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G-20 economies and their environmental commitments: Fresh analysis based on energy consumption and economic growth

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The impact of economic growth and energy use is still controversial regarding sustainability, and researchers have limited consensus in this regard. Electricity is considered more environmentally friendly compared with direct fossil fuel consumption. However, many developed economies still depend on fossil fuel sources for electricity generation. Therefore, this study attempted to verify the relationship between electricity consumption and carbon emissions in developed economies in the Group of Twenty (G20). Economic growth and foreign direct investment are other important variables for analyzing this relationship. For this purpose, a dataset from 1995–2018 was generated. The study used econometric methods including cross-sectional dependence, cointegration, Fully Modified Ordinary Least Square (FMOLS), Dynamic Ordinary Least Square (DOLS) estimators, and the Pair-wise panel Granger causality test to examine the relationship between dependent and independent variables. The findings show a positive relationship between electricity consumption and CO_2 emissions. This indicates that electricity production is still dependent on sources that help increase CO_2 emissions in G20 countries. Furthermore, the results show that gross domestic product and its square term confirm the Environmental Kuznets Curve (EKC) theory for these economies. These results suggest that policymakers promote green and clean electricity sources for sustainable economic growth.

KEYWORDS
environmental commitments, G-20, energy consumption, economic growth, EKC

Introduction

The Paris Agreement (COP21) has launched a policy to prevent possibly calamitous climate change by reducing greenhouse gases to well beneath 2°C and ideally to reach 1.5°C (Mace and Verheyen, 2016). Furthermore, it wants to progress the economic abilities to manage the effects of climate change and encourage these nations in their attempts to do so. The Conference of the Parties 26 (COP26) came to a close in Glasgow, with over 200 nations striking a deal in the Glasgow Climate Pact to maintain the 1.5°C target temperature and approve the remaining aspects of the Paris Agreement. These 2 week-long rigorous climate change negotiations concluded unanimously on the critical need to accelerate decarbonization (Stern et al., 2022).

In the COVID pandemic of 2019, the only positive thing that emerged was climate improvement; however, this change badly affected the world's economic growth. Energy consumption demand fell rapidly with quarantine measures during the pandemic periods. Although energy consumption gradually improved as the pandemic measures were steadily relaxed, it was below 10% in June 2020 compared with June 2019 in European economies (Radmehr et al., 2021). Therefore, the electricity demand was 5% down in the last week of July 2020 compared with July 2019 in European economies (Williamson et al., 2016). Observed economic growth, energy consumption, foreign direct investment, and population were the main factors affected during the Pandemic; however, the environmental quality improved significantly. Therefore, the current study focused on such aspects and attempts to estimate the impact of these factors on the environment. According to the International Energy Agency, the energy alteration in G-20 countries changed significantly. Numerous economies have managed their energy-changing plans based on global obligations, showing common but discriminated duties and abilities.

Figure 1 shows the gross domestic product (GDP) in the selected countries of the G-20. According to this, the European Union is the highest GDP producer followed by the USA and China.

Considering the above findings of economic growth, Figure 2 shows China is the top emitter of CO_2, followed by the United States and European Union. Thus, this dataset indicates a relationship between economic growth and carbon emission in G-20 countries.

Figure 3 shows that China was ranked first for the fastest emerging economic growth from electricity consumption perspective. The United States held the second position, followed by the European Union.

Finally, the foreign direct investment (FDI) trend in G-20 economies is presented in Figure 4, which shows a nonlinear trend. Japan had the largest share of FDI, followed by the United States and Germany, while these countries have low CO_2 emissions which is possibly due to employing renewable and green (environment friendly) energy sources to produce electricity instead of using fossil fuel. These outcomes based on the dataset show how G-20 economies are essential regarding environmental commitments. Therefore, this study estimated the impact of the main economic determinants of climate disturbance using a panel dataset. In this regard, this study will also fill the literature gap. The main goal was to examine the influence of economic growth on carbon emissions and to verify the Environmental Kuznets Curve (EKC) hypothesis presented by Kuznets (1955) which explains the quadratic relationship between economic growth

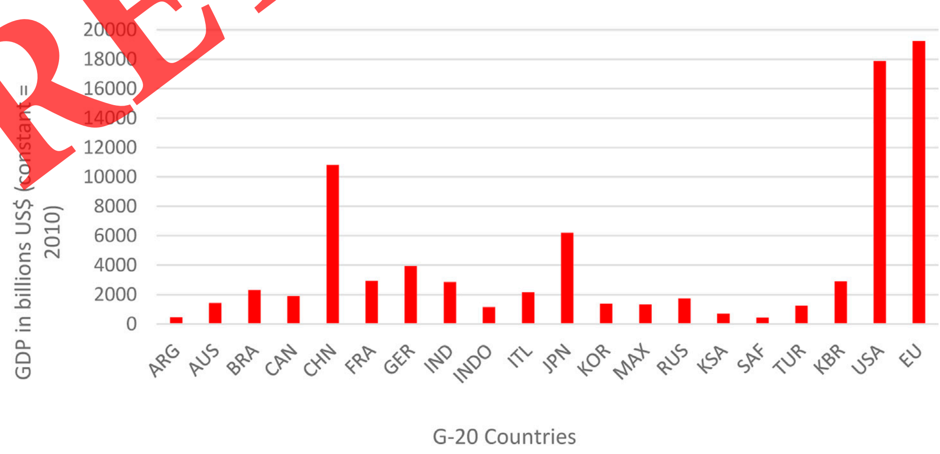

FIGURE 1
GDP of G-20 countries based on 2018 in billions of US$ (constant = 2010).

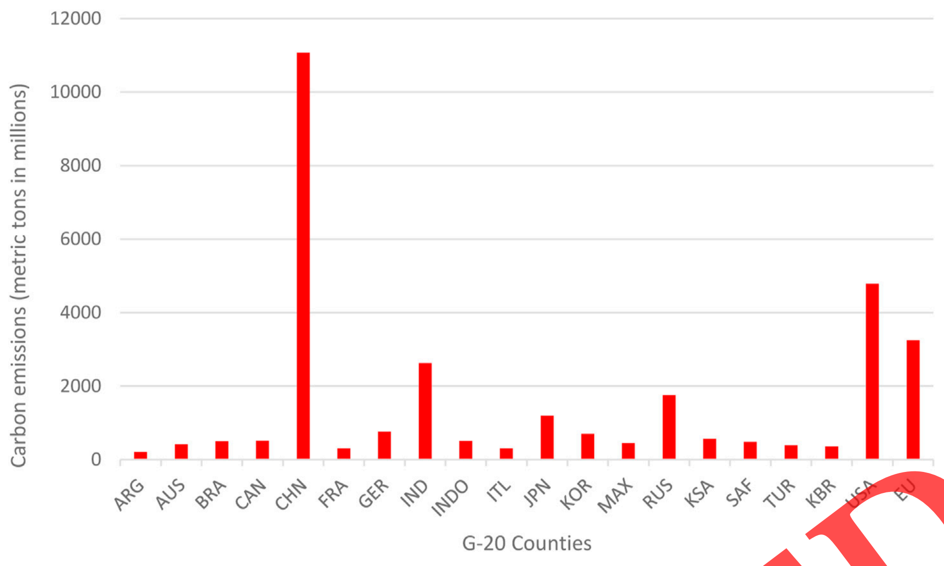

FIGURE 2
Carbon emissions status (metric tons in millions) of G-20 countries based on 2018.

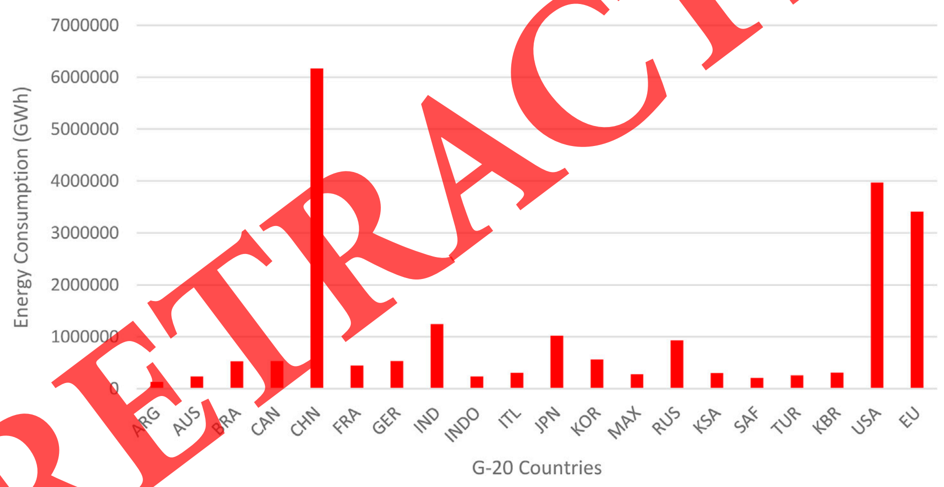

FIGURE 3
Energy consumption status [in Gigawatt hours (GWh)] of G-20 countries based on 2018.

and environmental degradation and can be expressed by inverted U-shape curve. Furthermore, we attempted to observe the role of energy on carbon emissions and examine the impact of FDI on carbon emissions. Finally, this study aimed to examine the impact of the population on carbon emissions.

The composition of the study includes a literature search, data, methodology, estimations, and a discussion, with the final portion presenting the conclusion and suggesting some policy points.

Literature review

Several studies have found a relationship between environmental degradation with variables such as economic growth, energy consumption, and FDI. For example, Alam et al. (2007) investigated the influence of income growth, energy consumption, and population on environmental degradation in Pakistan. Study showed that the development process depended on energy sources and caused carbon emissions. The speed of urbanization also indicated that

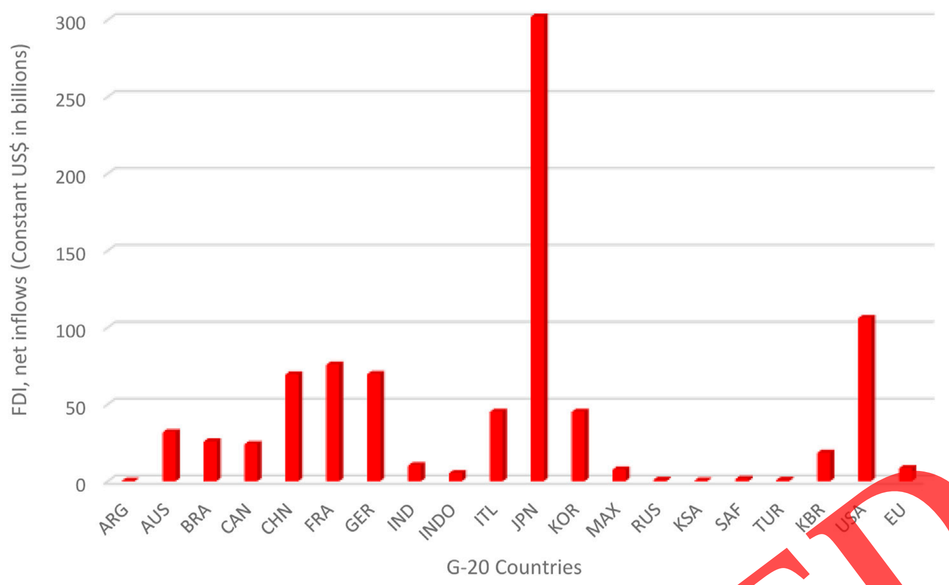

FIGURE 4
FDI, net inflows (Constant US$ in billions) of G-20 based on 2018. (Note: The data of FDI, net inflows (Current US$ in billions) for each country were converted into constant values by dividing it from GDP deflator).

FIGURE 5
Environmental Kuznets Curve (EKC) hypothesis of G-20 based.

population growth has positively effected environmental degradation. Jungho and Hyun Seok (2011) reported the relationships between energy use, trade, income growth, and carbon emissions for G-20 countries. The literature showed that income growth and trade positively impacted the environment in G-20 countries with high-income; however, a negative impact was recorded for low-income economies. The quality of environmental impurities might also instantly lower output, capital, and labor productivity (Borhan et al., 2012). The long-term effects of these ecological impurities can enhance harmful consequences on people and development.

A study by Peng et al. (2016) discovered a one-way relationship between FDI and carbon emissions. The connection between carbon emissions and income growth in emerging economies in the 21st century is significant (Huang and Zhou, 2020). The study also proved two-way relationships between power use and CO_2 emissions. When a study by Ghaderi et al. (2017) disaggregated energy based on different

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sources such as electricity, gas, oil, and coal, it confirmed evidence of the EKC. The long-run Granger test showed a bi-directional relationship between economic growth and carbon emissions. The study further suggested the prescription of carbon emissions by decreasing energy use, but it would be a high cost for economic growth.

Abokyi et al. (2019) explored the long-run causality between fossil fuel carbon release and economic growth. The study also found that the connection between energy sources and GDP was more closely related to emissions and renewable source of energy had a smaller impact on carbon emissions. Hanif et al. (2019) reported positive and significant impacts of FDI, fossil fuels, population, and economic growth on carbon emissions. Another study concluded that the degradation of the environment had occurred by the use of fossil fuels, but it was of benefit to economic growth (Diffenbaugh and Burke, 2019).

The existing literature has a gap related to checking the quadratic effects of GDP on CO_2 emissions, therefore this study fills in this gap by exploring the impact of economic growth, energy consumption, FDI, and the population on carbon emissions using the panel data of G-20 economies over the period of 1995–2018. Existing studies have primarily considered a single country. The current study fills the gap of existing studies in such a way as to consider all these ingredients in the context of global warming. Furthermore, the current study used an econometric method to analyze the relationship between economic growth and carbon emissions in selected economies.

Data and methodology

The critical issue is establishing the parametric impact of economic growth on emissions in selected G-20 member economies. How much energy consumption affects environment quality, and how do the FDI and population pressure the environment? Data on CO_2 emissions, GDP, electricity consumption (kWh), population, and real FDI (in constant $) were obtained from World Development Indicators (2020). The period considered for this study was between 1995 and 2018.

Carbon dioxide emissions (CO_2)

CO_2 per capita in metric tons is a dependent factor. EKC theory supposes that economic growth adds considerably to carbon emissions and shapes the inverted U. The EKC theory can be an upturned U-shape indicating an association between CO_2 release in the environment and economic development (Tan et al., 2015). Park and Lee (2011) favored the inverted U-shaped pattern.

Economic development

This variable uses the proxy of the annual rate of total GDP. The EKC theory adopts an N-shaped association between CO_2 release and development in the case of (Tan et al., 2015). The relationship between CO_2 and the economy was significant (Hitam and Borhan, 2012). The EKC relationship was determined using pollution indicator emissions, CO_2 in ASEAN countries. The GDP^2 was used to test the EKC theory (Tan et al., 2015) and verify the quadratic effect of economic growth in their models. The hypothesis was that GDP^2 has a negative association with CO_2 emissions.

Energy consumption (EC)

Annually, the EC (metric ton) is used to study the influence of energy consumption on carbon-dioxide releases (Rajabi Kouyakhi and Shavvalpour 2021; Trotta et al. 2021) employed carbon, energy (kWh), and economic growth. It found that the energy-consumption adds to carbon emissions. Allali et al. (2017) analyzed the positive relationship between CO_2 emissions and power consumption.

Foreign direct investment (FDI)

Annual FDI in millions of dollars was used to study its influence on CO_2 release. The FDI was used in other relevant studies, showing a negative impact on CO_2 emissions.

Population (pop)

The populace (millions) has been employed in many other studies (Zhou, Wang, and Wang 2019; Akorede and Afroz 2020).

This study followed the EKC theory, originating from the study by Kuznets (Akadırı et al., 2021). According to the EKC hypothesis, in the case of an inverted U-shape, economic growth initially increases CO_2 release after attaining a specific point; further increases in economic growth reduces CO_2 release.

The FDI increases the emission of CO_2 and verifies the haven hypothesis. According to the haven hypothesis, economies with a high demand for FDI and trade, and lesser demand for climate quality, will take on lax environmental standards to draw the attention of big corporations and export pollution-intensive goods (Hanif et al., 2019). However, according to the halo theory, "the ecological friendly firms that enter a host nation, decrease emissions because of their structured focus on green equipment or technology." The current study used different estimation techniques such as FMOLS, DLOS, and panel Granger causality, which can be applied to long panels. The model is written as:

$$\ln CO2 = \delta_1 + \ln\left(\delta_{2(GDP)}\right) + \ln\left(\delta_{3(GDP2)}\right) + \ln\left(\delta_{4(EC)}\right) + \ln\left(\delta_{5(FDI)}\right) + \ln\left(\delta_{6(Pop)}\right) + \mu, \quad (1)$$

The utilization of the econometric method depends upon the unit root results. For example, if it shows mixed integration and order, the cross-sectional dependence (CD) check depicts dependence in the given model. That is why this study employed FMOLS and DOLS to estimate the results.

The hypothesis of CD claims that dependence may occur in different CD, which produce defective and unfair consequences (Ali et al., 2019; Hasan, 2019; Ontaneda Jiménez, 2020). The dependence across selected economies is an essential issue to account for because of economies substantial economic and financial integration (Krüger and Mentzel, 2019; Mobrad et al., 2020; Christoforidis and Katrakilidis, 2021; Krishnappa et al., 2021). This indicates a strong interdependence between CD units (Trzepizur et al., 2020; Bouazza et al., 2021). Furthermore, it also permits the selection of suitable tests for unit root. Numerous tests performed to check for CD, such as (Anderu, 2021) applied Breusch and Pagan (1980) (Susca, 2020), checked dependence using Frees (1995), and Fang et al. (2021) employed the Pesaran (2004) check, which is appropriate for unbalanced or balance data. This study also applied robustness using a Lagrange Multiplier (LM) CD check.

After establishing the authentication of dependence in CD, we examined the data trend issue. For this purpose, this study applied a stationary check to investigate stochastic tendency, which is generally set to sophisticate on the supposition of dependence in CD. Numerous assessments for unit roots have been discussed in the literature, such as Maddala and Wu (1999), Hadri (2000), Breitung (2001), Levin et al. (2002), Im et al. (2003), and Pesaran (2007) tests. Scholars have divided these into first-generation tests (Hadri, Levin Lin Chu, and Breitung), which deal with independence in CD.

The cointegration process helps recognize long-run relationships between selected variables, which means that the variables proceed together over the long-term, which can help determine the long-period stability process. Thus, this study employed three cointegration techniques (Mehmood and Bilal, 2021; Ngameni et al., 2021; Xiong, 2021), Pedroni (2004), and the Fisher test to determine relationships between variables and Keo.

The DOLS technique is a parametric test for a normally-dispersed regressor that regulates errors by strengthening the regressors through leads and lags, values of regressors at the first differences. It also lowers the degrees of freedom in the procedure. However, FMOLS proposed by Pedroni for non-parametric tests, sets consideration correlations in the regressor's error term and the first differences. Thus, it considers less supposition. The FMOLS has numerous benefits because it permits endogeneity, serial correlation, and heterogeneity in CD.

TABLE 1 Descriptive statistics.

Variables	Obs	Mean	Std. Dev	Minimum	Maximum
CO_2	456	1.3109	1.9309	1.2508	1.1110
GDP	456	3.1612	4.3712	2.3311	1.9213
Pop	456	2.2808	3.5408	18072000	1.3909
EC	456	8.2611	1.1412	5.1910	6.1712
FDI	456	5.0910	2.0111	3199100	3.8712

Furthermore, it proposes two dimensions, including within and between. Both techniques construct consistent estimates, but scholars have divergent judgments about which technique fabricates more robust outcomes (Chen et al., 1999). The FMOLS technique can be executed as:

$$\omega_{GM} = N^{-1}\sum\nolimits_{i=1}^{N}\left[\sum\nolimits_{t=1}^{T}\left(\Delta x_{it} - x_i'\right)^2\right]^{-1}\left[\sum\nolimits_{t=1}^{T} X_{it} - x_i')Y_i' - T\tau_i\right], \quad (2)$$

$\omega_{GM} = N^{-1}\sum\nolimits_{i=1}^{N}\omega_{Mi.}\omega_{Mi}$, with FMOLS estimators for individual variables.

However, the DOLS technique is effective at removing feedback effects in the procedure. The DOLS equation can be written as:

$$Y_t = \gamma_i + x_i'\beta + d_{1t}\psi_1\sum_{j=r}^{q}\Delta x'_{t+j}\delta + \mu_{it}. \quad (3)$$

Thus, r and q permit different independent variables that remove long-run correlation in error terms. This process reveals a normal distribution by parametric analysis, the same as the FMOLS technique.

To examine causality, this study employed a Granger approach. The general form is as follows:

$$\Delta Y = \alpha_{1i} + \Sigma^L = 1\gamma_{1iL}\Delta Y_{it-L} + \Sigma^L = 1\gamma_{1iL}\Delta X + \epsilon_{1it}, \quad (4)$$

$$\Delta X = \alpha_{2i} + \Sigma^L = 1\gamma_{2iL}\Delta X_{it-L} + \Sigma^L = 1\gamma_{2iL}\Delta Y + \epsilon_{2it}, \quad (5)$$

Where $\alpha \,\&\, \gamma$ are adjustment coefficients and L is the number of lags.

Results analysis

Data has been collected from G-20 economies for 24 years, from 1995 to 2018. The descriptive analysis is shown in Table 1.

Descriptive statistics show the lowest value for carbon was 1.25 and the largest was 1.11, which belong to Argentina and China, respectively. The lowest value of GDP was 2.33 and the largest was 1.92; related to the economies of Argentina, respectively. The lowest value of energy consumption was 5.19, and the largest was 6.17, related to the economies of

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TABLE 2 Variance inflation factor (VIF) matrix.

Variables	CO_2	GDP	LECPC	FDI	POP
CO_2	--	--	--	--	--
GDP	2.45	--	--	--	--
EC	8.67	4.77	--	--	--
FDI	1.35	2.31	1.72	--	--
POP	2.23	1.36	1.66	1.06	--

TABLE 3 Results of unit root tests.

Variables	First-generation unit root test	
	LLC	IPS
CO_2	0.24	3.36
ΔCO_2	−7.03***	−9.05***
GDP	−2.63***	2.18
ΔGDP	−8.44***	−7.38***
EC	−4.08***	0.88
ΔEC	−8.32***	−8.1***
FDI	−3.75***	−4.77***
ΔFDI	−9.08***	−12.17***
POP	−1.82**	2.22
ΔPOP	−5.94***	−4.51***

H_0: series has a unit root

Indonesia and China, respectively. The lowest value for a population was 18,072,000; the two economies are Argentina and Australia, the maximum value was 1.39, and the related country is China. The minimum value for FDI was 3,199,100, and the maximum was 3.87, related to Indonesia and China, respectively. The values of Skewness were between 0.4 and 1, indicating Skewness was the most moderate of all variables tested.

According to Shahid (2017), if the values of variance inflation factor (VIF) are less than 10, then there is no issue of multicollinearity. After using the formula for VIF ($\frac{1}{1-r2}$) the results of all variables were less than the critical value. The maximum value of VIF for electricity consumption was 8.67, which is in the range of 10. Therefore, there is no issue of multicollinearity. The details are shown in Table 2.

The estimated values of the Levin, Lin, and Chu (LLC) and Im-Pesaran (IPS) stationarity tests are presented in Table 3. Here, most variables are stationary, but CO_2 is insignificant. IPS W-stat showed most variables are stationary; however, the FDI is insignificant at this level. Finally, IPS W-stat showed all variables are stationary.

It is usually considered that data disorder in panel techniques is CD unbiased. However, this study applied the Pesaran-CD check to validate panel dependency because it creates a loss in estimation efficiency with spurious consequences. In Table 4, the test outcome recommends that there is CD.

In Table 5, data using the Pedroni test for cointegration is presented. According to the test outcomes, two panels (PP-Statistics) and (ADF-Statistics) show cointegration from the within-dimension process whereas group PP-Statistics are from the between-dimension. The results of Kao based on ADF also confirm the existence of cointegration in the given panel. Finally, Johanse-Fisher confirmed the outcomes of Pedroni and Kae by the significance of trace and maximum eigenvalue. Therefore, this confirms the long-run association among selected variables, which are CO_2, GDP, EC, FDI, and total population (POP).

The FMOLS and DOLS data are detailed in Table 6. The sign and coefficient of the GDP and GDP square by FMOLS and DOLS are consistent with the theory of EKC. GDP had a significantly positive impact on CO_2 emissions (Manta et al., 2020; Long and Tang 2021). The quadratic effect (GDP^2) had a negative impact but had a significant effect on CO_2 (Ali et al., 2021; Alimi et al., 2020, Ajide, d Isola 2020) and income growth and ecological quality positively affected selected economies. The findings of Arminen and Menegaki (2019)

TABLE 4 Results of cross-sectional dependence tests.

Cross-section dependence test				
Variables	Breusch-pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
CO_2	1942.13***	95.77***	95.36***	2.96***
GDP	2981.37***	151.97***	151.55***	51.79***
EC	1857.81***	91.21***	90.80***	22.63***
FDI	385.64***	11.61***	11.19***	7.84***
POP	3154.79***	161.34***	160.93***	41.20***

H_0: No CSD
Note: *** and ** show significance levels at 1 percent and 5 percent, respectively.

TABLE 5 Results of Pedroni, Kao, and Fisher Cointegration analysis.

Pedroni		
Within-dimension	**Statistic**	**W. Statistic**
Panel v-Statistics	−2.04	−2.99
Panel rho Statistics	2.38	1.05
Panel PP-Statistics	−0.88	−4.95***
Panel ADF-Statistics	−1.63	−2.40***
Between-dimension		
Group rho-Statistic	3.40	1.00
Group PP-Statistics	−2.06	0.02**
Group ADF-Statistics	−1.22	0.11
Kao		
	T-Stat	Prob
ADF	−3.17***	0.00
Johansen-Fisher		
No of cointegration	Trace	Max Eigen
CE = 0	925.3***	496.9***
CE ≤ 1	551.1***	286.2***
CE < 2	340.5***	177.2***
CE < 3	202.4***	136.7***
CE < 4	107.2***	89.01***
CE < 5	72.58***	72.58***

Note: *** and ** show significance levels at 1 percent and 5 percent, respectively.

TABLE 6 Results of FMOLS and DOLS.

Variable	**FMOLS**	**DOLS**
GDP	1.16***	1.29***
GDP^2	−0.07***	−0.08***
POP	−0.05	−0.06
EC	0.68***	0.64***
FDI	0.01**	0.01*

Note: *** and ** show significance levels at 1 percent and 5 percent, respectively.

and Bibi and Jamil (2021) supported this study's outcomes. The statistical results are the same as those of Ahmad et al., (2020) and Baron, Montgomery, and Tuladhar (2010). The effects of POP, and (EC) have a significant impact on CO_2 emissions. The findings of all these results are consistent. Abokyi et al. (2021) found a positive long-run relationship between CO_2 emissions and energy consumption. In the short run, EC also had a significant positive impact on CO_2 emissions. According to the results of FMOLS and DOLS, the FDI had a positive and significant effect on CO_2. These results support the haven hypothesis, and (Oteman et al., 2017), reported similar results.

TABLE 7 Results of pair-wise Granger causality tests.

Null hypothesis	**Lag 1**		**Lag 2**	
	F-statistic	**Prob**	**F-statistic**	**Prob**
GDP (no) causality CO_2	27.07***	0.00	17.64***	0.00
CO_2 (no) causality GDP	85.99***	0.00	20.28***	0.00
EC (no) causality CO_2	15.94***	0.00	14.88***	0.00
CO_2 (no) causality EC	89.27***	0.00	23.92***	0.00
POP (no) causality CO_2	20.53***	0.00	15.37***	0.00
CO_2 (no) causality POP	58.36***	0.00	0.55	0.58
FDI (no) causality CO_2	24.13***	0.00	10.73***	0.00
CO_2 (no) causality FDI	15.73***	0.00	8.11***	0.00
EC (no) causality GDP	54.87***	0.00	16.72***	0.00
GDP (no) causality EC	19.72***	0.00	7.58***	0.00
POP (no) causality GDP	94.84***	0.00	21.12***	0.00
GDP (no) causality POP	191.09***	0.00	1.99	0.14
FDI (no) causality GDP	0.19	0.67	1.66	0.19
GDP (no) causality FDI	53.92***	0.00	24.29***	0.00
POP (no) causality EC	92.53***	0.00	29.73***	0.00
EC (no) causality POP	142.75***	0.00	1.03	0.36
FDI (no) causality EC	11.49***	0.00	5.24**	0.01
EC (no) causality FDI	29.34***	0.00	15.36***	0.00
FDI (no) causality POP	83.17***	0.00	3.32**	0.04
POP (no) causality FDI	3.81*	0.05	5.05***	0.01

The conclusion for Granger causality is presented in Table 7 and explains that some selected variables show Granger causality with each other in the G-20 panel. For example, the results show CO_2 has Granger causality with population, GDP has Granger causality with population, FDI has Granger causality with GDP, EC has Granger causality with POP, and FDI has Granger causality with POP at 5% and 10% significance levels.

$$\textbf{Turning Point} = Antilog\,of - \left(0.5 \times \frac{coefficient\ Attach\ with\ GDP}{Coefficient\ attached\ with\ the\ quadratic\ term\ of\ GDP}\right)$$

$$\textbf{Turning Point} = Antilog\,of - \left(0.5 \times \frac{3.25}{-0.14}\right)$$

$$\textbf{Turning Point} = Antilog\,(11.61)$$

$$\textbf{Turning Point} = 1.546E + 12.$$

The turning point of the EKC is 1.54 and the relationship between environment and economic growth is graphically presented in Figure 5 showing that when values move toward this position, the CO_2 starts to break down.

Discussion

A critical issue is establishing the parametric impact of economic growth on emissions in selected G-20 member economies. How much energy consumption affects environment quality, and how do the FDI and population pressure the environment? The main finding of this study is significant because, during the pandemic, these factors were severely affected. However, the quality of climate was improved, but these improvements were due to non-functioning economic institutions. This study found the GDP had a significantly positive impact on CO_2 emissions. The results of this study were the same as those reported by (Rajabi Kouyakhi and Shavvalpour, 2021), which examined the connection between CO_2 emissions and economic growth and proved EKC. The statistical findings align with those of Ahmad et al. (2020). EC had a significantly positive impact on CO_2 emissions in line with Abokyi et al. (2021) and Zhang (2019). FDI showed a positive significant effect on CO_2 emissions that advocated the haven hypothesis.

This study had some limitations regarding the availability of data for all G-20 nations and econometric techniques. Therefore, future studies can be enhanced by employing this model's most recent data of selected variables. The empirical analysis can be improved by employing more recent estimation techniques, such as AMG, CS-ARDL, or DCCE. Finally, the analysis can be extended by choosing different regions and other economies.

Conclusion and policy recommendations

This study investigated the influence of GDP, EC, and FDI on CO_2 emissions in selected economies using data from 1995 to 2018. The study followed an EKC theory. The GDP had a significantly positive impact on CO_2 emissions. The GDP^2 had a significant but negative impact on CO_2 emissions indicating they primarily increased as economic growth increased up to a specific position and then started to fall. Thus, this outcome fulfills the assumption of the EKC. Therefore, this study confirms the existence of the EKC theory for G-20 economies. However, the FDI had a significant positive impact on CO_2 emissions, which confirms the pollution haven hypothesis of G-20 economies.

An increase in economic growth in selected economies had a positive impact on the atmosphere. But there is still a need to focus and move the economy towards environmental sustainability. Population growth in selected economies puts more pressure on ecological sustainability and requires more attention. Electricity use is still the primary source of creating wealth, but its impact on the environment is huge, and this requires more attention. In G-20 economies, the FDI had an unfavorable effect on the quality of the environment. Thus, G-20 member economies should encourage environmentally friendly FDI policies to enhance sustainable investment. Furthermore, investment is necessary for economic growth but not sufficient for environmentally-friendly conditions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, and further inquiries can be directed to the corresponding author.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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