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What role economic growth and sustainability-oriented innovation play on the level of carbon emission: case of China

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ABSTRACT

Globally, carbon dioxide (CO2) emission is a significant element of environmental pollution because of corrupt economic activities that requires regulators' focus and researchers' emphasis. Hence, the current research evaluates economic growth on CO2 emissions in Chinese economy. The article has taken six factors of economic growth on board along with sustainable innovation to predict CO2 emissions. Secondary data, in this regard, has been used which has been borrowed from World Bank from 1986 to 2020. Augmented Dickey-Fuller test is employed to scrutnize unit root, while QARDL model has been run to identify the association between the constructs. Findings revealed that factors such as gross domestic product, national income, human capital, employment ratio, inflation and exports signifies CO2 emissions, hence are corrupt the environment. While sustainability oriented innovation reduces the emissions. This study monitors the policymakers while formulating regulators related to reducing the level of CO2 emission using economic growth factors and sustainability-oriented eco-innovation.

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1. Introduction

China is marked as one of the polluted economies due to high carbon emissions. It is said that the emissions from China are equal to the sum of emissions from developed economies. 2019 was the year when carbon emissions from China were accounted to cover one-quarter of the total carbon emissions all over the globe (Khan et al., 2021; Van Hoa et al., 2022). Besides, China also used to depend heavily on non-renewable

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resources such as fossil fuel in order to fulfil the local energy demand. However, the monotonic dependency on unclean resources pushed the country in the ranking of those countries who emit high emission figures especially in last decade. It is quite concerning situation for country like China because its coal consumption is equal to the half volume coal that is being consumed by globe economies. This truly indicates that how much country has a reliance on coal to grow its economy. This persistent rise in coal consumption and energy demand makes the nation in one of those countries which degrades the environmental quality at greater level (Khattak et al., 2021; Shibli et al., 2021).

The principal causes of pollution emissions such as CO2 emissions from the economy are the steady increase in the population and the spectacular expansion of the economy's scope. The expanding population contributes to the amount of CO2 in the air due to respiration and changing household and economic behaviors (Godil et al., 2021; Lan et al., 2022; Lin et al., 2022). China is the highest emitter of CO2 in the atmosphere when it is compared to other economies in terms of greenhouse gas emissions. As a result, many governments, scholars, and regulators consider China to be the most responsible country for change in the climate. However, the situation is more complicated than it appears on the surface. It is necessary to take a close look at the scenario. Observation reveals that this is the world's largest country with the ability to destroy the globe. The assessment of China's pollution problem makes it clear that the country's environmental situation is the worst it has ever been. China ranks top among international economies in terms of the increase in overall greenhouse gas emissions, according to an analysis (Hartani et al., 2021; Ojogiwa, 2021).

However, based on its emissions of 7.10 tons of CO2, the country is ranked 48th in the world in terms of per capita emissions. As per these figures, the country is still lagging behind. In comparison to the United States, China emits 12 times the amount of CO2 in tons. As a result, China is ranked 14th among the countries with significant CO2 emissions (Zhao et al., 2021; Zhao et al., 2022). According to environmental statistics, China emits 10.21 billion metric tons of CO2, while the United States emits 5.30 billion metric tons, accounting for roughly half of the Chinese economy's CO2 emissions. However, according to the same statistics, the country's total CO2 emissions account for 28% of global CO2 emissions. These figures show that the country is the world's top emitter of greenhouse gases (Liu et al., 2022a, 2022b). Because of the constant increase of CO2 emissions and its impacts on the environmental quality and economic development, it is need of the hour to focus on this issue and remove it. Thus, the CO2 emission has followed the increasing trend in China. Figure 1 shows the situation CO2 emission in China.

At present, China is putting efforts to curb the harmful emissions and for that the country is planning to adopt a path which leads them towards low-carbon economy, hence, setting the goal to be in carbon neutral economy by 2060. Despite the country's domestic commitment to phase out the emissions, China also endorsed the Paris Agreement and created pitch to opt for carbon-enemy policies in order to attain desired targets that are especially made to tackle climate related challenges (Moslehpour et al., 2022a, 2022b, 2022c). However, in recent COP26 conferences, China made alterations in its prior commitment by highlighting the matter to phase

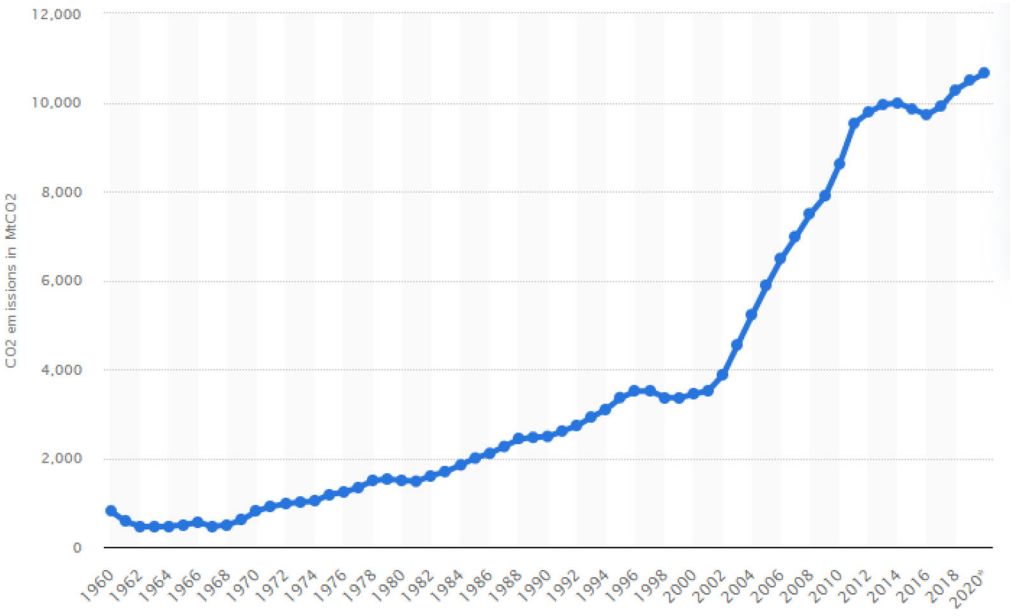

Figure 1. CO2 Emission in China (world development indictor).
Source: WDI.

down the consumption of coal, thus, vindicating its stance of peaking its carbon emissions patterns by 2030 before slowly and gradually degrading the emissions level leading to the 2060 goal. In either way, the country is determined to experience the transition and turn into zero carbon economy via diversified energy portfolio where the target is to increase renewable shares, hence, make less reliance on non-renewables (Kurniawan et al., 2022; Thitinan & Chankoson Khunanan, 2022).

In order to achieve zero carbon state, countries all over the globe are endeavouring to find those factors that helps them in the carbon detachment process without compromising economic growth. In this lieu, China has been planning to seek decoupling strategies that are especially effective for country in the accomplishment of 2060 goal (Sadiq et al., 2022a, 2022b). China, thereby, is showing commitment to attain the associated targets by espousing eco based innovative practices that helps in building modern energy system. This modernization process enhances energy efficiency and restrict the economy taking further benefit from fossil fuel in electricity generation. Sustainability-oriented ecological innovation not just in energy sector but within whole economic process signifies the importance of technological advancement, hence, making it contemporary yet effective strategy for zero-carbon transitioning (Appiah, 2018; Bhat, 2018; Sun et al., 2021).

In the light of the heated arguments build on facts and fugures, the study attempts to evalaute economic growth determinants such as "GDP, NNI, human capital, employment ratio, inflation" along with sustainability-oriented innovation, and exports on carbon emissions levels in China's economy. China is the world's fastest-growing country in terms of population and area. It has an upper-middle-income developing economy that is newly industrialized (Ali et al., 2022; Muhammad, 2019; Sadiq et al., 2022c, 2022d). The nominal gross domestic product (GDP) of the

country for 2021 is $16.6420 trillion, with an annual growth rate of 8.5 per cent. The country's nominal GDP puts it in second place in the list of global economies, but the GDP (PPP) puts it in the first place (Ainou et al., 2022; Sriyakul et al., 2022). The country's economy consists of three major sectors like industry with 40.6%, agriculture with 7.9%, and service with 51.6% share to the country's GDP. Agriculture-related businesses have the least negative influence on the environment and contribute significantly to improving environmental quality. The two main economic sectors, on the other hand, degrade the environment because of their greater reliance on energy, other resources, infrastructure, machinery, and a variety of other business strategies that can result in pollution emissions. According to figures from 2021, the country's overall population is 1,443,995,000 (Abdul Hamid et al., 2020; B. Wang & Wang, 2018).

This study, hence, makes a great contribution to the existing body of knowledge. First, in previous studies, simply greenhouse gases are taken as the environmental pollutants and the impacts of economic growth on greenhouse gas emissions. As per author's knowledge, no significant studies have been conducted for the analysis of the impacts of economic growth on CO2 emissions. The present study examines the impacts of economic growth on CO2 emissions, considering its potential to destroy the environment. Second, in prior studies, the economic growth impacts on CO2 emissions has not been examined in such detail as to describe with different perspectives. The current study examines the economic growth from the perspectives of "GDP, NNI, human capital, employment ratio, inflation, and exports" as well as eco-innovation for determining the level of CO2 emissions. Third, China is the country that is considered the greatest emitter of CO2 emissions is the perfect country to analyze the impacts of economic growth and sustainable innovation on the level of CO2 emissions. Unfortunately, only a few studies have chosen this context for analysis of economic growth and CO2 emissions. So, the present discusses this subject for China is a great addition to the literature.

The study is divided into several portions. In the next portion, the past literature is synthesized to provide the base line for outlined constructs. Soon after this, the process of data collection and the tests applied for checking the relationship between these factors and carbon emissions. Then, results explaining the relationships in nature are given. These results are matched with preceding studies, and the study ends with implications, conclusions, and limitations.

2. Literature review

Environmental quality is essential for the sustainable development of a country as it ensures social wellbeing, individuals' personal prosperity, and economic or financial progress of the country. CO2 emission is the recognized most hazardous polluting factor that degrades the environmental conditions. The natural sources maintain the balance of CO2 emissions and do not allow them to have any negative impact on the environment. But, human sources increase the CO2 emissions, disturbs its balance in the air, and allows it to destroy the environment. The increase in economic growth creates the human sources of CO2 emissions (Jermsittiparsert, 2021; Tan et al., 2021).

The urbanization, globalization, financial growth manufacturing activities, technologies use, and energy resources that are the outcomes of EG factors that affect the level of CO2 emissions. But if the economic growth is led by eco-innovation, it does not have much adverse impact on the environment, in this situation, CO2 emissions are minimal. The relation of GDP, NNI, human capital, employment ratio, inflation, exports, and eco-innovation with the level of CO2 emissions has a dominant place in literature (Bai et al., 2022; Chien, 2022a; Chien et al., 2022b;).

2.1. GDP and CO2 emission

In empirical research Chien et al. (2022c) and Wirsbinna and Grega (2021) identifies the relationship among renewable energy production, coal consumption, GDP, and CO2 emissions. This study analyzed the impacts of renewable energy production, coal consumption, and GDP on CO2 emissions in China, the USA, and India, which are considered the largest energy consumers and biggest sources of CO2 emissions. The study applied Machine Learning and Direction from Dependency (D2C) algorithm to select the variables and predict the nature of the relationship. The study findings showed that the increased use of nonrenewable energy to keep pace with increasing GDP enhances the CO2 emissions; so, in some countries, the GDP has a positive relation to CO2 emission because of the increasing use of unclean energy. But, the relationship becomes negative if there is a tendency, in high GDP achieving countries, to produce and consume renewable and clean energy. Ameyaw and Yao (2018) and Chien (2022d), examine the relationship between GDP and CO2 emissions in 5 West African countries over the period from 2007 to 2014 with the help of a panel data model. The results of the study revealed that GDP has a significant positive impact on CO2 emissions as when the use of resources increases in production at a larger scale, CO2 emission is high. The Study of Chien et al. (2021) and Gong et al. (2019) analyzing the datasets from the last four Five-Year Plans over the period 1995-2015 posits that GDP has a positive link to CO2 emissions. The study implies that with GDP increase, technological advancements, technologies usage and energy usage also increases, which causes a threatening effect on environmental quality.

2.2. National income and CO2 emission

A study was conducted by Barra and Zotti (2018) to investigate the impacts of national income environmental pollution. The national income and environmental were measured by GDP and CO2 emissions, respectively. The authors used a heterogeneous sample based on 120 countries for the time of 2000–2009. Study documented based on the evidences that when the country is making high national income, the production of goods and services within the country increases. When the technologies which need high potential energy are used for getting fast and innovative products or services which could meet the customers' requirements, environmental pollution is high because of the large CO2 emissions. Through a global empirical analysis, Zhang et al. (2019) analyzed the impacts of NNI through EKC on CO2 emissions in the construction and manufacturing industries. The study sample is based on the 121

world economies for the time from 1960 to 2014. Based on the evidences, study claims that when there is high NNI, the constrictive and developmental activities are at their peak in the country. The constructing and manufacturing technologies are found to increase the level of CO2 emissions into the air. Dong et al. (2020), proclaim that high NNI achievement improves an individual's capacity to make assigned tasks easier by using electric appliances, machinery, and vehicles that are powered by both renewable and nonrenewable energy sources. As a result, when the NNI is high, CO2 emissions into the air increase, polluting the atmosphere and making it difficult for living beings to breathe (Haroon et al., 2021; Kamarudin et al., 2021).

2.3. Human capital and CO2 emission

In a literary article, Mahmood et al. (2019) examined the relationships among economic growth, energy consumption, human capital, and CO2 emission. The authors applied the least square and ridge regression methods for the analysis of data from Pakistani for 1980-2014. The results reveal that human capital has a positive relation to CO2 emissions and environmental degradation. For creating more efficient human capital within the country, innovation in education, medical, social construction, and training is required. For this purpose, innovative technologies peculiar to the mentioned fields are applied, and this becomes the cause of increasing CO2 emissions. But, the study conducted by Bano et al. (2018) denotes human capital as both the contributor to CO2 emission and the solution to remove these environmental issues. The study was based on the information regarding human capital, carbon emissions, and their relationship from Pakistan for 1971-2014. The ARDL model and the VEC model were applied for analyzing the co-integration and causalities between the concerned factors. The preparation of human capital and the resultant increased production level enhances CO2 emissions. But the improvement of human resource efficiency reduces the CO2 emissions. Yao et al. (2020), analyzes the human capital influences on CO2 emissions in the long run with a dataset from 20 OECD countries for 1870-2014. Human capital is a source of labor or workers for various economic sectors, and energy consumption, in whatever form, emits damaging gases such as CO2 and degrades the environment.

2.4. Employment rate and CO2 emission

Balsalobre-Lorente et al. (2018), examines the economic growth influences on the CO2 emissions and environmental quality. EG was measured through employment ratio and its impacts on CO2 emission. When the country's population both at the rural and urban areas have access to employment, in both areas, the economic activities like practices of manufacturing, construction, transportation, and services enterprises increase. With the increase in economic activities, the use of fossil fuels or petrol for energy purposes rises. Fossil fuel or petrol combustion releases CO2 emissions and causes environmental deterioration. A study Dauda et al. (2019) examines the influences of employment ratio on environmental quality. The study reveals that when equal employment opportunities are given to people in the different areas of

the country, the purchasing power of the people increases, and they can afford personal vehicles. Consequently, the increase in the number of personal vehicles within the country increases CO2 emissions. Muhammad and Khan (2019), examines how the employment ratio in a country affects the environmental quality. This research revealed that in countries with a high employment rate, productivity across all sectors is high. A great number of machines with various sizes, fuel requirements, and productivity potential are utilized to produce a wide range of goods and services. These devices produce a lot of CO2, depending on their size and the quantity of energy they utilize. As a result, the increasing employment ratio boosts CO2 emissions. Similarly, the study of Odugbesan and Rjoub (2020), states that high employment ratio in a country means that there are more number of labor force hired in the economy to perform greater number of economic activities than earlier, and the increased economic activities causes larger CO2 emissions.

2.5. Inflation and CO2 emission

The study by Musarat et al. (2021) examines the influence of the inflation rate on CO2 emissions within a country with respect to the construction industry. The data which could be helpful in the required research was acquired from the Government Department of Malaysia. The correlation coefficient was performed through SPSS for the analysis of the influences of inflation on CO2 emissions. According to the claims, when there is inflation in the country, constructive work, especially on the part of the government, is going on at a peak, and the need for construction-related tools enhances productivity in the manufacturing sector and also develop creativity in the service sector. As a result of the technologies and energy use, the CO2 emissions rise and degrades the environmental conditions. Ullah et al. (2020), the experts in environmental literature, examine the GDP growth volatility and inflation instability impacts on environmental quality. The data relating to variables and their relations were acquired from the Pakistani economy for the time spanning from 1975 to 2018, employing ARDL methodological approach. This approach conveys that there are different effects of positive and negative shocks of inflation on environmental quality. When there are negative shocks, inflation instability positively contributes to CO2 and N2O. Whereas, when there are positive shocks, inflation instability negatively contributes to CO2 and N2O. Shahbaz et al. (2021), proclaims that the developmental investment increase in inflation boosts the productivity of several industries. Thus, it increases emissions levels.

2.6. Exports and CO2 emission

The paper conducted by Haug and Ucal (2019) investigated the effects of FDI and foreign trade (imports & exports) on CO2 emissions. Information regarding FDI, imports, and exports and their influence on CO2 emissions were acquired from Turkey with the help of linear and nonlinear ARDL models. The study indicates that the imports and exports themselves do not have much influence on the CO2 intensity and environmental quality. But, it is the financial development, increase in

industrialization, and urbanization as a result of imports or exports positively affect the CO2 emissions and degrades the environmental conditions. The research by Hasanov et al. (2018) examines the relationship between international trade and CO2 emissions. The study examines both the territory and consumption-based CO2 emissions and throws light on the influence of both imports and exports. The evidence for the true relations was collected through a panel of nine oil-exporting developing countries. The results were extracted with co-integration and error correction modelling. These results show that exports have a positive relation to CO2 emission as the exports increase the economic activities within the country and raise the foreign exchange. The study by Apergis et al. (2018) identifies the relation between export concentration and CO2 emissions with an empirical analysis of nineteen developed economies. For long term estimation PDOLS, PFMOLS, PMG, CCEMG and short term estimation PECM or PDR with GTSMS were implied. It posits that the high scale production for exports purpose leads to Increase CO2 emissions.

2.7. Eco-innovation and CO2 emissions

A literary workout by L. Wang et al. (2020) was to investigate the relationship of innovation in the domain of environment and renewable energy along with export diversification with CO2 emissions. A group of G7 nations like Germany, Italy, France, Japan, the United States, Canada, and the United Kingdom. The information on the relationship between eco-innovation and export diversification was collected from these countries for a period of 28 years spanning from 1990 to 2017. An analytical technique like a cross-sectionally augmented distributed lag (CS-ARDL) was applied in this study to analyze the required relationship between the selected factors both for the long and short-run. The results found a negative relationship between sustainability-oriented eco-innovation and CO2 emissions. As fast the tendency to adopt eco-innovation increases in the economy, the amount of CO2 emissions can be controlled more effectively. The study conducted by Ding et al. (2021) checks the association of energy production and eco-innovation with consumption-based CO2 emissions. The required quantitative data were collected from G7 countries from 1990 to 2018. The results showed that there is a negative relationship between eco-innovation and CO2 emissions in the sense that with the adoption of eco-innovation, the use of energy can be reduced and consequently, the CO2 emissions can be overcome.

3. Methodology

Present study makes an attempts to look in to the economic growth and sustainable innovation and their impact on CO2 emissions in China. The current article has taken six factors of EG such as “GDP, national income, human capital, employment ratio, inflation and exports”, to predict the CO2 emission. The secondary data from World Bank was used covering the period from 1986 to 2020. The present article has applied the ADF test to examine the unit root QARDL model has been run to

identify the association between the constructs. The authors have established the equation using understudy constructs given below:

$$CO2_t = \alpha_0 + \beta_1 GDP_t + \beta_2 NNI_t + \beta_3 HCI_t + \beta_4 ER_t + \beta_5 INF_t + \beta_6 \mathrm{EXP}_t + \beta_7 EIN_t + e_t \quad (1)$$

Where;
CO2 = Carbon Emission$t$ = Time Period
GDP = Gross Domestic Product
NNI = Net National Income
HCI = Human Capital Index
ER = Employment Ratio
INF = Inflation
EXP = Exports
EIN = Eco-innovation

The present study has been conducted on environmental degradation using carbon emission. Moreover, the current study has used the six economic growth factors such as GDP, national income, human capital, employment ratio, inflation and exports. Finally, the sustainability-oriented eco-innovation has also been used as the predictor (See Table 1).

The present article has also employed descriptive statistics to study the data properties. Moreover, the current article also used correlation matrix. In addition, the findings section also shows the ADF test that highlighted the unit root among the variables.

$$d(Y_t) = \alpha_0 + \beta t + \mathrm{Y}Y_{t-1} + d(Y_t(-1)) + \mathcal{E}_t \quad (2)$$

The ADF test results highlight the appropriate model for the study. The QARDL model is suitable when some variables have no unit root at I(0), and some variables have no unit root at I(1) (Jiang et al., 2021). Moreover, the QARDL technique is superior to other nonlinear techniques, such as the nonlinear ARDL, to capture the chaotic and nonlinear behavior of the study variables (Godil et al., 2020). In addition, the QARDL technique captures both the long-run and short-run nexus between y t and x t at any desired location in the conditional distribution. Firstly, the current study has established the ARDL equation mentioned below:

Table 1. Variables with measurements.

S#	Variables	Measurement	Sources
01	Carbon Emission	Carbon dioxide damages (% of GNI)	(McGrath et al., 2022)
02	Gross Domestic Product	GDP growth (annual percentage)	(Ramzan et al., 2019)
03	National Income	Net national income (annual % growth)	(Pei et al., 2020)
04	Human Capital Index	Human capital index (HCI) (scale 0-1)	(Collin & Weil, 2020)
05	Employment Ratio	Employment to population ratio, 15+, total (%)	(Abraham & Kearney, 2020)
06	Inflation	Inflation, consumer price (% annual)	(Usman & Musa, 2018)
07	Exports	Exports of goods and services (% of GDP)	(Ali, et al., 2018)
08	Eco-innovation	High-technology exports (% of manufactured exports)	(Mavi & Mavi, 2021)

Source: Authors estimations.

$$\begin{aligned}\Delta CO2_t = \alpha_0 + & \sum \delta_1 \Delta CO2_{t-1} + \sum \delta_2 \Delta GDP_{t-1} + \sum \delta_3 \Delta NNI_{t-1} \\ & + \sum \delta_4 \Delta HCI_{t-1} + \sum \delta_5 \Delta ER_{t-1} + \sum \delta_6 \Delta INF_{t-1} + \sum \delta_7 \Delta \mathrm{EXP}_{t-1} \\ & + \sum \delta_8 \Delta EIN_{t-1} + \varphi_1 CO2_{t-1} + \varphi_2 GDP_{t-1} + \varphi_3 NNI_{t-1} + \varphi_4 HCI_{t-1} \\ & + \varphi_5 ER_{t-1} + \varphi_6 INF_{t-1} + \varphi_7 \mathrm{EXP}_{t-1} + \varphi_8 EIN_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

In addition, the current study also wants to check the association among variables in various quartiles thus, the current article has used the 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80 and 0.90 quartiles in the study. QARDL expression constructed for the study is presented below:

$$\begin{aligned} Q_{CO2t} = & \alpha(\tau)_0 + \sum_{i=1}^{n1} b_i(\tau) CO2_{t-i} + \sum_{i=0}^{n2} c_i(\tau) GDP_{t-i} + \sum_{i=0}^{n3} d_i(\tau) NNI_{t-i} \\ & + \sum_{i=0}^{n4} e_i(\tau) HCI_{t-i} + \sum_{i=0}^{n5} f_i(\tau) ER_{t-i} + \sum_{i=0}^{n6} g_i(\tau) INF_{t-i} + \sum_{i=0}^{n7} h_i(\tau) \mathrm{EXP}_{t-i} \\ & + \sum_{i=0}^{n8} j_i(\tau) EIN_{t-i} + \varphi_1(\tau) CO2_{t-1} + \varphi_2(\tau) GDP_{t-1} + \varphi_3(\tau) NNI_{t-1} \\ & + \varphi_4(\tau) HCI_{t-1} + \varphi_5(\tau) ER_{t-1} + \varphi_6(\tau) INF_{t-1} + \varphi_7(\tau) \exp_{t-1} \\ & + \varphi_8(\tau) EIN_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

4. Research findings

The outcome has been highlighted that CO2 was maximum in 1993, while minimum in 2020. Moreover, the output also revealed that the GDP was highest in 2017, and lowest in 2020. In addition, largest value of NNI was in 2007 and lowest in 2020. Additionally, the outcome has been highlighted that HCI was maximum in 1986 and minimum in 2020. Moreover, the output also revealed ER was 82.970% in 1986 and 67.196% in 2020. In addition, INF was 18.812% in 1988, −1.401% in 1999. Moreover, EXP was 36.035% in 2006 and 8.712% in 1986. Finally, EIN was 32.124% in 2010 while the minimum in 1986. Table 2 shows all of these figures.

In addition, the present article has also employed descriptive statistics for data normality. The results showcase that CO2 mean vlaue is 5.526%, while GDP average value is 9.103% followed by NNI 9.545%. Moreover, average value of HCI is 0.781 followed by ER 74.153, INF 5.022, and EXP 2.338. Finally, EIN mean vlaule was 30.503%. Table 3 shows all of these figures.

Moreover, the current article also runs the correlation matrix that shows the linkage among the variables but is not able to show the significance of the association. The results revealed that all the economic growth factors are correlated with CO2

Table 2. Descriptive statistics year-wise.

Years	CO2	GDP	NNI	HCI	ER	INF	EXP	EIN
1986	6.670	8.950	8.784	0.927	82.970	6.892	8.712	30.013
1987	8.228	11.657	8.922	0.918	82.437	7.234	12.482	30.042
1988	8.160	11.223	9.059	0.910	81.904	18.812	14.382	30.071
1989	7.909	4.206	9.196	0.901	81.371	18.246	11.844	30.100
1990	8.183	3.920	9.333	0.893	80.839	3.052	13.615	30.129
1991	8.554	9.263	9.470	0.884	80.306	3.557	14.488	30.157
1992	8.428	14.225	9.607	0.875	79.773	6.354	15.658	30.186
1993	9.097	13.884	9.744	0.867	79.240	14.610	16.702	30.215
1994	7.952	13.037	9.882	0.858	78.707	24.257	18.537	30.244
1995	7.024	10.954	10.019	0.850	78.174	16.791	17.951	30.273
1996	6.476	9.923	12.660	0.841	77.641	8.313	17.923	30.301
1997	6.044	9.237	9.520	0.833	77.109	2.786	19.493	30.330
1998	5.622	7.846	8.751	0.824	76.576	−0.773	18.342	30.359
1999	5.459	7.662	9.559	0.816	76.043	−1.401	18.163	30.388
2000	5.283	8.490	9.591	0.807	75.320	0.348	20.893	30.417
2001	5.125	8.336	11.651	0.798	75.340	0.719	20.312	30.445
2002	5.330	9.134	12.239	0.790	74.430	−0.732	22.645	30.474
2003	5.775	10.038	11.938	0.781	73.820	1.128	26.981	30.503
2004	5.914	10.114	11.376	0.773	73.230	3.825	31.061	30.532
2005	6.036	11.395	13.030	0.764	72.800	1.776	33.830	30.561
2006	5.818	12.721	14.456	0.756	72.440	1.649	36.035	30.589
2007	4.837	14.231	15.513	0.747	72.020	4.817	35.435	30.151
2008	4.377	9.651	7.195	0.738	71.430	5.925	32.603	29.364
2009	4.096	9.399	13.385	0.730	70.890	−0.728	24.750	31.938
2010	4.134	10.636	9.088	0.721	69.180	3.175	27.185	32.124
2011	3.877	9.551	4.631	0.713	68.890	5.554	26.568	30.484
2012	3.659	7.864	10.661	0.704	68.740	2.620	25.493	30.849
2013	3.492	7.766	6.788	0.696	68.610	2.621	24.599	31.574
2014	3.302	7.426	8.849	0.687	68.470	1.922	23.510	29.695
2015	3.201	7.041	7.958	0.679	68.360	1.437	21.354	30.422
2016	3.176	6.849	8.538	0.670	68.170	2.000	19.584	30.243
2017	3.107	6.947	7.927	0.673	67.930	1.593	19.692	30.907
2018	2.984	6.750	5.200	0.647	67.660	2.075	19.112	31.467
2019	3.086	5.950	5.082	0.621	67.350	2.899	18.410	30.783
2020	2.990	2.348	4.487	0.653	67.196	2.419	18.497	31.274

Source: Authors estimations.

Table 3. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2	35	5.526	1.921	2.984	9.097
GDP	35	9.103	2.797	2.348	14.231
NNI	35	9.545	2.597	4.487	15.513
HCI	35	0.781	0.088	0.621	0.927
ER	35	74.153	5.107	67.196	82.970
INF	35	5.022	6.176	−1.401	24.257
EXP	35	21.338	6.753	8.712	36.035
EIN	35	30.503	0.578	29.364	32.124

Source: Authors estimations.

Table 4. Correlation matrix.

Variables	CO2	GDP	NNI	HCI	ER	INF	EXP	EIN
CO2	1.000							
GDP	0.455	1.000						
NNI	0.322	0.543	1.000					
HCI	0.937	0.356	0.314	1.000				
ER	0.938	0.317	0.273	0.992	1.000			
EXP	0.429	0.317	0.400	−0.516	−0.575	−0.348	1.000	
EIN	−0.621	0.142	0.645	−0.432	−0.373	0.252	0.337	1.000

Source: Authors estimations.

emission in positive manner while EIN has a negative association with CO2 emissions. Table 4 and Figure 2 show all of these figures.

In addition, the findings section also shows the ADF test that highlighted the unit root among the variables. Findings showcase that CO2, HCI, ER and INF have no unit root at the level, but GDP, NNI, EXP and EIN have no unit root at the first difference (see Table 5)

The results revealed that "GDP, national income, human capital, employment ratio, inflation and exports" are positively linked with carbon emissions, and EIN has a negative association with CO2 emission. Evidence exposed that GDP and CO2 significant in 1 to 8 quartile in the short-run and in 1 to 6 quartile in the long-run. In case of NNI, it is significant in 1 to 5 and 8-9 quartiles in short-run where as in long-run, it is significant in 1 to 6 quartile. Moreover, HCI and share significant relationship in quartiles 1-4 and 7-8 in case of short-run, where as in long-run, the significance has been shown in quartile 1-6. In addition, ER and carbon emissions are significant in quartiles 1-5, 9 and 1-6 and 8 in short and long-run respectively. INF and carbon emissions share significant linkage in quartile 1-4 and 6 and 8 in case of short-run where as in case of long-run in 1-7 quartile. Moreover, EXP and carbon emissions are significant in 1-5 and 9 quartiles in short run and 1-5 and 8-9 quartile in case of long-run. Lastly, EIN and carbon emissions are significant to each other in 1-7 quartile and 1-8 quartile in short and long-run respectively. Table 6 shows these figures (Figure 3).

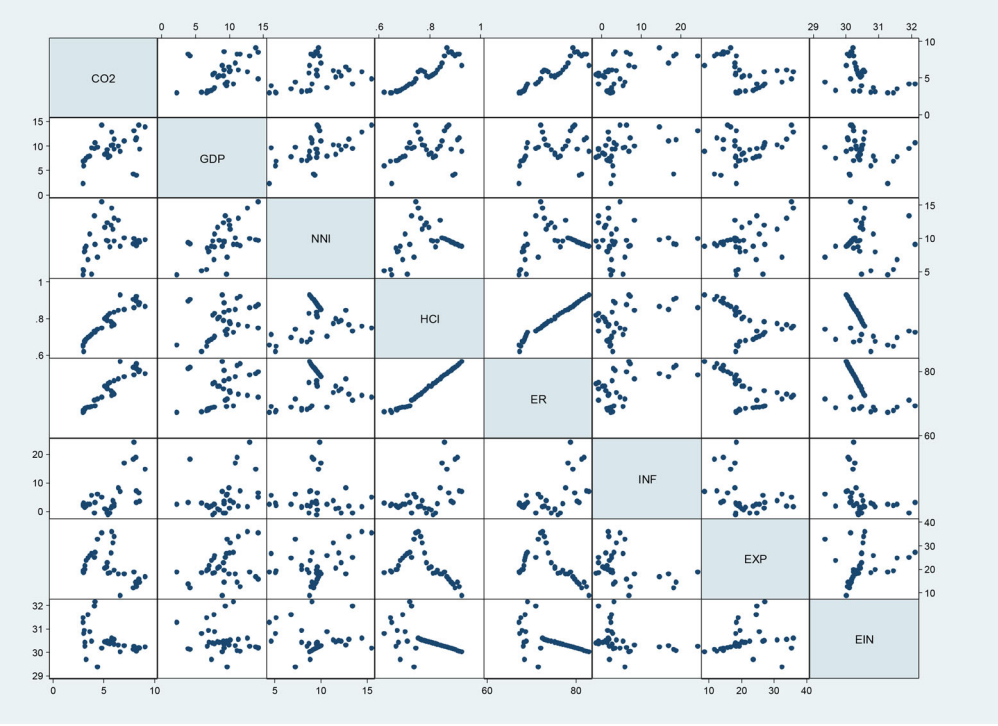

Figure 2. Correlation matrix.
Source: Authors estimations.

Table 5. Unit root test.

ADF	Level	t-stats	p-values
CO2	I(0)	−4.882	.012
GDP	I(1)	−5.990	.00
NNI	I(1)	−5.262	.00
HCI	I(0)	−2.101	.035
ER	I(0)	3.189	.015
INF	I(0)	−3.302	.027
EXP	I(1)	−5.108	.00
EIN	I(1)	−5.127	.00

Source: Authors estimations.

Table 6. QARDL model.

	GDP	NNI	HCI	ER	INF	EXP	EIN
Panel A: Short-run Coeff							
Q0.1	.54*	.32*	.51**	.43**	.43**	.37*	−.34*
Q0.2	.38**	.29**	.60**	.56*	.39*	.54**	−.43*
Q0.3	.72*	.20*	.31*	.49*	.51*	.53**	−.76**
Q0.4	.10*	.61***	.75**	.55**	.47*	.52*	−.57*
Q0.5	.62***	.72*	.15	.67***	.26	.55**	−.34*
Q0.6	.81*	.04	.07	.17	.52**	.17	−.54*
Q0.7	.70*	.12	.91**	.08	.17	.12	−.12*
Q0.8	.62*	.82*	.52*	.18	.28*	.10	−.03
Q0.9	.01	.72**	.19	.65**	.10	.73**	−.10
Panel B: Long-run Coeff							
Q0.1	.38*	.54*	.34**	.29**	.43*	.54**	−.45*
Q0.2	.48**	.29**	.61**	.35*	.56**	.37*	−.64*
Q0.3	.39*	.72***	.44*	.91***	.84**	.40*	−.76**
Q0.4	.65*	.43**	.30*	.33*	.92**	.32*	−.87**
Q0.5	.68**	.28*	.23*	.23*	.62**	.20*	−.36*
Q0.6	.32*	.19*	.83***	.19*	.22*	.01	−.46*
Q0.7	.10	.12	.04	.12	.30*	.10	−.42*
Q0.8	.19	.10	.02	.23*	.03	.39*	−.31*
Q0.9	.13	.19	.18	.02	.06	.53*	−.11
Panel C: Diagnostics							
Ad. R square	.65						
Reset	1.47*						
LM	.98						
CUSUM	S						
CUSUMQ	S						

Source: Authors estimations.

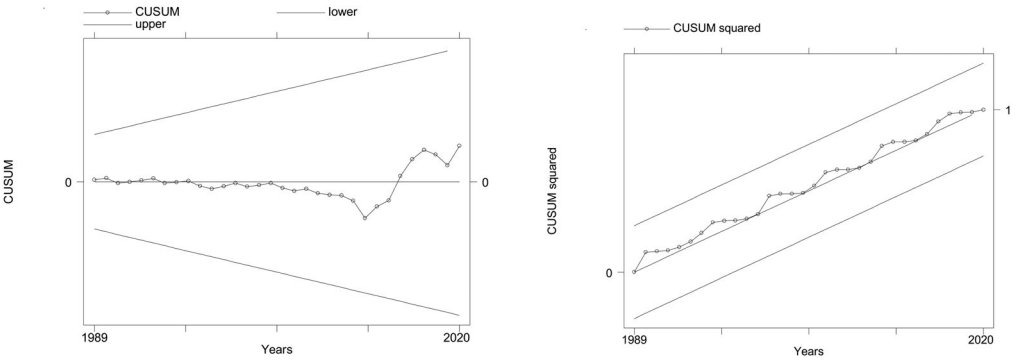

Figure 3. CUSUM and CUSUM square.
Source: Authors estimations.

5. Discussions

The results stated that GDP is in a positive relation to the level of CO2 emissions from the country. These results are in line with Wasti and Zaidi (2020), which shows that the achievement of a high GDP growth rate enables a number of businesses to increase the level of production of goods and services. For this purpose, they have to make additions to particular resources and processes for which large energy resources are required. The energy smoked causes the firms to emit a large amount of CO2 emissions, and thus, they degrade the country's climate and endanger the economy. These results are supported by Mehmood et al. (2021), which is an investigation about the economic growth impacts on CO2 emission and environmental quality. This study reveals that in the economy, which is making progress in achieving a high economic growth rate by sustaining the GDP, the technological field makes rapid progress. The increase of the technologies used in the economy for production and delivery purposes enhances the emission of a greenhouse gas like CO2 emission and adds to environmental deterioration. These results are also supported by Bekhet and Othman (2018), which highlights that when the country is making rapid progress in achieving a high GDP, its next motive is to sustain this production level, which it can make possible with the use of fast processing machinery and plants which are the source of CO2 emissions.

The results indicated that NNI is in a positive relation to the level of CO2 emissions from the country. These results agree with Adedoyin et al. (2020), which shows that in the countries where the NNI is high, the different private and government entities have abilities to carry on the economic developmental activities. For these development activities, technologies and energy usage increase within the boundaries of a country, and CO2 amount increases in the air which affects the weather pattern, resources quality, and public wellbeing. These results are in line with Mikayilov et al. (2018), which shows that high NNI achievement enhances the individual's ability to facilitate routine operations through applying electric appliances and machinery & vehicles that are fueled by both renewable and nonrenewable energy resources. So, in the case of the high NNI, emission of CO2 into the air increases and pollute the atmosphere, where it becomes difficult for living beings to breathe in. These results are supported by Cai et al. (2018), which tells that because of the increased consumption of all sorts of energy resources during the economic period with high NNI, the carbon in the air increases and converts into CO2 emissions.

The results also revealed that human capital is in a positive link to the level of CO2 emissions from the country. These results agree with Anwar et al. (2020), which states that human capital is the source of labor or workers to the different economic fields like technology, manufacturing, construction, transportation, tourism etc. The operations of these businesses are done with the help of liquid, solid, or gaseous forms of energy. Energy consumption, whether it is in any form, releases harmful gas like CO2 emissions which, because of causing excessive temperature into the earth, destroys the natural beauty and the quality of its resources, the necessary ingredients of economic development. These results also match with Gorus and Aydin (2019), which highlights that the increase in human capital plays a key role in the expansion of business practices. The increased business practices prolonged and more effective

processes, high power technology which could give larger productivity and efficient performance, and for all these, large energy sources. The excessive use of energy and large wastes as a result of business expansion causes CO2 emissions in the large amount.

The results showed that the employment ratio is in a positive relation to the level of CO2 emissions in a country. These results agree with Lin and Xu (2020), which show that in the countries where the employment rate is high, the productivity in all sectors is high. For the production of a large variety of goods and services, a large number of machines with different sizes, the requirement of fuel, and productivity potential are used. These machines emit a large amount of CO2, which depends on their size and amount of energy used. Hence, the increased employment ratio enhances the CO2 emissions. These results match with Z. Wang et al. (2018), which shows that in an economy, only when the employment rate is high if productivity in the country is at a large scale. At the same time, productivity at a large scale needs many technological and energy resources along with raw materials. These things are the source of CO2 emissions and environmental degradation. These results agree with Wu et al. (2018), which reveals that the higher employment ratio gives equal opportunities to people to raise their living standard and their purchasing power. When they can afford and actually purchase the small or large technologies to facilitate themselves, they become a source of CO2 emissions.

The results indicated that inflation is in a positive relation to the level of CO2 emissions from the country. These results match with Ahmad et al. (2021), which reveals that the rise in the process of the items produced by the firms increases the profitability of the marketing of these products. The expectations that they can achieve higher earnings out of sales motivate the firms to focus on increasing the productivity level. For the increase in the number of goods and services produced, heavier machinery and plants are employed, and additional energy applied. Moreover, the waste from the production processes is greater. In this situation, the chances of GHG or CO2 emissions are greater than usual. These results are also in line with Alola et al. (2019), which shows that during inflation, the investment into the developmental projects is greater than earlier. This investment into the developmental projects triggers the productivity of different manufacturing, construction, transportation, mining, and agriculture businesses etc. The increase in the production processes enhances the use of energy resources and relevant technologies, which increases the CO2 emissions for releasing the carbon into the air containing oxygen. These results also match with Meo et al. (2018), which states that in the situation when there is inflation in the economy, the use of machines, plants, ICT technologies, and different heating processes are applied. For all these, different energy sources mostly nonrenewable energy sources, are utilized. It enhances the CO2 emissions.

The results revealed that exports are in a positive relation to the level of CO2 emissions. These results match with Adamu et al. (2019), which highlights that when the government allows but focuses on the exports of different items in the country, the business firms, in order to commercialize their products at a grand level through exports, enhance the production quantity and products quality. The improvement in the level of production requires the use of technological instruments, additional

infrastructure, and energy resources that emit harmful gases like CO2 emissions. These results also match with Murshed and Dao (2022), which shows that which proclaims that the countries engaged in the exports of energy emit greenhouse gases in large amounts because, during energy generation like fossil fuels production, electricity from fossil fuels, and electricity from nuclear power all are the big source of CO2 emissions. When, for exports purposes, the electricity production within the country increases, the level of CO2 emissions gets high.

The results showed that eco-innovation has a negative relationship with the level of CO2 emissions. These results are supported by Fethi and Rahuma (2019), which indicates that the adoption of eco-innovation results in the use of energy efficient technologies. When the business firms adopt the energy efficient technologies, the use of the energy is reduced to the largest possible extent and the adverse impacts which they impart on the environment is also reduced. The reduced energy usage, reduces the CO2 emissions from the business firms. So, the eco-innovation has a negative relation to CO2 emissions. These results are also in line with Tao et al. (2021), which reveals that the in the eco-innovation, such resources and processes are employed for the business operations including communication, production, and marketing which require less amount of energy as compared to the traditional resources and processes. The decreased amount of energy in usage, reduces the GHG emissions like CO2 and thus, the whole environment remains clean leading to sustainable economy.

6. Implications

The prime concern of policy makers and economic activitists, right now, is to formulate strategies to fight against harmful emissions that are daunting the nature and environment. The existing pile of studies indeed explored various factors that are connected with the environment. Howoever, the constant rise in pollution demands the fresh evidences and perspectives to formulate effective strategies that could be helpful in the reduction of carbon emissions. In this regard, there are many areas where this study would be applicable. The study highlights there must be made policies on the part of government authorities and economists through some innovations or reformations. This study monitors the policymakers while formulating regulators related to reducing the level of CO2 emission using economic growth factors. The adverse impacts of an increase in GDP and NNI must be controlled. Similarly, human capital creation must be made in such a way as the human resources not only increase the productivity level within the country, but they must have the ability to control negative environmental impacts like CO2 emissions because of the increase in the economic practices. Similarly, the study guides that through effective policies regarding the employment ratio, exports and inflation, their contribution to CO2 emissions can be controlled.

Other than that, there is a need of institutional reforms to encourage the ecological innovation agenda in order to achieve green growth. Local governments, thereby, must implement environmental policies and market novel consumer influxes in order to utilize sustainability oriented eco-innovation. Higher investments must be made in R & D areas by respective entities that promotes green technology innovation all over

the country, this ultimately enhances the efficiency of energy systems. Consequently, leading to pollution and emission reduction.

7. Conclusion

The economy of China is considered the largest source of greenhouse gas emissions and climate change because of the increased economic activities, including technology usage, personal and state-owned vehicles, production and consumption of energy resources etc. CO2 emissions are taken as one of the most destructive environmental pollutants causing the greenhouse effects and climate change. As the environment is a crucial factor to public wellbeing and sustainable economic development, it's been the need to explore the factors affecting environmental quality. The current study was written to explore the influences of economic growth indicators like GDP, NNI, human capital, employment ratio, inflation, and exports, and eco-innovation on the level of CO2 emissions.The research revealed a positive relationship between GDP, NNI, human capital, employment ratio, inflation, exports, sustainable oriented eco-innovation and the level of CO2 emissions. The results stated that with the increase in the GDP and NNI, the total production of goods and services within the country increases and when energy consumption with other technological resources increase, the level of CO2 emissions gets high. The results also revealed that with the policies to increase the employment ratio, the operations of different businesses increase, and the increase in the technological operations causes an increase in the level of CO2 emission. The results showed that inflation in the economy enhances technological advancements and developmental & constructional activities, which enhances the use of energy resources within the country and make it emit a large amount of CO2 emissions. The study also concluded that the increase in exports level motivates domestic firms for innovating, technological advancements, and an increase in productivity causes an increase in the level of CO2 emissions. The results showed a negative relationship between eco-innovation and CO2 emissions. The innovation in different business practices like infrastructure, manufacturing, transportation, and communication system, in the way that it aims to reduce the environmental impacts of business practices as well as encourages the use of renewable energy. This reduces the CO2 emissions within the country.

8. Limitations

Several limitation are associated with the study. For suppose, the study considere economic growth dimensions like the "GDP, NNI, human capital, employment ratio, inflation, exports" along with sustainable oriented eco-innovation as predictor of carbon emissions. However, there are many other factors that influence CO2 emissions such as green finance, FDI, energy production or consumption, nature of energy, and geographical conditions. The current study has ignored all these factors while analyzing the change in the level of CO2 emissions. The future must focus here and remove this lack of study by analyzing the impacts of these factors on CO2 emissions as well. Moreover, this study only examines pollutants like CO2 emissions instead of all

greenhouse gases, which are detrimental to environmental quality, so the study is limited and needs authors' attention. The present article about the relation between GDP, NNI, human capital, employment ratio, inflation, export, and eco-innovation, and the level of CO2 emission is linked to only the Chinese economy. In future, the influences of GDP, NNI, human capital, employment ratio, inflation, and exports, and sustainable oriented eco-innovation on the level of CO2 emission must be checked in multiple economies.

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References

Abdul Hamid, B., Azmi, W., & Ali, M. (2020). Bank risk and financial development: Evidence from dual banking countries. *Emerging Markets Finance and Trade*, *56*(2), 286–304.

Abraham, K. G., & Kearney, M. S. (2020). Explaining the decline in the US employment-to-population ratio: A review of the evidence. *Journal of Economic Literature*, *58*(3), 585–643.

Adamu, T. M., Haq, I. U., & Shafiq, M. (2019). Analyzing the impact of energy, export variety, and FDI on environmental degradation in the context of environmental Kuznets curve hypothesis: A case study of India. *Energies*, *12*(6), 1076–1087. https://doi.org/10.3390/en12061076

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., & Balsalobre-Lorente, D. (2020). Modelling coal rent, economic growth and CO2 emissions: Does regulatory quality matter in BRICS economies? *The Science of the Total Environment*, *710*, 136284. https://doi.org/10.1016/j.scitotenv.2019.136284

Ahmad, W., Ullah, S., Ozturk, I., & Majeed, M. T. (2021). Does inflation instability affect environmental pollution? Fresh evidence from Asian economies. *Energy & Environment*, *32*(7), 1275–1291. https://doi.org/10.1177/0958305X20971804

Ainou, F. Z., Ali, M., & Sadiq, M. (2022). Green energy security assessment in Morocco: Green finance as a step toward sustainable energy transition. *Environmental Science and Pollution Research*, https://doi.org/10.1007/s11356-022-19153-7

Ali, A. A., Ali, A. Y. S., & Dalmar, M. S. (2018). The impact of tax revenues on economic growth: A time series evidence from Kenya. *Academic Research International*, *9*(3), 163–170.

Ali, M., Ibrahim, M. H., & Shah, M. E. (2022). Impact of non-intermediation activities of banks on economic growth and volatility: An evidence from OIC. *The Singapore Economic Review*, *67*(01), 333–348.

Alola, A. A., Yalçiner, K., & Alola, U. V. (2019). Renewables, food (in) security, and inflation regimes in the coastline Mediterranean countries (CMCs): The environmental pros and

cons. *Environmental Science and Pollution Research*, *26*(33), 34448–34458. https://doi.org/10.1007/s11356-019-06576-y

Ameyaw, B., & Yao, L. (2018). Analyzing the impact of GDP on CO2 emissions and forecasting Africa's total CO2 emissions with non-assumption driven bidirectional long short-term memory. *Sustainability*, *10*(9), 3110–3128. https://doi.org/10.3390/su10093110

Anwar, A., Younis, M., & Ullah, I. (2020). Impact of urbanization and economic growth on CO2 emission: A case of far east Asian countries. *International Journal of Environmental Research and Public Health*, *17*(7), 2531–2558. https://doi.org/10.3390/ijerph17072531

Apergis, N., Can, M., Gozgor, G., & Lau, C. K. M. (2018). Effects of export concentration on CO2 emissions in developed countries: An empirical analysis. *Environmental Science and Pollution Research*, *25*(14), 14106–14116. https://doi.org/10.1007/s11356-018-1634-x

Appiah, M. O. (2018). Investigating the multivariate Granger causality between energy consumption, economic growth and CO2 emissions in Ghana. *Energy Policy*, *112*, 198–208. https://doi.org/10.1016/j.enpol.2017.10.017

Bai, X., Wang, K. T., Tran, T. K., Sadiq, M., Trung, L. M., & Khudoykulov, K. (2022). Measuring China's green economic recovery and energy environment sustainability: Econometric analysis of sustainable development goals. *Economic Analysis and Policy*, https://doi.org/10.1016/j.eap.2022.07.005

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions? *Energy Policy*, *113*, 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bano, S., Zhao, Y., Ahmad, A., Wang, S., & Liu, Y. (2018). Identifying the impacts of human capital on carbon emissions in Pakistan. *Journal of Cleaner Production*, *183*, 1082–1092. https://doi.org/10.1016/j.jclepro.2018.02.008

Barra, C., & Zotti, R. (2018). Investigating the non-linearity between national income and environmental pollution: International evidence of Kuznets curve. *Environmental Economics and Policy Studies*, *20*(1), 179–210. https://doi.org/10.1007/s10018-017-0189-2

Bekhet, H. A., & Othman, N. S. (2018). The role of renewable energy to validate dynamic interaction between CO2 emissions and GDP toward sustainable development in Malaysia. *Energy Economics*, *72*, 47–61. https://doi.org/10.1016/j.eneco.2018.03.028

Bhat, J. A. (2018). Renewable and non-renewable energy consumption—Impact on economic growth and CO2 emissions in five emerging market economies. *Environmental Science and Pollution Research*, *25*(35), 35515–35530. https://doi.org/10.1007/s11356-018-3523-8

Cai, Y., Sam, C. Y., & Chang, T. (2018). Nexus between clean energy consumption, economic growth and CO2 emissions. *Journal of Cleaner Production*, *182*, 1001–1011. https://doi.org/10.1016/j.jclepro.2018.02.035

Chien, F. (2022a). How renewable energy and non-renewable energy affect environmental excellence in N-11 economies? *Renewable Energy*. https://doi.org/10.1016/j.renene.2022.07.013

Chien, F. (2022d). The mediating role of energy efficiency on the relationship between sharing economy benefits and sustainable development goals (Case Of China). *Journal of Innovation & Knowledge*, https://doi.org/10.1016/j.jik.2022.100270

Chien, F., Chau, K. Y., Sadiq, M., & Hsu, C. C. (2022c). The impact of economic and non-economic determinants on the natural resources commodity prices volatility in China. *Resources Policy*, https://doi.org/10.1016/j.resourpol.2022.102863

Chien, F., Hsu, C. C., Sibghatullah, A., Hieu, V. M., Phan, T. T. H., & Hoang Tien, N. (2021). The role of technological innovation and cleaner energy towards the environment in ASEAN countries: Proposing a policy for sustainable development goals. *Economic Research-Ekonomska Istraživanja*, https://doi.org/10.1080/1331677X.2021.2016463

Chien, F., Zhang, Y., Sharif, A., Sadiq, M., & Hieu, M. V. (2022b). Does air pollution affect the tourism industry in the USA? Evidence from the quantile autoregressive distributed lagged approach. *Tourism Economics*, https://doi.org/10.1177/13548166221097021

Collin, M., & Weil, D. N. (2020). The effect of increasing human capital investment on economic growth and poverty: A simulation exercise. *Journal of Human Capital*, *14*(1), 43–83.

Dauda, L., Long, X., Mensah, C. N., & Salman, M. (2019). The effects of economic growth and innovation on CO2 emissions in different regions. *Environmental Science and Pollution Research*, *26*(15), 15028–15038. https://doi.org/10.1007/s11356-019-04891-y

Ding, Q., Khattak, S. I., & Ahmad, M. (2021). Towards sustainable production and consumption: Assessing the impact of energy productivity and eco-innovation on consumption-based carbon dioxide emissions (CCO2) in G-7 nations. *Sustainable Production and Consumption*, *27*, 254–268. https://doi.org/10.1016/j.spc.2020.11.004

Dong, K., Hochman, G., & Timilsina, G. R. (2020). Do drivers of CO2 emission growth alter overtime and by the stage of economic development? *Energy Policy*, *140*, 111–128. https://doi.org/10.1016/j.enpol.2020.111420

Fethi, S., & Rahuma, A. (2019). The role of eco-innovation on CO2 emission reduction in an extended version of the environmental Kuznets curve: Evidence from the top 20 refined oil exporting countries. *Environmental Science and Pollution Research*, *26*(29), 30145–30153. https://doi.org/10.1007/s11356-019-05951-z

Godil, D. I., Sharif, A., Afshan, S., Yousuf, A., & Khan, S. A. R. (2020). The asymmetric role of freight and passenger transportation in testing EKC in the US economy: Evidence from QARDL approach. *Environmental Science and Pollution Research*, *27*(24), 30108–30117.

Godil, D. I., Yu, Z., Sharif, A., Usman, R., & Khan, S. A. R. (2021). Investigate the role of technology innovation and renewable energy in reducing transport sector CO2 emission in China: A path toward sustainable development. *Sustainable Development*, *29*(4), 694–707. https://doi.org/10.1002/sd.2167

Gong, B., Zheng, X., Guo, Q., & Ordieres-Meré, J. (2019). Discovering the patterns of energy consumption, GDP, and CO2 emissions in China using the cluster method. *Energy*, *166*, 1149–1167. https://doi.org/10.1016/j.energy.2018.10.143

Gorus, M. S., & Aydin, M. (2019). The relationship between energy consumption, economic growth, and CO2 emission in MENA countries: Causality analysis in the frequency domain. *Energy*, *168*, 815–822. https://doi.org/10.1016/j.energy.2018.11.139

Haroon, O., Ali, M., Khan, A., Khattak, M. A., & Rizvi, S. A. R. (2021). Financial market risks during the COVID-19 Pandemic. *Emerging Markets Finance and Trade*, *57*(8), 2407–2414.

Hartani, N. H., Haron, N., & Tajuddin, N. I. I. (2021). The impact of strategic alignment on the sustainable competitive advantages: Mediating role of it implementation success and it managerial resource. *International Journal of eBusiness and eGovernment Studies*, *13*(1), 78–96.

Hasanov, F. J., Liddle, B., & Mikayilov, J. I. (2018). The impact of international trade on CO2 emissions in oil exporting countries: Territory vs consumption emissions accounting. *Energy Economics*, *74*, 343–350. https://doi.org/10.1016/j.eneco.2018.06.004

Haug, A. A., & Ucal, M. (2019). The role of trade and FDI for CO2 emissions in Turkey: Nonlinear relationships. *Energy Economics*, *81*, 297–307. https://doi.org/10.1016/j.eneco.2019.04.006

Jermsittiparsert, K. (2021). Linkage between energy consumption, natural environment pollution, and public health dynamics in ASEAN. *International Journal of Economics and Finance Studies*, *13*(2), 1–21.

Jiang, C., Zhang, Y., Kamran, H. W., & Afshan, S. (2021). Understanding the dynamics of the resource curse and financial development in China? A novel evidence based on QARDL model. *Resources Policy*, *72*, 102–111.

Kamarudin, F., Anwar, N. A. M., Chien, F., & Sadiq, M. (2021). Efficiency of microfinance institutions and economic freedom nexus: Empirical evidence from four selected ASIAN countries. *Transformations in Business & Economics*, *20*(2b), 845–868.

Khan, I., Hou, F., & Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: Fresh evidence from the United States of America. *The Science of the Total Environment*, *754*, 142222. https://doi.org/10.1016/j.scitotenv.2020.142222

Khattak, M. A., Ali, M., & Rizvi, S. A. R. (2021). Predicting the European stock market during COVID-19: A machine learning approach. *MethodsX*, *8*, 101198. https://doi.org/10.1016/j.mex.2020.101198

Kurniawan, K., Supriatna, J., Sapoheluwakan, J., Soesilo, T. E. B., Mariati, S., & Gunarso, G. (2022). The analysis of forest and land fire and carbon and greenhouse gas emissions on the climate change in Indonesia. *AgBioForum*, *24*(2), 1–11.

Lan, J., Khan, S. U., Sadiq, M., Chien, F., & Baloch, Z. A. (2022). Evaluating energy poverty and its effects using multi-dimensional based DEA-like mathematical composite indicator approach: Findings from Asia. *Energy Policy*, https://doi.org/10.1016/j.enpol.2022.112933

Lin, B., & Xu, B. (2020). How does fossil energy abundance affect China's economic growth and CO2 emissions? *The Science of the Total Environment*, *719*, 137503. https://doi.org/10.1016/j.scitotenv.2020.137503

Lin, C. Y., Chau, K. Y., Tran, T. K., Sadiq, M., Van, L., & Phan, T. T. H. (2022). Development of renewable energy resources by green finance, volatility and risk: Empirical evidence from China. *Renewable Energy*. *201*, 821–831.

Liu, Z., Lan, J., Chien, F., Sadiq, M., & Nawaz, M. A. (2022b). Role of tourism development in environmental degradation: A step towards emission reduction. *Journal of Environmental Management*, https://doi.org/10.1016/j.jenvman.2021.114078

Liu, Z., Yin, T., Surya Putra, A. R., & Sadiq, M. (2022a). *Public spending as a new determinate of sustainable development goal and green economic recovery: Policy perspective analysis in the post-COVID era*. Climate Change Economics. https://doi.org/10.1142/S2010007822400073

Mahmood, N., Wang, Z., & Hassan, S. T. (2019). Renewable energy, economic growth, human capital, and CO2 emission: An empirical analysis. *Environmental Science and Pollution Research*, *26*(20), 20619–20630. https://doi.org/10.1007/s11356-019-05387-5

Mavi, R. K., & Mavi, N. K. (2021). National eco-innovation analysis with big data: A common-weights model for dynamic DEA. *Technological Forecasting and Social Change*, *162*, 120–129.

McGrath, L., Hynes, S., & McHale, J. (2022). The air we breathe: Estimates of air pollution extended genuine savings for Europe. *Review of Income and Wealth*, *68*(1), 161–188.

Mehmood, U., Tariq, S., Ul-Haq, Z., & Meo, M. S. (2021). Does the modifying role of institutional quality remains homogeneous in GDP-CO2 emission nexus? New evidence from ARDL approach. *Environmental Science and Pollution Research*, *28*(8), 10167–10174. https://doi.org/10.1007/s11356-020-11293-y

Meo, M. S., Chowdhury, M. A. F., Shaikh, G. M., Ali, M., & Masood Sheikh, S. (2018). Asymmetric impact of oil prices, exchange rate, and inflation on tourism demand in Pakistan: New evidence from nonlinear ARDL. *Asia Pacific Journal of Tourism Research*, *23*(4), 408–422. https://doi.org/10.1080/10941665.2018.1445652

Mikayilov, J. I., Galeotti, M., & Hasanov, F. J. (2018). The impact of economic growth on CO2 emissions in Azerbaijan. *Journal of Cleaner Production*, *197*, 1558–1572. https://doi.org/10.1016/j.jclepro.2018.06.269

Moslehpour, M., Chau, K. Y., Du, L., Qiu, R., Lin, C. Y., & Batbayar, B. (2022). Predictors of green purchase intention toward eco-innovation and green products: Evidence from Taiwan. *Economic Research-Ekonomska Istraživanja*, 1–22.

Moslehpour, M., Chau, K. Y., Tu, Y. T., Nguyen, K. L., Barry, M., & Reddy, K. D. (2022). Impact of corporate sustainable practices, government initiative, technology usage, and organizational culture on automobile industry sustainable performance. *Environmental Science and Pollution Research*, *29*(55), 83907–83920.

Moslehpour, M., Shalehah, A., Wong, W. K., Ismail, T., Altantsetseg, P., & Tsevegjav, M. (2022). Economic and tourism growth impact on the renewable energy production in Vietnam. *Environmental Science and Pollution Research*, *29*(53), 81006–81020.

Muhammad, B. (2019). Energy consumption, CO2 emissions and economic growth in developed, emerging and Middle East and North Africa countries. *Energy*, *179*, 232–245. https://doi.org/10.1016/j.energy.2019.03.126

Muhammad, B., & Khan, S. (2019). Effect of bilateral FDI, energy consumption, CO2 emission and capital on economic growth of Asia countries. *Energy Reports*, *5*, 1305–1315. https://doi.org/10.1016/j.egyr.2019.09.004

Murshed, M., & Dao, N. T. T. (2022). Revisiting the CO2 emission-induced EKC hypothesis in South Asia: The role of Export Quality Improvement. *GeoJournal*, *87*(2), 535–563. https://doi.org/10.1007/s10708-020-10270-9

Musarat, M. A., Alaloul, W. S., Liew, M., Maqsoom, A., & Qureshi, A. H. (2021). The effect of inflation rate on CO2 emission: A framework for Malaysian construction industry. *Sustainability*, *13*(3), 1562–1578. https://doi.org/10.3390/su13031562

Odugbesan, J. A., & Rjoub, H. (2020). Relationship among economic growth, energy consumption, CO2 emission, and urbanization: Evidence from MINT countries. *SAGE Open*, *10*(2), 2158–2174. https://doi.org/10.1177/2158244020914648

Ojogiwa, O. T. (2021). The crux of strategic leadership for a transformed public sector management in Nigeria. *International Journal of Business and Management Studies*, *13*(1), 83–96.

Pei, C., Wang, Z., & Sun, J. (2020). *Primary distribution and macro distribution patterns of national income the basic income distribution system of China* (pp. 45–80): Springer.

Ramzan, M., Sheng, B., Shahbaz, M., Song, J., & Jiao, Z. (2019). Impact of trade openness on GDP growth: Does TFP matter? *The Journal of International Trade & Economic Development*, *28*(8), 960–995.

Sadiq, M., Amayri, M. A., Paramaiah, C., et al. (2022b). How green finance and financial development promote green economic growth: Deployment of clean energy sources in South Asia. *Environmental Science and Pollution Research*, https://doi.org/10.1007/s11356-022-19947-9

Sadiq, M., Lin, C. Y., Wang, K. T., Trung, L. M., Duong, K. D., & Ngo, T. Q. (2022d). Commodity dynamism in the COVID-19 crisis: Are gold, oil, and stock commodity prices, symmetrical? *Resources Policy*, *79*, 103033.

Sadiq, M., Ngo, T. Q., Pantamee, A. A., Khudoykulov, K., Ngan, T. T., & Tan, L. L. (2022a). The role of environmental social and governance in achieving sustainable development goals: Evidence from ASEAN countries. *Economic Research-Ekonomska Istraživanja*, https://doi.org/10.1080/1331677X.2022.2072357

Sadiq, M., Ou, J. P., Duong, K. D., Van, L., Ngo, T. Q., & Bui, T. X. (2022c). The influence of economic factors on the sustainable energy consumption: evidence from China. *Economic Research-Ekonomska Istraživanja*, https://doi.org/10.1080/1331677X.2022.2093244

Shahbaz, M., Sharma, R., Sinha, A., & Jiao, Z. (2021). Analyzing nonlinear impact of economic growth drivers on CO2 emissions: Designing an SDG framework for India. *Energy Policy*, *148*, 119–134. https://doi.org/10.1108/CG-01-2020-0047

Shibli, R., Saifan, S., Ab Yajid, M. S., & Khatibi, A. (2021). Mediating role of entrepreneurial marketing between green marketing and green management in predicting sustainable performance in Malaysia's organic agriculture sector. *AgBioForum*, *23*(2), 37–49.

Sriyakul, T., Chienwattanasook, K., & Chankoson, T. (2022). Does industrialization and renewable energy consumption determine economic growth? Empirical evidence from ASEAN countries. *International Journal of Economics and Finance Studies*, *14*(03), 264–279.

Sun, Y., Duru, O. A., Razzaq, A., & Dinca, M. S. (2021). The asymmetric effect eco-innovation and tourism towards carbon neutrality target in Turkey. *Journal of Environmental Management*, *299*, 1136–1149. https://doi.org/10.1016/j.jenvman.2021.113653

Tan, L. P., Sadiq, M., Aldeehani, T. M., Ehsanullah, S., Mutira, P., & Vu, H. M. (2021). How COVID-19 induced panic on stock price and green finance markets: Global economic recovery nexus from volatility dynamics. *Environmental Science and Pollution Research*, https://doi.org/10.1007/s11356-021-17774-y

Tao, R., Umar, M., Naseer, A., & Razi, U. (2021). The dynamic effect of eco-innovation and environmental taxes on carbon neutrality target in emerging seven (E7) economies. *Journal of Environmental Management*, *299*, 1135–1148. https://doi.org/10.1016/j.scitotenv.2020.141853

Thitinan, T. S., & Chankoson Khunanan, S. (2022). Modelling the impact of e-government on corruption for the COVID-19 crisis. *International Journal of eBusiness and eGovernment Studies*, *14*(3), 26–45.

Ullah, S., Apergis, N., Usman, A., & Chishti, M. Z. (2020). Asymmetric effects of inflation instability and GDP growth volatility on environmental quality in Pakistan. *Environmental Science and Pollution Research*, *27*(25), 31892–31904. https://doi.org/10.1007/s11356-020-09258-2

Usman, O., & Musa, M. S. (2018). Revisiting exchange rate pass-through to consumer price inflation in Nigeria: A cointegrated vector autoregressive approach. *Academic Journal of Economic Studies*, *4*(1), 60–67.

Van Hoa, N., Van Hien, P., Tiep, N. C., Huong, N. T. X., Mai, T. T. H., & Phuong, P. T. L. (2022). The role of financial inclusion, green investment and green credit on sustainable economic development: Evidence from Vietnam. *Cuadernos de Economía*, *45*(127), 1–10.

Wang, B., & Wang, Z. (2018). Imported technology and CO2 emission in China: Collecting evidence through bound testing and VECM approach. *Renewable and Sustainable Energy Reviews*, *82*, 4204–4214. https://doi.org/10.1016/j.rser.2017.11.002

Wang, L., Chang, H.-L., Rizvi, S. K. A., & Sari, A. (2020). Are eco-innovation and export diversification mutually exclusive to control carbon emissions in G-7 countries? *Journal of Environmental Management*, *270*, 1108–1125. https://doi.org/10.1016/j.jenvman.2020.110829

Wang, Z., Zhang, B., & Wang, B. (2018). The moderating role of corruption between economic growth and CO2 emissions: Evidence from BRICS economies. *Energy*, *148*, 506–513. https://doi.org/10.1016/j.energy.2018.01.167

Wasti, S. K. A., & Zaidi, S. W. (2020). An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. *Journal of Building Engineering*, *28*, 1011–1027. https://doi.org/10.1016/j.jobe.2019.101104s

Wirsbinna, A., & Grega, L. (2021). Assessment of economic benefits of smart city initiatives. *Cuadernos de Economía*, *44*(126), 45–56.

Wu, Y., Zhu, Q., & Zhu, B. (2018). Decoupling analysis of world economic growth and CO2 emissions: A study comparing developed and developing countries. *Journal of Cleaner Production*, *190*, 94–103. https://doi.org/10.1016/j.jclepro.2018.04.139

Yao, Y., Ivanovski, K., Inekwe, J., & Smyth, R. (2020). Human capital and CO2 emissions in the long run. *Energy Economics*, *91*, 1049–1064. https://doi.org/10.1016/j.eneco.2020.104907

Zhang, Y., Chen, X., Wu, Y., Shuai, C., & Shen, L. (2019). The environmental Kuznets curve of CO2 emissions in the manufacturing and construction industries: a global empirical analysis. *Environmental Impact Assessment Review*, *79*, 1063–1078. https://doi.org/10.1016/j.eiar.2019.106303

Zhao, L., Chau, K. Y., Tran, T. K., Sadiq, M., Xuyen, N. T. M., & Phan, T. T. H. (2022). Enhancing green economic recovery through green bonds financing and energy efficiency investments. *Economic Analysis and Policy*, https://doi.org/10.1016/j.eap.2022.08.019

Zhao, L., Zhang, Y., Sadiq, M., Hieu, V. M., & Ngo, T. Q. (2021). Testing green fiscal policies for green investment, innovation and green productivity amid the COVID-19 era. *Economic Change and Restructuring*, https://doi.org/10.1007/s10644-021-09367-z