Pol. J. Environ. Stud. Vol. 30, No. 2 (2021), 1095-1104
DOI: *10.15244/pjoes/123198* ONLINE PUBLICATION DATE: 2020-10-13

Original Research

An Empirical Research on the Relationship Between Renewable Energy Investment and Low Carbon Growth in China

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Received: 31 March 2020
Accepted: 31 May 2020

Abstract

The aim of this paper is to investigate the relationship between renewable energy investment and economic growth in China for the period 1990-2018. The unit root test, co-integration test, vector error correction model, impulse response function analysis, and Granger causality test were employed by including intermittent variables namely foreign direct investment and carbon dioxide emissions. The empirical results indicate that there is a bi-directional long term causality between renewable energy investment and economic growth. This study implies that growing economy in China is propitious for the development of renewable energy sector which in turn helps to boost economic growth. Additionally, economic growth and foreign direct investment influence renewable energy investment in the short term. The outcome of causality test reveals a two-way Granger causal relationship from renewable energy investment to economic growth, and a one-way Granger causal relationship from foreign direct investment to renewable energy investment.

Keywords: renewable energy investment, economic growth, carbon dioxide emissions, co-integration test, VECM

Introduction

Since the reform and opening-up in the late 1970s, China has experienced rapid urbanization and high economic growth for four decades. To sustain its growing economy, a great extent pushed up the demand for energy consumption, total carbon dioxide emissions also increased from 1430 million tons in 1978 to 9428 million tons in 2018, or an increase of about 6.5 times. Excessive carbon dioxide emissions have caused cumulatively severe environmental problems, and the rising trend of carbon dioxide emissions has also added concerns about sustainable economic growth in the future. In the global context, energy efficiency improvement and carbon reduction by macroeconomic regulation and micro-technical means have become the focus of research [1]. Among them, using renewable

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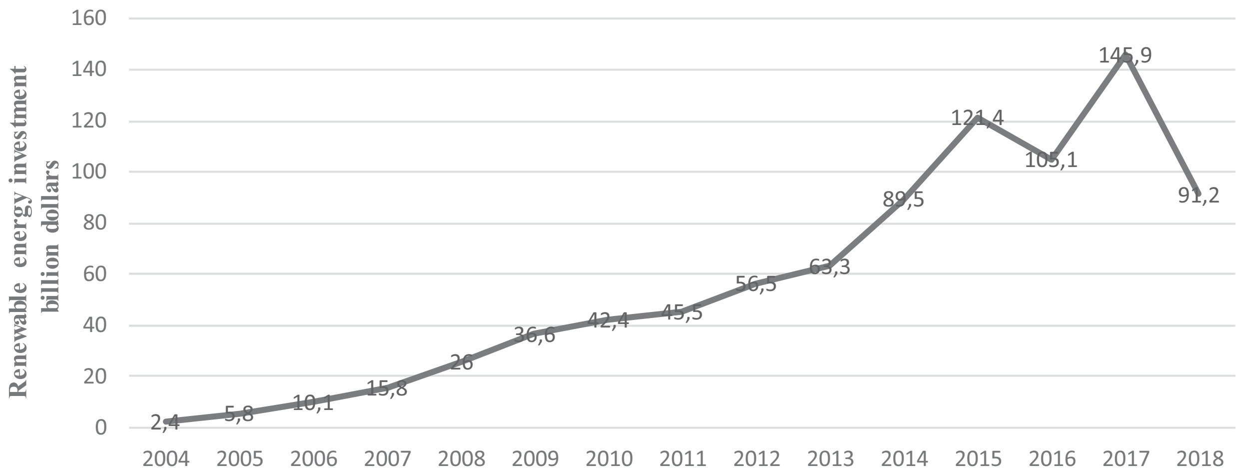

Fig. 1. China's renewable energy investment, 2004-2018.

energy is becoming an important means to create a cleaner environment, reduce carbon dioxide emissions, optimize the energy structure and enhance energy security.

The renewable energy generation in China has already grown 15-fold in the past 30 years, but it only accounted for 26.7% of the total energy produced in 2018. In other words, most of the energy consumed is still derived from fossil fuels that are harmful to the environment. To improve the development and utilization of renewable energy, the Chinese government has been increasing investment and subsidies for renewable energy. For the seventh year in a row, China has been the world's largest investor in renewable energy. In 2018, China accounted for almost a third of the world's investment in renewable energy, reaching $91.2 billion. China's renewable energy supply is growing and its renewable energy technology is leading the world. It can be implied that in order to ensure sustainable economic development, China attaches great importance to the development of renewable energy. It is also noteworthy that, due to a large amount of investment and subsidies used to promote the development of renewable energy, China has had a subsidy gap for several years. As we can see in Fig. 1, the total amount of renewable energy investment has also fallen for the first time in 2018, but it has been on an upward trend for the past 14 years. This raises concerns about whether high levels of renewable energy investment can be sustained. Therefore, it is of great significance to explore the nexus between renewable energy investment and economic growth in China.

With the rapid development of economic globalization, the use of foreign direct investment (FDI) has become increasingly important for a country's economic development, especially for developing countries. According to the "Investment Trends Monitor" issued by the United Nations, China's foreign direct investment in 2018 reached $ 140 billion, continuing to become the second largest country that attracted FDI inflow. The inflow of FDI could help to accelerate the process of transferring knowledge, technology and management experience of the home country to the host country [2]. FDI is also crucial for renewable energy development, as foreign direct investment can provide funding and technical support for the development of renewable energy [2]. On the other hand, foreign direct investment can also stimulate investment in renewable energy by stimulating domestic economic development [3].

In existing studies, economists pay close attention to the relationship between renewable energy consumption and economic development. Tugcu et al. [4] explored the dynamic causal relationships between renewable and non-renewable energy consumption and economic growth of G7 countries through the autoregressive distribution lag (ARDL) model. Their results suggest that there exists bi-directional causality between non-renewable energy consumption and economic growth for each country, and there is no causal relationship between renewable energy consumption and economic growth in France, Italy, Canada, and the USA. Amri [5] investigated economic growth-energy consumption nexus in Algeria between 1980 and 2012, concluding that solid evidence for only non-renewable energy has a causal relationship with economic growth and the role of renewable energy is not obvious. Lin and Moubarak [6] pointed out that there was a two-way long-term causal relationship between renewable energy consumption and economic growth using an autoregressive distribution lag model (ARDL). Similarly, Ito [7] analyzed the GMM and PMG of 42 developed countries and concluded that the long-term contribution of renewable energy consumption to economic growth is positive. Similar results were provided by Huang [8] and Bhattacharya et al. [9]. In contrast, Ocal and Aslan [10] found that renewable energy consumption has a negative impact on economic growth in Turkey. The same result was found for West Africa by Maji et al. [11]. The relationship between renewable energy and economic growth has also proved to be neutral. Payne [12] compared the causal relationship between non-renewable energy and renewable energy consumption and economic growth in the US from 1949 to 2006, the Toda-Yamamoto causality tests showed the relationship between these variables were neutral. Similar results were also proved in other countries, such as Yıldırım [13], Akhmat [14].

There is also plentiful research on the relationship between renewable energy, carbon emissions and FDI. Khoshnevis and Shakouri [15] studied the data of Germany from 1975-2014 through the VAR model, and found that non-renewable energy consumption played an important role in increasing CO_2 emissions, as did economic growth. Renewable energy has a positive effect on reducing CO_2 emissions and economic growth. Similarly, Ang [16] also obtained the same results. Ben et al. [17] investigated Granger causality between renewable energy consumption, tourism numbers, trade openness, economic growth, foreign direct investment (FDI), and carbon dioxide emissions, showing that renewable energy and FDI contribute to the reduction of carbon emissions, while trade and economic growth lead to higher carbon emissions. Toumi [18] also found that foreign direct investment inflows will accelerate innovation in clean technologies and accelerate renewable energy development, which will help developing countries achieve sustainable development goals. Mert et al. [19] investigated foreign direct investment (FDI) and the potential of renewable energy consumption on carbon dioxide (CO_2) emissions in 21 Kyoto countries, concluding that economic growth cannot ensure environmental protection itself, and due to the development of renewable energy and the inflow of foreign direct investment, carbon dioxide emissions will be greatly reduced.

Some scholars have also discussed the development status and development policies of renewable energy in the world. Liu et al. [20] introduced the current development situation of renewable and sustainable energy in China and found that there are some obvious questions during the renewable energy development, such as policy barrier, economy barrier, technology barrier, market barrier, and so on. To achieve a low carbon economy and society in the future, it is important to solve those questions. Certainly, this requires strong financial and policy support of central and local governments. Chen [21] used a dynamic system-GMM panel model to explore the effect of economic growth, CO_2 emissions, foreign trade, and urbanization on renewable energy consumption, concluding that economic development has an important positive impact on renewable energy consumption, and China must continue to design policies include economic landscape free of corruption and good monetary and fiscal policies encourage promote economic growth to promote sustainable economic development. Schuman and Lin [22] described the mechanisms established by the Renewable Energy Law and its implementing regulations, showing that China is gradually advancing its renewable energy development goals and is doing its best to solve some of the development challenges. These efforts can help China achieve a cleaner electricity supply and future sustainable development. Zhang et al. [23] introduced the energy structure and the development status of renewable energy in China and found that the only way to resolve the contradiction between economic growth and high carbon dioxide emissions is to integrate renewable energy into China's future energy system. However, there are still many problems in the development of renewable energy, such as poor quality of renewable energy power generation and low operating efficiency. Kuhns and Shaw [24] investigated the impact of several renewable energy sources such as wind, solar, and hydropower on American society, showing that the development of renewable energy has a positive effect on the US market and jobs, infrastructure planning, and economics.

There is also some research focused on exploring the impact of energy investment. Samouilidis and Mitropoulos [25] indicated that energy investment has promoted economic growth, especially in the context of increasing energy prices. Lu et al. [26] also pointed out GDP and carbon emissions increase significantly with energy investment. Sim [27] studied the economic and environmental value of renewable energy investments, with the conclusion that the government should increase renewable energy subsidies and investment, and should also reevaluate its R&D investment strategy to reduce carbon emissions. Zhai and Song [28] also conducted a similar study on China and found that there is no causal relationship between the impact of economic growth and investment in renewable energy on carbon emissions, regardless of the short-term or long-term relationship. However, the reduction of carbon emissions caused by the development of renewable energy has a negative impact on the economy.

Reviewing the existing literature, some attempts have been made to examine the relationship between renewable energy and economic development. However, previous studies of the relationship between renewable energy and economic development mainly emphasized renewable energy consumption, research conducted on the relationship between renewable energy investment and economic growth is rare. Therefore, the purpose of this paper is to investigate the causal relationship between economic growth and renewable energy investment. Since FDI and carbon dioxide emissions may be affected by or influence changes in renewable energy investment and economic growth, we have incorporated these two variables into the framework. The main contributions of this study are as follows. First of all, this study for the first time quantitatively examines the relationship between total GDP, renewable energy investment, carbon dioxide emissions and FDI in China. Given that China is in the energy transition phase, while ensuring economic growth, China needs to adjust energy structure and reduce carbon emissions through the development of renewable energy. Moreover, FDI is of great significance for both economic growth and renewable energy investment. Hence, the comprehensive analysis of the relationship between the four variables is very meaningful and reasonable. Second, the analysis of factors affecting the investment of renewable energy provides significant policy implications on how to accelerate the development of renewable energy in China by formulating and coordinating proper policies on economic development. To the best of our knowledge, few studies have utilized the VECM model to reveal the causal relationship between renewable energy investment and economic growth, which will be the main contribution of our paper.

The remainder of the paper is as follows: Section 2 provides a brief literature review on the relationship between renewable energy and economic growth. Section 3 presents the data and explains the method employed. The results and discussion is provided in Section 4, while the conclusion and policy implications are outlined in Section 5.

Data and Methodology

Considering the availability of data, annual data covering the period of 1990-2018 are used. In this paper, the data include renewable energy investment, economic growth, foreign direct investment and carbon dioxide emissions. All original data were collected from the official website of the Statistical Office of the People's Republic of China, China Energy Statistics Yearbook, British Petroleum statistical review of World Energy and Global Trends In Renewable Energy Investment product by Bloomberg. In order to reduce the impact of price factors and heteroscedastic factors on the research results, GDP, renewable energy investment and FDI series were converted into data based on the 1990 retail price index as the base period. To ensure the stability of the data, the natural logarithm of the data was used.

This paper used the vector error correction model (VECM) to study the relationship between economic growth (GDP), renewable energy investment(REI), FDI and carbon dioxide emissions(CO_2) from the perspective of long-term equilibrium relationship and short-term dynamic relationship. During the calculation, we defined y_t = (lnGDP, lnREI, lnFDI, $\ln CO_2$)′, and the four VAR models could be obtained with a lag period of k, which could be expressed as:

$$y_t = a_t + \sum_{j=1}^{k} \prod_j y_{t-j} + u_t \tag{1}$$

...where at = (a_1, a_2, a_3, a_4)′, ut = (u_1, u_2, u_3, u_4)′

Among them, y_t is 4*1 order time series vector, u_t is 4*1 order constant term column vector, and the mean value is the white noise of 0, Πj is 4*4 order parameter matrix. Making a differential transformation of equation (1) results in:

$$\Delta y_t = \sum_{j=1}^{k-1} \Gamma_j \Delta y_{t-j} + \prod y_{t-1} + \varepsilon_t \tag{2}$$

In equation (2), $\prod = \sum_{j-1}^{k} \prod j - I$, $\Gamma_j = -\sum_{i=1+j}^{k} \prod j$, ε_t is white noise with the mean value of 0.

If there is a co-integration relationship among the three variables represented by equation (1), then equation (2) can be represented by the error correction model (3):

$$\Delta y_t = \sum_{j=1}^{k} \Gamma_j \Delta y_{t-j} + \beta \, VECM_{t-1} + \varepsilon_t \tag{3}$$

In formula (3), VECM is determined by the long-term equilibrium relationship of economic growth (GDP), renewable energy investment(REI), FDI and carbon dioxide emissions (CO_2), the absolute value of reflects the rate of adjustment to the long-term equilibrium value after the sequence is impacted by the short-term impact. The greater the absolute value, the faster the adjustment [29].

Results and Discussion

Unit Root Test

Before establishing the model, the stability of the research variables was tested to ensure that there were no spurious regressions. In this paper, Augmented Dickey-Fuller(ADF) and Phillips-Perron (PP) statistics were adopted in the unit root tests to ensure the stability of the time series. The test results are shown in Table 1.

As shown in Table 1, for the ADF and PP-Choi tests of the time series, we found that the p-values of lnGDP, lnREI and $\ln CO_2$ were all greater than 0.05, that is, the null hypothesis was rejected. Then the first-order difference was used to correct the non-stationary series. Moreover, the p-values of these four series were all less than 0.05. It can be seen that lnGDP, lnREI and $\ln CO_2$ were all first-ordered I(1) processes, and lnFDI was an I(0) process. By eliminating the unit root, a smooth time series was obtained, to pave the way for the next co-integration test.

Co-Integration Test

If the linear combination of time series of multiple variables is stationary, there is a co-integration relationship between the series. Discrimination and determination of co-integration relationship is an important prerequisite for regression analysis between variables. This paper used Johansen-Juselius co-integration to test whether there was a long-term equilibrium relationship between lnGDP, lnREI, InFDI and $\ln CO_2$. The results in Table 2 demonstrate a long-term equilibrium relationship between the variables.

Table 1. The unit root tests.

	Order	lnGDP		lnREI		$lnCO_2$		lnFDI	
		Statistics	p-value	Statistics	p-value	Statistics	p-value	Statistics	p-value
ADF	Zero order	-0.5786	0.8597	-1.0541	0.7192	-0.9897	0.7416	-4.9206	0.0005
	First order	-4.9179	0.0005	-4.6632	0.0010	-2.4422	0.0047	-7.0175	0.0000
PP	Zero order	-0.2470	0.9209	-1.0256	0.7299	-0.9798	0.7463	-4.9803	0.0005
	First order	-4.9199	0.0005	-4.8049	0.0007	-3.9864	0.0029	-7.8626	0.0000

Note: Eviews10 has been used for the tests. lnGDP, lnREI, $lnCO_2$ and lnFDI stand for logarithmic total GDP, logarithmic total renewable energy investment, logarithmic total carbon dioxide emission and logarithmic total FDI, respectively. The meanings of these symbols are identical in the following tables.

According to Table 2, there are three co-integration relationships among the four time series, showing that co-integration relationships exist between the variable sequences, which can be used to build a VEC model. Among them, we choose one of the representative co-integration equations which can be represented as follows:

$$lnGDP = 0.733lnFDI + 0.432lnREI + 1.126ln\mathrm{CO}_2 - 0.1\ 0.18$$

This co-integration equation reveals the long-run elasticity of the research variables. It shows that carbon dioxide emissions are the most important factor affecting economic growth, every 1% increase in carbon dioxide emissions will cause economic growth of 1.126%. It can also be seen that renewable energy investment and FDI also have a positive impact on economic growth. A similar result was provided by Lin and Moubarak [6]. After proving the long-term co-integration relationship of the variables through the co-integration test, we can continue to build a VECM model to verify the relationship between the variables.

VECM Model Analysis

VECM model is a VAR model based on the co-integration relationship of variables, the term representing the deviation from the long-term equilibrium relationship is put into the model as an explanatory variable, describing a long-term adjustment to the equilibrium deviation. This error correction model based on co-integration theory can reflect not only the long-term related information between different economic sequences but also the short-term deviation from the long-term equilibrium correction mechanism. It is a model with a combination of long-term and short-term stability and reliability. The estimation results are shown in Table 3.

We are generally more concerned about the overall test results of the VECM model, as we see in Table 3, AIC = -8.8117, SC = -7.4679, both test statistics are small, indicating that the model estimation works well.

The size of the error correction term coefficient reflects the adjustment effort for deviation from long-term equilibrium. As can be seen from Table 3, the coefficients of the error correction terms are 0.01285, 0.16746 and 0.08731. This means that when economic

Table 2. Co-integration test results.

Hypothesized no. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob
None	0.8893	119.5726	47.8561	0.0000
At most 1	0.7676	63.3427	29.7970	0.0000
At most 2	0.5824	24.3943	15.4947	0.0018
At most 3	0.0628	1.6872	3.8414	0.1940
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob
None	0.8893	57.2298	27.5843	0.0000
At most 1	0.7676	37.9484	21.1316	0.0000
At most 2	0.5824	22.7071	14.2646	0.0019
At most 3	0.0628	1.6872	3.8414	0.1940

Note: Probabilities are computed using asymptotic Chi-square distribution.

Table 3. VECM estimation results.

Error Correction:	D(lnGDP)	D(lnFDI)	D(lnREI)	D(lnCO_2)
CointEq1	0.012853	0.167461	0.087311	-0.004182
	(0.01393)	(0.01636)	(0.04896)	(0.00540)
	[0.92267]	[0.2368]	[1.78325]	[-0.77377]
D(lnGDP(-1))	0.016671	-0.005126	1.428249	-0.161643
	(0.18933)	(0.22234)	(0.66547)	(0.07346)
	[0.08805]	[-0.02305]	[2.14623]	[-2.20042]
D(lnFDI(-1))	-0.081501	0.236683	-0.260846	0.033654
	(0.06796)	(0.07980)	(0.23885)	(0.02637)
	[-1.19932]	[2.96579]	[-1.09207]	[1.27639]
D(lnREI(-1))	0.116173	0.042876	-0.224979	-0.019304
	(0.05874)	(0.06898)	(0.20646)	(0.02279)
	[1.97779]	[0.62156]	[-1.08971]	[-0.84703]
D(lnCO_2(-1))	0.629025	-0.113467	1.871500	0.902456
	(0.31793)	(0.37336)	(1.11747)	(0.12335)
	[1.97851]	[-0.30391]	[1.67477]	[7.31595]
C	0.071532	0.090994	0.039955	0.023052
	(0.02868)	(0.03368)	(0.10081)	(0.01113)
	[2.49414]	[2.70167]	[0.39636]	[2.07161]

Note: Akaike information criterion = -8.8117, Schwarz criterion = -7.4679

growth, FDI and renewable energy investment are disturbed and deviated from equilibrium, they will be subject to speed adjustments of 0.01285, 0.16746, and 0.08731 on the same side, making it possible for them to return to equilibrium in the short term. For carbon dioxide emissions, if it deviates from equilibrium, it will be subject to 0.00418-speed adjustment on another side to make it possible to return to an equilibrium level in the short term.

Dynamic Impact Analysis: Impulse Response Function

The impulse response function was used to analyze the trajectory of the information's current and future impact of a standard deviation shock, and these effects were transmitted to all other endogenous variables through the dynamic structure of the VECM model, which can more intuitively depict the dynamic interaction between variables.

Fig. 2-1 shows the response of lnGDP to lnREI, lnFDI and lnCO_2. First, The response of lnREI on lnGDP doesn't respond at the initial stage, and then the influence rate shows a clear upward trend, and reaches the maximum value in the eighth period, and then gradually stabilizes, showing a trend of convergence. This shows that the long-term stable pulling effect of economic growth to renewable energy investment is increasing. Second, the response of lnGDP to lnCO_2 has an inverted "U" trend, while the magnitude of the influence (absolute value) is relatively high, suggesting that carbon dioxide emissions and economic growth may have stable driving effects on each other. The impact of economic growth on FDI is at first negative and then positive, while the magnitude of the influence (absolute value) is relatively small, similar in Fig. 2-2 and Fig. 2-4, to a certain extent, that means there may be short-term interactions between several variables.

In Fig. 2-2, the response of lnREI to lnGDP is on the rise, starting to converge after the seventh cycle, indicating that the impact of renewable energy investment on economic growth is positive. The response of lnREI on lnCO_2 increases first and then decreases, this is similar to the situation in China. Initially, investment in renewable energy did not cause carbon dioxide emissions reduction. With the investment scale and technology maturity, more renewable energy investment will cause the reduction of carbon dioxide emissions.

In Fig. 2-3, the response of lnFDI on lnGDP decreases first and then increases, but the magnitude of the influence (absolute value) is relatively high, it indicates that FDI has a clear driving effect on economic growth. The response of lnFDI on lnREI

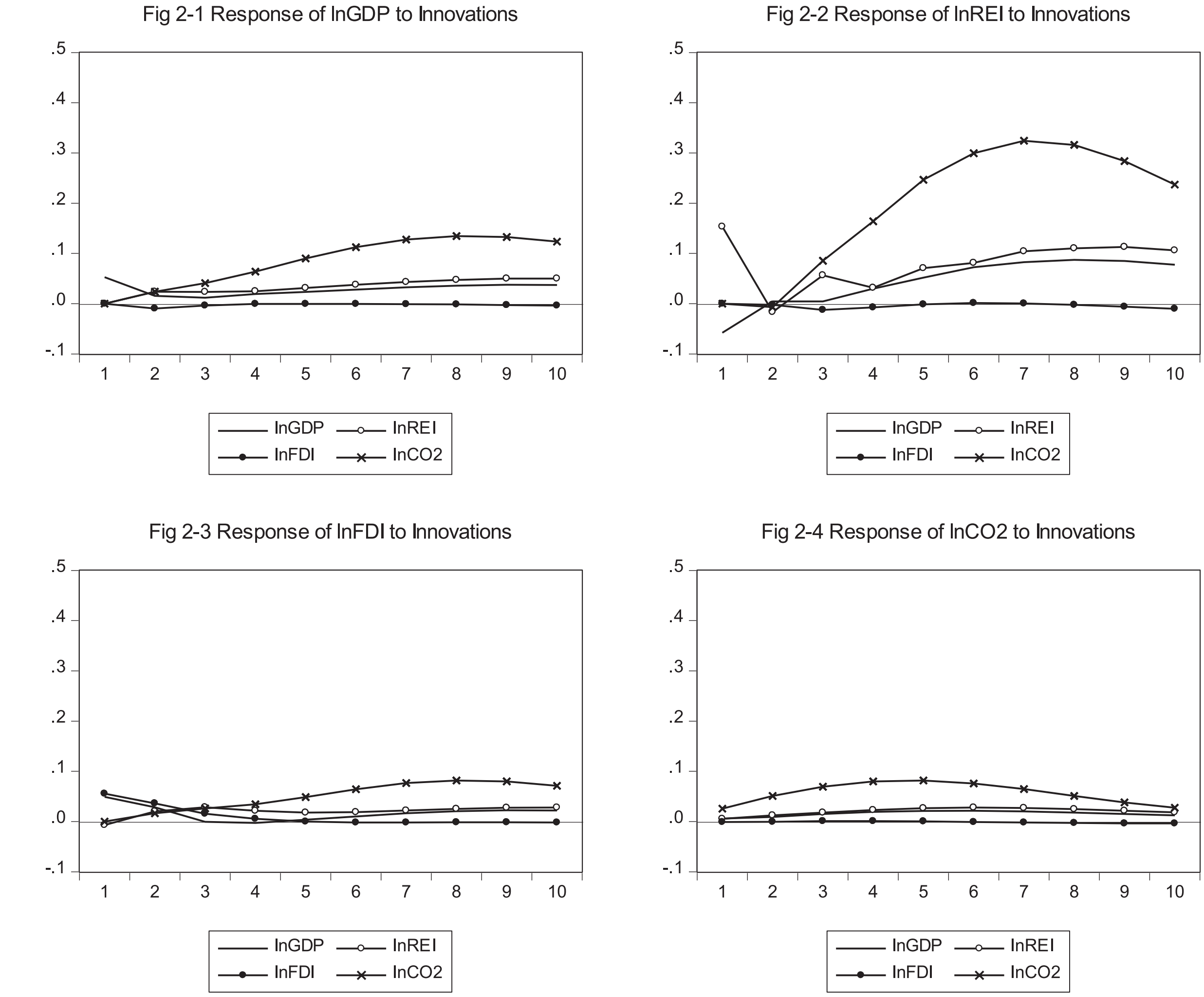

Fig. 2. Impulse response of the variables used in the study.

grows to a steady level after the third period, as the shock cycle goes on, the positive effect between lnFDI on lnREI gradually stabilizes. It can be seen that FDI has a certain promotion effect on renewable energy investment. Foreign countries promote the development of renewable energy in the host country through technology transfer or financial support. However, the response of lnFDI on $lnCO_2$ has an inverted "U" trend, while the magnitude of the influence (absolute value) is high. It can be seen that FDI while boosting economic growth and promoting renewable energy investment, has also increased host country carbon dioxide emissions.

Fig. 2-4 shows that the response of $lnCO_2$ to lnREI and lnGDP all peaked in the sixth period and then converged. In other words, China's economic development has always been inseparable from the consumption of traditional energy, but the carbon dioxide emitted by the consumption of large amounts of fossil energy has also caused serious environmental problems. Therefore, China should promote the development of renewable energy and increase investment in renewable energy.

Granger Causality Test

As can be seen from Table 4, the F-statistic of the null hypothesis that "ΔREI cannot Granger cause ΔGDP" is 6.2449, which means that we can reject the null hypothesis at the 10% significance level. At the same time, we can also reject the null hypothesis that "ΔGDP cannot Granger cause ΔREI". Results in Table 4 indicate that renewable energy investment does have a two-way Granger causal relationship with economic growth. It can be seen that at the same time as economic development, China is also vigorously developing renewable energy, and increasing investment in renewable energy guarantees the smooth development of renewable energy. Investment in renewable energy has also directly caused economic growth. It can be found that there is a two-way Granger causality relationship between carbon dioxide emissions and economic growth, which means that the development of China's economy at the current stage is inseparable from the consumption of traditional energy.

The causality test at the 10% level of significance shows that for ΔFDI, ΔREI reject the null hypothesis

Table 4. Granger causality test results.

Null Hypothesis:	F-Statistic	Prob	Conclusion
ΔREI cannot Granger cause ΔGDP	6.2449	0.0194	Reject null hypothesis
ΔGDP cannot Granger cause ΔREI	4.3554	0.0472	Reject null hypothesis
ΔFDI cannot Granger cause ΔGDP	0.1549	0.6972	Accept null hypothesis
ΔGDP cannot Granger cause ΔFDI	3.4497	0.0751	Accept null hypothesis
ΔCO_2 cannot Granger cause ΔGDP	20.1996	0.0001	Reject null hypothesis
ΔGDP cannot Granger cause ΔCO_2	4.4542	0.0450	Reject null hypothesis
ΔFDI cannot Granger cause ΔREI	5.8233	0.0235	Reject null hypothesis
ΔREI cannot Granger cause ΔFDI	0.0766	0.7842	Accept null hypothesis
ΔCO_2 cannot Granger cause ΔREI	27.9150	0.0000	Reject null hypothesis
ΔREI cannot Granger cause ΔCO_2	9.2130	0.0055	Reject null hypothesis
ΔCO_2 cannot Granger cause ΔFDI	4.5497	0.0429	Reject null hypothesis
ΔFDI cannot Granger cause ΔCO_2	0.0270	0.8706	Accept null hypothesis

Note: The conclusions in this table are judged at a significance level of 10%.

that FDI cannot cause renewable energy investment. This also confirms our previous analysis. For ΔCO_2, ΔREI and ΔFDI reject the null hypothesis, indicating that carbon dioxide emissions are a Granger cause of renewable energy investment and FDI. We can also find that carbon dioxide emissions do have a two-way Granger causal relationship with renewable energy investment.

From the perspective of China's current economic development, the development of China's economy has caused a large amount of carbon dioxide emissions, and at the same time, it has also driven investment in renewable energy. The development of renewable energy is the key to reducing carbon dioxide. Therefore, it is necessary to reasonably arrange investment in renewable energy. From the aspect of FDI, FDI also directly causes investment in renewable energy, and making good use of FDI is also conducive to achieving carbon dioxide reduction goals.

Conclusion

This study is the first study to examine the relationship between economic growth, renewable energy investment, FDI and carbon dioxide emissions in China. The unit root test, co-integration test, VECM model, and impulse response function analysis are used to analyze the relevant data from 1990 to 2018. The results indicate the existence of a co-integration relationship among the variables. Moreover, by VECM model estimation, the results suggest that the four variables are affected by the equilibrium relationship. If the equilibrium relationship is broken, it will be adjusted to the long-term equilibrium level in the short term. Further analysis from impulse response function indicates that, renewable energy investment and carbon dioxide emissions are both positively influenced by economic growth, also found renewable energy investment and economic growth are both positively influenced by FDI. Moreover, through Granger Causality tests, we can indicate that renewable energy investment and carbon dioxide emissions do have a two-way Granger causal relationship with economic growth, and they also exit Granger causal relationships from FDI to renewable energy investment.

According to the results obtained from the empirical study summarized above, this paper reveals some important policy implications. From the perspective of economic growth, increasing the investment in renewable energy is currently conducive to economic growth, and it is also conducive to the reduction of carbon dioxide. The empirical results in this study also confirm that FDI can promote China's renewable energy investment, how to turn FDI growth into faster growth of renewable energy is an important issue that policy makers need to seriously consider. Although China has published and formulated a series of laws and policies for renewable energy development, including China Renewable Energy Law and the 13th Five-Year Plan for renewable energy development, there are still some problems remaining for the development of renewable energy. The main goals of China Renewable Energy Law and the 13th Five-Year Plan for renewable energy development are to increase renewable energy utilization, increase energy supply, improve energy structure and ensure energy security, but there are also some limitations, In China, traditional energy companies are the main taxpayers in many provinces, and there exists local government protection. Due to technical reasons, the exploitation of renewable energy usually has a high risk, which many private enterprises cannot bear. At the same time, these two policies have not proposed how to establish good market competition mechanisms to reduce the cost of renewable energy generation to ensure that the potential of renewable energy is fully explored. FDI will be an effective tool in these regards. The renewable energy industry in developed countries is relatively mature and can promote China's renewable energy development. So the government should reasonably arrange a renewable energy investment plan, guide funds into the renewable energy industry promote renewable energy technology innovation. reasonable financial subsidies and maintain reasonable price levels to attract more small and medium private enterprises into the renewable energy industry, promoting the marketization of renewable energy.

As we all know, China's economic development is highly dependent on investment and exports. After China's economy entered a new normal in 2014, an important goal of China's economic structural transformation was to transform the engine of economic growth from capital accumulation to innovation.Traditional industry investment was relatively saturated, and the demand for investment in emerging industries was increasing. Renewable energy is an emerging high-tech technology industry and a multidisciplinary technology-intensive industry.But the current technological level of renewable energy in China limits the development of renewable energy, and many core technologies came from abroad. It is essential to increase R&D spending, make better use of talents in universities and research institutions, strengthen cooperation with enterprises, and accelerate basic research and team building for renewable energy technologies, which will help accelerate the commercialization of new energy technologies. In addition, using FDI to guide the upgrading of industrial structure is also a very important issue, but policy makers should also consider that when introducing FDI, China should pay more attention to the investment quality and avoid becoming the "pollution haven" of developed economies. Future FDI policy should prevent polluting enterprises from entering the market in the energy industry. The government should also promote renewable energy in a variety of ways, deepen the public's understanding and concern about renewable energy, increase public environmental awareness, and promote renewable energy consumption. In emerging countries like China, although fossil fuels will remain the most important source of energy in the near future, in order to ensure sustainable development, it is necessary to further promote renewable energy.

Acknowledgements

The authors are very grateful to reviewers and Editor-in-Chief Prof. Jerzy Radecki for their insightful comments that helped us sufficiently improve the quality of this paper.

Conflict of Interest

The authors declare no conflict of interest.

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