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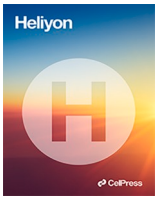

Research article

The impact of FDI on energy conservation and emission reduction performance: A FDI quality perspective

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ABSTRACT

According to the climate emission reduction commitment of the Paris Agreement, all countries are actively seeking a new path of energy conservation and emission reduction, and trying to "bend downward" the global greenhouse gas emission curve. For China's carbon peak before 2030 and carbon neutral target before 2060, explore whether FDI can reduce China's energy consumption and carbon emissions. From the new research perspective of FDI quality, this paper explores the potential ways to improve regional energy-carbon emission performance (ECEP), and applied dynamic threshold effect and two-stage least squares for validation. The specific results are as follows: FDI quality improvement can have a significant positive impact on regional ECEP. The development level of renewable energy, the optimization of industrial structure and the enhancement of green innovation ability can positively regulate the impact of FDI on energy-carbon emission performance. At the same time, the results of the dynamic panel threshold model demonstrate that with the economic growth pressure of local governments decreases and the fiscal decentralization increases, the role of FDI quality in promoting the ECEP could be stronger. The influence of FDI quality on ECEP has regional heterogeneity, and the influence of FDI quality on ECEP is regional heterogeneous, and the influence of FDI quality on ECEP is more significant in inland and midwestern regions than in coastal and eastern regions. This study provides experience for FDI to formulate the quality assessment system and formulate foreign investment policy.

1. Introduction

With the frequent occurrence of global warming and extreme natural disasters, countries around the world are facing huge environmental pressure. The acceleration of industrialization has brought unprecedented development opportunities to the world, and also caused serious environmental problems [1]. At present, countries around the world are strengthening environmental pollution control, forming a new stage of global ecological environment co-governance [2]. At the 2015 Paris Climate Conference, China pledged to achieve a peak in total carbon emissions around 2030. In October 2021, The State Council Information Office issued a white paper titled "China's Policies and Actions to Address Climate Change," highlighting the important role of promoting high-quality development of the manufacturing industry.As a major carbon emitter, China's economy has created a growth miracle, but the growth model

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at the cost of natural resources and ecological environment has made the problems of energy depletion and environmental pollution increasingly serious [3].

And FDI is both a major promoter to global economic growth and a contributor to carbon emissions [4]. With China's opening to the outside world, FDI grew from $11.07 billion to $190 billion from 1992 to 2022. FDI has provided huge economic benefits to China with capital, foreign exchange, technology, and opportunities to strengthen competition and access to foreign markets [5]. With the continuous requirements for environmental protection in developed countries, and the strong growth of China's industry has obvious three high characteristics: high investment, high energy consumption and high pollution, which makes pollution-intensive enterprises flow into China's low-end manufacturing and high-pollution industries in the form of FDI, aggravating the pollution of China's natural environment, [6,7]. In addition, the "Made in China 2025″ proposed to "comprehensively promote green manufacturing" and continue to narrow the gap with the world's leading green manufacturing capabilities.Compared with the previous "quantity" of foreign investment, more attention on "quality", in the future, attracting high-quality foreign investment to bring advanced technology and management experience [8]; on the other hand, guiding foreign investment into low-carbon industry, new energy, advanced manufacturing, information technology and other fields [9]. As shown in Fig. 1, FDI shows a positive correlation with ECEP, and it is distributed near the trend line with a strong correlation. Therefore, it is of key theoretical and significance to explore the influence mechanism of FDI quality on ECEP.

And for FDI quality, a basic consensus has been formed on the FDI quality evaluation system, which mainly forms key indicators for assessing FDI quality through variables such as profitability, management ability, export ability, actual scale and technical level. However, due to the availability of data, the measurement of domestic FDI quality is mainly concentrated at the provincial level. Through the five aspects of FDI indicators, the quality of imported FDI can comprehensively feedback the impact on the economic effect and environment of the host country.

At present, the research on FDI quality mainly focus on exploring the scale of FDI quality and its economic effects, and there are few studies on the effects of energy environment and emission reduction from the perspective of FDI quality. This paper mainly solves the following problems: (i) The impact of five dimensions of FDI quality on ECEP. (ii) Does the quality of foreign direct investment affect China's ECEP through indicators including green innovation, renewable energy development level and industrial structure upgrading? (iii) Is there a threshold effect on the impact of FDI quality on ECEP?

There are three marginal contributions to the existing research in this paper. (i) The existing research mainly focuses on the overall impact of FDI on the absolute pollution level of a country or region and the impact of environmental regulation on the location selection of FDI. This paper focuses on the impact of five dimensions of FDI quality on ECEP in China, deeply analyzes the impact mechanism and effect of each dimension of FDI on energy-carbon emission performance, and enriches the research perspective in this field. (ii) Data processing. Based on the relevant statistics of 30 provinces, five FDI quality dimensions were used to comprehensively evaluate the quality level of FDI. We also used the DEA method to construct a non-radial directional distance function to measure, and calculate a comprehensive energy carbon emission index — ECEP. (iii) Considering China's unbalanced economic development, the local governments introduce foreign economic goals, this paper to the economic growth pressure of local government and the degree of financial decentralization as the threshold variable, with dynamic threshold test the government work target and the degree of fiscal decentralization for FDI quality affect energy carbon emissions performance has the threshold effect, so as to adjust measures to local conditions to formulate investment policy, promote foreign investment for the sustainable development of local economy to provide decision basis.

According to the requirements of high-quality economic development and the goal of double carbon, it is of great significance to explore the relationship between FDI quality and energy consumption and carbon emission performance to help solve practical problems.The research results of this paper are helpful to improve China's investment policy and explore the sustainable development path to provide reference.

The content structure of this paper is presented as follows: The second section of the article reviews the references on FDI and energy conservation and environment protection, and proposes the internal mechanism of FDI quality affecting the ECEP. The third section is Theoretical mechanism and research hypotheses. The fourth section is measurement model setting, index selection and data

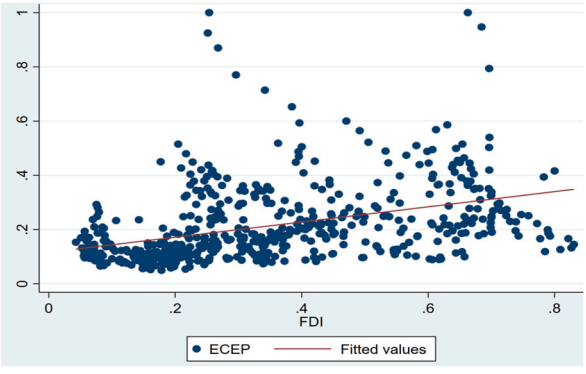

Fig. 1. FDI-ECEP NEXUS

source description. The fifth section is empirical results and analysis. The sixth section conducts robustness tests. The last section is policy and conclusion.

2. Literature review

2.1. Impact assessment of the FDI

At present, the research on FDI affecting economic development mainly describes economic growth from different perspectives of innovation ability, industrial structure, energy conservation and environmental protection, wage and employment [10,11]. Zhang et al.(2022) [12] found that FDI brings capital, technology and other factors to the host country, and promotes the embedding of domestic production, supply, sales and other environments into the global value chain system. FDI has effectively promoted the economic growth and regional economic development, and significantly optimized the industrial structure and industrial chain, and promoted R&D innovation and technological advance [13]. Moreover, FDI can improve the efficiency of economic growth, and it can also boost China's innovation ability and labor quality through imitation, competition and labor interaction [14]. The entry of foreign capital will improve the degree of competition in the domestic market by increasing product supply and improving product quality. As the competition, the welfare of domestic consumers will be improved. Moreover, it will force enterprises to carry out technological innovation and improve product quality [15], which can also make enterprises lacking innovation and core competitiveness withdraw from the market, so as to optimize resource allocation and promote green economic evolution.

2.2. The relationship between the FDI and environment

At present, research on FDI and energy environment are mainly divided into two categories. One is that FDI plays a positive role in the energy environment in the host country and supports the "pollution halo" hypothesis [1]. Wang C.C. et al. (2019) [15] thinks that the introduction of FDI is not the key to the deterioration of the energy environment in the host nation. The introduction of foreign capital can bring about advanced technology and management concepts, and the technology spillover of FDI can bring about the improvement of production efficiency, reduce the waste of resources, and improve the efficiency of energy use [16]. FDI suppresses environmental pollution [17]. Uche et al.(2023) [18] believes that FDI is beneficial to the improvement of energy consumption efficiency and promotes the green development of regional economy. Adeel-Farooq et al.(2021) [19] found that FDI from developed countries improved overall environmental performance in income host countries such as low, low and middle income and high school. FDI has a conspicuous positive impact on environmental quality by lowering pollutant levels [20,21]. Xie et al.(2023) [22] simulated the relationship between FDI and environmental pollution, and found that FDI inflow played a negative effect on alleviating the impact of industrialization on environmental degradation.

Another type of research agrees with the "pollution paradise" hypothesis. Jun et al. [23] believes that the parent country can significantly reduce domestic industrial waste-water emissions and industrial sulfur dioxide emissions through outward direct investment, which will lead to the deterioration of the environment in the imported countries. Santos and Forte (2021) [24] found that the host country will take the initiative to lower the level of environmental regulation so as to attract FDI, which will directly lead to the deterioration of the domestic environment. In order to avoid the high environmental regulations, foreign investors choose to enter the host country with low environmental regulations, and will continue to enter the industry enterprises with high energy consumption and high pollution, which will directly aggravate environmental pollution [25,26]. Adeel et al. (2021) [19] examining the impact of FDI in developed and developing countries on the overall environmental quality of 76 countries found that the entry of foreign capital will hinder the improvement of energy efficiency, and found that FDI from developing countries is not conducive to the development of the environment in developing countries [27,28].

2.3. Research on FDI quality and energy carbon emission performance

Kumar [29] took the lead in putting forward the FDI quality evaluation index system and pointed out that the core connotation of FDI quality is that FDI brings positive benefits to host countries, including new knowledge, capacity building of industrial technology, commodity market competitiveness, etc. Then Zou Jianhua et al. [30] constructed a FDI quality evaluation system using scale, proportion of manufacturing investment to total investment, export-oriented development, and technology spillover potential. Jun W. et al.(2020) [23] concluded that FDIs increased carbon emission and improve energy concluded that FDIs increased carbon emission and affected environmental quality negatively. Findings show that energy investments of public-private partnerships hinder the improvement of environmental performance.There is an inverse U relationship between FDIs and carbon emissions up to a certain investment level, and emissions begin to decrease after the investment level reaches the threshold value.

FDI spills over through technology the effect will improve the environmental quality of the host country, and high-quality FDI has a higher level of technology and is easier to play[31].Spillover effect of green production technology. High-quality FDI is more likely to promote the economic development and technology of the host country.According to existing studies, the quality of FDI affects the economy and environment mainly through the mechanism of improving productivity, green technology progress, green total factor productivity and enhancing independent research and development. [31,32].

To sum up, some relevant studies have mainly focused on the impact of FDI on economic development, green development and other aspects, but mainly based on the perspective of FDI technology effect, industrial transformation and upgrading and scale effect, but there are still few studies on FDI and energy and environmental issues from the perspective of FDI quality. Most of the literature is

more focused on analyzing the impact of FDI on the host country environment from the perspective of FDI scale. Based on this, this paper deeply analyzes the effect of FDI quality on the ECEP of local energy sources, starting from the five quality characteristics of FDI. Through the classification of FDI quality characteristics, the influence on ECEP in China is analyzed comprehensively and hierarchically. In the mechanism analysis, the possible regulation effect and threshold effect of foreign investment quality on ECEP are studied. By clarifying the important role of FDI in promoting ECEP, some policy recommendations are made to optimize local government policies to attract high-quality foreign investment and achieve green development goals.

3. Theoretical mechanism and research hypotheses

In view of the differences in FDI sources, investment objectives and research and development capacity, which determine the poor and different FDI quality, the research on whether the improvement of FDI quality can promote economic growth and improve the ecological environment has become a research hot-spot [33]. Due to the foreign advanced technology, management experience and capital covered by FDI, FDI can fully play its positive role as FDI enters the host country, including improving technology level, enhancing profitability, enhancing management level, enhancing export competitiveness, obtaining capital support and other factors [34]. The quality of FDI mainly affects the performance of energy-carbon emission performance through the following ways (Fig. 2).

Hypothesis 1. Improving the quality of FDI will significantly improve ECEP.

Firstly, with the continuous improvement of renewable energy development level in the host country, carbon emissions can be reduced through the improvement of energy intensity. FDI in various industries of the host country also uses more new energy to replace non-renewable energy, thus reducing carbon emissions. Thus, the improvement of regional renewable energy development level can make FDI quality have a more significant positive impact on ECEP [35]. Secondly, in the process of economic development of the host country, the industrial structure continues to upgrade, and the proportion of the secondary and tertiary industries continues to increase, from low-value-added labor-intensive industries to high-value-added technology-intensive industries [1]. As the proportion of the primary industry declines, more foreign investment will enter the secondary and tertiary industries with low pollution and energy consumption, which can reduce carbon emissions. At the same time, when foreign capital enters technology-intensive industries with high added value, more technology spillover can be achieved to improve production efficiency and reduce carbon emissions. Industrial structure upgrading strengthens the positive influence of FDI quality on ECEP. Finally, with the development of economy and the continuous enhancement of environmental awareness, the development of green innovation technology is becoming the key to future technological innovation. With the continuous improvement of green innovation capability, it can attract higher quality FDI, bring technology spillover and R&D capability to further improve the regional green innovation capability, and make the positive impact of FDI on regional ECEP more significant [35]. Therefore, this paper proposes.

Hypothesis 2. Renewable energy development level, industrial structure upgrading and green innovation capacity improvement can positively regulate energy conservation and emission reduction in FDI and regions.

When FDI is introduced in a host country, the quality of FDI will also affect the performance of FDI and regional energy carbon emission based on different investment targets [10,36]. The factors affecting FDI and energy conservation and emission reduction are mainly reflected in local financial decentralization and economic development pressure [37]. On the one hand, fiscal decentralization enables local governments to compete around the pursuit of economic indicators and political achievements. However, the unbalanced economic development in China leads to different fiscal decentralization and different standards and requirements for attracting investment, resulting in different energy conservation and emission reduction effects [4,38]. On the other hand, different economic

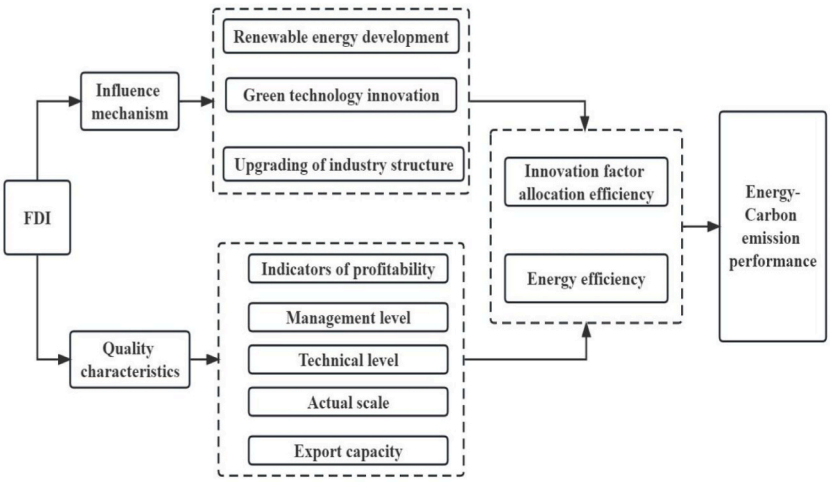

Fig. 2. Mechanism of FDI quality on ECEP.

development pressure, makes the local government to develop different development goals, if the GDP growth as the goal, the local government will pay more attention to the size of the FDI, if regional green development as the goal, local governments will actively attract high-quality FDI, around the difference of the economic development pressure will make the FDI for energy-carbon emissions performance produce different effect. Based on this, this paper proposes that.

Hypothesis 3. Fiscal decentralization and political incentives will have a threshold effect on FDI and ECEP.

4. Models and data

4.1. Measurement model setting

This paper takes 30 provinces, municipalities and autonomous regions in China from 2001 to 2019 to analyze how FDI quality improves regional ECEP. In order to test the impact of FDI quality on regional ECEP, the fixed effect model is fit for regression. The specific model is set as shown in formula (1):

$$ECEP_{it} = \beta_0 + \beta_1 \ ln\ FDI_{it} + \sum \beta_2 X_{it} + \eta_i + \sigma_t + \varepsilon_{it} \tag{1}$$

Among them, the subscript i represents the province, and t is the year. Explained variable select the $ECEP_{it}$ of each province logarithmic; Core explanatory variable $ln\ FDI_{it}$ represents through FDI profitability, FDI management level, FDI technology level, FDI technology level, FDI export capacity and FDI scale of five quality dimensions through the entropy weight method to construct FDI quality index logarithm; X_{it} is the control variable; η_i and σ_t respectively indicate the fixed effect of the province and the year fixed effect, ε_{it} is a random disturbance term.

In order to test the progressive and accumulation effects of FDI quality on ECEP, according to hypothesis 2, considering the regulatory role of regional green emission reduction, green technology innovation capacity and industrial structure adjustment, the model is set as follows:

$$ECEP_{it} = \beta_0 + \beta_1 \ ln\ FDI_{it} + \beta_2 \ ln\ FDI_{it} \times RED_{it} + \beta_3 \ X_{it} + \eta_i + \sigma_t + \varepsilon_{it} \tag{2}$$

$$ECEP_{it} = \beta_0 + \beta_1 \ ln\ FDI_{it} + \beta_2 \ ln\ FDI_{it} \times GIN_{it} + \beta_3 \ X_{it} + \eta_i + \sigma_t + \varepsilon_{it} \tag{3}$$

$$ECEP_{it} = \beta_0 + \beta_1 \ ln\ FDI_{it} + \beta_2 \ ln\ FDI_{it} \times UIS_{it} + \beta_3 \ X_{it} + \eta_i + \sigma_t + \varepsilon_{it} \tag{4}$$

In the formula, RED_{it} represents renewable energy development level, GIN_{it} represents regional green innovation ability, UIS_{it} represents upgrading of an industrial structure as the regulatory variable to cross FDI and test the regulatory mechanism. (2), (3) and (4) main concern coefficient β_1, β_2 and β_3. Other variables in the model are consistent with (1), and will not be repeated.

Considering that regional financial decentralization and political incentives will affect the ECEP of FDI quality promotion, the degree of improvement, the impact is nonlinear, showing interval effect, and there may be threshold effect. Therefore, we uses the threshold regression model of Hansen [39] to internally divide the interval according to the characteristics of the data itself, and then study the relationship between FDI quality and ECEP in different intervals. This paper uses the dynamic threshold panel model of Seo and Shin [40], analyzes FDI, whether the influence of quality on ECEP has threshold effect, and establishes the following threshold regression model:

$$ECEP_{it} = \beta_0 + \beta_1 \ ln\ FDI'_{it} + \beta_2 \ X_{it} + (1, ln\ FDI_{it})\delta 1\{q_{it} > \gamma\} + \sigma_t + \varepsilon_{it} \tag{5}$$

In formula 5, $ln\ FDI'_{it}$ is the core variable with a delay of one period, and q_{it} is the threshold variable. Fiscal decentralization and political incentive q_{it} are the threshold variables, γ is the threshold variable. $\delta 1$ is the indicator function, set the dummy variable $\delta 1(\gamma) = \{q_{it} <= \gamma\}$, if $q_{it} <= \gamma$, $\delta 1 = 1$ otherwise $\delta 1 = 0$. The equation divides FDI quality parameters into two parts according to whether fiscal decentralization and political incentives are greater than the separation value. It is assumed that the possible values of each threshold variable are substituted into γ one by one, and the estimated value is obtained by minimizing $S(\gamma)$, where ε_{it} is the random disturbance term.

4.2. Variable design and data source

4.2.1. Energy-carbon emission performance (ECEP) setting

This paper selects the DEA (data envelopment analysis) method to measure ECEP, Since DEA does not require preset parameters in advance can effectively reduce the influence of subjective factors and errors on efficiency results, are commonly used in the efficiency assessment, while incorporating undesired output into the efficiency assessment system. Using Yu et al. [41] and Borga et al. [42], Build a (NDDF) non-radial directional distance function to measure ECEP of each province. In this way, energy and environmental factors can be included in the measurement framework, and the ECEP in economic production can also be measured more accurately by analyzing the ratio between input and output.

Step 1. the production framework is designed as follows:

$$(X, Y, E, G, C) : \sum_{i=1}^{T}\sum_{n=1}^{N}\mu_{ni}X_{ni} \le X; \sum_{i=1}^{T}\sum_{n=1}^{N}\mu_{ni}Y_{ni} \le Y; \sum_{i=1}^{T}\sum_{n=1}^{N}\mu_{ni}E_{ni} \le E;$$

$$\sum_{i=1}^{T}\sum_{n=1}^{N}\mu_{ni}G_{ni} \le G; \sum_{i=1}^{T}\sum_{n=1}^{N}\mu_{ni}C_{ni} = C; \mu_{ni} \ge 0; n = 1, \ldots, N; t = 1, \ldots, T$$

Step 2. define the equation for the NDDF:

$$\overrightarrow{D}(X, Y, E, G, C; p) = sup\left\{w^T\beta : (X, Y, E, G, C) + diag(\beta) \bullet p \in M\right\} \tag{6}$$

In the formula(6): X represents capital input, Y represents labor input, E represents energy input as the input variable in the production framework, G expected output is GDP, and C represents the carbon emission level in the production process of undesired output. $w = (w_X, w_Y, w_E, w_G, w_C)$ represents the weight vector of each input and output, $P = (P_X, P_Y, P_E, P_G, P_C)$ represents the direction vector of the input and output, and $\beta = (\beta_X, \beta_Y, \beta_E, \beta_G, \beta_C)$ is a relaxation vector. Giving equal weight to inputs, desired outputs, and undesirable outputs, The direction vector w^T and the weight vector p are set as (-X, -Y, -E, G, –C) and (0,0,1/3,1/3,1/3) respectively. Using (0,0,1/3,1/3,1/3), ECEP can be measured without changing labor and capital input, which is an indicator of single-factor energy efficiency and single-factor carbon emission efficiency. On this basis, the ECEP index is obtained by linear programming method.

$$ECEP = \frac{1/4[(1-\beta_X) + (1-\beta_Y) + (1-\beta_E) + (1-\beta_C)]}{1+\beta_\gamma} \tag{7}$$

In formula 7, it can be found that *ECEP* results between 0 and 1, and the closer the result is to 1, the higher the regional *ECEP* is.

4.2.2. Setting of the FDI quality of the core explanatory variable

This paper draws on Buckley [43] and other ideas, and constructs the FDI quality characteristic system from the five indicators of FDI profitability, management ability, technical content, scale of foreign investment and export capacity.

Profitability: Profitability is the ability of an enterprise to obtain profits. The higher the profitability of the foreign-funded enterprise, the better the operating condition of the foreign-funded enterprise, the more ability to provide capital support and capital reinvestment for scientific and technological innovation. Therefore, the higher the profitability of foreign capital, the higher the quality of its FDI. Therefore, profitability is represented by "cost-expense profit margin of FDI industrial enterprises/cost-expense profit margin of industrial enterprises above designated size".

Management ability: Management level is one of the important standards to measure the quality of foreign investment. A sound management system can form a reasonable incentive and constraint system, which plays an important role in the realization of organizational goals. The contribution rate of total assets can be used to measure the ability of an enterprise to obtain profits. This efficiency value can show the management level of the enterprise. Therefore, "Contribution rate of total assets of FDI industrial enterprises/Contribution rate of total assets of industrial enterprises above designated size" is used to represent management ability.

Technology content: As an important driving force for the development of modern enterprises, technology content can help enterprises gain sustainable competitiveness. Foreign-funded enterprises with higher technological content can promote the improvement of the technical level of enterprises in the host country, so as to promote the specialization of production and improve the use efficiency and output efficiency of production factors. Therefore, "(output value of FDI industrial industry/number of employees in FDI industrial industry)/(output value of industrial industry above designated size/number of employees in industrial industry above designated size)" is used to represent technological content.

Scale of foreign investment: the larger the scale of individual FDI, the stronger the investment strength of foreign-funded enterprises, the more able to provide guarantee for technological innovation activities. Therefore, "the actual amount of FDI/the number of contracts" is used to measure the scale of foreign investment.

Export capacity: Foreign investment can provide host countries with new access to international markets. Meanwhile, the host country can improve the quality of export products and the competitiveness of participating in the international market by introducing the advanced technology of foreign capital. Therefore, "Export value of FDI enterprises/total export value of provinces and cities" is used to represent the level of FDI export capacity.

In order to comprehensively evaluate the quality level of FDI, the above five indicators are concentrated as a comprehensive index by factor analysis method. This paper uses the processing method of Peter (2004), uses the entropy weight method and the information entropy of each index to calculate the weight of each index, and finally obtains the quantitative FDI quality level index.

Step 1 is to standardize each index. When standardizing the index, the FDI quality index system is treated as formula (8):

$$\overline{x_{ij}} = \frac{\alpha_{ij} - \min\left\{\alpha_{1j}, \ldots, \alpha_{nj}\right\}}{\max\left\{\alpha_{1j}, \ldots, \alpha_{nj}\right\} - \min\left\{\alpha_{1j}, \ldots, \alpha_{nj}\right\}} \tag{8}$$

Step 2 is to calculate the weight of each index and calculate the proportion of the i region under the j index in the index according to formula (9):

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{9}$$

Calculate the entropy value of the j-item index according to formula (10):

$$e_i = -(\ln m)^{-1} \sum_{i=1}^{m} \left(P_{ij} \ln P_{ij}\right) \tag{10}$$

Where, the condition is satisfied $e_i \geq 0$.

Calculate the weight of each index from formula (11):

$$w_j = \frac{(1 - e_j)}{\sum_{j=1}^{n} (1 - e_j)} \tag{11}$$

Step 3. calculate the comprehensive score of FDI quality in each region by formula (12):

$$FDI = \sum_{1}^{n} w_j p_{ij} \tag{12}$$

4.2.3. Setting of the control variables and the regulatory variables

The main control variables selected in this paper are as follows: On the basis of previous FDI quality literature, the following control variables are selected: domestic fixed investment (DFI), environmental regulation level (ERL), government intervention (GI), infrastructure (INF) and human resources (HR). Select renewable energy development level (RED), green innovation capacity (GIN) and upgrading of industrial structure (UIS) as regulatory variables. The threshold variable is measured by financial decentralization (FID) and economic growth pressure (EGP) respectively.

The original data of this paper are from China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Environmental Statistical Yearbook and China Population and Health Statistical Yearbook and the Statistical Yearbook of all provinces, municipalities directly under the Central Government and autonomous regions. Table 1 reports the statistical description of the above-mentioned variables statistics.

5. Empirical results and analysis

5.1. Benchmark regression results

In this paper, the ECEP index of 30 provinces, municipalities and autonomous regions in China from 2001 to 2019 is calculated. Table 2 reports the benchmark regression results of model (1). The core explanatory variable, FDI, in this paper, on ECEP is always significantly positive. Column (1) tests the effect of FDI on ECEP. The coefficient of FDI is significantly positive at the 1% level, indicating that the quality improvement of FDI can play a significant role in promoting ECEP. It is similar to the empirical results that improving the quality of foreign investment can reduce carbon emissions [44].

While other conditions remain unchanged, for every 1% increase in the FDI quality level, the regional ECEP index on average increases by 0.094%. Column (2), (3) and (4) indicate that the quality improvement of FDI after the gradual addition of DFI, ERL, GI, INF, and HC still has a significant impact on ECEP, and the impact coefficient on ECEP index is significantly positive, the influence coefficient on ECEP index are significantly positive, after adding all the control variables, FDI quality level every 1%, the region ECEP index increased by 0.084%, that FDI quality improvement contributes to regional energy conservation and emission reduction, verify hypothesis 1.

5.2. Analysis of heterogeneity effects

There is a large gap in economic development level among different regions in China, and the quality and types of FDI introduced

Table 1
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
ECEP	570	0.212	0.143	0.05	1
FDI	570	0.345	0.203	0.043	0.83
DFI	570	0.638	0.255	0.21	1.48
ERL	570	0.004	0.003	0	0.029
GI	570	0.208	0.095	0.077	0.628
INF	570	7810.461	5011.549	340.966	21884.264
HC	570	8.635	1.099	5.438	12.681
RED	570	337.63	498.643	0.76	3416.53
GTI	570	1962.202	4040.255	1	32269
UIS	570	1.02	0.55	0.494	5.154

Table 2
Regression results.

Variable	ECEP (1)	ECEP (2)	ECEP (3)	ECEP (4)
FDI	0.094*** (4.08)	0.087*** (3.92)	0.088*** (4.02)	0.084*** (3.80)
DFI		−0.074** (−2.16)	−0.015 (−0.43)	−0.015 (−0.44)
ERL		−0.889*** (−6.13)	−0.076*** (−5.28)	−0.077*** (−5.33)
GI			−0.374*** (−4.30)	−0.381*** (−4.37)
INF			−0.205*** (−3.96)	−0.198*** (−3.78)
HC				−0.296 (−0.97)
Year	Yes	Yes	Yes	Yes
State	Yes	Yes	Yes	Yes
_cons	−2.050*** (−36.87)	−2.624*** (−26.57)	−1.582*** (−3.46)	−1.085 (−1.58)
R2	0.832	0.845	0.854	0.855
N	570	570	570	570

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses.

are different. Therefore, the impact of FDI quality level on regional ECEP may be quite different in different regions. This paper according to the regional economic development, samples will be divided into eastern and Midwest sample regression, Table 3 column (1) and (2) respectively shows the heterogeneity of eastern and Midwest results, it can be seen that compared with the eastern region, the Midwest of the FDI quality for energy-carbon emissions performance improvement effect is more obvious. This is because compared with the eastern regions, the central and western regions themselves are relatively low, and the FDI quality from low to high can significantly promote the improvement of the ECEP in the central and western regions.

At the same time, the samples were divided into coastal and inland areas according to the functions of the economic zone. Column (3) and (4) showed the heterogeneity results of coastal and inland areas respectively, showing that FDI quality is more effective on improving the ECEP in inland areas. This is because of the small scale and low quality of FDI in China's Midwest and inland areas, and more investment in high-polluting industries [45] whose empirical results are consistent with this result. which makes FDI quality have a significant impact on the ECEP of inland areas, but no obvious impact on the ECEP of coastal areas.

5.3. Sub-dimension results analysis

Table 4 shows the influence of five quality characteristics of FDI on energy-carbon emission performance. Column (1) tests the influence of FDI profitability on energy-carbon emission performance. The results show that the improvement of FDI profitability does not significantly promote the improvement of energy-carbon emission performance, which is because capital is for profit. This indicates that FDI with strong profitability invests more in industries with high energy consumption and high resource consumption, and the influence of FDI profitability on energy-carbon emission performance is not significant [46]. Column (2) tested the influence of FDI management ability on ECEP, and the results showed that the influence of FDI management ability on ECEP was significantly positive. The stronger the management ability, the stronger the regional ability to allocate FDI, the significantly positive influence on ECEP. Column (3) examines the impact of FDI technology level on ECEP, the results show that the impact of FDI technology level on ECEP is significantly negative. Column (4) examines the regression results of the influence of FDI scale on energy-carbon emission performance, and the results show that FDI scale significantly promotes the improvement of energy-carbon emission performance. This indicates that the scale of FDI investment significantly promotes regional economic development, thus making more funds available for regional environmental improvement and green development. Column (5) tests the regression of the impact of FDI export level on ECEP, the results show that FDI export level significantly promotes the improvement of regional ECEP, and the foreign export capacity measures the proportion of FDI enterprises in the export trade of the host country. Stronger FDI export capacity means stronger enterprise competitiveness and higher export quality, which promotes the optimization and upgrading of regional industrial structure, so as to achieve green and sustainable development.

Table 3
Heterogeneity analysis.

Variable	Eastern	Midwest	Coastal region	Inland region
FDI	−0.033 (−0.48)	0.101*** (4.16)	0.069 (0.68)	0.103*** (4.28)
Control variables	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
State	Yes	Yes	Yes	Yes
_cons	−1.476 (−1.19)	−2.951*** (−3.59)	0.087 (0.06)	−2.346** (−2.98)
R2	0.919	0.852	0.925	0.850
N	209	361	209	361

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses.

Table 4
Results of fractal dimension regression of FDI quality.

Variable	ECEP (1)	ECEP (2)	ECEP (3)	ECEP (4)	ECEP(5)
FDI (profit)	0.052 (0.31)				
FDI (management)		11.768** (2.52)			
FDI (technology)			−0.103*** (−5.55)		
FDI (scale)				0.085*** (6.58)	
FDI (export)					0.056*** (4.45)
Control variables	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
State	Yes	Yes	Yes	Yes	Yes
_cons	−1.135 (0.104)	−1.075 (−1.56)	−0.763 (−1.12)	−0.912 (−1.36)	−1.187* (−1.74)
R2	0.850	0.854	0.859	0.862	0.856
N	570	570	570	570	570

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses.

5.4. Investigation of function channels

As indicated above, FDI quality can significantly promote ECEP, but it needs to be further tested by what mechanism influences ECEP. According to hypothesis 2, this paper proposes that FDI quality affects ECEP through three channels including green emission reduction, green technology innovation and industrial structure upgrading.

5.4.1. Renewable energy development level(RED)

According to formula (2), (3) and (4) respectively, the regression coefficient of the product term of FDI quality and green emission reduction RED_{it} in column (1) of Table 5 is significantly positive, indicating that green emission reduction enhances the positive influence of FDI quality on ECEP. The possible reason is that after the improvement of FDI quality, more FDI flows into low-carbon and environmental protection industries, which significantly improves the energy and environmental protection efficiency of FDI enterprises, reduces the emission of pollutants, promotes the green upgrading of enterprises, and thus improves the regional ECEP.

5.4.2. Green technology innovation(GTI)

As shown in column (2), the regression coefficient of the product term of FDI quality and green technology innovation GTI_{it} is significantly positive, indicating that green technology innovation enhances the positive influence of FDI quality on ECEP. This result indicates that the improvement of FDI quality promotes regional economic development, and more funds can be invested in the research and development of green and environmental protection technologies, thus affecting the improvement of regional ECEP.

5.4.3. Upgrading of industrial structure(UIS)

As shown in column (3), the regression coefficient of the product term of FDI quality and industrial structure upgrading UIS_{it} is significantly positive, indicating that industrial structure upgrading can enhance the positive impact of FDI quality on ECEP [47]. Hypothesis 2 is verified. The possible reason is that the improvement of FDI quality makes more FDI flow into the secondary and tertiary industries, thus promoting the upgrading of regional industrial structure. At the same time, the improvement of FDI quality will generate technology spillover effect, promote the improvement of production technology and productivity of enterprises, further enhance the optimization of industrial structure and further improve the efficiency of regional energy consumption and reduce carbon emissions.

Based on the dynamic threshold panel model of SEO and shin (2016), this paper established a dynamic threshold model and obtained the results in Table 6 from equation (5), showing the single threshold regression results of the energy-carbon emission effect of variables such as economic growth pressure and fiscal decentralization on FDI quality. Column (1) indicates that local economic growth pressure has a single threshold effect on FDI quality energy-carbon emission effect. When the local economic growth pressure is

Table 5
Inspection of channels and mechanisms.

Variable	ECEP (1)	ECEP (2)	ECEP (3)
FDI	−0.435*** (−9.10)	−0.165*** (−4.00)	0.081*** (3.66)
FDI*RED	0.091*** (11.93)		
FDI*GTI		0.007*** (7.06)	
FDI*UIS			0.053** (2.01)
Control variables	Yes	Yes	Yes
Year	Yes	Yes	Yes
State	Yes	Yes	Yes
_cons	−2.084*** (−3.39)	−1.005 (−1.46)	−2.440*** (−3.56)
R2	0.886	0.855	0.867
N	570	570	570

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses.

Table 6
Threshold effect result.

Variable	D = lnegp	D = lnfid
L1.ECEP	0.890*** (33.00)	0.875*** (32.93)
Below_thres_enr	0.095*** (3.04)	0.074** (2.28)
Above_thres_enr	0.072** (2.25)	0.098*** (3.14)
Control variables	Yes	Yes
Year	Yes	Yes
State	Yes	Yes
Threshold value	−2.622	−0.117
N	570	570

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses.

less than or equal to the threshold value −2.622, the FDI quality caused by the local economic growth pressure has a significant effect on energy-carbon emission; when the threshold value is exceeded, the increase of the local economic growth pressure leads to the significant but decreasing effect of FDI quality on energy-carbon emission performance. This indicates that when the pressure of local economic growth increases, local governments are more likely to take economic growth as the goal to reduce the expenditure on environmental quality, thus inhibiting FDI's ECEP [48].

Column (2) shows that fiscal decentralization has a single threshold effect on ECEP of FDI quality. When fiscal decentralization is less than or equal to the threshold value −0.117, FDI quality caused by local fiscal decentralization has a significant effect on ECEP; when beyond the threshold value, the improvement of fiscal decentralization leads to a significant effect and improved effect of FDI quality on ECEP [26]. This indicates that when the decentralization and autonomy is improved, the government can increase the environmental governance expenditure and environmental protection subsidies to promote enterprises to engage in more green technology innovation activities, thus significantly promoting the ECEP effect of FDI.

6. Robustness test

6.1. Endogeneity problem

Consider the possible reverse causal relationship between FDI quality and local ECEP, where areas with higher energy-environment performance are more likely to introduce high-quality FDI. In attempting to solve the endogeneity problem, we take the practice of [48–50] as reference to conduct regression of FDI quality with first-order lag and second-order lag respectively. From column (1) and (2) of Table 7, it can be seen that FDI quality of the lag order has a significant positive impact on ECEP. From the positive and negative attributes and significance of coefficient values of the estimation results of the lag effect, the estimated results are still robust, which further proves that the influence of FDI quality on energy conservation and emission reduction has a lag effect [51–53]. In order to further mitigate the deviation of estimation results caused by the endogenous problem of variables, this paper draws on the practice of [54–57] and uses the first-order and second-order FDI quality lag as instrumental variables (IV) to perform the two-stage least square method (2SLS) estimation, as shown in Column (3) in Table 7. The results are still significant.

Table 7
Robustness tests.

Variable	Explanatory variable lag		IV-2SLS	Replace the explanatory variable
	ECEP (1)	ECEP (2)	ECEP (3)	ECEP (4)
FDI	0.098*** (4.37)	0.086*** (3.71)	0.106*** (3.98)	0.059*** (2.72)
DFI	0.024 (0.67)	0.054 (1.49)	0.022 (0.46)	0.202*** (5.20)
ERL	−0.071*** (−4.98)	−0.065*** (−4.51)	−0.069*** (−4.31)	−0.083*** (−5.42)
GOVERNMENT	−0.414*** (−4.68)	−0.497*** (−5.48)	−0.406*** (−4.08)	−0.408*** (−4.76)
INF	−0.210*** (−3.85)	−0.195*** (−3.33)	−0.219*** (−4.44)	−0.105* (−1.92)
HC	−0.052 (−0.16)	0.053 (0.17)	−0.053*** (−0.17)	−0.297 (−0.97)
Year	Yes	Yes	Yes	Yes
State	Yes	Yes	Yes	Yes
_cons	−1.375** (−1.87)	−1.885** (−2.43)	−0.315 (−0.38)	−1.731** (−2.50)
Underidentification test			141.204	
Weak instrumental variable checking			1435.323	
Overrecognition test			0.000	
R2	0.860	0.860	0.935	0.860
N	540	510	510	494

Notes: *, **, and *** indicate the significance at the confidence level of 10%, 5%, and 1%, separately; t-statistics in parentheses. Kleibergen-Paap rk LM statistic, Kleibergen-Paap rk Wald F statistic and Hansen J statistic for insufficient, weak instrumental variables and over-identification, respectively.

6.2. Change in the sample range

In order to eliminate the bias of estimation results caused by differences in regional economic development levels, and enhance the general adaptability of FDI quality to regional ECEP results, and considering that Beijing, Tianjin and Chongqing, the four municipalities directly under the central Government, are relatively developed in economy and have certain advantages in FDI quality, energy conservation and emission reduction, this paper will exclude sample data of municipalities directly under the central government and then conduct regression analysis. As shown in column (4) of Table 7, the positive impact of FDI quality on regional ECEP is significant at the 1% level, and the estimated results in this paper have good robustness.

7. Conclusion and policy implications

7.1. Conclusion

This paper explores the effect of FDI quality on ECEP by using 30 provincial administrative regions in China during 2001–2019. The empirical results show that: (i) FDI quality can significantly affect regional energy-carbon emission performance, which is conducive to regional green development. This conclusion is still valid after a series of robustness tests including endogeneity test and sample range change. (ii) The development level of renewable energy, green technology innovation and industrial structure upgrading have strengthened the impact of FDI on ECEP. With the change of regional economic growth pressure and fiscal decentralization, the positive influence of FDI quality on ECEP has a significant single threshold effect. When the economic growth pressure crosses the threshold value, the energy carbon emission effect of FDI quality presents a marginal decreasing feature, while when the fiscal decentralization crosses the threshold value, the energy carbon emission effect of FDI quality presents a marginal increasing feature. (iii) The influence of FDI quality on regional energy-carbon emission performance is characterized by heterogeneity, and the promotion effect is more obvious in central and western regions and inland regions. (iv) Among the five dimensions of FDI quality, management level, scale and export level have a significant positive effect on ECEP, while technology level has a significant negative effect on ECEP, while FDI profit level has no significant effect on ECEP.

7.2. Policy implications

The research conclusions of this paper are helpful to deepen the understanding of the quality improvement of FDI, and can provide references for local governments to formulate policies to introduce FDI and assess the quality of FDI, and comprehensively analyze the economic and environmental effects of FDI. First, foreign capital with high management level, advanced technology and high added value should be introduced to improve the technological level of the country through the spillover of advanced management and technology brought by foreign capital, and the quality of export products should be improved through the export of high added value FDI. At the same time, on the premise of ensuring the quality of FDI, further expand the scale of foreign investment into the green environmental protection industry.

Secondly, FDI should be introduced differentiated according to the characteristics of economic development in different regions. It is suggested to introduce FDI with high added value to the eastern region with large export scale, so as to improve the quality and efficiency of export and reduce energy consumption and carbon emission. For the central and western regions, it is suggested to introduce FDI with high management level and advanced technology to maximize the technological spillover of FDI and improve the technical level and environmental quality of the central and western regions.

Third, to prevent developed countries from transferring backward industries with high pollution and energy consumption to China, and to avoid becoming the "pollution refuge" for polluting enterprises in developed countries, FDI should be evaluated and selected, a long-term management mechanism should be implemented, and ecological assessment standards should be introduced to promote the transition of FDI to neutral investment and then to high-quality investment.

Finally, according to the conclusions of this paper, China should continuously improve the quality of foreign investment while expanding the scale of investment introduction, improve the foreign direct investment evaluation system by drawing lessons from the design experience of developed countries such as Europe and the United States, and give full play to the green technology spillover effect of high-quality foreign investment, so as to promote domestic enterprises to benchmark the environmental protection standards of Europe and the United States, and achieve high-quality and sustainable development of regional economy.

7.3. Limitations

This paper studies the impact of FDI quality on regional energy-carbon emission performance. However, there is still some room for improvement in the research perspective. (i) This paper draws corresponding conclusions by analyzing macro data of 30 provinces, cities and autonomous regions in China and draws corresponding conclusions, but there is no evidence at the city or micro enterprise level. We can consider using the microscopic data of industrial enterprises or listed companies at the city level for research and discussion. (ii) The influence of FDI from different countries on the ECEP of the host country can also be studied and analyzed from the perspective of the source country of FDI.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Fei Wang: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Linwei Ye:** Conceptualization. **Xiaohua Zeng:** Methodology, Supervision. **Wei Zhang:** Supervision.

Declaration of competing interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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