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Dynamic association between energy transition technologies, renewable energy production, trade openness, green investment, carbon tax, and carbon neutrality: empirical evidences from China

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ABSTRACT

The existing millennium documents the most adverse consequences of global warming which in contrast to pre-industrial era are more devastating. Thus, these prevailing consequences raise numerous concerns regarding the well-being of future and current generation. Scholars, in this regard, are putting efforts punctiliously towards methods that could halt the surging emissions. This paper also attempts to contributes to existing literature by reporting the empirical evidences regarding the role of energy transition technologies, renewable energy production (REP), trade openness, green investment, and carbon taxes in carbon neutrality in Chinse economy covering the time span of 1980–2020. By employing Dynamic Auto-regressive Distributed Lags (DARDL) model to check the association, findings exposed that electricity production from water sources, electricity production from solar sources, REP, trade openness, green investment, and carbon taxes are negatively correlated with CO_2 emissions. Study offers policymakers a help in formulating policies related to achieve carbon neutrality using renewable sources of energy production, carbon taxes, and green investment.

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1. Introduction

The desperate need to address devastating challenges of global warming appears to be the most topical issue of present era. The reason is to make the peaceful coexistence of humankind and balancing ecosystem (Liu et al., 2022a; Sadiq et al., 2022c, 2022d).

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Amongst various reasons, every progress that has made in favour of economic growth, comes with environmental consequences, hence making environment a global issue. Policy makers, government institutions, international communities, in fact all entities are taking keen interest in finding way which can stabilise the economy and environment simultaneously, hence, aiming to reach 2030 sustainable goals. The particular edition of UN climate conferences, that held in 2021 with 200 nations, stressed out this important fact that governments of all economies must show commitment in order pursue 2050 carbon neutrality goal (Wang et al., 2021).

The net zero emission road map within targeted period has disclosed several factors that are bring identified as culprits of harmful emissions. For suppose, COP26 goals point out the need of reduction in coal power, fossil fuel resources that are estimated around 5.9 trillion dollars. Nonetheless Ness, vantage points stated above signal the efforts of economies which they are trying to minimise GHG emissions by initiating a steady, gradual yet persistent transitioning of non-renewables (Ainou et al., 2022; Zhao et al., 2022a; Wu et al., 2022). Along with it, the economies are also looking forward ways to promote technological innovation, considering it as an essential and effective method. Other than that, indicators such as carbon taxes, green investment, trade openness have also been proven effective predictors of environmental quality. These multitude efforts in attaining net zero emissions have been photographed under the advocacy of carbon neutrality, among which the outlined constructs contain higher rankings. As carbon neutrality is global goal, thereby, it is divine for all economies to welcome the ideology and make practical effort to embrace the target. Most profoundly, COP26 reputedly documented the commitment from 153 economies which made pledge to add meaningful practical contribution on "Nationally Determined Contributions" (NDCs). Among these economies, China is also one of those nations which promised to fulfil the commitment of net zero emissions and for that the country is working rigorously by opting those methods which help the country to achieve the targeted goal (Bai et al., 2022; Shi et al., 2021).

As discussed, this research is about enumerating carbon neutrality in China by analysing CO_2. China is an emerging country with an upper-middle-income economy. Its total population will be 1,451,432,510 by 2022. The nominal GDP of China is \$18.32 trillion, which shows the country at the 2nd rank among the world countries, while the GDP (PPP) is \$30.07 trillion, according to which it ranks 1st among largest economies. There are three economic sectors, out of which Agriculture has a 7.9% GDP share, Industry and services have 40.5% and 51% in the country GDP (Sun et al., 2021; Sadiq et al., 2022a, 2022b). The environmental conditions in China are getting worse, keeping pace with the increasing population and economic expansion. About 10.67 billion metric tons of CO_2 emissions were released from China in 2020, and it shows a 177.90 million tons annual increase in CO_2 emissions from 2019 to 2020. China's per capita CO_2 emissions are 7.41 tons, and cumulative country's CO_2 emissions will be 235.56 billion tons by 2020. These figures for China's CO_2 emissions show it was the largest polluter that year across the globe. Due to COVID-19, most countries saw significant reductions in emissions in 2020, but China was ranked in those economies that witnessed the increase in emissions (Chen & Lin, 2021; Chien, 2022a).

Although China only really began to contribute to global CO_2 emissions at the beginning of the twenty-first century. It has yet to produce the 2^{nd} largest amount of CO_2 emissions ever in terms of cumulative production. China's cumulative CO_2 emissions will be 235.56 billion tons by 2020, while the United States' cumulative emissions will be 416.72 billion tons. This is still about half of what is produced in the United States, where industrialisation started far earlier (Chien et al., 2022b; Xu et al., 2022). Moreover, China makes a 30.65% share of annual global CO_2 emissions, whereas its share of global accumulative CO_2 emission is 13.89%. China's reliance on coal in its energy mix is one of the primary causes of its high emissions levels. China set an ambitious plan in 2020 to achieve carbon neutrality by 2060, necessitating a massive shift away from fossil fuel-powered energy and transportation (Chien et al., 2022c; Liu et al., 2022b).

China is the largest polluter and emitter of CO_2 in contrast with other economies. The large volume of CO_2 emissions year by year raise environmental issues for the country itself and also affects the climate in other areas of the world. The decreasing environmental quality is a hurdle in the country's everlasting development and achieving sustainable social progress as well as it also creates problems for neighbouring countries. Though the concerned authorities have considered all these issues and made a plan for achieving carbon neutrality by 2060 progress in this regard is not enough (Chien, 2022b; Koondhar et al., 2021).

Against the afore-mentioned discussion, the current study explores the proposed hypothetical arguments which proclaim that energy transition technologies, renewable energy production (REP), trade openness, green investment and carbon taxes are those predictors that stands out among other factors, hence, providing a better chance of carbon neutrality in economies like China which pledges to work devotedly for the sake of well-being of current and future generations. Besides, the preceding evidences reported strong empirical backing regarding energy transition technologies as a negative predictor of carbon emissions (Lin et al., 2022). Hence, keeping in mind its effectiveness towards zero carbon goal underscores its consideration in proposed framework. Further, the need to open for other economies, with the passage of time, has become inevitable for host countries. This proposition is backed by the fact that global openness increases the economic growth with faster pace. Hence, encourages the authors to inculcate trade openness in the framework. Moreover, the prior claims regarding trade environment seems to be inconclusive, hence, diverging the assumptions regarding positive and negative nexus of the construct with others. Thereby, the study intends to spotlight these two perspectives along with other factors such as green investment, carbon taxes and REP in recent times (Ibrahim, 2022; Kamarudin et al., 2021).

Under these propositions, the study offers few novelties in existing plethora. Firstly, the study adds fresh evidences regarding China's economy by investigating the nexus among outlined constructs as the country made an official statement to commit to achieve net zero emissions in COP26 conference. Secondly, a junction of technological energy transitions with trade openness, green investment and carbon taxes in the carbon neutrality framework appears to be add novelty in the context of China's economy. Also, with DARDL, the study offers interesting evidences which are helpful in the formulation of all-inclusive policies based on the knowledge fountain of proposed carbon neutrality model.

The present article comprises the following parts: The 2nd part presents a review of previous studies to discuss the relationship among electricity production from water and solar sources, renewable energy production, trade openness, green investment, carbon taxes and carbon neutrality. The 3rd part relates the methods applied for the collection of data and procedures to analyse this data for results. Research findings are described and confirmed with the views of similar studies. Then, study implications are described, a short conclusion is given, and limitations are highlighted.

2. Literature review

2.1. Energy transition technologies and carbon neutrality

When carbon emissions and carbon absorption are in balance, this is referred to as being carbon neutral. When carbon neutrality is attained, the environment can be preserved, and the quality of the air, soil, water, minerals, energy sources, food and non-food crops, trees, and living resources can all be maintained. In these circumstances, the countries may achieve sustainable economic development thanks to a healthy, pleasant workplace and an abundance of high-quality natural resources (Chien et al., 2022a; Li et al., 2021). Although a variety of human activities contribute to CO_2 emissions. There is a large amount of literature about electricity production from water and solar sources, renewable energy production, trade openness, green investment, and carbon taxes' role in reducing CO_2 emissions and achieving carbon neutrality. The current study checks the relations of electricity production from water and solar sources as energy transition technologies, renewable energy production, trade openness, green investment, and carbon taxes with carbon neutrality in light of the literature review.

2.2. REP and carbon neutrality

The production of electric energy applying water sources leads to the discouragement of mining of oil, coal, and gas as well as people stop moving towards nuclear power plant construction and nuclear reaction to fulfil energy requirements. The reduction in fossil fuels and nuclear energy reduces the CO_2 emissions from different technical practices. Thereby, carbon neutrality is attained (Algarvio, 2021; Dinh et al., 2022). Research was conducted by Feng et al. (2022) and Wirsbinna and Grega (2021) to investigate the relationship among electricity production from water, energy transition, and carbon neutrality. The data were collected from the Chinese economy. The authors have the view that in most areas, people are able to acquire sustainable energy supplies if there is an increase in production of electricity from using water sources in the country. In this situation, the propensity of people to use renewable energy is growing, replacing the use of typical fossil fuel energy to keep on their functioning in different life spheres. This energy transition has the effect of reducing CO_2 emissions. As a result, carbon neutrality is feasible. In a research article, Irfan et al. (2021) and Jermsittiparsert (2021) examines the relationship between electricity production from water, energy consumption, energy transition, and carbon neutrality. The required information for electricity production from water, energy consumption, energy transition, and CO_2 emissions were obtained from 38 IEA countries. The authors find that the increasing electricity production from the water gives carbon-free energy and when there is energy, carbon neutrality can be accomplished

Electricity production through the application of solar power systems, helps to increase the supply of clean and replenishing energy based on natural sources. This increasing energy supply discourages the firms' management from utilising backwards sources of energy and ore to achieve their professional goals. While wastes and pollution-emitting fossil fuels are discouraged from being used, there is a reduction in CO_2 emissions, and carbon neutrality can be achieved (Duong & Hai Thi Thanh, 2022; Hosseini & Wahid, 2020). Hartani et al. (2021) and Schreyer et al. (2020), examines the impacts of electricity from solar sources on carbon neutrality. The authors have the opinion that there is no danger associated with using solar energy. There is no concern about the generation of waste or the release of harmful gases or toxic compounds after using electricity in some procedures. Therefore, using electricity produced from solar resources ensures that there would be no excessive CO_2 emissions, which would otherwise constitute an imbalance in the volume of natural carbon. It indicates progress toward carbon neutrality. Ojogiwa (2021) and Razmjoo et al. (2021), throws light on electric power from solar systems, renewable energy, and CO_2 emissions. The authors acquired information from hybrid renewable systems specific to electricity production in Iran. The authors employed HOMER software for the analysis of the relationship between the factors. The supply of sustainable energy as the result of increased electricity from solar panel systems allows business organisations to adopt a sustainable energy consumption pattern. The energy transition from fossil fuels energy to renewable/sustainable energy reduces the organisations' CO_2 emissions. Hence, it becomes possible to achieve carbon neutrality (Phuoc et al., 2022; Quynh et al., 2022).

Fossil fuel and energy from nuclear power plants are preferred to be utilised in order to fuel business operations and also perform some household activities. But the utilisation of fossil fuel and nuclear power causes CO_2 emissions and are destructive to the environment. The supply from renewable energy production assists in overcoming fossil fuel and nuclear energy consumption and fighting against CO_2 emissions without causing hurdles the business operations and other human activities. Hence, increasing RE increases the capacity to achieve zero carbon goal (Gil & Bernardo, 2020; Lan et al., 2022). Dahal et al. (2018) and Shibli et al. (2021), did research to explore the influences of renewable energy production on the achievement of carbon neutrality. The demand for energy rises as human requirements rise in tandem with population growth, and people are forced to carry out more activities. It is now possible to meet rising human needs without causing CO_2 thanks to the development of renewable energy generation, which also helps to boost the energy supply to keep up with the rapidly rising energy demand. Thus, it is feasible to reach carbon neutrality. Shan et al. (2021), investigates the relationship between REP and green technology innovation with the degree of progress in achieving carbon neutrality. The authors employed the STIRPAT model to check the linkage between renewable energy production and green technology innovation and carbon emissions in Turkey over the time from 1990 to 2018. The results showed that renewable energy production has a positive association with progress in achieving carbon neutrality because the resultant REC reduces emissions.

2.3. Trade openness and carbon neutrality

Usually, trade openness is considered the source to increase CO_2 emissions with respect to a dramatic increase in household and commercial consumption levels. But, it also strengthens the country's capacity to combat emissions, for it generates high revenues, encourages technological development, and improves the knowledge about eco-friendly strategies applied in foreign countries. The actual reduction in CO_2 emissions, as the result of effective trade openness, is helpful to achieve zero carbon goal (Lahiani et al., 2021; Moslehpour et al., 2022b). Dauda et al. (2021), examines trade openness and innovation on carbon emissions. The nine African countries are the context of analysis for trade openness and innovation on CO_2 emissions over the period of 1990–2016. The research implies that in trade openness, the import of RE or the instruments essential to produce renewable energy encourages the transition of fossil fuel resources. Consequently, the considerable decrease in CO_2 emissions improves work on carbon neutrality. Moslehpour et al. (2022c) and Park et al. (2018), integrates association among TO, FD, EG, and ICT and carbon neutrality in EU context. The results showed that trade openness is helpful in planning and executing eco-friendly activities within the country. With the undertaking of such activities, CO_2 emissions can be overcome, and carbon neutrality can be attained. Hence, trade openness is positively linked to carbon neutrality.

2.4. Green investment and carbon neutrality

Green investment is helpful in ensuring eco-friendly innovation, which combats emissions (Ji et al., 2021; Liu et al., 2021b; Liu et al., 2022). Shen et al. (2021), investigates the green investment, NRR, and financial development and their effectiveness on carbon emissions. The panel data collected from thirty provinces of China and CS-ARDL approach is applied to test the relationship covering time span of 1995–2017. Green investments are able to draw a sizable amount of attention due to public awareness and interest, which makes the work of raising funds for eco-friendly activities much simpler. This reduces CO_2 emissions and improves carbon neutrality. Sharif et al. (2022) and Zhao et al. (2021), identifies the relationship of green investment and green technological innovation with carbon neutrality in G7 countries for the time of 1995–2019. Authors revealed that GI and carbon neutrality are positively significant as the green investment enables the firms to employ green technological innovation and, thereby, reduce carbon emissions. Lyeonov et al. (2019) and Tan et al. (2021), integrate the relations green investment role in carbon neutrality for attaining sustainable development. EU countries provide a context for the empirical analysis of the involved factors over the time from 2008 to 2016. The study implies that the execution of green programs requires financial resources. The green investment meets this requirement and assures CO_2 reduction. Hence, green investment has a positive link to carbon neutrality.

2.5. Carbon taxes and carbon neutrality

Numerous human activities, including social, personal, and the majority of commercial ones, have the potential to release carbon, which reacts with oxygen in the atmosphere to form CO_2. Taxes are forced by government institutions on people and businesses that indulge in carbon-intensive activities. The goal of carbon taxes is to reduce CO_2 emissions. How effectively carbon taxes are implemented will influence how well CO_2 emissions can be reduced. This determines the progress on achieving carbon neutrality (Moslehpour et al., 2022a, 2022b; Tirkaso & Gren, 2020). Ghazouani et al. (2020) and Nguyen et al. (2021), check the carbon taxes' role in achieving carbon neutrality. The authors carried out a test on the economies of two groups of European nations: one with implemented carbon taxes and one without any carbon taxes at all. In order to examine the impact of carbon taxes on CO_2 emissions, the propensity score matching method was applied. According to the study's findings, the effectively implemented carbon taxes speed up the decrease of CO_2 emissions and prepress carbon neutrality. In a study on environmental taxes and environmental quality, Wolde-Rufael and Mulat-Weldemeskel, (2021) and Zhao et al. (2022b) examine carbon taxes' role in achieving carbon neutrality in E7 context. The results showed that in countries where the government imposes carbon taxes, individuals and firms change their behaviours while making a choice of resources, techniques, and processes as they do not cause CO_2 emissions. In this situation, carbon neutrality is easy to achieve.

3. Research methods

The present paper examines energy transition technologies REP, trade openness, green investment, and carbon taxes and their effectiveness on carbon neutrality in China's economy. Secondary data was used extracted from various resources considering the period 1981-2020. The article has built the equation which is stated below:

$$CO2E_t = \alpha_0 + \beta_1 EPWS_t + \beta_2 EPSS_t + \beta_3 REP_t + \beta_4 TRO_t + \beta_5 GINV_t + \beta_6 CRT_t + \beta_7 URB_t + e_t \quad (1)$$

where CO_2E = Carbon Dioxide Emission; t = Time Period; EPWS = Electricity Production from Water Sources; EPSS = Electricity Production from Solar Sources; REP = Renewable Energy Production; TRO = Trade Openness; GINV = Green Investment; and CRT = Carbon Taxes.

Carbon neutrality is used as the dependent variable in the study and four predictors such as energy transition technologies, trade openness, green investment and carbon taxes are viewed as the study predictors (see Table 1)

Table 1. Variables with measurements *(Author Estimation).*

S#	Variables	Measurement	Sources
01	Carbon Neutrality	CO_2 emissions (metric tons per capita)	Climate watch
02	Energy Transition Technologies	Electricity production from water sources (% of total)	WDI
		Electricity production from solar sources (% of total)	WDI
03	Renewable Energy Production	REP (% of total electricity output)	EIA
04	Trade Openness	imports + exports normalised by GDP	WDI
05	Green Investment	The investment in green projects to total investment	OECD
06	Carbon Taxes	Taxes on wastage (% of revenue)	WDI

Note: WDI = World development indicators, EIA = Energy information administration, OECD = Organisation for Economic Co-operation and Development.
Source: Authors' Estimation.

The paper performed descriptive method to evaluate data properties. In addition, the study applied the matrix of correlation to check the directional connection among variables. Additionally, the study also used the Phillips-Perron (PP) and augmented Dickey-Fuller (ADF) test to assess unit root. The equation for the test is given as under:

$$d(Y_t) = \alpha_0 + \beta t + \Upsilon Y_{t-1} + d(Y_t(-1)) + \varepsilon_t \tag{2}$$

In addition, the study also applied the (Westerlund & Edgerton, 2008) approach to check the co-integration among variables. The equations for this approach are mentioned below:

$$\mathrm{LM}_{\varphi}(\mathrm{i}) = \mathrm{T}\hat{\varphi}_{\mathrm{i}} \ (\hat{\mathrm{r}}_{\mathrm{i}}/\hat{\sigma}_{\mathrm{i}}) \tag{3}$$

$$\mathrm{LM}_{\tau}(\mathrm{i}) = \hat{\varphi}_{\mathrm{i}}/\mathrm{SE}(\hat{\varphi}_{\mathrm{i}}) \tag{4}$$

Equations (3) and (4) estimate beside standard error represents by $\hat{\boldsymbol{\varphi}}_{\boldsymbol{i}}$, while long-run measured variance is represented by $\hat{r}^2$, scalar polynomial with L lag length represented by $\boldsymbol{\varphi}\mathbf{i}\ (\mathbf{L}) = \mathbf{1} - \Sigma\ \boldsymbol{\varphi}_{\mathbf{ij}}\mathbf{L}^{\mathbf{j}}$, and factor loading parameters vector I represented by ρ_i.

Moreover, ARDL model was also employed to scrutinise the variables association. The model is appropriate for the situation when some variables have no unit root at I(0) or I(1) (Nazir et al., 2018). In addition, it also provides long as well as short-run nexus among understudy constructs. Finally, it manages the effects of autocorrelation and heteroscedasticity (Zaidi & Saidi, 2018). The ARDL expression for the study is given below:

$$\begin{aligned}\Delta CO2E_t = \alpha_0 &+ \sum \delta_1 \Delta CO2E_{t-1} + \sum \delta_2 \Delta EPWS_{t-1} + \sum \delta_3 \Delta EPSS_{t-1} \\ &+ \sum \delta_4 \Delta REP_{t-1} + \sum \delta_5 \Delta TRO_{t-1} + \sum \delta_6 \Delta GINV_{t-1} + \sum \delta_7 \Delta CRT_{t-1} \\ &+ \varphi_1 CO2E_{t-1} + \varphi_2 EPWS_{t-1} + \varphi_3 EPSS_{t-1} + \varphi_4 REP_{t-1} \\ &+ \varphi_5 TRO_{t-1} + \varphi_6 GINV_{t-1} + \varphi_7 CRT_{t-1} + \varepsilon_t\end{aligned} \tag{5}$$

Finally, the study used DRADL approach to test the association among variables. The approach is proposed by Jordan and Philips (2018). It has the ability to get rid of the shortcoming that exists in the ARDL model. In addition, this approach is also suitable when co-integration exists. The DARDL equation is mentioned below:

$$\Delta CO2E_t = \alpha_0 + \sum \delta_1 \Delta CO2E_{t-1} + \sum \delta_2 \Delta EPWS_t + \sum \delta_3 \Delta EPWS_{t-1} + \sum \delta_4 \Delta EPSS_t + \sum \delta_5 \Delta EPSS_{t-1} + \sum \delta_6 \Delta REP_t + \sum \delta_7 \Delta REP_{t-1} + \sum \delta_8 \Delta TRO_t + \sum \delta_9 \Delta TRO_{t-1} + \sum \delta_{10} \Delta GINV_t + \sum \delta_{11} \Delta GINV_{t-1} + \sum \delta_{12} \Delta CRT_t + \sum \delta_{13} \Delta CRT_{t-1} + \varepsilon_t \quad (6)$$

4. Findings results

The findings in Table 2 indicates that carbon mean value is recorded 3.611 metric tons per capita followed by EPWS 1.014 percent, EPSS 79.818 percent, REP 17.975 percent, TRO 36.291 percent, while the GINV 51.070 percent, and CRT 0.104 percent.

Moreover, year-wise descriptive statistics can be shown in Table 3. The findings indicated that the CO2E highest value was recorded 8.191 metric tons per capita in 2020, the EPWS largest value was recorded 4.857 in 2015, while the EPSS largest value was recoded 82.843 percent in 2007, and the REP highest value was recorded 23.927 percent in 2015. In addition, the findings indicated that the TRO largest value was recorded 64.479 percent in 2006, while the GINV highest value was recorded 56.370 percent in 2020, and the CRT largest value was recorded 0.270 percent in 2008.

In addition, the study applied the matrix of correlation to check the directional connection among variables. The findings exposed that electricity production from water sources, electricity production from solar sources, REP, trade openness, green investment, and carbon taxes have a are negatively correlated with carbon emissions in China. These values are mentioned in Table 4.

Additionally, the study also applied the PP test along with the ADF test to assess unit root among constructs (see Table 5). The findings indicated that the CO2E, EPWS, EPSS, GINV, and CRT have no unit root at I(0). Contrastingly, results indicated that the REP and TRO have no unit root at I(1).

The study also applied the (Westerlund & Edgerton, 2008) approach to check the co-integration among variables. The findings exposed that the t-values are $>$ 1.96

Table 2. Descriptive statistics *(Author Estimation)*.

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2E	40	3.611	2.785	−0.970	8.191
EPWS	40	1.014	1.431	0.011	4.857
EPSS	40	79.818	2.180	72.962	82.843
REP	40	17.975	1.807	15.037	23.927
TRO	40	36.291	14.295	13.566	64.479
GINV	40	51.070	3.178	45.894	56.370
CRT	40	0.104	0.044	0.005	0.270

Source: Authors' Estimation.

Table 3. Descriptive statistics (Years) *(Author Estimation).*

	CO2E	EPWS	EPSS	REP	TRO	GINV	CRT
1981	−0.970	0.011	78.805	16.614	14.897	45.894	0.101
1982	−0.735	0.011	77.295	16.683	14.225	45.939	0.102
1983	−0.500	0.011	75.427	16.753	13.566	45.998	0.103
1984	−0.265	0.011	77.005	16.823	15.770	46.893	0.104
1985	−0.030	0.011	77.509	16.893	20.690	46.984	0.105
1986	0.205	0.011	78.971	16.963	19.898	46.990	0.106
1987	0.440	0.011	79.888	17.033	20.745	47.401	0.107
1988	0.674	0.011	79.980	17.102	23.026	47.673	0.108
1989	0.909	0.011	79.756	17.172	19.135	47.944	0.108
1990	1.915	0.011	79.592	20.408	22.199	48.216	0.109
1991	2.001	0.011	81.529	18.471	24.066	48.488	0.110
1992	2.076	0.017	82.415	17.585	26.098	48.760	0.111
1993	2.245	0.017	81.683	18.125	25.900	49.032	0.112
1994	2.322	0.054	80.322	18.088	35.770	49.303	0.113
1995	2.563	0.306	79.513	19.214	34.277	49.575	0.114
1996	2.522	0.152	81.120	17.552	33.815	49.847	0.115
1997	2.548	0.259	81.218	17.512	34.533	50.119	0.116
1998	2.606	0.245	80.731	18.061	32.424	50.390	0.117
1999	2.517	0.244	82.113	16.681	33.524	50.662	0.118
2000	2.650	0.234	82.126	16.639	39.411	50.934	0.119
2001	2.775	0.225	79.862	18.959	38.527	51.206	0.120
2002	2.976	0.210	80.862	17.619	42.747	51.478	0.121
2003	3.427	0.191	82.695	15.037	51.804	51.749	0.122
2004	3.954	0.179	81.486	16.223	59.506	52.021	0.123
2005	4.468	0.297	81.702	16.175	62.208	52.293	0.124
2006	4.910	0.387	82.494	15.593	64.479	52.565	0.124
2007	5.306	0.477	82.843	15.263	62.193	52.836	0.126
2008	5.435	0.860	80.290	17.737	57.613	53.108	0.270
2009	5.798	1.292	80.248	17.864	45.185	53.380	0.005
2010	6.335	1.674	79.401	18.623	50.717	53.652	0.005
2011	6.901	2.138	81.174	16.762	50.741	53.924	0.005
2012	7.046	2.658	77.860	19.966	48.268	54.195	0.081
2013	7.324	3.565	77.424	20.296	46.744	54.467	0.070
2014	7.294	4.057	74.823	22.609	44.905	54.739	0.044
2015	7.146	4.857	72.962	23.927	39.464	55.011	0.138
2016	7.115	2.883	79.908	19.058	36.894	55.282	0.117
2017	7.231	3.026	79.914	19.128	37.632	55.554	0.146
2018	7.487	3.170	79.920	19.197	37.566	55.826	0.093
2019	7.606	3.313	79.925	19.267	35.890	56.098	0.069
2020	8.191	3.456	79.931	19.337	34.589	56.370	0.058

Source: Authors' Estimation.

Table 4. Matrix of correlations *(Author Estimation).*

Variables	CO2E	EPWS	EPSS	REP	TRO	GINV	CRT
CO2E	1.000						
EPWS	−0.850	1.000					
EPSS	−0.017	−0.466	1.000				
REP	−0.504	0.743	−0.625	1.000			
TRO	−0.690	0.303	0.344	−0.034	1.000		
GINV	−0.986	0.821	0.033	0.452	0.710	1.000	
CRT	−0.234	−0.293	0.151	−0.155	0.034	−0.179	1.000

Source: Authors' Estimation.

while the p-values are $<$ 5%. These outcomes exposed co-integration exists (see Table 6)

The study also applied the DARDL model to check the connection among variables. The findings exposed that electricity production from water sources, electricity

Table 5. Unit root test *(Author Estimation)*.

ADF PP				
Series	Level	First difference	Level	First difference
CO2E	−3.903***	—	−2.783***	—
EPWS	−2.744***	—	−2.812***	—
EPSS	−2.167***	—	−3.009***	—
REP	—	−5.893***	—	−5.649***
TRO	—	−4.021***	—	−6.328***
GINV	−3.892***	—	−2.095***	—
CRT	−3.776***	—	−3.196***	—

Source: Authors' Estimation.

Table 6. Co-integration test *(Author Estimation)*.

	No Shift		Mean Shift		Regime Shift	
Model	Test Stat	p-value	Test Stat	p-value	Test Stat	p-value
LM_{τ}	−3.907	0.000	−4.893	0.000	−4.893	0.000
LM_{φ}	−3.735	0.000	−4.721	0.000	−4.376	0.000

Source: Authors' Estimation.

Table 7. Dynamic ARDL model *(Author Estimation)*.

Variable	Coefficient	t-Statistic	Prob.
ECT	−4.390***	−2.902	0.020
$EPWS_{t-1}$	−3.724***	−3.781	0.004
EPWS	−2.534**	−5.904	0.000
$EPSS_{t-1}$	−4.893*	−4.965	0.000
EPSS	−2.884***	−2.893	0.024
REP_{t-1}	−3.784***	−5.764	0.000
REP	−0.564***	−4.810	0.000
TRO_{t-1}	−0.693**	−3.780	0.005
TRO	−2.831**	−4.839	0.000
$GINV_{t-1}$	−1.782**	−2.109	0.035
GINV	−3.742**	−4.875	0.000
CRT_{t-1}	−2.728***	−4.783	0.000
CRT	−4.882**	−3.773	0.006
Cons	3.590**	3.787	0.005

R square = 64.938 Stimulation = 5000.
Source: Authors' Estimation.

production from solar sources, REP, TRO, GINV, and CRT have a negative linkage with carbon emissions in China. These values are mentioned in Table 7.

5. Discussions

The results showed that electricity production from water sources has a positive association with carbon neutrality. Hence, consistent with Zhao and You (2020), which shows that when in a country the electricity production from utilising water sources is getting progressing, the people in the greater area of land are provided with renewable and clean energy. The increase in people tend to utilise replenishing clean energy, and overcome the use of coal, oil, gas, or ore to acquire and utilise energy to continue their functioning. As a result of reducing such energy, CO_2 emissions are controlled. Hence, carbon balance in the air is possible. Findings are also backed up by Bogdanov et al. (2021) and Van Hoa et al. (2022), which states that a country with the efficiency to produce electrical energy from water can arrange large supply of energy with fewer side effects for the public. The use of electrical energy from water is effective in mitigating CO_2 emissions for leaving no gases and wastes. In this situation, carbon neutrality is likely to be achieved. Matching with the evidences of Wang et al. (2022), results highlight that through water sources, electricity production enhances the ability of the country to combat environmental pollution like CO_2 emissions, which is mostly because of naturally developed fossil fuel consumption as in this process, carbon is released in heavy amounts. That's why with increasing, electricity production, carbon neutrality can be attained.

The results showed that electricity production from solar sources is linked with carbon neutrality in positive manner and backed up by Shahsavari and Akbari (2018), which states that the solar system contains solar panels that attract the heat from the sunshine and help generate electricity, and are safe to be handled and used. In this way, the electricity production from the solar systems removes the effects of CO_2 emissions and provides a way to achieve zero carbon objective. Sriyakul et al. (2022) and Wang et al. (2021) also back up the study evidences that examines solar power's role in carbon neutrality. The study posits that the electricity from a solar system is safe to be utilised, and there is no fear of emission of toxic gases, hazardous chemicals, and waste creation after going through certain process where electricity is utilised. Hence, the use of electricity from a solar system is sure not to produce excessive CO_2, which causes an imbalance in natural carbon volume, and it denotes carbon neutrality. Results are consistent with Thitinan and Chankoson Khunanan, (2022) and Vaka et al. (2020). According to this past study, the increase in electricity production from solar systems reduces the energy producers' pressure on fossil fuels consumption for generating electricity. Less dependency on fossil fuels for electricity production lowers the probability of emissions, leading to zero carbon goal.

The results showed that REP is positively linked with carbon neutrality. Results are backed up by De La Peña et al. (2022), that proclaims that the increase in RE by applying the replenishing natural resources enhances the supply of energy for innovative energy-efficient technologies. With the availability of low-voltage renewable energy, these innovative technologies consume less and give better outcomes causing lower environmental pollution. In this case, CO_2 emissions can be controlled. So, increasing renewable energy production improves carbon neutrality. These results are supported by the research of Ibrahim (2022) and Kurniawan et al. (2022), which is about renewable energy's role in achieving carbon neutrality. Authors say that as the human's socioeconomic needs are increasing, to keep pace with the larger population and consequently, people have to carry out numerous activities, the demand for energy increases. The increase in REP, enhancing the energy supply to cope with the fast-increasing energy demand, makes it possible to meet increasing socio-economic needs without creating CO_2 environmental problems. Hence the achievement of carbon neutrality is possible. Findings are backed up by Zhang et al. (2022), that indicates that the scaling in energy production by employing renewable natural resources, CO_2 is emitted by machines, plants, and other technologies for using energy can be reduced.

Trade openness and carbon neutrality are also linked positively according to study findings and backed up by study Li and Haneklaus (2022), which indicates that a country having high trade openness can develop an ability to generate sustainable energy like solar energy, bioenergy, wind power, and hydroelectric power etc., and in this case, the use of renewable & clean energy increases within the country. The economy of this country is less likely to create CO_2, and therefore, it is more likely to achieve zero carbon goal. Findings are backed up by Khan et al. (2022), which posits that trade openness enables the country to establish relations with experts in economic and scientific fields and get knowledge about their initiatives to mitigate the repercussions of excessive energy usage. By applying these initiatives, CO_2 emissions can be controlled, which adds to carbon neutrality. These results also match with the past studies of Wang et al. (2022), which denotes that trade openness opens the way for economists to give rise to sustainable energy technologies and encourage business organisations to implement these technologies. Under the implementation of sustainable energy technologies, CO_2 emissions are minimum, and thereby, zero carbon goals is attainable.

The results showed that green investment has a positive association with carbon neutrality. These results are in line with the previous study Qin et al. (2021). According to the study, the implementation of green investment makes it easy for the business management to carry out business operations and, side by side, tackle the environmental issues that these operations are likely to cause. In this situation, managers succeed in reducing carbon emissions and helps in achieving zero carbon goals. These results are supported by the research of Zahan and Chuanmin (2021), that indicates that when the financial institutions have the policy make an investment in green programs through funding, ecologically friendly programs and activities are being encouraged by public and private organisations. Thus, these organisations can reduce CO_2 emissions from economic and social practices and therefore, it is easy to attain green agenda. Findings are matched with Meo and Abd Karim (2022), which states that the encouragement for green investment help mitigate CO_2 release and assures the achievement of carbon neutrality.

Carbon taxes and carbon neutrality are positively correlated, hence, confirming the evidences of Withey et al. (2022), which shows that when the government of some country makes amendment to laws and regulations that the carbon taxes are enforceable within the country, the practices, which include the utilisation of energy sources, chemicals, and wastes are brought to an end. As a result, there would be a dramatic decrease in CO_2 emissions, and the country has the capacity to maintain carbon neutrality. These results are supported by the research of Renner et al. (2018), which examines the carbon taxes impacts on carbon neutrality. The study claims that if the carbon taxes are imposed effectively, businesses and individuals try to have knowledge of which resources or processes would be responsible for CO_2 emissions and which practices they must perform in order to mitigate CO_2 emissions. This knowledge is helpful in achieving carbon neutrality. These results also match with the past study of Freire-González and Ho (2019), which indicates that the effective enforcement of carbon taxes discourages carbon-emitting social and economic activities.

Hence, carbon neutrality can be achieved because, in this situation, CO_2 emissions decreases.

6. Implications

The study is significant for further learning of researchers on account of its contributions to literature. The major concern of the research is the attainment of carbon neutrality. The authors make a distinction in analysing the electricity production from water and solar sources, renewable energy production, trade openness, green investment, and carbon taxes' role in carbon neutrality for China. From the documented evidences, it is quite apprehensive that the alleviating effect of renewable energy on carbon emissions, confirms this belief that the transitioning of non-renewable resource in to renewable energy subdues the environmental and health-related problems which typically happens due to high emissions. In this lieu, making investment in RE products must be promoted at macro and micro both levels. Moreover, government institutions can also enforce tax free policies for those organisations that are utilising 70–90% RE sources in their production, manufacturing and operations. RE based products can also be promoted publicly in order to increase it accessibility and affordability. Also, making investments in infrastructures in order to meet the needs of growing population can also be helpful in energy transition technologies. Carbon alluring trade openness can also be poised with the help of trade policies, hence guiding the practitioners regarding the inflow and outflow of country in the form of goods/services. By giving priority to imports that matches with the notion of zero carbon goal, could also help economy to reach the carbon neutrality goal within given time

Moreover, the study also guides that policy maker, both at the public, and private levels must enhance electricity production from water sources in order to achieve carbon neutrality. Similarly, policymakers must take care of the volume of electricity production from solar sources to mitigate CO_2 emissions and achieve carbon neutrality. The study makes a guideline that economic and environmental policies must encourage renewable energy production to accelerate progress towards carbon neutrality. It is suggested to policymakers that the government and economists must struggle to enhance trade openness and, hereby, increases the probability of achieving carbon neutrality. The study helps the policymakers in developing policies related to achieve carbon neutrality using renewable sources of energy production, carbon taxes, and green investment. The study conveys that at the private and government levels, the green investment must be encouraged so that carbon neutrality can be achieved. Authors also guide that government must enforce carbon taxes in order to attain carbon neutrality.

7. Conclusion

The study aimed to examine electricity production from water and solar sources, renewable energy production, trade openness, green investment, and carbon taxes on carbon neutrality. The Chinese economy is visited to acquire data for electricity production from water and solar sources, renewable energy production, trade openness, green investment, carbon taxes and CO_2 emissions. With the empirical data from China, the authors showed a positive relationship between electricity production from water and solar sources, renewable energy production, trade openness, green investment, carbon taxes and carbon neutrality. The results revealed that the increase in the electricity production from water sources raises the energy in plenty of quantity and assists in energy transition leading to removing CO_2 emissions and achieving carbon neutrality. Likewise, clean energy can be attained in abundance; if electricity is produced from solar sources; it becomes easy to reduce CO_2 and maintain carbon neutrality. The results also showed that the existing CO_2 could be reduced, and further CO_2 emissions can be controlled by applying renewable energy production systems and enhancing the total energy supply from these systems. So, renewable energy production helps achieve carbon neutrality. The results also stated that many social and human activities cause CO_2 emissions. The green investment encourages the undertaking of ecologically friendly practices and, thereby reduces CO_2 emissions and their effects. Hence, carbon neutrality can be achieved. The study concluded that the people who have to face heavy carbon taxes try to avoid the things which cause carbon emissions and can contribute to carbon neutrality.

8. Limitations

Some limitations are still associated with the current study. These limitations can be removed in further studies when researchers put in extra effort and are more alert. First, the authors have analysed only the limited variables like electricity production from water and solar sources, renewable energy production, trade openness, green investment, and carbon taxes, evaluating carbon neutrality. The limited factors under consideration for the analysis of carbon neutrality makes the research limited. It is recommended to researchers that they must consider more factors for a comprehensive research study on carbon neutrality. China is considered the country at the top of the list of CO_2 emitters. Other countries emit relatively lower CO_2 into the air, and their economic as well as geographical conditions are comparatively different. The present study can be valid in those countries to a limited extent. The researchers must pay attention to this weakness of the research and arrange a survey of a greater number of countries so a more general and valid study can be presented.

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