign commercial firms with higher payment and equipment can entice people away from public facilities: an "internal" brain drain. Furthermore, the health system may become diverged with high medical quality care for the rich and that of lower for the poor. However, foreign direct investment and renewable energy consumption reduce CO_2 emissions in the country (Schwela & Haq, 2020). The expansion of renewable energy consumption due to FDI may replace traditional fossil fuel energy that emits a tremendous amount of carbon dioxide. Thus, the diseases such as respiratory diseases; lungs cancer caused by CO_2 emissions will decline. Furthermore, low CO_2 emissions will reduce adverse effects such as heat damage, food mildew, and hypoxia (Solarin et al., 2022).

Past studies have examined relationship between FDI, health and renewable energy such as Chiappini et al. (2022); Shah et al. (2022) and Burns et al. (2017) and examine health and FDI from the different aspects; however there is not study that specifically analyze the case of China. Therefore, this paper investigates the relationship between FDI inflow, CO_2 emissions, renewable energy consumption, and population health quality in China; The study adds to the existing body of knowledge in several ways; firstly, we use health quality with FDI, which has not been analyzed in the past literature especially in context of China. Secondly, we constructed an index for health quality, which has not been developed in previous studies. Thirdly, we use the VECM approach, which could provide both short and long-run estimations of FDI for the health quality and other related variables in the study. The rest of the paper is organized as Section 2 contains the literature review; Section 3 is related to the stylized facts of the study. Sections 4 and Section 5 provide the methodology, results, and study discussion, respectively. Section 6 is based on the conclusion of the study.

2 Literature review

Jafri et al. (2022) analyzed an asymmetric impact of remittances and foreign direct investment (FDI) on China's CO_2 emissions from 1981 to 2019 using the NARDL approach for data analysis. Their findings suggest that foreign remittances and CO_2 emissions have a negative relationship in the short run and long run. FDI has a negative effect on CO_2 emissions both in the short run and long run. However, the long run is more relatively effective than the short run. They concluded that the Chinese government should redesign its environmental policies to boost the country's foreign investors and local environmental quality. Li et al. (2022) analyzed China's CO_2 and FDI association. They find that the impact of the negative shock of remittances is more significant than the negative shock of FDI on CO_2 emission in China. Marques and Caetano (2022) explored the effects of FDI on CO_2 emissions in 15 OECD countries. They applied the ARDL model for analysis. Their findings reported that total fixed asset construction reduces pollution except for the mining industry. Furthermore, all OECD countries are under pressure from the tradable sector. They recommended that government should promote energy efficiency based FDI in the region. Furthermore, the host country needs to implement relevant laws and regulations to control the CO_2 emissions produced by FDI.

Mahalik et al. (2022) explore the impact of CO_2 emissions on life expectancy in developing countries from 1990–2017. They used disaggregated panel data analysis to examine the relationship between CO_2 emissions and life expectancy. The study mentioned two types of CO_2 emissions: consumption- or production-based CO_2 emissions. Furthermore, the economic level of national development is used as a controlled variable; the results conclude that there is a negative relationship between CO_2 emissions and life expectancy in emerging countries, and CO_2 emissions reduce life expectancy regardless of the source of CO_2 emissions. Their findings suggest that the positive effect of CO_2 emissions on life expectancy can be attributed to consumption, not production. In addition, an increase in income does not necessarily reduce environmental degradation and create a healthier life. Mohmmed et al. (2019) investigated the factors contributing to CO_2 emissions in the top 10 emitting countries. They used the ARIMA approach to analyze the impact of CO_2 emissions from different sectors, such as agriculture, industry, manufacturing, energy, Etc., and its effect on the Human Development Index (HDI), life expectancy, and economic growth. The results suggest a strong

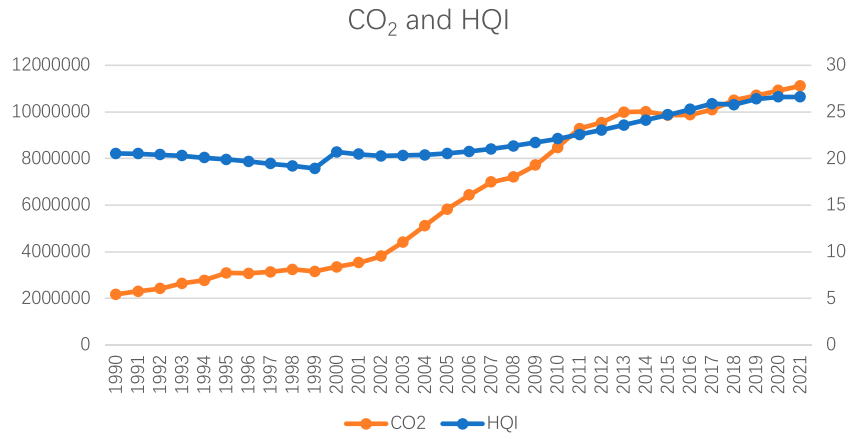

FIGURE 1
CO_2 Emissions and HQI in China. Source: WDI indicators.

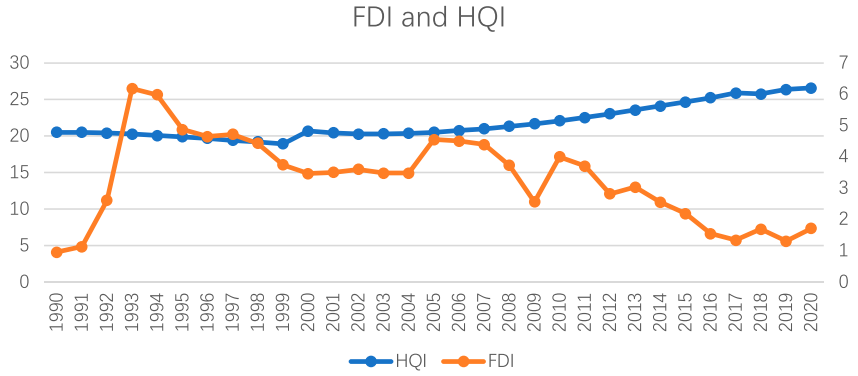

FIGURE 2
Fdi inflow and HQI in China. Source: WDI.

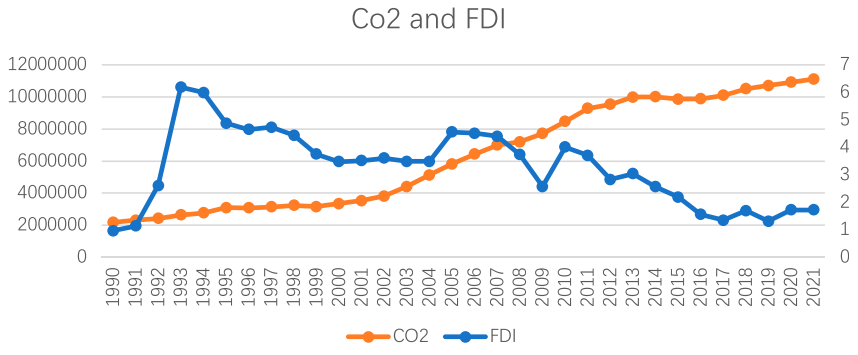

FIGURE 3
CO_2 emissions and FDI in China. Source: WDI.

relationship between included variables and CO_2 emissions in most countries. In addition, they recommended implementing environmental protection laws to provide better health quality and reduce CO_2 emissions.

Immurana (2020b) analyzed the impact of FDI on health outcomes such as life expectancy and mortality rate for 43 African countries from 1980 to 2018. They applied the fixed effects method and found that FDI improves health outcomes. Furthermore, his study

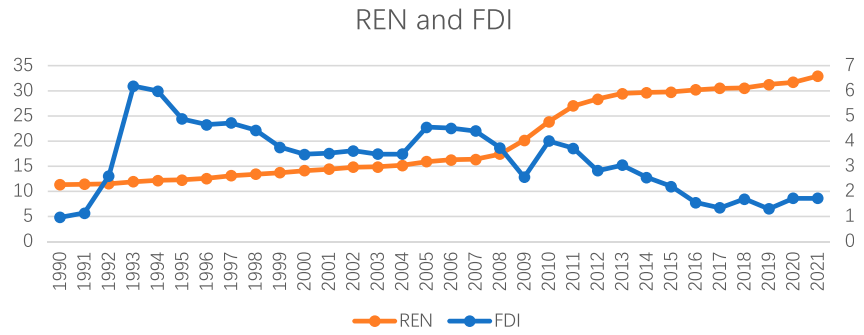

FIGURE 4
REN and FDI in China. Source: WDI.

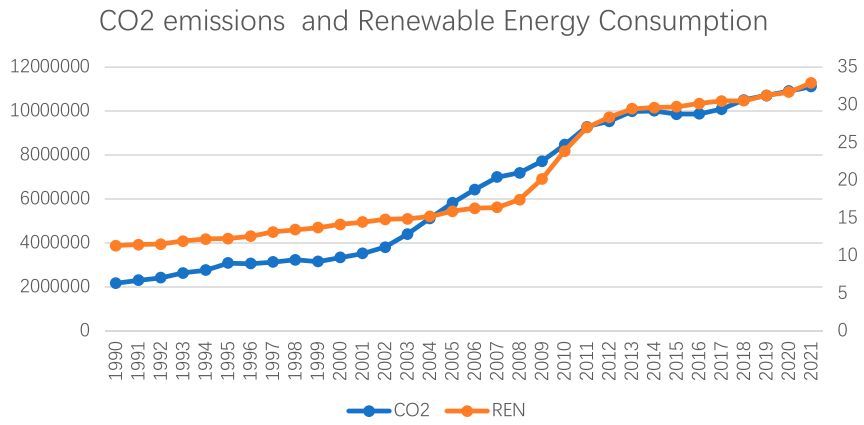

FIGURE 5
REN and CO_2 in China. Source: WDI.

has some limitations because it only covers African countries with a generally low level of economic development, and policy implications are limited to the African region. Nagel et al. (2015) in panel data for 179 countries between 1980 and 2011, found a non-linear relationship between FDI and Health. Specifically, the low-income countries found that FDI positively affects health, but this effect diminishes as income increases and even becomes negative at a high-income level. Immurana (2020a) also analyzed the impact of foreign direct investment (FDI) inflows on population health in Ghana from 1980 to 2018. Life expectancy, infant mortality, and malaria are health indicators of population health. They applied Simultaneously equation, and Ordinary least squares (OLS) method for data analysis, and their results indicate that FDI significantly affects health outcomes. They concluded that FDI inflow could improve population health in Ghana. In addition, mental health is also an essential component of life expectancy for human health.

Jiang and Chen (2022) studied the influence of air pollution on mental health by using the moderating effect of foreign direct investment in China. They applied fixed-effects panel regression and threshold models for analysis using 2015–2018 data. The results show that air pollution significantly negatively affects mental health. Furthermore, FDI has a mitigating effect on the negative association between air pollution and mental health. Air pollution and FDI impact are based on regional characteristics, including location, medical resources, technology investment, and individual traits, covering age, education level, and income. Deng et al. (2021) analyze FDI and renewable energy consumption in BRICS countries from 1990–2019 and apply ARDL-PMG and NARDL-PMG methods. According to ARDL-PMG's implication, the change in foreign direct investment has no significant effect on renewable energy consumption in the long run. At the same time, the NARDL-PMG model also shows the same result. The outcomes revealed that a negative inflow in foreign direct investment would improve the environmental quality, positively affecting the residents' health. They recommended that eco-friendly technology and innovations should be implemented in the country to increase the usage of renewable energy consumption. Li et al. (2021) also investigated the between FDI and renewable energy consumption in China using the provisional level data for 1995–1917. In provinces with high renewable energy use, FDI inflow accompanying renewable energy can reduce environmental degradation and improve health among the population. Meanwhile, some regions in China have been recommended to optimize their energy structure and implement higher renewable energy usage to improve the population's health. Most of the past studies discuss the FDI with CO_2 emissions and renewable energy consumption such as Xie et al. (2020); Salahuddin

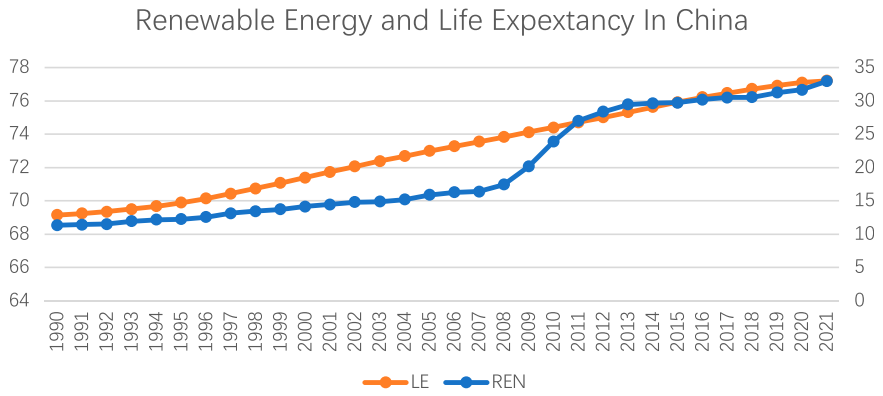

FIGURE 6
REN and LE in China. Source: WDI.

et al. (2018); Salahodjaev and Isaeva (2022) and Farooq (2022); Zhang and Zhou (2016); Faheem et al. (2022); Gyamfi et al. (2022) and Shabir et al. (2022) analyzed the relationship between FDI and CO_2 emissions. Other studies including Schwela and Haq (2020); Mirziyoyeva and Salahodjaev (2022); Saleem et al. (2022) and Qudrat-Ullah (2022) examine the renewable energy and CO_2 emission. Less attention is given to health and FDI however there are some studies related to FDI and health such as Chiappini et al. (2022); Shah et al. (2022) and Burns et al. (2017). Thus, study added the existing literature by covering FDI, CO_2 emissions and renewable energy and health quality in China.

3 FDI, renewable energy, population health in China

Figure 1 demonstrates a graphical relationship between carbon dioxide emissions and the health quality index from 1990–2021. The figure shows that from 1990 to 1999, the HQI has a minor negative relationship. However, from 2002 to 2011, both HQI and CO_2 emissions movie with comparatively faster speed, and still, the negative association persists. From 2012 to 2021, the relationship between CO_2 emissions and HQI became negative but lower rate. However, overall, the CO_2 emissions and HQI have a negative relationship. China had the lowest discharge amount of CO_2 emissions in 1990. This was primarily due to a small population, a low number of automobiles, and a slower pace of industrial development. According to Chen et al. (2019), after 1990 Chinese government developed the secondary industry, contributing to the increasing tendency of carbon dioxide emissions, which is accompanied by discharging of much more environmentally hazardous industrial waste. Although the Chinese government also promoted the development of the tertiary industry (tourism, real estate, and financial industry) in recent years, the proportion of economic profit created by the secondary industry of gross domestic profit (GDP) still accounts for almost 40% in 2020. That confirms that industrial emissions will undoubtedly keep increasing in the following years.

Figure 2 illustrates the connection between foreign direct investment (FDI) inflows and China's health quality index (HQI). The relaxation of trade restrictions brings a large amount of FDI to the country. FDI witnessed the highest rate from 1990 to 1993 and gradually declined from 1994. Despite a recovery between 2004 and 2006, some fluctuations in FDI exist, which means the variations arise due to structural changes in China. From a macro perspective, FDI shows considerable variation in the 30 years, and HQI still exhibits a decreasing tendency during this period. FDI inflow in sectors such as mining and manufacturing brings the great possibility of negative externalities which deteriorate the environment and health of the people. Immurana (2020b) suggests that harmful foreign products could affect the environment and human health. Immurana et al. (2021) have found that FDI promotes the production and consumption of toxic products such as tobacco and adversely affects human health. The deviation in the FDI and HQI does not provide an explicit association, and it is possible that in some years, FDI may have a positive or negative effect on the HQI.

Figure 3 represents a relationship between China's carbon dioxide emissions and foreign direct investment (FDI). Although it depicts the causal relationship between CO_2 emissions and FDI inflows, especially when FDI reached the highest level in 1993, FDI and CO_2 emissions still exhibit a negative correlation. The regulations of FDI in Europe and north Asia reduce the emissions in these countries. However, FDI in China has significantly increased CO_2 emissions and put pressure on environmental resources. Furthermore, the CO_2 emissions, based on fossil fuel, leading to environmental degradation and discourage future FDI inflow in the country, adversely affecting human health. CO_2 emissions have an increasing trend in China from 1990 to 2021, which implies that industrial development in the transition period leads to a constant increase in CO2 emissions in the country. This hypothesis is supported by Huang et al. (2019), who found that foreign enterprise in developing countries has a higher rate of CO_2 emissions.

Figure 4 shows the relationship between renewable energy consumption (REN) and foreign direct investment (FDI) in China from 1990 to 2021. There is a slight negative association between these two variables. This implies that FDI in China is mostly based on fossil fuels, leading to higher CO_2 emissions. However, renewable energy consumption can improve the living environment, leading to a healthy environment and labor productivity. Furthermore, increasing labor productivity will attract FDI inflow, Mustapha Immurana (2020a). Besides there are other reasons for the FDI inflow in the country besides renewable energy. FDI is not complementary to advanced

TABLE 1 Unit Root Test.

Variables	At level	First difference	Conclusion
CO_2	1.0966 (−1.9524)	−1.6755 (−1.9524)	Non-stationary at level and stationary at first difference
FDI	−0.579,234 (−1.9520)	−4.4187 (−1.9524)	Non-stationary at level and stationary at first difference
RNE	−0.1345 (−2.9677)	−2.9983 (−2.9677)	Non-stationary at level and stationary at first difference
HQI	2.8473 (−1.9520)	−4.0412 (−1.9524)	Non-stationary at level and stationary at first difference

technology from developed countries, and it causes the "Pollution Haven," which implies that foreign investment from countries possibly triggers a higher level of carbon dioxide emissions instead of stimulating renewable energy adoption. FDI in China has a deviating trend, and it is suggested that FDI and renewable energy cannot be predicted in the short run. Statistical analysis may provide more robust estimations and a clear picture.

Figure 5 illustrates China's historical trend between CO_2 emissions and renewable energy consumption (REN) from 1990 to 2018. The CO_2 emissions increasing trend from 1990 to 2018. This suggests that due to industrial and economic development, there is a constant increase in CO_2 emissions in China. China mainly uses traditional energy sources such as coal and oil for energy supply. The utilization of these energy sources accounts for more than 80% of the total usage. These types of energy sources release many gases that are harmful to the environment, such as carbon dioxide. In addition, the rapid development of China's manufacturing industry and the surge in production from 2010 to 2018 are also reasons for the high rate of carbon dioxide emissions. Therefore, the carbon dioxide emission rate accelerated from 2010 to 2014, while the impact of industrial expansion on the environment was moderated from 1990 to 2010. However, significant incentives have been provided to adopt renewable energy, such as wind and solar energy, whose contribution and production have significantly increased, reducing carbon dioxide emissions. Nevertheless, traditional energy still dominates in China and is the dominant source of energy production.

Figure 6 presents the derivation between Renewable Energy (REN) and Life expectancy. The long-term REN curve is constant, showing a mild and stable increase in renewable energy consumption from 1990 to 2008. Renewable energy follows the increasing trend from 2009 to 2012. The developing speed has declined since 2013 but still demonstrates moderate increases in subsequent years. Wind, hydro, and photovoltaic power account for major renewable energy production sources. The curve of life expectancy is flatter compared to the curve of renewable energy consumption proportion, rising steadily at the same rate overall. This symbolizes the positive impact of sustainable energy development on health levels. Moreover, the positive impact of renewable energy development on the population's health has improved life expectancy. From the figure, it can be concluded that renewable energy and life expectancy have an increasingly positive trend, and an increase in renewable energy has improved life expectancy in China.

4 Materials, model and methodology

This section presents the method and data we apply for the analysis. The data is compiled from World Bank Database for China during 1980–2020. The variable CO_2 represents *per capita* carbon dioxide emissions (Kt). In addition, FDI represents inflows of foreign direct investment *per capita* (Mert & Boluk, 2016). On the contrary, we construct the following index: HQI stands for Health Quality index and calculated by average value of some factors such as "life expectancy", HIV, Mortality, Hospital beds (per 1,000 people), People using safely managed sanitation services (% of population); RNE (renewable energy) stands for the renewable energy consumption (measured in kilotons of oil equivalent) *per capita*.

The following model contains the relationship of our study:

$$Health\,Quality\,Index = f(FDI, RNE, CO2\,emissions) \quad (1)$$

Following the ordinary least square model, we conduct a preliminary analysis of the basic impact of FDI, CO_2, and RNE on health quality by confirming the model's parameters and validity. This model provides the linear regressions to test whether the PHH hypothesis/EKC or the theory that the trend of FDI and RNE is positive correct or not since the ordinary least squares model can analyze the correlation of variable

$$HQI_t = \alpha_1 FDI_t + \alpha_2 CO2_t + \alpha_3 RNE_t + \epsilon_t \quad (2)$$

This study applies Vector Error Correction Model (VECM), which is based on the long run relationship and short run deviations. The model is estimated VAR framework and it assumes that all variables in the system hold same order of integration. We are using long-term time series data; it is essential to analyze the unit root parameters of the variables. It is indeed possible to get misleading results if the variables are non-stationary. The first step in VECM method is to estimate the order of integration, furthermore it is assumed that all variables should hold a same order of integration. There is different method that perform to test the unit root, Augumnetd Dickey and Fuller (1981) (ADF) and Ducky Fuller (DF) (1979). are most common methods to stationarity of the variables. The following equations represents the unit root test

$$\Delta Z = \gamma Zt - 1 + \partial t \quad (3)$$

$$\Delta Z = z_0 + \gamma Zt - 1 + \partial t \quad (4)$$

$$\Delta Z = z_0 + z1i + \gamma Zt - 1 + \partial t \quad (5)$$

Eq. (1)–(3) mainly performed to estimate γ, Dickey and Fuller (1979) test the hypothesis H0: 0, Zt is non-stationary if the γ is insignificant. Furthermore, the Dicky Fuller (DF) assumes that errors and residuals in statistics are uncorrelated. But if this error term is correlated to then DF method unable to estimate the stationary properties. Therefore, we use lag values and of dependent value which augments this equation, and Augmented Dicky Fuller (ADF) test could test the hypothesis as follow

$$\Delta Zt = x0 + \beta 1i + \gamma Zt - 1 + \Sigma \beta iZt - n + \varepsilon t \ldots \quad (6)$$

Mackinnon's critical and t (tau) statistics are used to test parameter Yt-1 in the ADF unit root test. If it reaches 0, it means there is a unit root, which indicates the variable is non-stationary, and *vice versa*. After evaluating the order of integration, the next step is the

TABLE 2 Johansen Cointegration Test.

Rank	Rank Test (Trace)		Rank test (Maximum Eigenvalue)	
	Trace statistics	Prob. value	Maximum eigen values	Prob. value
$r_0 = 0$	74.1780	0.0000	33.3112	0.0082
$r_1 \leq 1$	40.8668	0.0018	22.7689	0.0292
$r_2 \leq 2$	18.0979	0.0198	17.9817	0.0123
$r_3 \leq 3$	0.11618	0.7332	0.11618	0.7332

TABLE 3 Dependent variable: HQI.

Variable	Coefficient
CO2	−3.4208
	(0.0000)
FDI	0.32568
	(0.0000)
RNE	0.27326
	(0.0000)
R-squared = 0.9191	

estimate the long run relationship. The study test applied Johansen cointegration for the long run estimation; the primary requirement of the cointegration is the same order of integration. Engle and Granger (1987); Johansen (1991); and (Johansen, 1995). There are several ways for cointegration, including Engle and Granger (1987) and Johansen (1991); (Johansen, 1995); are the main method to test the long run relationship. The Engle and Granger (1987) method estimate the when system has two variables in the system and it cannot provide information for long run estimation. However for the multiple vectors Johansen (1991); and (Johansen, 1995) can be applied. Johansen test perform estimation based on following equations.

$$\Delta M = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta M_{t-1} + \Pi M_{t-1} + \varepsilon_t \ldots \quad (7)$$

The error term in the in Johansen techniques follow the likelihood ratios (LR) to the test the hypothesis of cointegration. The test provides two statistics, one is trade statistics and second is maximal eigen values. The first test assumes that the rank is equal to or less than the cointegrating vector (r), whereas the second uses trace statistics.

$$\lambda \,\text{trace} = -T \sum_{i=r+1}^{n} \text{In}\,(1 - \lambda i) \ldots \quad (8)$$

A second test will test for the maximum eigenvalue, and for the null hypothesis, it is tested for the number of cointegrating vectors as follows:

$$\lambda \max = -T \,\text{In}\,(1 - \lambda_r) \ldots \quad (9)$$

VAR framework is used to test these statistics and for the optimal lag length Akike and Shward criterion is applied. If cointegration is found, the next step is to test the short run dynamics which is known as Error correction model.

$$\Delta HQI_t = \sum_{i=1}^{k} \beta_1 FDI_{t-i} + \sum_{i=1}^{k} \beta_2 CO_{2t-i} + \sum_{i=1}^{k} \beta_3 Ren_{t-i} + ECM_{1,t-1} \ldots \quad (10)$$

$$\Delta FDI_t = \sum_{i=1}^{k} \beta_5 HQI_{t-1} + \sum_{i=1}^{k} \beta_6 CO_{2t-i} + \sum_{i=1}^{k} \beta_7 Ren_{t-i} + ECM_{2,t-1} \ldots \quad (11)$$

$$\Delta CO_{2t} = \sum_{i=1}^{k} \beta_9 FDI_{t-i} + \sum_{i=1}^{k} \beta_{10} HQI_{t-1} + \sum_{i=1}^{k} \beta_{11} Ren_{t-i} + ECM_{3,t-1} \ldots \quad (12)$$

$$\Delta Ren_t = \sum_{i=1}^{k} \beta_{13} CO_{2t-1} + \sum_{i=1}^{k} \beta_{14} HQI_{t-i} + \sum_{i=1}^{k} \beta_{15} FDI_{t-1} + ECM_{4,t-1} \ldots \quad (13)$$

$\beta_1, \beta_2, \beta_3 \ldots \beta_n$ are the coefficient values of the vectors in the system and lag value of ECM presents the long run causality. Furthermore, it is assumed that significant value ECM indicates that long run causality. The data for the relevant variables are extracted from the World Bank Development Indicators, which are publicly available. However, the Health Quality Index is created by the using different health-related variables.

5 Results and discussion

4.1 Unit root test

This paper uses the VECM method for analysis; the initial step is to check the stationarity of the variables at level and first difference, more precisely, to check whether they are integrated with order two or not because the same order of integration enables them to proceed the VECM technique. We use the ADF unit root test to identify the order of integration (Wozniak, 2019). Table 1 provides the results of the ADF unit root test; the variables are tested by critical value at a 5 percent level. We concluded that all the variables are non-stationary at the level and stationary at the first difference. The results show that data of variables can be considered to proceed with the cointegration.

4.2 Cointegration test

We found that all variables are I (1); the next step is to test the cointegration among all of the variables. We use Johansen

TABLE 4 Long run and Short Run Causality.

	Short run Effect (causality)							Long effect (causality)
	D (CO_2(-1))	D (CO_2 (−2))	D (FDI (-1))	D (FDI (-2))	D (HQI (-1))	D (HQI (-2))	D (RNE (-1))	D (RNE (-2))	Ect (-1)
D (CO_2)	0.3939 (0.2167)	0.1501 (0.2108)	0.0020 (0.0345)	0.0222 (0.0360)	−0.0392 (0.0718)	−0.0074 (0.0706)	0.1036 (0.0558)	−0.0476 (0.0685)	0.05010 (0.0249)
D (FDI)	−0.8755 (0.8486)	−0.5497 (0.8253)	0.4196 (0.1352)	−0.0093 (0.1409)	−0.2529 (0.2810)	−0.3107 (0.2764)	−0.1383 (0.2184)	0.7579 (0.2681)	0.5849 (0.0976)
D (HQI)	−0.5773 (0.6746)	−0.5703 (0.6561)	−0.0837 (0.1074)	−0.0799 (0.0920)	−0.0218 (0.2234)	0.0702 (0.2197)	0.0866 (0.1737)	0.0116 (0.2131)	−0.0232 (0.0776)
D (RNE)	−0.8923 (0.6863)	1.2471 (0.6675)	−0.0934 (0.1093)	−0.0693 (0.1139)	−0.1808 (0.2273)	0.1048 (0.2235)	1.2108 (0.1766)	−0.4704 (0.2168)	0.1278 (0.0789)

cointegration to estimate the long-run relationship among variables. Johansen test are reported in Table 2; there have two statistics, trace statistics and eigenvalues, in Johansen cointegration. The result of trace statistic and eigenvalues conclude that there are at most three cointegration relations at 0.05 level and the null hypothesis of no cointegration can be rejected. The result shows strong evidence long-run relationship between HQI, Carbon dioxide emissions, foreign direct investment, and renewable energy consumption.

4.3 Long and short relationship estimation

We use ordinary least squares to find the long-term relationship among the variables. Table 3 presents the coefficient that describes the parameters of the linear regressions for the basic model. There is a positive and significant effect on the FDI on HQI. The FDI inflow, in the long run, creates more jobs and, at the same time, raises the overall income of Chinese citizens and improves the general affordable medical conditions. Furthermore, with a rise in income, people can easily do medical treatment, minimizing financial problems and ensuring better medical care. Higher-income levels can also afford better quality food. A more varied diet has also led to improved health indicators.

The results of CO_2 are negative and significant, implying that in the long run, the CO_2 emissions negatively affect the health quality and reduce the health quality. Furthermore, the renewable energy coefficient is positive and significant with health quality which suggests that an increase in renewable energy consumption improves the health quality.

The next step is to find out the short-term estimates of the co-cointegration model. Table 4 shows long-run and short-run causality—the model of D (HQI) initial target to compare with the long-term. Corresponding to the short-term results of FDI is negative but insignificant, which suggests that in the short run, FDI does not affect the HQI. This suggests that FDI does not affect health quality in the short run. However, in the long run, FDI could improve health quality; this implies that foreign direct investment in China has been shifting industries for decades. In the initial investment stage, foreign investors tend to invest in China's manufacturing industry to expand the original scale of production rapidly. At the same time, residents in the low-income stage can only get the original level of even lower medical facilities. CO_2 emissions are insignificant in the short run, while in the long run, it causes the HQI, which indicates that in the short run, CO_2 emissions do not affect HQI. This suggests that with production and trade in China, some relatively backward technologies spread, especially those not conducive to environmental protection. In the short term, such a manner would promptly increase carbon dioxide emissions, offsetting the positive income benefits. In addition, the amount of foreign investment in China has been shrinking in recent years, indicating that China has begun to pay attention to the importance of limiting carbon dioxide emissions and reforming domestic market policies. Foreign direct investment that can bring advanced technology and a clean environment will be encouraged. Moreover, more foreign direct investment is transferred from manufacturing to tertiary industries, such as tourism and finance, with low carbon dioxide emissions. It also hints at the overall rise of China's economy as the focus of capital shifts from being a source of investment to an exporter. The self-control system of the domestic market is gradually progressing. To conclude, the advantages of FDI outweigh its disadvantages, even with

some potential risks. However, it is essential to emphasize that the positive health impact of FDI is not the increase in carbon dioxide emissions but the increase in income caused by carbon dioxide emissions. The REN also found an insignificant effect on the HQI in the short run, which implies that in the short run, health quality does not improve the health quality. Renewable energy has a positive and significant effect on Health quality in the short run at a 5 percent significance level. This suggests that renewable energy could improve the health quality of the people, and renewable energy has a low level of CO_2 emissions and provide a healthy environment and improve the quality of health of people. The significance of the error term tests the long-run causality test. The error term (ECT-1) is negative and significant, which implies that all variable, such as CO_2, FDI, and REN has long-run causality, implying that all variables cause health quality in the long run.

RNE is the most significant factor in the short run that reduces CO_2 emissions and substantially improves health. China's rapidly expanding renewable energy sources, such as photovoltaic, solar and wind, and power, could significantly reduce carbon dioxide emissions. Carbon dioxide can cause cardiovascular disease and other diseases caused by the greenhouse effect. Therefore, the negative effects environment can be greatly relieved. Some variable has no effect in the short run because it may be due to the slow development of the new energy industry caused by the poor economic capacity of China in the 20th century and the limitation of laggard technology. The result of this study has several implications; firstly, the FDI are mostly engaged in the production sector which contributed to CO_2 emissions. The CO_2 emission from FDI can be compensated by imposing carbon tax on foreign firm that could help to reduce the CO_2 emission in the country. Secondly the government should promote the implementation of renewable energy especially in the production process, additionally the renewable energy could provide clean energy to system but also improve the health quality of the people in the county. Thirdly the regulation for nature of FDI inflow is key aspects; tax incentives or tax exemption can be provided to those foreign that uses renewable energy in the production; which could help to achieve both environment and health objectives. Furthermore, firms need to adopt capital-intensive technology-oriented solutions rather than labor-enhanced solutions (Shahbaz et al., 2022). In addition, foreign direct investment in clean energy or cutting-edge technology could promote domestic industries and ensure the sustainable development (Doytch & Narayan, 2016). (Nepal et al., 2021). The results of this study in line with other past studies such as Shah et al. (2022); Xie et al. (2020); Salahuddin et al. (2018); Salahodjaev and Isaeva (2022); Farooq (2022); Ullah et al. (2020) and Pablo-Romero et al. (2016).

6 Conclusion

A significant amount of foreign direct investment has been attracted to China, which raises health and environmental concerns. Most of the previous studies analyzed the FDI and with CO_2 emissions or with renewable energy, however health aspect especially for Chinese economy still not address in literature. Therefore, this study investigates the relationship between FDI, CO_2, renewable energy consumption, and population health in China for the period 1980–2020. We constructed a health quality index (HQI) and used it as a dependent variable, while foreign direct investment (FDI), carbon dioxide emission (CO_2), and renewable energy consumption (REC) as independent variables in the model. We applied the VECM method for data analysis to test the short and long-run relationship between the variables. The results suggest that in the short run, only renewable energy causes the HQI, which implies that REN improves health quality in the short run. However, in the long run, all variables, such as renewable energy and FDI, improve health quality, while CO_2 emissions negatively affect health quality in China. These results have some policy recommendations; firstly, renewable energy is an essential factor that could improve health quality both in the short and long run. Therefore, government should promote renewable energy both in households and industries. The government may provide subsidies on the price of solar panels and renewable energy equipment. Secondly, the government should welcome and provide special incentives to boost FDI inflow, mainly those using renewable energy in production. The government may provide corporate tax reductions for the FDI firms that use renewable energy in the process and operation. Thirdly government should implement a carbon tax to reduce the CO_2 emissions in the country and to improve the health of the environment. Fourthly, tax revenue collected from the heavily CO_2 emitted industry could be used to provide tax relief to those industries that adopt renewable energy in the production process. Besides, to improve the quality of health, the government should improve the healthcare unit, especially in the rural and remote areas, which could improve the quality of health of the people in the country. This study has some limitations; firstly, we only discuss the case of China; consequently, we can test this hypothesis by adding multiple countries. Secondly, we constructed the HQI based on variables such as life expectancy, mortality rate, death rate, number of hospital beds, and people using safely managed sanitation services; future research may construct a stronger index by adding some new health quality-related variables. Thirdly, this study uses renewable energy consumption, CO_2 emissions, and FDI variables in the model; future studies may use additional variables to test this hypothesis.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://data.worldbank.org/country/CN.

Author contributions

ZZ: Conceptulaization FN and LD: Review the main draft and analyze the data IU: data extraction and review the main draft SX, YJ, and ZY, and CY: write the main draft.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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