FDI Quality, Technology Absorption Capacity and Renewable Energy Total Factor Productivity - Mechanism Analysis Based on Quartile Regression Analysis of Belt and Road Countries

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ABSTRACT

Based on the renewable energy industry of the countries along the "Belt and Road", this paper selects the panel data from 2000 to 2020 to study the mechanism of the Foreigner Direct Investment (FDI) quality on the Renewable Energy Total Factor Productivity (RTFP) of the host country through the technology absorption capacity, furthermore, takes 2015 as a node to compare the changes in the RTFP after accession to the "Belt and Road". The finding shows that: (1) FDI quality significantly promote the RTFP in the host country, and the growth is obvious after 2015; (2) the technology absorption capacity can strengthen the spillover effect of FDI quality, the moderating effect was significant and the value is 0.032; (3) the FDI quality plays a facilitating role in RTFP through the dimensions of FDI production capacity and FDI technological contribution, but the impact of FDI localization is not significant. In addition, for countries with low RTFP, the promotional effect of technology absorption capacity is not significant, and as the RTFP continues to improve, the more significant of technology absorption capacity on FDI quality technology spillover. Therefore, Belt and Road countries should improve the quality of their FDI and increase their investment in R&D in conjunction with the upgrading of industrial to enhance their technological absorptive capacity. At the same time, by taking advantage of the member countries of the "Belt and Road" economic cooperation, realizing the development of renewable energy industry.

1.Introduction

The development and utilization of renewable energy have become important means for many countries to improve their energy structure, cope with global warming, and achieve sustainable socio-economic development [1]. According to the report of the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), Asia, Eastern Europe, and Latin America have become active regions in the development of renewable energy. In terms of employment opportunities created by the renewable energy industry, the Asian region has consistently accounted for more than 60% of the global proportion [2], and the proportion of FDI in the field of renewable energy in this region is the second largest in the world, second only to the European region [3].

Compared with traditional fossil energy, renewable energy is more dependent on the natural environment, application technology, and capital, which also causes the renewable energy industry to face practical difficulties such as technology, cost, and promotion [4], resulting in the weaker willingness of market players to independently develop relevant technologies, and thus the RTFP is relatively low. Globally, the improvement of RTFP in various countries mainly relies on the input of capital and manpower, but due to the different levels of economic development and industrialization in various countries, the strength of capital and manpower input for the renewable energy industry is heterogeneous.

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In order to solve the difficulties of renewable energy industry, such as lack of capital, backward infrastructure, and weak technology, countries generally choose to introduce FDI, which can generally meet the needs of host countries in terms of capital, management experience, and advanced technology for the development of the renewable energy industry, and thus improve the total factor productivity of the industry. However, the impact of FDI on RTFP has a two-way result, namely, the "pollution paradise" effect [5] and "efficiency halo" effect [6,7]: the introduction of a large number of labor-intensive FDI to a certain extent on the local ecological environment to produce more pressure, technology-intensive FDI will produce more technology spillover effect, can effectively improve the host country's ren ewable energy total factor productivity, but with the enhancement of technical barriers, FDI brought by the technology spillover effect has a greater weakening, the country with higher technology absorption capacity can be more fully enjo y the technology spillover brought by the FDI, and vice versa, will produce the technology crowding out effect, which re quires that the countries to improve the quality of FDI.

Therefore, how to improve the quality of FDI and make it promote energy efficiency in host countries has become a concerned subject for scholars. Under the background of trade globalization, in order to achieve sustainable economic growth and development, countries have formed a number of economic cooperation organizations, and member countries actively absorb high-quality FDI through deepening cooperation, joint development, expanding trade, and other ways to promote the development of their own economies. China put forward the initiative of building the "Belt and Road" economic cooperation in 2013, and now more than 150 countries and economic organizations have particip ated [8]. Based on the principle of "common business, common construction, common sharing," this initiative aims to p romote in-depth and multidisciplinary cooperation and facilitate the flow of FDI among member countries.

Against this background, this paper aims to complement the current empirical research on FDI quality and renewable energy productivity, especially after the establishment of the Belt and Road economic cooperation organization (BRI) on renewable energy productivity in member countries. The main contributions of this paper are: (1) innovating the evaluation system of FDI quality (QFDI), which is complementary and informative to the current research on QFDI; (2) taking RTFP as the research objective, placing RTFP, QFDI, and technology absorption capacity in the same theoretical framework, which innovates the perspective of research on RTFP; (3) explicitly calculating the technology absorption capacity's moderating effect; (4) innovatively researching the mechanism of QFDI's influence on RTFP; (5) illustrating the important role of technology absorption capacity on RTFP of each country through quantile regression.

The remainder chapters of this paper are organized as follows: chapter 2 presents the literature review, which provides the theoretical and empirical support for this study; chapter 3 describes the econometric model and sample data; chapter 4 reports the results of the data analysis and develops the findings; chapter 5 discusses the findings and develops the conclusions of the study, as well as proposes countermeasures for countries to improve the RTFP, and finally states the research limitations and the future research plan.

2. Literature Review and Hypotheses Development

Scholars have conducted more studies on the role of FDI, and it is generally confirmed that FDI is the main form of international flow of capital, which plays an important role in the development of relevant industries in the host country. Chawla and Kumar [9] indicated that the introduction of FDI can improve production capacity and international trade through learning advanced international trade experience from multinational corporations, and ultimately improve its position in the global value chain and inject vitality into the economic development of the host country. Fazaalloh [10] claimed that FDI can effectively bring real benefits to the host country, at the same time, due to the technology transfer and accumulation brought by FDI, it enhances the production efficiency of the host country, and the production efficiency of different industries has been improved to different degrees. Sahoo and Dash [11] stated that FDI has a complementary effect on the exports of the host country, especially for the emerging countries. FDI plays an important role in the industrial development of the host country through the direct role of capital and indirect technology transfer [12,13].

2.1 FDI and RTFP

It has become a consensus that FDI can promote the economic development of the host country, but to achieve the goal of sustainable economic development, a more in-depth study on the improvement of economic efficiency by FDI is needed. In recent years, scholars have researched the results of FDI and RTFP, of which there are two main views: positive and negative.

Tiwari et al. [14] analyzed the panel data of 16 Asian economies and concluded that in countries where capital is relatively scarce, FDI promotes the use of renewable energy in the host country through investment activities, which contributes to the improvement of RTFP. Gyimah and Yao [15], by comparing the structure of energy consumption in African countries, concluded that FDI plays a promotion role in the use of renewable energy, in addition, the promotion of the application of renewable energy in the host country can also attract more FDI inflows. Saqib and Dinca [16] concluded that FDI can increase the utilization rate of renewable energy in the host country to reduce environmental pollution, at the same time, improve the efficiency of the use of renewable energy.

Shahbaz et al. [17] studied the public-private cooperative investment in the energy sector in China and concluded that FDI participation in the process of energy construction stimulates carbon dioxide emissions, thus causing a decline in the quality of the ecological environment and inhibiting the RTFP, and this conclusion is similar to that of Doytch and Narayan [7], which indicates that FDI prioritizes the consumption of traditional energy sources, which is not conducive to the RTFP. Caetano et al. [5] used a panel autoregressive distribution lag model to study the relationship between FDI and renewable energy in OECD countries, and concluded that developed countries' transfer of their own energy-consuming industries through FDI increases the host country's energy use, especially the consumption of traditional energy, which is detrimental to the development of the host country's renewable energy industry. Voumik et al. [18], through the study of Australia's energy structure, claimed that FDI will consume more energy through production activities and increased employment, and the consumption of traditional energy will increase the burden on the environment, the use of renewable energy can effectively change the quality of economic development in the long-term development.

In summary, FDI has a two-way effect on the host country, which is manifested as follows: 1. FDI can provide the host country with sufficient financial flows and drive the technological progress of the host country through technological spillover, and the host country's imitation and learning of the advanced technology or secondary development can effectively reduce the cost of new technological development, which improves the total factor productivity of the host country; 2. FDI can cause technological monopoly or transfer of backward production capacity to the host country, the typical conclusion is “pollution transfer”, resulting in a negative relationship of FDI on the total factor productivity of the host country.

2.2 FDI and Technology Absorption Capacity

Most scholars claimed that there is a positive correlation between FDI technology spillover and host country's technology absorption capacity. Mahbub et al. [19] indicated that FDI can have a driving effect on host country's technological progress through technology transfer and technology spillover effect, in addition, FDI's own financial advantage is conducive to host country to carry out further technological innovations, but the host country must implement effective policies to encourage the innovation of local firms. Qamruzzaman [20] argued that FDI not only accelerates capital accumulation in the host country, but also improves the host country's production capacity, labor force quality and market management level through management experience and technology transfer. Bournakis and Tsionas [21] proposed a new method to measure the spillover effect of FDI by analyzing the data at the enterprise level, which indicated that the spillover effects of FDI depends on the technology absorption capacity of the firms.

Technology spillover and cross-border management experience are the main advantages of FDI to the host country [22,23], but due to the imbalance of scientific and economic development of each country, the technology spillover effect generated by FDI needs to improve its technology absorption capacity [24,25]. Kottaridi et al. [26] claimed that improving education investment can enhance the quality of labor force, higher learning ability can fully absorb the results of technology spillover generated by FDI, on the other hand, higher labor quality can absorb better quality FDI. Moralles and Moreno [24], after studying the impact of FDI in Brazilian counties, confirmed that only when the local technology absorption capacity exceeds a certain threshold can it positively contribute to the increase in productivity. Furthermore, when the technology receiver and the FDI investor are geographically closer, the positive effect is higher. Nam et al. [27] claimed that the technology absorption capacity of the host country is an important regulator of the positive FDI spillover effect, and the government needs to formulate more macro policies to guide and promote the improvement of the local technology absorption capacity.

On the contrary, some scholars indicated that due to the large gap between the initial technology level of FDI and the initial level of local enterprises, the technology spillover effect is not significant, but the “technology crowding out” effect is obvious [28,29], which inhibit the host country's technology absorption capacity to improve, however, with the deepening of research, the reason for the insignificant lies in the inability of local enterprises to effectively identify, transform and absorb advanced technologies [30]. This paper claims that the reason lies in the inability to accurately locate the role of the influence of technology absorption capacity, which leads to the host country's neglect of the macro-guidance.

The divergence of the above findings may stem from the heterogeneity of the degree of technology spillovers from different FDIs and the host country's technology absorption capacity. Therefore, what role does technology absorption capability play in the relationship between FDI and industry total factor productivity? This requires more in-depth research.

2.3 FDI Quality

The core connotation of QFDI is the positive benefits brought by FDI to the host country, including new knowledge , industrial technology capacity improving, and commodity market competitiveness, etc. [31]. Pan et al. [32] used seemingly unrelated regression (SUR) method to study the FDI in Chinese provinces, which concluded that that the impact of FDI is somewhat hidden, so the study of the impact of FDI on energy efficiency needs to study from the perspective of the quality of FDI. Wang and Luo [33] analyzed the relationship between QFDI and carbon emissions, which concluded that when the QFDI is low, the effect is not significant, and as the QFDI continues to improve, the environmental pollution is gradually suppressed. Becker et al. [34] argued that from the perspective of the regulating role of the corporate tax, that the government should not reduce corporate tax to attract FDI, should focus on the improvement of FDI quality, FDI quality can significantly improve the contribution to labor income, while improving the efficiency of the development of technology-intensive industries. Li and Xiao [35] analyzed the impact mechanism of business environment on the QFDI, in the affirmation of the positive role of the FDI quality, that a good business environment, higher quality of labor force, better ecological environment and social environment can improve the QFDI and maximize the technology spillover effect of FDI.

Due to the two-way role of FDI, scholars are prompted to pay more attention to the QFDI, but there is not yet a unified view on the way of evaluating the QFDI, according to the literature, this paper selects a representative evaluation method, as shown in Table 1:

Table1 QFDI Evaluation Methodology Statistics

Author	Methodology	Indicator
Pan et al. [32]	Alternative Variable	Labor productivity in the FDI industrial tors/ Labor productivity in the industrial tors above designated size
Becker et al. [34]	Alternative Variable	profitability and payroll intensity of investment
Zhang [36]	Principal Component Analysis	FDI scale, share of manufacturing investment, total exports, technology spillovers
Wang et al. [31]	Principal Component Analysis	Profitability, management capacity, technology level, FDI scale, export capacity
Famanta et al. [37]	Segmentation method	Total FDI in low-carbon production and service sectors

It is necessary for countries to strengthen the introduction of FDI, however, it must comprehensively consider own endowment and technology absorption capacity, choose the one suitable for needs. Compared with the traditional FDI evaluation system, improving the QFDI can more significantly improve the total factor productivity of the host country's industry. In the field of renewable energy, there is a relative lack of results in the study of the QFDI and the RTFP of host country, there is a practical significance for further research.

2.4 Framework and Hypothesis

Based on the literature analysis tabled above, scholars have made useful researches on the relationship between FDI and total factor efficiency of the industry, the technology spillover and technology absorption capacity. However, there is a relative lack of research on the QFDI in the field of renewable energy industry, which is mainly manifested in the following aspects: 1) FDI is studied as a whole as a homogeneous factor, the quantitative indicators such as FDI flow, FDI stock, FDI share of GDP, and so on cannot accurately portray the mechanism of FDI quality on the host country, nor can answer what kind of FDI is more favored by the host country; 2) There are more studies on the correlation between the FDI technology spillover and the host country's technology absorption, which claimed that the stronger the host country's technology absorption capacity, the more adequate the efficiency of the FDI technology spillover, however, the upgrading

process of host country's technology absorption capacity is not considered. Therefore, based on previous studies, this paper answers what kind of FDI is more able to promote the RTFP of the host country through the impact of QFDI, furthermore, considers the technology absorption capacity as a mediator variable to explore the mechanism of the impact of QFDI quality on RTFP of the host country. The theoretical framework is shown in Figure 1.

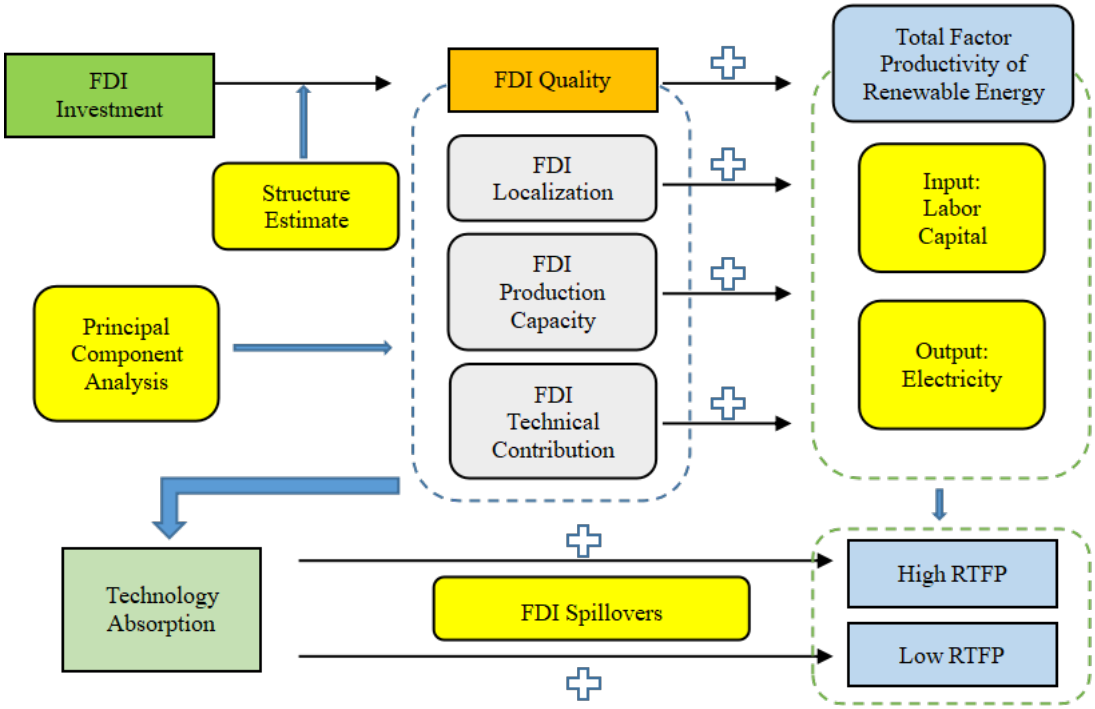

Figure1 Theoretical Framework

According to the theory of development economics and national development experience, the improvement of productivity mainly relies on the input of labor and capital, therefore, this paper from the perspective of FDI quality, firstly, constructs the QFDI evaluation index system, and then observes the development change of QFDI on the RTFP of host country. On this basis, considering the influence of the host country's technology absorption capacity, this paper will deeply explore the influence mechanism of QFDI on the RTFP of the host country.

According to the literature analysis and the framework of this paper, FDI has a two-way effect [38-40]: Through management practices, technical training and other ways to cultivate a large number of talents for the host country, to promote the host country's RTFP, on the contrary, due to the introduction of FDI, resulting in the intensification of competition in host country market competition has intensified and entered a rapid "survival of the fittest" stage, whic h may lead to a significant crowding out effect and inhibit the improvement of RTFP. Therefore, the host country is not a large number of FDI can achieve the improvement of RTFP, it should be chosen high quality FDI, which can be better im prove the host country's economic development.

Due to the existence of a certain degree of concealment of the impact role of FDI, and the current QFDI evaluation system mostly takes FDI scale, export scale, investment structure, and so on as indicator variables [31,36,41], which cannot accurately locate the impact role of FDI in the industry, especially the renewable energy industry is an emerging industry with clear industry characteristics. Therefore, based on the research of previous scholars, this paper constructs a new QFDI evaluation system for the renewable energy industry, taking the FDI localization, the FDI production capacity, and the FDI technical contribution as the constituent indexes, comprehensively evaluating the QFDI in the renewable energy industry.

FDI localization refers to the contribution of FDI in the renewable energy industry to the development of the local economy, FDI as a capital factor, first of all, to provide financial support for the development of the industry in the host

country [41], the total amount of FDI in the industry is the basic indicator of the QFDI; FDI production capacity is a characteristic factor in the renewable energy industry and refers to the proportion of the growth in the amount of electricity generated by renewable energy. The main product of renewable energy is electricity, and it is a clean power energy [42,43], therefore, the more FDI investment in the renewable energy industry, the more power growth in output means the higher the QFDI; FDI technical contribution is an indicator representing the FDI technology spillover, which is calculated by the change in energy consumption, and the more adequately the technological spillover is digested by the industry, the more conducive it is to the renewable energy productivity improvement, meanwhile, has a driving effect on the upgrading of energy consumption structure [44,45].

Based on the above analysis, Hypothesis 1 is proposed:
H1: QFDI has a positive effect on RTFP in the host country.
H1a: FDI localization has a positive effect on RTFP in the host country.
H1b: FDI production capacity has a positive effect on RTFP in the host country.
H1c: FDI technical contribution has a positive effect on RTFP in the host country.

Scientific and technology progress is an important booster to realize the healthy and sustainable development of the national economy. Technologically backward countries or regions, through the introduction of FDI, obtain the technological spillover and narrow the gap with technologically advanced countries through their own technology absorption capacity [46,47]. However, as technologically advanced countries increase the protection of their own technology, it need to improve the host country's technology absorption capacity in order to promote technological progress [28,48]. Therefore, when the national technology absorption capacity is weak, the crowding-out effect generated by FDI may be larger than the spillover effect, and when the national technology absorption capacity is strong , FDI plays a fuller role in RTFP [49,50]. It can be seen that the level of host country's technology absorption capacity has a significant moderating effect on the QFDI performance. Based on the above analysis, hypothesis 2 is proposed:

H2: Technology absorption capacity positively affects the path of QFDI on RTFP.
H2a: Technology absorption capacity has a positive impact on the absorption of FDI spillovers in low RTFP countries.
H2b: Technology absorption capacity has a positive impact on the absorption of FDI spillovers in high RTFP countries.

3.Model Development and Sample Data

3.1Basic Econometric Model

According to the framework, this paper combs the empirical research results on QFDI, RTFP and technology absorption capacity in recent years, as shown in Table 2:

Table 2 Empirical Findings of FDI， RTFP, and Technology Absorption Capacity

Author	RTFP	QFDI	Technology Absorption Capacity	Methodology
Wang et al. [31]	/	QFDI：profitability，management，technical，scale，export	/	Fix model of regression
Pan et al. [32]	SBM-DEA：Input: energy, capital, and labor；Output: CO2 and GDP	QFDI: Productivity in FDI sector/ total productivity	RD intensity	Seemingly unrelated regression
Famanta et al. [37]	/	Green FDI: FDI in carbon-free processes and low-carbon goods and services	/	Feasible generalized least squares
Nyangchak [51]	Super-SBM：Input：fixed asset investment, labor, and energy；Output: CO2 and GDP	/	/	Regression
Saqib [16]	/	FDI net inflows/GDP	Renewable energy patents/total patents	Regression
Wang and Luo [33]	/	QFDI: performance index of FDI	Patent applications accepted per ten thousand people	EKC theoretical model

According Table 2, regression is a commonly used method to study the relationship between the variables, based on this, this paper also uses regression analysis to develop the underlying econometric model, see Equation (1):

$$RTFP_{it} = \alpha_1 Qfdi_{it} + \alpha_j C_{it} + \mu_{it} + \varepsilon_{it} \quad (1)$$

Where, RTFPit denotes renewable energy total factor productivity, Qfdiit denotes FDI quality, α is the coefficient of each variable, C is the set of control variables, i represents the country, t represents the time, μ_{it} is the fixed effect, and ε_{it} is the random perturbation term. Further, the following model is developed by considering the influential role of the host country's technology absorption capacity, see Equation (2):

$$RTFP_{it} = \alpha_1 Qfdi_{it} + \alpha_2 Tech_{it} + \alpha_j C_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

Where, Tech denotes technology absorption capacity and other variables have the same meaning as Equation (1). Through the introduction of technology absorption capacity, the impact of QFDI on RTFP is comparatively analyzed. In order to clarify the specific effect played by technology absorption capacity, this paper draws on the methods of Wu et al. (52)and He et al. He et al. (53) to measure the specific impact role of technology absorption capacity, see Equation (3) - (5):

$$RTFP_{it} = a * Tech_{it} + \alpha_j C_{it} + \mu_{it} + \varepsilon_{it} \quad (3)$$

$$Qfdi_{it} = b * Tech_{it} + \alpha_j C_{it} + \mu_{it} + \varepsilon_{it} \quad (4)$$

$$RTFP_{it} = c * Qfdi_{it} + d * Tech_{it} + \alpha_j C_{it} + \mu_{it} + \varepsilon_{it} \quad (5)$$

Based on Equation (3) - (5), if the coefficients are all significant, it means that technology absorption capacity plays a moderating role, the specific moderating value is bc, and bc=a-d.

3.2 Variables Measurement

3.2.1 Renewable Energy Total Factor Productivity

According to the literature, this paper adopts the non-parametric data envelopment analysis (DEA) to measure the RTFP in each country, according to the DEA model, the capital input factor is considered as the total invested capital of renewable energy in each country, and the labor input factor is considered as the number of employment in the renewable energy industry, however, due to the serious lack of data in this item, this paper adopts renewable energy carbon emissions/total carbon emissions as the conversion factor of the indicators of renewable energy. Therefore, the number of people employed in the renewable energy industry = the number of people employed in the industry ×conversion factor. The output factor is considered as the total annual renewable energy power generation in the host country, since renewable energy power generation produces almost no carbon emissions, this paper does not consider the unde sired output.

3.2.2 Foreigner Direct Investment

This paper draws on the measurement principles of Wang et al. (2024) and Zhang (2024) to develop QFDI measurement model from three perspectives (see Table 3):

Table 3 Evaluation System of QFDI

Indicator	Code	Explanation	Source	Data Source
FDI localization	LD	Total actual utilization of renewable energy FDI/ industrial value added above designated size	Saqib [16]	World Bank
FDI production capacity	PC	Growth of renewable energy generation/growth of national energy electricity	Pan et al. [32]	IRENA
FDI technical contribution	TC	Renewable energy consumption/total energy consumption	Wang et al. [31]	IEA

(1) FDI localization (LD), the degree of localization reflects the FDI investment to the host country to bring the actual value added to the industry, but also through the ratio of inputs to outputs to measure the economic quality of FDI, in this paper, LD is expressed by the renewable energy industry FDI total divided by the value added to the industry.

(2) FDI production capacity (PC), this indicator mainly reflects the impact of FDI investment on the output of the renewable energy industry, as the final product of the renewable energy industry is still dominated by electricity, PC is expressed by the growth of renewable electricity divided by the total growth of the country's electricity.

(3) FDI technical contribution (TC), this indicator mainly considers that FDI, through technological transformation, improves the consumption of renewable energy in the host country and reduces the consumption of traditional energy, so as to achieve the goal of transformation of the energy structure, meanwhile, the higher the technological of FDI, the greater the impact on the transformation of the energy structure, so this paper adopts the consumption of renewable energy divided by the country's total consumption of energy to express TC.

According to the above indicators to develop QFDI evaluation system, this paper adopts the principal component analysis to measurement three dimensions, see Equation (6):

$$\mathrm{Qfdi}_{it} = A(LD, PC, TC) + a_{ij}\varepsilon \qquad (6)$$

Where, A is the factor loading matrix, $A(\cdot)$ is the matrix of each factor, a_{ij} is the standardized coefficients, ε is the special factor, which denotes the portion that cannot be explained by the factor indicators.

3.2.3 Technology Absorption Capacity

According to the empirical results of scholars, there are more methods to measure technology absorption capacity , such as the number of tertiary educations, the number of scientific per million people, the government's public expenditure on education, the number of patents, and the full-time workload of scientific, and so on [33,54]. This paper draws on the methodology of Ahamed et al. [55] and Pan et al. [32], claims that the R&D intensity represents the host country's emphasis on scientific development, higher R&D investment can promote the development of science and technology in the country, so this paper takes R&D intensity as a representative indicator of the host country's technology absorption capacity.

3.2.4 Control Variables

(1) The level of economic development (gdp). The level of economic development has a significant impact on the degree of development of the national renewable energy industry, at the same time, countries with a high level of economic development, the per capita disposable income is relatively high, which can support the market sales of renewable energy products [20,33]. Therefore, combined with the availability of data, this paper uses the GDP of each country to reflect the level of economic development, in order to eliminate the impact of inflation and other factors, the index is converted to the standard 2015 constant dollars.

(2) Industrial structure (industrial). The industrial structure affects the national economic development, renewable energy industry is mainly subordinate to the secondary industry, renewable energy in the secondary industry utilization for a larger proportion is conducive to secondary industry structural adjustment, furthermore, has a positive effect on the total factor productivity in host country or region (31). In this paper, the value added of the secondary industry in each country is divided by GDP to reflect the industrial structure indicators.

(3)The level of urbanization (urbanization). According to the special nature of renewable energy products, the consumption of energy in cities is much higher than that in rural areas, which effectively improves the structure of energy use in cities. Higher urbanization is conducive to the improvement of RTFP, however, with more population consume energy, higher urbanization may lead to more emission (18,37,56). In this paper, the urban population divided by the total population is used to reflect the indicator of urbanization level.

(4) The degree of openness (openness). The degree of openness affects the willingness of the host country to absorb FDI, what ' s more, according to the theory of international trade, the production efficiency of outward-oriented enterprises is higher than that of inward-oriented enterprises, a high degree of openness, which is conducive to the renewable energy industry, "Going out" and "Bringing in", resulting in improving the RTFP (10,57). This paper uses the export value divided by GDP to reflect the degree of openness.

3.3 Robustness Test Model

Combined with the research objectives, this paper adopts two robustness tests, the first is to draw on conducting the sub-dimension analysis of Wang et al. (31), to test the effect of three sub-dimension variables, which constitute the QFDI, on the RTFP through the technology absorption capacity. The second method is to draw on the quantile regression method of Khan et al. (58) to observe the role of technology absorption capacity in influencing RTFP while conducting robustness analysis by dividing the explanatory variables into three sets of data, namely, $0 \leq$ RTFP < 25%, 25% $\leq$ RTFP < 50%, 50% $\leq$RTFP < 75%.

3.4 Sample and Data

Taking the panel data of renewable energy industry of member countries along the "Belt and Road" from 2000 to 2020, this paper investigates how the QFDI affects the RTFP in host countries. Due to the impact of COVID-19 pandemic, some countries' data in 2021-2023 are seriously missing, therefore, based on the availability and completeness of the data, this paper proposes four economies that have withdrawn from the first batch of 66 participating countries announced by the Chinese government in 2015: Latvia, Estonia, Lithuania, and Philippines, and deletes 38 economies with serious missing data: Afghanistan, Albania, Armenia, Bahrain, Bangladesh, Bhutan, Bosnia, Brunei, Cambodia, East Timor, Egypt, Georgia, Indonesia, Iran, Iraq, Jordan, Kuwait, and the United States. Jordan, Kuwait, Lao PDR, Lebanon, Macedonia, Maldives, Mongolia, Montenegro, Myanmar, Nepal, Oman, Pakistan, Palestine, Qatar, Sri Lanka, Syria. Tajikistan, Turkmenistan, United Arab Emirates, Vietnam, Yemen. Eventually, 25 countries panel data (including China) are retained for analysis.

These data are derived from UNESCO, World Bank, International Energy Agency (IEA) statistical reports and International Renewable Energy Agency (IRENA) statistics.

4.Finding

4.1 Empirical Test of QFDI and RTFP

According to the econometric model, the RTFP in 25 countries along the "Belt and Road" is measured from 2000 to 2020. Due to the large amount of data, the RTFP in each country is only reported for the years 2000, 2010 and 2020, as shown in Table 4:

Table 4 RTFP Statistic in “Belt and Road” Countries

Country	2000	2010	2020	Country	2000	2010	2020
Azerbaijan	0.1476	0.0077	0.7223	Poland	0.0101	0.0067	0.0071
Belarus	0.1223	0.0056	0.0915	Romania	0.0033	0.0157	0.0644
Bulgaria	0.0159	0.0522	0.0408	Russia	1	1	1
China	1	1	1	Saudi Arabia	0.0843	0.015	0.0027
Croatia	1	0.8981	0.0761	Serbia	0.0524	0.0141	0.008
Czechia	0.0102	0.0074	0.0068	Singapore	0.0588	0.0165	0.0085
Hungary	0.0138	0.0095	0.0466	Slovakia	0.2133	0.0281	0.0983
India	0.0087	0.0335	0.1269	Slovenia	0.4019	1	1
Israel	0.0015	0.001	0.0014	Thailand	0.0701	0.0896	0.0226
Kazakhstan	0.0913	0.0112	0.0063	Turkey	0.0391	0.132	0.1635
Kyrgyzstan	1	1	1	Ukraine	0.0144	0.0211	0.0219
Malaysia	0.0266	0.3365	0.419	Uzbekistan	0.065	0.0043	0.0011
Moldova	1	0.0502	0.3362				

Note: Data from IRENA and World Bank.

From Table 4, the RTFP gap is large, but the trend is upward, indicating that countries are gradually increasing the importance and investment in renewable energy industry. However, Croatia, Moldova, Slovakia and Thailand have abnormal values, which is manifested in the RTFP value in 2020 is significantly abnormal than the other years, combined with the original data, excluding the risk of data errors, the government input, employment and renewable energy generation growth appeared to varying degrees of reduction in four countries, resulting in the distance from the cross section.

Combined with the total amount of FDI, Poland, Turkey and other similarity countries, renewable energy input and the proportion of FDI capital are relatively high, but the RTFP is low, it can be seen that there is uncertainty in the mechanism of the impact of FDI on the RTFP, so there is a need to establish a system for evaluating the quality of FDI, which aims to fully absorbing the spillover effect of FDI through the introduction of high-quality FDI. According to the Equation (6), this paper evaluates the QFDI through three dimensions: FDI localization, FDI production capacity, FDI

technical contribution, which applies the principal component analysis method to calculate the final score to indicate the QFDI. Furthermore, takes 2015 as the boundary to analyze the changes in RTFP and QFDI of each member country after joining the “Belt and Road” (see Figures 2 and 3).

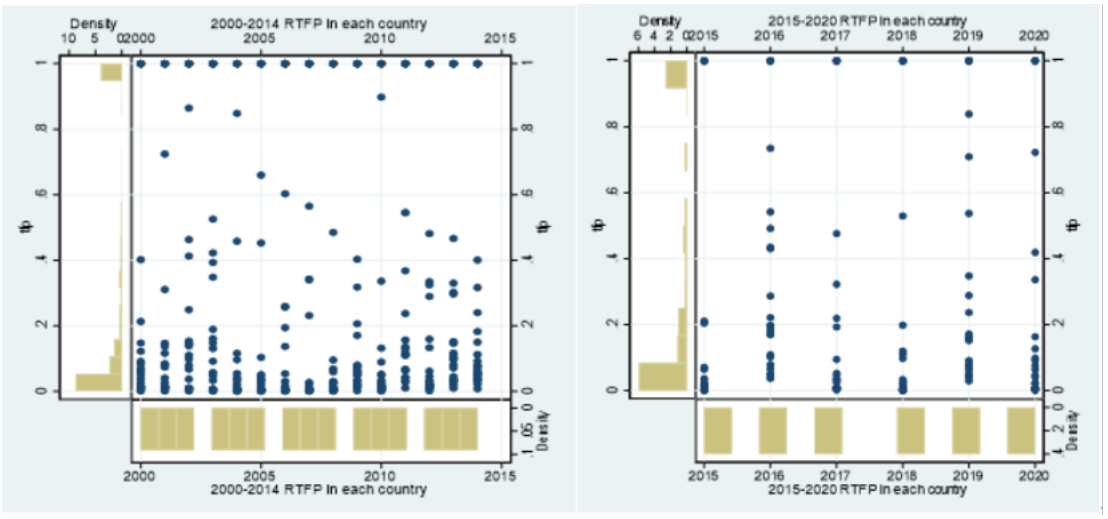

Figure 2 Statistics on RTFP Development in Countries Before and After 2015

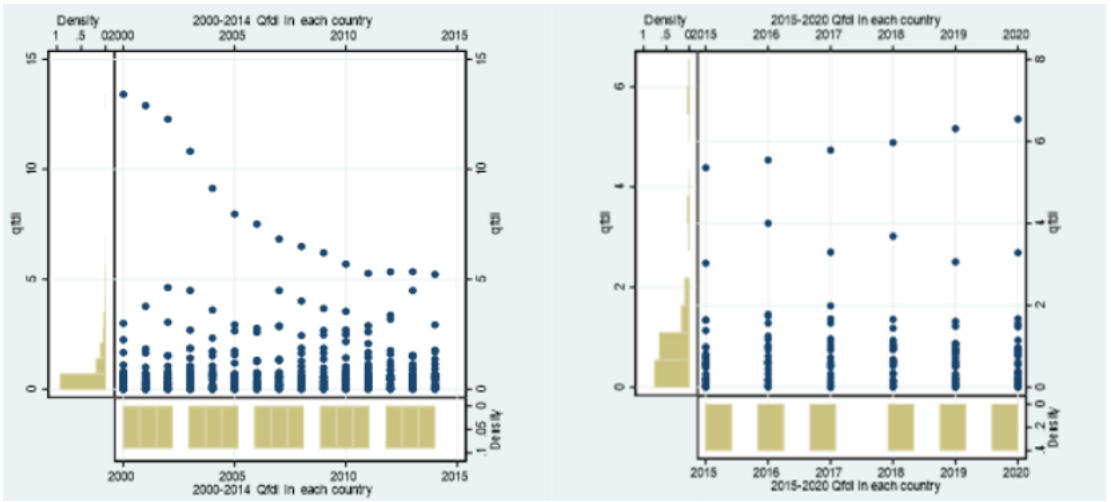

Figure 3 Statistics on QFDI Development in Countries Before and After 2015

From Figure 2, it can be seen that the RTFP of the Belt and Road member countries has generally increased after 2015, and the countries located at the low RTFP have obviously decreased, intermediate level has gradually increased; From Figure 3, it can be seen that the QFDI of the countries has appeared to rise significantly after 2015 and is gradually developing to a higher level, which means that after joining the “Belt and Road”, the countries, thr ough the economic cooperation and the joint consultation and construction, have truly promoted the development quality of renewable energy. In order to understand more clearly the role of QFDI on RTFP, this paper carries out statistical analysis of Equation (1)-(5).

Firstly, through the VIF test, the test value of each variable is less than 5, which determines that there is nomulticollinearity in the panel data and can be used to estimate the econometric model.According to the Hausman test, this paper should be analyzed using a fixed effects model, in order to reduce the impact of the dummy variables on the panel data, this paper adopts the Multi-Dimensional Panel Fixed Effect method for measurement (59), Table 5 reports the descriptive statistics of the panel data, and Table 6 reports the results of stepwise regression of Equation (1):

From Table 6, model (1)-(5) report the results of stepwise regression of QFDI and control variables on RTFP. QFDI positively promotes RTFP in host country and is significant at 1% level. Where for every 1% improvement in QFDI, the RTFP is able to improve by 0.111%, thus H1 of this paper is validated.

Table 5 Descriptive Statistics

VARIABLES	N	mean	sd	min	max
RTFP	525	0.293	0.392	0.0004	1
LD	525	0.193	0.321	0.0010	4.370
PC	525	0.888	1.053	0.0010	5.790
TC	525	1.511	3.415	0.0010	29.63
QFDI	525	1.017	1.634	0.0010	13.40
Tech	525	0.941	0.874	0.0423	5.706
lngdp	525	25.64	1.611	21.98	30.31
lnindustrial	525	3.404	0.273	2.814	4.197
lnurbanization	525	4.083	0.280	3.320	4.605
lnopenness	525	3.820	0.533	2.173	5.434

Table 6 Stepwise Regression Result of the Impact of QFDI on RTFP

VARIABLES	(1) RTFP	(2) RTFP	(3) RTFP	(4) RTFP	(5) RTFP	(6) RTFP
QFDI	0.098***	0.121***	0.121***	0.110***	0.111***	0.106***
	(10.16)	(11.66)	(11.62)	(9.94)	(9.99)	(9.49)
Tech						0.080***
						(3.47)
lngdp		-0.056***	-0.061***	-0.051***	-0.057***	-0.072***
		(-5.22)	(-5.39)	(-4.34)	(-4.37)	(-5.32)
lnindustrial			0.085	0.083	0.101	0.216***
			(1.39)	(1.37)	(1.60)	(3.04)
lnurbanization				-0.151**	-0.118*	-0.220***
				(-2.53)	(-1.74)	(-2.99)
lnopenness					-0.035	-0.053
					(-0.99)	(-1.51)
Constant	0.193***	1.597***	1.444***	1.833***	1.904***	2.336***
	(10.46)	(5.93)	(4.96)	(5.59)	(5.67)	(6.59)
Fixed	Yes	Yes	Yes	Yes	Yes	Yes
Observations	525	525	525	525	525	525
R-squared	0.192	0.234	0.237	0.246	0.248	0.266

Note: *** p<0.01, ** p<0.05, * p<0.1. t-statistics in parentheses.

Regarding the role of control variables: (1) The level of economic development is negatively correlated with RTFP, and the effect is significant, this result is contrary to expectations. The improvement of a country's economicle vel can provide more financial support for the development of renewable energy, but the results show that the level of economic development does not promote the growth of RTFP, this paper argues that the research sample is mostl y developing countries, and energy consumption per unit of GDP is also mainly rely on the contribution of non-rene wable energy, therefore, the increase in GDP did not form a positive promotion of renewable energy.

(2) The proportion of value added in the secondary industry is positively related to RTFP, but the effect is not significant. From the perspective of the impact relationship, the secondary industry is an important pillar of the economic development, but also a large energy consumption industry, the development of the secondary industry will inevitably bring about a large amount of energy consumption. A country wants to achieve the upgrade of the energy consumption structure, mainly relying on renewable energy sources, which will positively promote the development of the renewable energy industry, so as to improve the RTFP. (3) The level of urbanization is negatively correlated with the RTFP, which is significant at the 10% level. Higher urbanization level increases energy consumption, but at present the energy consumption of cities in all countries is still dominated by traditional energy, so the higher the level of urbanization, on the contrary, is not conducive to RTFP. (4) The openness is negatively correlated with RTFP, but the effect is not significant. The reason is that the current renewable energy products in a single form, mainly electricity, cannot effectively form the support of economic development, so temporarily show a negative correlation, but with the gradual improvement of the renewable energy system, the level of openness on RTFP will gradually turn into a positive direction.

In summary, the QFDI has a positive effect on the RTFP in host countries, implying that countries need to focus on the QFDI and give full play to the role of FDI in their countries. By analyzing the regression results of model (6) in Table 6, the degree of technology absorption plays a moderating role in the process of QFDI affecting RTFP. To further demonstrate the role of technology absorption, the moderating effect analysis is carried out below.

4.2 Moderating Test

The previous data results have shown that the QFDI for RTFP has a positive effect, which is the essential needs of FDI to host country, but FDI is essentially a kind of economic capital, for renewable energy industry technology needs do not exist in a direct relationship, based on the previous analysis, the technology is the economic element attached to the FDI, whether it can play a facilitating role is related to the host country's own technology absorption capacity. Therefore, hypothesis 2 needs to be further analyzed.

Model (6) in Table 6 reports the positive effect of technology absorptivity on RTFP and changes the coefficient of QFDI on RTFP, combined with the Equation (3)-(5), this paper continues to measure the moderating effect of technology absorption capacity, Table 7 reports the results.

Table 7 Moderating Effect

VARIABLES	(7) RTFP	(8) QFDI	(9) RTFP
QFDI			0.106***
			(9.49)
Tech	0.112***	0.301***	0.080***
	(4.51)	(3.27)	(3.47)
lngdp	-0.024*	0.456***	-0.072***
	(-1.77)	(8.98)	(-5.32)
lnindustrial	0.264***	0.458	0.216***
	(3.44)	(1.61)	(3.04)
lnurbanization	-0.485***	-2.505***	-0.220***
	(-6.56)	(-9.14)	(-2.99)
lnopenness	-0.037	0.150	-0.053
	(-0.97)	(1.07)	(-1.51)
Constant	2.033***	-2.870**	2.336***
	(5.30)	(-2.02)	(6.59)
Fixed	Yes	Yes	Yes
Observations	525	525	525
R-squared	0.133	0.316	0.266

Note: t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

According to the analysis of the results in Table 7, the positive impact of QFDI on RTFP still holds. The technology absorption capacity has a positive correlation on RTFP, and the impact value is: 0.032, H2 is verified. concerning other control variables impact are consistent with previous analysis, which will not be repeated here.

4.3 Robustness Test

4.3.1 Sub-dimension Test

Based on the theoretical framework, to further explore the mechanism of the impact of QFDI on RTFP, this paper uses the three sub-dimension variables of QFDI in separate regressions to estimate the impact roles, same, as a method of robustness checking in this paper. Table 8 reports the impact role of each sub-dimension.

Table 8 Sub-dimension and Mechanism Test

VARIABLES	(10) RTFP	(11) RTFP	(12) RTFP
LD	-0.062		
	(-1.11)		
PC		0.078***	
		(4.85)	
TC			0.050***
			(9.18)
Tech	0.112***	0.124***	0.071***
	(4.50)	(5.07)	(3.01)
lngdp	-0.025*	-0.039***	-0.070***
	(-1.81)	(-2.82)	(-5.11)
lnindustrial	0.250***	0.329***	0.170**
	(3.22)	(4.32)	(2.37)
lnurbanization	-0.479***	-0.405***	-0.235***
	(-6.46)	(-5.47)	(-3.19)
lnopenness	-0.028	-0.066*	-0.035
	(-0.71)	(-1.75)	(-0.99)
Constant	2.045***	1.889***	2.448***
	(5.33)	(5.02)	(6.84)
Fixed	Yes	Yes	Yes
Observations	525	525	525
R-squared	0.135	0.172	0.258

Note: t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

According to the results reported in Table 8, FDI localization shows an inhibitory effect on RTFP, but the effect is not significant. this paper attributes this situation to the fact that the total amount of renewable energy FDI is relatively small, and its contribution to RTFP is still in the input stage, its positive stimulating effect will gradually appear as FDI continues to rise. The FDI production capacity and the FDI technical contribution present a promoting effect, indicating that in the Belt and Road countries, FDI plays an important role in promoting the growth of renewable energy power generation and reducing energy consumption, meanwhile, promotes the growth of RTFP in the host country.

Therefore, the hypothesis H1a of this paper is rejected, H1b and H1c are verified.Therefore, among the Belt and Road countries, this paper confirms that the mechanism of QFDI impact on RTFP, at this stage, works mainly through increasing FDI production capacity and FDI technical contribution, while the mechanism of FDI localization is not significant.

After the mechanism analysis, the role of the influence of each variable is consistent with the previous analysis, indicating that the econometric model in this paper has stability.

4.3.2 Panel Quantile Regression Test

To further estimate the relationship between technology absorption capacity and RTFP, this paper uses panel quantile regression model to observe. Table 9 reports the different roles of technology absorption capacity at different quantiles of RTFP. Figure 4 reports the trend and confidence intervals of each variable on RTFP.

Table 9 Panel Quantile Regression Test

VARIABLES	25% RTFP	50% RTFP	75% RTFP
Qfdi	0.056***	0.126***	0.203***
	(2.75)	(5.05)	(8.95)
Tech	0.011	0.041*	0.154**
	(1.33)	(1.68)	(2.13)
lngdp	-0.008	-0.045***	-0.164***
	(-0.98)	(-2.79)	(-7.02)
lnindustrial	0.056	0.162***	0.295***
	(1.64)	(3.29)	(3.10)
lnurbanization	-0.013	-0.124*	-0.282**
	(-0.49)	(-1.89)	(-2.17)
lnopenness	-0.009	-0.003	-0.067
	(-1.22)	(-0.09)	(-1.04)
Constant	0.088	1.099**	4.726***
	(0.43)	(2.15)	(7.64)
Observations	525	525	525

Note: t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

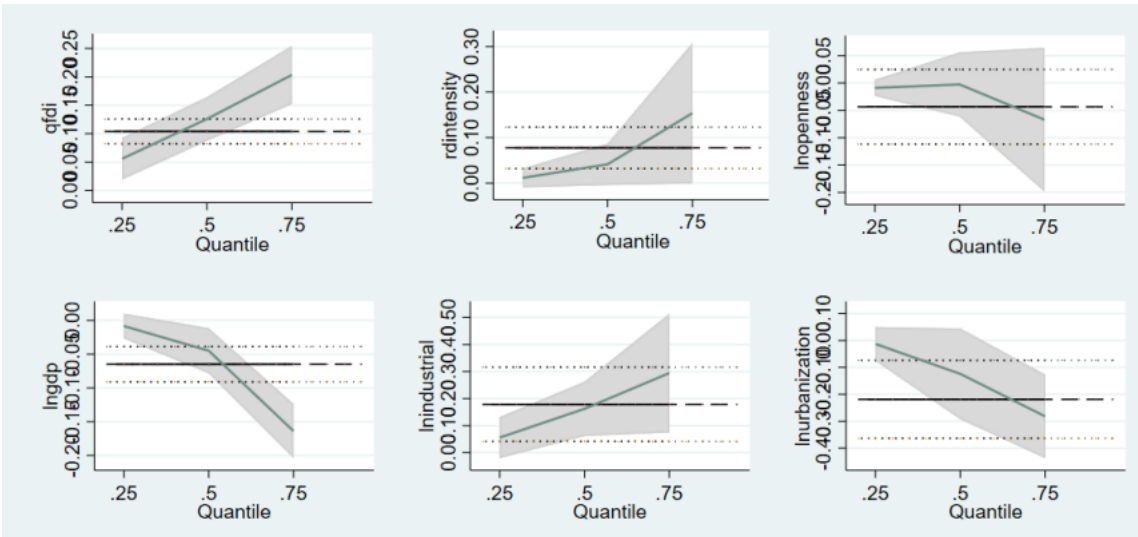

Figure 4 Quartile Regression Trend and Confidence Intervals for Each Variable

According to the results of Table 9 and Figure 4, when RTFP is lower than 25%, the impact of technology absorption capacity on RTFP is positive but not significant, indicating that the host country's investment in renewable energy is relatively low, and the spillover effect of FDI has not been fully transformed by technology absorption capacity. After RTFP is higher than 25%, the impact of technology absorption capacity on RTFP starts to be significant, and the impact increasessignificantly. It indicates that as the increase in RTFP, technology absorption capacity can more fully absorb the FDI spillover. Therefore, the hypothesis H2a is rejected and H2b is verified.

Based on the panel quantile regression results, it can be found that the effect of variables are consistent with the basic regression, proving the stability of the model in this paper.

5.Discussion and Conclusion

5.1 Discussion

According to the results of the econometric model analysis, QFDI shows a significant promotion effect on RTFP, indicating that the introduction of high-quality FDI can promote the RTFP in the host country, therefore, there is a need to change the introduction of FDI from a crude to a qualitative, this result is similar to the conclusions of Wang et al. (31) and Pan et al. (32). However, in the process of mechanism analysis and robustness analysis, this paper finds that the FDI localization does not play a significant role in the growth of RTFP, contrary to the basic expectation, according to the analysis of indicator calculation, the FDI in the field of renewable energy is still at a relatively low level, resulting in the effect is not significant. The FDI production capacity and the FDI technical contribution show a significant positive effect, indicating that QFDI has a promotional effect on RTFP by improving the dimensions of production capacity and technical contribution.

Further analysis reveals that the host country's technology absorption capacity plays a moderating role in the relationship between QFDI and RTFP, the moderating effect value is 0.032. It implies that the host country can better utilize the spillover effects of FDI and reduce the negative impacts brought by FDI by improving its technology absorption capacity. This conclusion is similar to Wang and Luo (33) and Mahbub et al. (19). However, owing to the panel quantile regression analysis, it is found that when the host country's RTFP is at a low level, the effect of technology absorption capacity is not significant, while with the increase of RTFP, the effect of technology absorption capacity is gradually enhanced, which indicates that the host country needs to pay more attention to the renewable energy industry so that the technology absorption capacity can better absorb the spillover effect brought by FDI.

5.2 Conclusion

Based on the panel data of countries along the “Belt and Road” in 2000-2020, this paper investigates the mechanism of QFDI on the RTFP in host countries, then draws the following conclusions:

QFDI is positively correlated with host country RTFP. High-quality FDI balances both quantitative and qualitative, which means not only in terms of the quantity of capital to meet the development needs of the industry, but also in terms of quality to improve the development of local enterprises in the host country, especially with a significant positive effect on driving the development of host country industries. However, there is a negative correlation or insignificant effect in promoting urbanization and export in the host country.

Technology absorption capacity has a promotional effect on RTFP and plays an obvious moderating role in the mechanism in this paper. Technology absorption capacity has a positive correlation with QFDI. However, based on the initial technology gap in the host country, when RTFP is low, technology absorption capacity does not effectively absorb the spillover effect; when RTFP is gradually increased, technology absorption capacity will gradually and positively contribute to the growth of RTFP.

In the analysis of the impact mechanism of QFDI on RTFP, QFDI promotes the growth of RTFP through the improvement of FDI production capacity and FDI technical contribution, in which the technology absorption capacity plays the role of positive promotion, but the role of FDI localization is not significant, indicating that FDI in the field of renewable energy is still at a low level.

5.3 Implication

Corresponding with the above conclusions, this paper proposes the following implications:

“Belt and Road” countries accurately identify their financial and technological needs according to their national conditions. For countries with low technology absorption capacity, under the condition of ensuring the stability of the national market, expanding the scale of FDI to improve the development and technological progress of the national renewable energy industry; For countries with high technology absorption capacity, it is necessary to combine their own resource endowment to introduce appropriate FDI, improve the quality of FDI, and realize faster upgrading of the domestic renewable energy industry structure, so as to promote the improvement of RTFP.

Upgrading the structure of the renewable energy industry and strengthening the technology absorption capacity. Under the peaceful development environment, the country can improve the total factor productivity through renewable energy industry structure upgrading, so as to obtain certain economic benefits, what’s more, the technology absorption capacity is the main measurement standard, for the countries with weak technology absorption capacity, it is necessary to improve the education investment, scientific research investment, and cultivate more local high-quality talents; For countries with strong technology absorption capacity, they can strengthen the upgrading and innovation of core technologies.

Utilizing the powerful force of regional economic cooperation organizations. Cooperation and development are the theme of world economic development. A regional economic cooperation organization is a multi-country organization in a certain region to complement the strengths of cooperation. “Belt and Road” construction can be more closely linked to most of the countries on the Asian and European continents. The countries in the field of renewable energy have diff erent resource endowments. Through strengthening the division of labor cooperation, it can promote the communicatio n of technology and industrial development, consequently, realize the improvement of RTFP.

5.4 Limitation

In this paper, in the process of calculating the RTFP, the total number of employments in the industrial sector is multiplied by the coefficient for substitution, which has a certain bias, in the future research, more attention should be paid to the specific employment in the field of renewable energy. Moreover, in the regression analysis, the FDI localization appears to be non-significant, contrary to the actual expectation, which reflects a certain bias in the eigenvectors of the indicator, in the future research, there is a need to define the FDI localization indicator in more detail and to update the calculation method.

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CRediT authorship contribution statement

Chengjia Ning: Writing – original draft, Visualization, Econometric software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Haslindar Ibrahim**: Writing – review & editing, Validation, Supervision. **Xiaolong Ma**: Writing – review & editing, Data analysis.

Declaration of competing interest

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

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