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Research Article

Revisiting the environmental Kuznets curve hypothesis in the context of renewable and non-renewable energy in China

Çin'de yenilenebilir ve yenilenemez enerji bağlamında çevresel Kuznets eğrisi hipotezinin yeniden gözden geçirilmesi

Zikrullah Zaland[1]

Hatice Imamoglu[2]

[1] PhD. Candidate, Faculty of Economics, Administrative and Social Sciences, Cyprus Science University, Dr Fazıl Küçük Caddesi, Ozanköy, 99320, Kyrenia / TRNC Mersin 10 – Turkey, zikrullahzaland15@gmail.com

ORCID: 0000-0001-9544-5341

[2] Assoc. Prof. Dr., Department of Banking and Finance, Faculty of Economics, Administrative and Social Sciences, Cyprus Science University, Dr Fazıl Küçük Caddesi, Ozanköy, 99320, Kyrenia / TRNC Mersin 10 – Turkey, haticeimamoglu@hotmail.com

ORCID: 0000-0002-3299-499X

Corresponding Author:

Hatice Imamoglu

Cyprus Science University, Dr Fazıl Küçük Caddesi, Ozanköy, 99320, Kyrenia / TRNC Mersin 10 – Turkey, haticeimamoglu@hotmail.com

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Abstract

This research paper attempts to determine the effect of fossil fuel, renewable energy, and economic growth on carbon dioxide emissions and revisits China's Environmental Kuznets curve (EKC) hypothesis. The time series analysis will be performed for the years 1990 to 2020. To begin, Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests will be performed to verify the series' stationarity. Second, the cointegration test will be utilized to determine the validity of a cointegration vector before performing the Fully Modified Least Square approach to conduct long- and short-term estimation. The empirical analysis illustrates that renewable energy negatively and significantly affects short- and long-run carbon dioxide emissions. However, fossil fuel consumption only positively and significantly affects carbon dioxide emissions in the short run. The empirical evidence supports the Environment Kuznets Curve's hypothesis in China. Fossil fuel consumption has a considerably higher effect on carbon dioxide emissions than renewable energy. To avoid ecological damage in China, authorities must pay more consideration to encouraging the use of energy from renewable sources. This demonstrates that China's overall environmental performance first deteriorates before gradually improving with economic growth.

Keywords: Fossil Fuel, Renewable Energy, EKC Hypothesis, China

Jel Codes: C22, O44, Q43

Öz

Bu araştırma makalesi fosil yakıtların, yenilenebilir enerjinin ve ekonomik büyümenin karbondioksit emisyonları üzerindeki etkisini belirlemeye çalışmaktadır ve Çin'deki Çevresel Kuznets eğrisi (EKC) hipotezini yeniden ele almaktadır. 1990-2020 yılları için zaman serisi analizi gerçekleştirilmiştir. Başlangıç olarak serinin durağanlığını doğrulamak için Artırılmış Dickey-Fuller (ADF) ve Phillips Perron (PP) testleri gerçekleştirilecek. İkinci olarak, uzun ve kısa vadeli tahmin yapmak için Tamamen Değiştirilmiş En Küçük Kareler yaklaşımını uygulamadan önce bir eşbütünleşme vektörünün varlığını belirlemek için eşbütünleşme testi yapılmıştır. Ampirik analiz, yenilenebilir enerjinin kısa ve uzun vadeli karbondioksit emisyonları üzerinde olumsuz ve anlamlı etkileri olduğunu göstermektedir. Ancak fosil yakıt tüketimi yalnızca kısa vadede karbondioksit emisyonları üzerinde olumlu ve önemli ölçüde etkiler ortaya koymaktadır. Ampirik kanıtlar Çin'deki Çevre Kuznets Eğrisi hipotezini desteklemektedir. Fosil yakıt tüketiminin karbondioksit emisyonları üzerinde yenilenebilir enerjiye göre çok daha yüksek bir etkisi vardır. Çin'de ekolojik hasarı önlemek için yetkililerin yenilenebilir kaynaklardan enerji kullanımını teşvik etmeye daha fazla dikkat etmesi gerekiyor. Bu, Çin'in genel çevre performansının önce kötüleştiğini, ardından ekonomik büyümeyle birlikte kademeli olarak iyileştiğini göstermektedir.

Anahtar Kelimeler: Fosil Yakıt, Yenilenebilir Enerji, EKC Hipotezi, Çin

Jel Kodları: C22, O44, Q43

Introduction

This research objective is to reconsider the reliability of the EKC hypothesis in China by considering fossil fuels and renewable energy consumption. One of this century's most significant environmental issues has been global warming. In 2013, climate change would have a major and significant effect on regional economic and social development, according to the Intergovernmental Plane on Climate Change (IPCC, 2021) Fifth Report. Additionally, the report held that carbon dioxide (CO2) emissions from burning fossil fuels were the primary contributors to global warming and climate change.

Since China joined the World Trade Organization (WTO, 2021), it has significantly improved social and economic development and human welfare in the past few decades. This has led to an increase in China's need for energy, particularly fossil fuels. Fossil fuels continue to be the primary source of energy use in China, accounting for nearly 70% of all domestic energy consumption, regardless of significant efforts to reduce pollution and promote energy usage from renewable sources, energy efficiency, and saving energy (WDI, 2018). Consequently, China has a significant environmental degradation problem that the rest of the world needs to deal with. This is one of the main issues that both developed and developing countries equally are currently facing. In 1997, the Kyoto Protocol was signed by over 100 countries. That protocol targets countries to reduce carbon dioxide to protect humanity and global warming. China has been signed the Kyoto Protocol in 1998. At that time, China was listed as a developing nation and initially ignored environmental issues. However, it repaid growth in population and economy. It became the biggest user of energy and the biggest emitter of carbon dioxide worldwide, putting China under enormous worldwide pressure to reduce CO2 emissions.

In 1996, China became a net importer of petroleum, causing a risk that has been integrated into the energy security strategy. China became a net coal importer in 2009, indicating an increase from its previous 53% reliance on oil imports (Wu, Liu, Han, and Wei 2012). There are several elements to the concept of energy security. Energy security is defined by several elements, such as the sufficient supply of energy at affordable prices, which is the most accepted definition of energy security (Yergin, 1988; Bielecki, 2002; Lin, 2009). The three energy security components focus on two essential elements of this idea: technology and economics. As environmental protection has gained public attention, the concept of energy security has introduced new possibilities - the environment (Board, 2007; OCED, 2007). International organizations focus on the environment when addressing energy security (Yao and Chang, 2014). Energy consumption is one of the main determinants that contribute to environmental degradation. In general, environmental quality literature is based on the EKC hypothesis.

The EKC hypothesis describes an "inverted U-shaped" relationship between income level and CO2 emissions in this regard. Carbon emissions increase during the first stage, reaching a tipping point (also called the turning point) with economic growth. In further stages of economic growth, the carbon dioxide emission starts to decrease. In 2014, China and the United States intend to significantly decrease carbon dioxide emissions to control climate change (Liu, Guan, Moore, Lee, Su, and Zhang, 2015). Following China's policy to open up, the demand for increased non-renewable energy consumption affected natural disasters and caused severe damage to the environment. The main reasons for increasing carbon dioxide emissions are fossil fuel usage, oil, gas, and coal. As an outlook, China must change its energy production ratio and improve its renewable energy production ratio to achieve sustainable environmental and long-term growth.

China is currently the second-biggest economy in the world and has faced numerous challenges during decades of unprecedented economic growth, making it an interesting case to conduct research in China. There are more severe challenges concerning China's energy. China surpassed the United States as the world's largest energy consumer in 2010, representing 20.3% of the world's energy use. The ongoing rise in energy demand has increased reliance on oil, which will exceed 70% by 2020 (Yuan, Zhang, Wang, Huang, Fang, and Liang, 2020). Furthermore, the concentration of import resources and several economic and geopolitical factors in crises endanger China's energy security supply (Yuan et al., 2020; Sun, Hao, and Li, 2022). Also, with no oil price authority, China can passively suffer shifts in oil prices (Hu, Wang, Su, and Umar, 2022). Concerns regarding energy security have increased the public's understanding of energy security (Wang, Zhao, Su, and Lobonţ, 2023). Energy security understanding may influence how individuals live and use energy, decreasing carbon dioxide emissions (Li, Zhang, and Su, 2019). On the other hand, (Golley and Meng, 2012) stated that education and awareness regarding energy usage impact the environment. However, the critical question is whether one indicator can capture the complex nature of the environment's status and degradation and how economic activities and development can influence it. The lack of agreement in the literature may be linked to these differences in factors.

The research paper is structured as follows: section 2 gives a literature review, section 3 points out theoretical contexts, section 4 explains data and methodology, section 5 empirical findings, and section 6 concludes and makes suggestions for policy.

Literature review

There is significant literature on the EKC hypothesis in China's non-renewable and renewable energy context. Prior research indicates a positive relationship between renewable and unrenewable energy usage. Some of the significant research investigates the effect of renewable and non-renewable energy usage on CO2 emissions for various countries, such as China, the UK, the USA, France, Pakistan, and OECD countries (Khizar and Anees, 2023; Zhang, 2022; Qin, Raheem, Murshed, Miao, Khan, and Kirikkaleli, 2021; Shen, Su, Malik, Umar, Khan, and Khan, 2021; Zhou, Tang, and Zhang, 2020; Ren, Shao, and Zhong, 2020; Temiz Dinç and Akdoğan, 2019; Dogan and Seker, 2016; Govindaraju and Tang, 2013). However, for a sustainable environment, it is necessary to increase the use of renewable energy to reduce carbon dioxide emissions. A higher CO2 emission level will encourage an increase in fossil fuel energy use and impact environmentally sustainable investments (Ren et al., 2020).

Temiz Dinç and Akdoğan (2019) focused on the causal relationship between economic development and renewable energy usage. The outlook of this paper illustrates that energy usage and production have supported long- and short-term relations with economic development. Although there is a bidirectional relation in the long and short term between renewable energy usage and economic development, which also encourages suggestions, increased renewable energy and related energy source usage are vital for sustained development, and this process aims to minimize energy usage, which can negatively impact growth. However, changes in economic development will be represented in energy demand. (Govindaraju et al. 2013) stated that China has a long-term relationship with coal, CO2 emissions, and economic development. There are also unidirectional solid links between them. Therefore, (Murshed, Elheddad, Ahmed, Bassim, and Then, 2021) stated that the increase in carbon dioxide emissions was statistically caused by foreign direct investment (FDI), negatively affecting ecological stability. Although FDI encourages renewable energy production, both FDI and production can reduce the destructive impact on the environment.

In order to investigate the CO2 Kuznets curve of China, Jalil and Mahmud (2009) used time series data and the auto-regressive distributed lag (ARDL) methodology; the findings corroborated the EKC hypothesis. Using province-level data from China, (Wang, Zhou, Zhou, and Wang, 2011) investigated the CO2 Kuznets curve using panel techniques and discovered a U-shaped relationship between CO2 emissions and economic growth. However, (Yin, Zheng, and Chen, 2015) calculated the moderating impact of developments in technology and environmental regulation on China's CO2 Kuznets hypothesis and discovered an inverted-U Kuznets curve. So far, the EKC theory has also been examined for other environmental degradation indicators in China, such as PM2.5 and environmental impact, using a geographical econometric approach. For example, (Wang, Kang, Wu, and Xiao, 2013b) used a geographical econometric model and found demonstrated promoting an inverted U-shaped EKC between economic growth and ecological footprint, as opposed to ordinary least square regression. Hao and Liu (2015) used the spatial lag model (SLM) and the spatial error model (SEM) to verify their EKC theory for PM2.5 in China and account for the spatial effects of PM2.5. On the other hand, Junyi (2006) examined the existence of an EKC relationship between economic growth and carbon dioxide emissions using Chinese provincial data from 1993 to 2002. The finding shows the negative impact of carbon dioxide emission on economic growth and labour's positive effect on economic growth. Although the abatement equation also finds that physical capital and the secondary industry share a positive impact on pollution abatement expenses, pollutant emissions still have a positive effect.

Mallick and Mahalik (2014) investigated the economic development, energy consumption, and financial growth nexus in China and India using data from 1971 to 2011. In China, empirical evidence from the autoregressive distributed lag model suggests that financial development, economic growth, and industrial output negatively impact energy consumption. Furthermore, financial development, energy consumption, and industrial output all harm growth. (Zhang, Anaba, Ma, Li, Asunka, and Hu 2020) investigated the relationship between solar energy technology, the environmental impact of energy systems, economic growth, and CO2 in China between 1990 and 2017. The empirical findings suggest the enhancing effect of energy and economic growth, while solar energy technology decreases emissions levels. Zhang and Cheng (2009) investigated the relationship between China's energy use, economic growth, and carbon dioxide emissions. It discovered the causal relationship between economic growth and energy use, as well as between energy use and carbon dioxide emissions. According to Govindaraju et al. (2013), CO2 emissions, economic growth, and use of coal are all cointegrated in China. The researchers emphasized unidirectional causality from economic growth to CO2 emissions and a bidirectional relationship between economic growth and the use of coal in both the short and long term.

Environmental issues are prevalent and trendy topics that scholars frequently address. Although there is extensive literature on the environmental Kuznet's curve, this paper will review some of it (Al-Mulali, Ozturk, and Solarin, 2016). They examined the nexus of economic growth, renewable energy usage, and environmental quality within the context of the EKC hypothesis for 107 countries from 1980 to 2010. The results show that using renewable energy with lower Co2 emissions in Eastern, Central, and Western Europe, America, South Asia, and East have supported the environmental Kuznets curve hypothesis. (Shahbaz, Chaudhary, and Ozturk, 2017) examined the relationship between urbanization and energy usage in Pakistan from Q1 1972 to Q4 2011. The findings suggest that urbanization, economic growth, and technology raise energy demand.

Some researchers have used spatial analysis to investigate environmental issues. EKC research using spatial models began in the 1990s and continued into the early 21st century. Zhou et al. (2010) utilized Chinese provincial panel data from 1989 to 2007 to test the EKCs on seven industrial pollutants. They discovered an inverse N-shaped relation between five types of industrial pollution emissions and economic growth per capita. (Wang, Wang, Wei, and Ye, 2013a) and Wang et al. (2013b) investigated the environmental effects of the environmental footprint using data on national per capita use, production, and biocapacity. The empirical findings reject the Environmental Kuznets Curve hypothesis rejected. Hao et al. (2016) used 73 Chinese cities 2013 to analyze the connection between economic growth indicators and air quality. Their findings indicated an inverted U-shaped EKC for the environment in China. Kang et al. (2016) used geographic panel data for carbon dioxide emissions from 1997 to 2012. It discovered an inverse N-shaped relationship between economic development and CO2 emissions and indications of geographic spillover effects on EKC. (Qian, Liu, and Forrest, 2022) examined how financial agglomeration impacts the growth of China's green economy. Based on the findings, it can be concluded that technological advancements that support integrated economic growth, energy efficiency, and emissions reduction are the main ways of improving green total factor productivity. (Jiang, Wang, and Xia, 2020) investigated the factors influencing China's carbon emission changes. It concentrated on the significance of renewable energy expansion and determined that non-renewable energy reduced China's carbon dioxide emissions.

Zhou et al. (2020) examined the effect of the growth of economy and environmental quality in 30 Chinese provinces in the period 2010-2017. The model investigated if green financing is substantially connected with economic development and the environment. The paper's findings suggest that green money has a favourable effect on environmental progress. As an outlook, a model of the influence of sustainability on the relationship between economic growth and environmental quality is produced based on the concept of the EKC. Dogan et al. (2016) investigate the determinants of Co2 emissions in the European Union. The empirical evidence validates the EKC hypothesis. Trade and renewable energy lowers CO2 emissions while non-renewable energy raises CO2 emissions; thus, there is a bidirectional relationship between renewable energy and CO2 here and a one-way causal relation from income to CO2.

Theoretical settings

This paper investigates the effect of both renewable and non-renewable energy consumption on carbon dioxide emissions. In addition, this paper also examines the validity of the EKC Hypothesis in China. To examine the nexus mentioned above, the following functional form is proposed for this paper;

$$CO2_t = f\,(Y_t^{\beta_1}, Y_t^{2\beta_2},\ RE_t^{\beta_3},\ FF_t^{\beta_4}) \quad (1)$$

whereas t stands for year and β_1, β_2, β_3, and β_4 are applied as a coefficient for explanatory variables of the econometric model.

This paper uses the following model in long-run and short-run form to capture the long-term effect.

$$ln\,(CO2)_t = \beta_0 + \beta_1 lnY_t + \beta_2 lnY_t^2 + \beta_3 lnRE_t + \beta_4 lnFF_t + u_t \quad (2)$$

Where lnCO2 stands for carbon dioxide emissions in logarithmic form; lnY stands for income (gross domestic product) in logarithmic form; lnRE stands for renewable energy in logarithmic form; lnFF stands for fossil fuel in logarithm form; finally, u stands for disturbance term.

Data and methodology

Data

The study will focus on environmental issues in the context of renewable energy and fossil fuel usage in China from 1990 to 2020. The data are extracted from the World Bank (WDI, 2022). Carbon dioxide emission, income level, renewable energy, and fossil fuels are the variables of interest. CO2 is presented as carbon dioxide emission as "kt"; Y as the gross domestic product as a constant 2015 US$; RE is represented as renewable energy; FF is represented as fossil fuel usage. Table 1 provides the descriptive statistics of the factors of interest.

Table 1: Descriptive Statistics

	CO2	Y	RE	FF
Mean	15.5139	29.1545	2.9653	4.4252
Median	15.6276	29.1772	2.8277	4.4584
Maximum	16.223	30.3912	3.5288	4.4884
Minimum	14.5918	27.658	2.4283	4.3152
Standard deviation	0.572	0.8472	0.4138	0.0602
Skewness	-0.1654	-0.1539	0.0971	-0.485
Kurtosis	1.4197	1.7485	1.2821	1.6272
Jarque Bera	3.4759	2.2147	3.9853	3.7671
Probability	0.1759	0.3304	0.1363	0.1521
Sum	496.4434	932.9437	94.8909	141.6062
Sum Sq. Dev	10.1415	22.2507	5.3086	0.1124

Source: Author's calculations.

Methodology

Unit root tests

This paper uses one of the most popular and conservative stationarity tests to confirm the nature of the data, namely Dickens-Fuller's (ADF) and Phillips-Peron's (PP) unit root tests. These tests identify the order of integration of series, "Dickey and Fuller, 1981" and "Philips and Perron, 1988". The ADF and PP tests transform a string error variance into an autocorrelation (Ekanayake, 1999).

Cointegration tests

The cointegration test will be conducted to show the long-term equilibrium between the series (Zahoor, Khan, and Hou, 2022). In order to examine if a cointegration vector exists between the series, this research will use the Johansen cointegration test. This test has two types of tests: maximum Eigenvalue and Trance. The cointegration approach involves finding the relation among the variables by investigating the number of cointegration vectors between the series. The Johansen cointegration test argues that the Trance test is more appropriate than the Maximum Eigenvalue test (Awokuse, 2003). The Johansen (1988) and Juselius (1990) approaches simplify the estimation of cointegration vectors between regresand and regressors. Johansen's cointegration test is the contemporary method to avoid the issues of the Engel-Granger method (1987).

Short and long-term estimations

For the model estimation in this research, the econometric model estimation of the FMOLS method will be adopted (Jamil and Ahmad, 2010; Govindaraju et al., 2013; Khan and Hou, 2021; Peng et al., 2020). A residual-based test with practical outcomes for cointegrated factors will be adopted using the FMOLS regression approach. When the sample size is acceptable, and the issues of heterogeneity and serial relation among the factors are eliminated, the FMOLS method provides a credible estimate. The FMOLS method will estimate both short- and long-term estimates.

Empirical analysis

All the empirical estimations are carried out in Eviews 12 statistical software. The unit root tests of ADF and PP were employed to evaluate the stationarity condition of the factors. Unit root tests are performed for all series at the level form and first difference. Table 2 provides the ADF unit root test results. Table 2 illustrates the outlook of the unit root test in the level form I(0) and first difference I(1) for all variables of interest, namely CO2, Y, RE, and FF. At level form, none of the factors is stationary, Although, at the I(1), the series becomes stationary except for gross domestic product. The results suggest that variables become stationary at a 10 per cent or 5 per cent significance.

Table 2: Unit Root Test (ADF) Augmented Dickey-Fuller

Variable		None (s-statistic)	Prob.	constant (s-statistic)	Prob.	Trend and intercept (s-statistic)	Prob.
CO2	I (0)	1.8687	0.9828	-1.1965	0.6627	-1.3449	0.8564
	I (1)	-1.7916*	0.0699	-2.6938*	0.0868	-2.8351	0.1966
Y	I (0)	1.8516	0.9822	-2.3234	0.1715	-1.6449	0.7504
	I (1)	-0.6337	0.4343	-2.1484	0.2283	-3.1543	0.1127
RE	I (0)	-0.7836	0.3682	-1.533	0.5035	-1.1958	0.8933
	I (1)	-1.8425*	0.063	-1.8841	0.3349	-2.1463	0.5006
FF	I (0)	2.3406	0.994	-2.5979	0.1045	-1.5231	0.7987
	I (1)	-2.5102**	0.0139	-3.5802**	0.0124	-4.2333**	0.0116

Note: [i]CO2 represents the carbon dioxide emission; Y represents the gross domestic product; RE represents the renewable energy consumption; FF represents the fossil fuel. [ii] *, **, and *** denote null hypothesis rejection at alpha-10 percentage, five percentages, and one percentage, respectively.

Source: Author's calculations.

Table 3 provides PP unit root test results. Phillips Perron test (1988) also utilizes a more conservative test to analyze the stationarity and identify the order of integration variables (Wang et al., 2016). Table 3 illustrates the finding of the PP test in both levels and the first difference between CO2, Y, RE, and FF. As a result, the series is not stationary at the I(0) but becomes stationary at the I(1), which shows that all factors integrate at I(1).

Table 3: Unit Root Test of (PP) Phillips Perron

		None (s-statistic)	Prob.	Constant (s-statistic)	Prob.	trend and intercept (s-statistic)	Prob.
Variables							
CO2	I (0)	3.8612	0.9999	-1.1642	0.6769	-1.061	0.9197
	I (1)	-1.6993*	0.0841	-2.7887*	0.0719	-2.9329	0.167
Y	I (0)	10.7109	1.0000	-3.0184	0.4442	-0.2374	0.989
	I (1)	-0.5161	0.4846	-2.1587	0.2247	-3.2798*	0.089
RE	I (0)	-1.4992	0.1231	-1.268	0.6315	-0.6725	0.9665
	I (1)	-1.7920*	0.0699	-1.8696	0.3414	-2.1134	0.5179
FF	I (0)	2.6562	0.9972	-1.3777	0.5802	-0.7873	0.9561
	I (1)	-2.683***	0.0091	-3.6942***	0.0094	-4.2364***	0.0115

Note: [i]CO2 represents the carbon dioxide emission; Y represents the gross domestic product; RE represents the renewable energy consumption; FF represents the fossil fuel. [ii] *, **, and *** denote null hypothesis rejection at alpha-10 percentage, 5 percentages, and 1 percentage, respectively.

Source: Author's calculations.

Since the unit root test results indicate that all series are stationary at I(1), for further analysis, the Johansen cointegration test will be adopted to check if there is a cointegration vector between CO2, Y, RE, and FF or not. The cointegration test promoted by Johansen and Juselius (1990) and Johansen (1988) is utilized in this research. According to the cointegration test, the Johansen test can assess whether a cointegrating relation exists among factors. Tables 4 and 5 provide the Johansen test results of Trance and Max Eigen, respectively. The null hypothesis of no cointegration can be rejected if the test statistics exceed the critical value and the probability value is less than 5 per cent.

The finding of the Johansen cointegration test shows that the cointegration test of Trance has found three cointegration vectors among the variables, but the cointegration test of Max-Eigen has found only one cointegration vector among the variables. The bottom line is that both test statistics confirm the existence of a cointegration vector. Therefore, there is a long-run relationship between CO2 emission and its determinants. The FMOLS method will be employed to estimate short- and long-term coefficients for further estimations.

Table 4: Cointegration Test (Johansen- Trance)

Unrestricted Cointegration Rank "Trace" test				
Hypothesized		Trace	0.05	
No. of coefficient (s)	Eigen-value	Statistic	Critical Value	Probability**
None*	0.769023	110.3894	69.81889	0.000
At most1*	0.689339	66.42624	47.85613	0.0004
At most2*	0.447932	31.3547	29.79707	0.0328
At most3	0.363006	13.53217	15.49471	0.0967
At most4	7.80E-05	0.002341	3.841466	0.9593

Source: Author's calculations.

Table 5: Cointegration Test (Johansen- Max Eigen)

Unrestricted Cointegration Rank "Maximum Eigenvalue" Test				
Hypothesized		Max Eigen	0.05	
No. of CE(s)	Eigen-value	Statistic	Critical-Value	Probability
None *	0.769023	43.96312	33.87687	0.0023
At most 1	0.689339	35.07154	27.58434	0.0045
At most 2	0.447932	17.82253	21.13162	0.1366
At most 3	0.363006	13.52983	14.26460	0.0651
At most 4	7.80E-05	0.002341	3.841466	0.9593

Source: Author's calculations.

Table 6 provides long-run estimations of the fully modified least square method. The findings suggest that economic growth, as income level, has a significant and positive long-term effect on carbon dioxide emissions. However, renewable energy usage and squared income negatively impact CO2 emissions. However, fossil fuels have a negative insignificant effect on CO2. However, the analysis shows that if one unit of economic growth increases, carbon dioxide emissions go up by 0.615629 units. If renewable energy consumption increases, carbon dioxide emissions lessen by 0.494378 units, and if one unit of squared income increases, CO2 emissions decrease by 0.003358 units. However, fossil fuel usage does not have a significant long-run impact on CO2 emissions. The estimations from the FMOLS methodology validate the EKC hypothesis in the long term. The findings of this research imply that adopting renewable energy promotes environmental sustainability without reducing economic growth. Furthermore, it suggested that preferring renewable energy rather than fossil fuels may help avoid adverse environmental effects (Khan, Hou, Zakari, and Tawiah, 2021; Khan et al., 2021).

Table 6: Long-Run Estimation

Variable	Coefficient	Standard. Error	T-statistic	Probability
Y	0.615629**	0.250492	2.457684	0.0207
Y2	-0.003358**	0.003908	-0.859259	0.0397
RE	-0.494378***	0.085557	-5.778328	0.0000
FF	0.4267766	0.868956	0.491126	0.6273
R-squared	0.696538	Mean dependent var		15.5436
Adjusted R-squared	0.696153	S.D. dependent var		0.5557
S.E. of regression	0.034466	Sum squared resid		0.032074
Long-term variance	0.002679			

Note: [i]CO2 represents the carbon dioxide emission; Y represents gross domestic product; RE represents renewable energy consumption; FF represents the fossil fuel. [ii] *, **, and *** denote null hypothesis rejection at alpha-10 percentage, five percentages, and one percentage, respectively.

Source: Author's calculations.

The estimation from FMOLS methodology in the short term is illustrated in Table 7. The empirical results indicate that economic growth (Y) has a significantly positive impact on CO2 emissions. Unlike the long-term estimations, fossil fuels significantly and positively impact CO2 emissions in the short term. Nevertheless, Y2 has a significantly negative impact on CO2 emissions. Moreover, renewable energy usage has a significantly negative impact on carbon dioxide emissions in the short-run, which indicates its remedial effect on environmental quality that is similar to the long-run estimation result. Moreover, if the economic growth (Y) goes up one unit, carbon dioxide emissions go up by 10.51165 units, and if the Y2 has increased by one per cent, the carbon dioxide emission decreases by 0.173817, which validates the inverted –U shape of the relationship between the income level and carbon dioxide emissions. If renewable energy goes up by one unit, carbon dioxide emissions will lessen by 0.53627 units; however, if the fossil fuel increases by one per cent, the carbon dioxide emission will increase by 1.731097. On the other hand, the short-run estimation shows that intercept has a statistically significant and negative effect, that without any change in economic growth, renewable energy usage, or fossil fuel usage that the carbon dioxide emission mitigates in China, even though empirical estimations on trend shows the positive and trivial effect on carbon dioxide emission. Similarly, the long-term and short-term estimations of the FMOLS method provide evidence of the existence of the EKC hypothesis. ECT has an expected sign showing that environmental degradation in the model converges by 23.7125% toward its long-run equilibrium level. Nevertheless, short-run coefficients are highly significant and interact with environmental degradation similarly to long-term ones.

Table 7: Short-Run Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Y)	10.51165**	3.791751	2.772241	0.0111
D(Y2)	-0.173817**	0.064295	-2.703444	0.0130
D(RE)	-0.536927***	0.060259	-8.910285	0.0000
D(FF)	1.731097***	0.461017	3.754953	0.0011
ECT(-1)	-0.237125***	0.081873	-2.896251	0.0084
C	-0.068387**	0.024869	-2.74993	0.0117
TREND	0.0043659***	0.001006	3.635164	0.0015
R-squared	0.90532	Mean dependent variable		0.052568
Adjusted R-squared	0.879499	Standard deviation dependent variable		0.04721
S.E. of regression	0.016388	Sum squared resid		0.005909
Long-term variance		0.000108		

Note: [i]CO2 represents the carbon dioxide emission; Y represents the gross domestic product; RE represents the renewable energy consumption; FF represents the fossil fuel. [ii] *, **, and *** denote null hypothesis rejection at alpha-10 percentage, five percentages, and one percentage, respectively. **Source:** Author's calculations.

Conclusion

This paper aims to reconsider the environmental quality in the context of renewable energy and fossil fuel usage in China from 1990 to 2020. The FMOLS method is carried out for long- and short-term estimations. The findings of the empirical analysis show that there is a significant positive relationship between economic growth and carbon dioxide emission. At the further stages of growth, the effect lessens carbon dioxide emissions. In the short-run, fossil fuel usage has a positive significant impact on CO2 emissions. Besides, the findings suggest a statistically significant and negative impact of renewable energy usage on short- and long-run carbon dioxide emissions.

Several previous researchers have examined the relationship between China's fossil fuel usage, renewable energy usage, and carbon dioxide emissions. (Long, Naminse, Du, and Zhuang, 2015) discovered that fossil fuel usage significantly influences carbon dioxide emissions and economic growth. Changing the structure of fossil fuel energy usage in China is crucial. It should decrease the rate of fossil fuel energy usage and put more value on reducing CO2 emissions. Nevertheless, more focus should be put on renewable energy usage to decrease the amount of CO2 emissions in China. On the other hand, (Abbasi, Shahbaz, Zhang, Irfan, and Alvarado, 2022) show that fossil fuel energy usage increases carbon dioxide emissions in China in the short and long term. Although economic growth also increases carbon dioxide emissions in the long run, it will lessen environmental degradation. However, using renewable energy has a negative short-run effect on carbon dioxide emissions. It is suggested that decreasing carbon dioxide emissions will positively affect the quality of China's environment. Moreover, (Chen, Wang, and Zhong, 2019) suggest that long-term economic growth and fossil fuels increase carbon dioxide emissions. The empirical results of different research show similar findings.

Furthermore, as has already been stated, China might achieve a long-term environmental goal by increasing renewable energy consumption as a substitute for fossil fuel consumption. Reduced fossil fuel energy usage should have a direct effect on CO2 emissions. China should encourage energy-saving technology and improve energy efficiency if it desires a sustainable environment. In the last thirty years, China has imported and begun manufacturing domestically low-carbon technologies (Guan, Klasen, Hubacek, Feng, Liu, He, and Zhang, 2014). The Chinese government develops and operates efficient strategies to maximize renewable energy usage, build structures to replace fossil fuel energy consumption and promote environmental sustainability. Policies are implemented that promote technologies that have low carbon dioxide emissions for production and increase green investment, especially in technologies with low carbon dioxide emissions (Zhang, Zhang, Wu, Deng, Lin, and Yu, 2013). Once the goal is achieved, the formula for sustainable environmental management will gradually decarbonize. The analysis undertaken in a research paper shows that reducing fossil fuels and increasing renewable energy usage are achievable ways to bring sustainable environmental change to China. Its empirical result suggests some policy implications that China should focus more on the usage and growth of renewable energy to reduce carbon dioxide emissions. On the other hand, China must continue to promote renewable energy to decrease air pollution. As well as it should provide financial, legal, and policy advice to implement the "renewable energy law." In addition, China ought to grow the percentage of renewable energy usage while decreasing non-renewable energy use.

Further research could focus on various types of renewable energy sources and different ecological indicators, both in time series and panel data estimations. Additionally, considering their interaction, future studies can focus on the causality between ecological indicators and economic growth within the framework of simultaneous formulations. Finally, it is suggested that the EKC hypothesis can be examined using appropriate econometric methods in the context of other ecological variables used in the current study. New perspectives can be gained in future studies.

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