

## Article

# The Effect of Energy Consumption and Economic Growth on Environmental Sustainability in the GCC Countries: Does Financial Development Matter?

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**Abstract:** Achieving environmental sustainability whilst minimizing the climate change effect has become a global endeavor. Hence, this study examined the effect of energy consumption, economic growth, financial development, and globalization on CO<sub>2</sub> emissions in the Gulf Cooperation Council (GCC) countries. The research utilized a dataset stretching from 1995 to 2018. In a bid to investigate these associations, the study applied cross-sectional dependence (CSD), slope heterogeneity (SH), Pesaran unit root, Westerlund cointegration, cross-sectionally augmented autoregressive distributed lag (CS-ARDL), and Dumitrescu and Hurlin (DH) causality approaches. The outcomes of the CSD and SH tests indicated that using the first-generation techniques produces misleading results. The panel unit root analysis unveiled that the series are I (1). Furthermore, the outcomes of the cointegration test revealed a long-run association between CO<sub>2</sub> emissions and the regressors, suggesting evidence of cointegration. The findings of the CS-ARDL showed that economic growth and energy consumption decrease environmental sustainability, while globalization improves it. The study also validated the environmental Kuznets curve (EKC) hypothesis for GCC economies. In addition, the results of the DH causality test demonstrated a feedback causality association between economic growth and CO<sub>2</sub> emissions and between financial development and CO<sub>2</sub> emissions. Moreover, there is a one-way causality from energy consumption and globalization to CO<sub>2</sub> emissions in GCC economies. According to the findings, environmental pollution in GCC countries is output-driven, which means that it is determined by the amount of energy generated and consumed.

**Keywords:** CO<sub>2</sub> emissions; economic growth; energy consumption; environmental sustainability; financial development; globalization



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## 1. Introduction

Substantial economic expansion and industrialization have resulted in rising energy consumption and environmental deterioration, posing challenges to sustainable development [1]. In 2019, global primary energy consumption grew by 1.3% [2]. Energy is a requirement for economic growth as well as the primary cause of environmental deterioration, and climate change is connected to the utilization of energy and greenhouse gases (GHGs) emissions [3]. Numerous environmental research studies have emphasized the need of reducing GHGs, specifically carbon dioxide (CO<sub>2</sub>) emissions, which account for the largest chunk of GHGs [4]. Understanding the reasons for rising CO<sub>2</sub> emissions and developing suitable mitigation plans is vital for all governments and is specifically important for the Gulf Cooperation Council (GCC) nations due to their unique features. The six Gulf countries of GCC (Kuwait, Oman, Bahrain, United Arab Emirates (UAE), Qatar, and Saudi Arabia) are rich in resources and control 19.8% of global natural-gas holdings [2]. In fact, Saudi Arabia, UAE, and Qatar are amongst the globe's leading emitters [5].

Fossil fuels, an arguably abundant resource in GCC, are the foundation of these nations, which rely on earnings from fossil fuel exports to fund industrial activities, which, in turn, have a negative impact on environmental quality [6]. Although renewable energy sources account for a small portion of these economies' energy mix, they are heavily dependent on fossil fuels. In addition, the energy consumption in this region is increasing as a result of expanding populations, fast urbanization, and economic expansion, presenting a fundamental challenge to environmental sustainability [7]. These nations generate 2.4% of global GHGs, which is more than that of the European Union (EU). GCC countries are likewise anticipated to see a large upsurge in energy utilization as income grows, and the demand for luxury goods increases [7].

This research investigated the links between energy consumption (EC), economic growth (GDP), financial development (FD), globalization (GLO), and CO<sub>2</sub> emissions (CO<sub>2</sub>) in GCC countries. Many researchers have focused on globalization in recent years since the globalization process can impact sustainability. [8] created the globalization index, which is made up of economic, social, and political variables. It is a combination of political, social, and economic indices in the first dataset; nevertheless, subsequent research by [9] included some more sub-indices for a better understanding of this process. The association between GLO and CO<sub>2</sub> has been investigated by prior studies; however, their outcomes were inconclusive. For instance, the studies of [10] for the top 10 electricity consuming countries, [11] for 23 African countries, and [12] unveiled a negative GLO–CO<sub>2</sub> connection, while the studies of [13] for BRICS, [14] for WAME countries, and [15] found a positive GLO–CO<sub>2</sub> connection.

Furthermore, financial development (FD) is a big component that can impact levels of environmental deterioration in a variety of ways. For instance, financial institutions' lending can lead to business development, which can increase energy use, land use, and waste creation. Individuals' financial demands are also supported by financial institutions, and a rise in purchasing power can increase resource consumption, resulting in more damage to the environment. On the other hand, financial institutions may encourage technical progress that reduces the utilization of energy and therefore decrease environmental damage [16]. In addition, financial institutions may play a beneficial role in supporting initiatives that may lead to technological innovation since innovation is unachievable without adequate investment in research and development. There are conflicting data on the FD–CO<sub>2</sub> relationship. For instance, the research of [17] and [18] found a negative FD–CO<sub>2</sub> connection, while the studies of [19] and [20] found a positive FD–CO<sub>2</sub> connection.

The different perspectives of these research studies suggest that globalization, energy usage, economic expansion, and financial development have varying effects on environmental deterioration. GCC countries are presently confronted with increased globalization processes as well as increased utilization of energy and GDP, posing a considerable challenge in the context of ecological quality. As a result, the current study may assist policymakers in pursuing more pragmatic planning and maximizing decision-making linked to environmental abatement in general, and particularly, in GCC nations. This study also offers several major contributions to the existing literature. Basically, it investigated the impact of energy consumption, economic growth, financial development, and globalization on CO<sub>2</sub> emissions in GCC countries, whilst incorporating factors that are essential to the region's economic prosperity. Besides, and for the purpose of addressing the issue of CSD and heterogeneity, this study utilized an advanced panel data estimate approach, and it used a novel CS-ARDL model to solve the problems of heterogeneity and CSD of panel data, which are ignored by previous studies.

The remainder of the paper includes different sections. Section 2 is a review of the literature, and Section 3 involves the research methodology with an explanation of the empirical models, data, and methods. Section 4 presents the study results and the findings along with the discussion of these findings. Finally, Section 5 depicts the conclusion and the policy path.

## 2. Literature Review

This section of the paper discusses in detail prior research studies conducted regarding the association between energy consumption (EC), economic growth (GDP), financial development (FD), globalization (GLO), and CO<sub>2</sub> emissions (CO<sub>2</sub>).

### 2.1. Energy Consumption, Economic Growth, and CO<sub>2</sub> Emissions

In the empirical literature, it is generally acknowledged that there is a connection between EC, GDP, and CO<sub>2</sub>. Energy is needed for production, which spurs economic expansion and stimulates environmental decline. The study of [21] in Tunisia, utilizing impulse response and cointegration approaches between 1971 and 2005, unveiled a positive connection between EC and CO<sub>2</sub>. Likewise, in GCC economies, [22] assessed the EC–GDP–CO<sub>2</sub> connection by utilizing pooled mean group (PMG) and panel causality from 1980 to 2012. The empirical outcomes unveiled an insignificant connection between GDP and CO<sub>2</sub>, while EC impacted CO<sub>2</sub> positively. Furthermore, feedback causality linkage was observed between EC and CO<sub>2</sub>. Using Toda–Yamamoto causality, [23] assessed the EC–GDP–CO<sub>2</sub> connection in India by utilizing a dataset between 1971 and 2011. The outcomes of the study disclosed feedback causality linkage between EC and CO<sub>2</sub>. The study of [24] in 170 economies, which utilized data from 1980 to 2011 and used vector error correction model (VECM), uncovered that both EC and GDP triggered CO<sub>2</sub>. While feedback causality linkage has been demonstrated between EC and CO<sub>2</sub>, there was also contrasting evidence of a one-way causality from GDP to CO<sub>2</sub>. In the United States, using panel ordinary least squares (OLS) and data from 1997 to 2016, [25] found that EC and GDP impacted CO<sub>2</sub> positively, and the study validated the environmental Kuznets curve (EKC) hypothesis. Utilizing dynamic autoregressive distributed lag (ARDL), and frequency domain causality approaches, [26] examined the EC–GDP–CO<sub>2</sub> in Pakistan using data covering the period from 1972 to 2018. The outcomes unveiled that both EC and GDP contributed to environmental decline, and GDP Granger caused an increase in CO<sub>2</sub>. The positive CO<sub>2</sub>–GDP–EC association was validated by the study of [27]. Moreover, [28] assessed the CO<sub>2</sub>–GDP–EC connection in Brazil using datasets from 1990 to 2018. The investigators employed the fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and frequency domain causality approaches to demonstrate that an upsurge in EC and GDP contributed to the deterioration of the environment. Besides, the empirical analysis of the study done by [3] in South Korea, using a dataset from 1965 to 2019 and employing the ARDL, DOLS, and FMOLS approaches, showed that emissions triggered economic growth and EC mitigated GDP in South Korea. Likewise, a study conducted by [29] found that an upsurge in GDP triggered emissions levels in Australia. Moreover, the study of [30] using a dataset from 1980 to 2017 in Nigeria revealed that degradation of the environment was caused by an upsurge in both energy utilization and economic growth.

### 2.2. Financial Development and CO<sub>2</sub> Emissions

The study of [31] on the association between FD and CO<sub>2</sub> in G8 and D8 countries, which utilized data from 1999 to 2013 and used PMG and panel ARDL, showed that there was a positive correlation between FD and CO<sub>2</sub> in both G8 and D8 economies. In addition, there was a one-way causal linkage from FD to CO<sub>2</sub>. Similarly, [32] looked at the connection between FD and CO<sub>2</sub> in 184 nations from 1990 to 2017. The investigators used the generalized method of moments (GMM) to show that there was a negative connection between FD and CO<sub>2</sub>, suggesting that FD contributed to the sustainability of the environment in the 184 countries. On the contrary, the study of [33] in China, using data from 1980 to 2016 and ARDL, revealed a negative FD–CO<sub>2</sub> association, which demonstrated that FD contributed to the degradation of the environment. Similarly, the study of [34] on the association between FD and CO<sub>2</sub>, which was conducted on the South Asian economies and covered the years ranging from 1990 to 2014, indicated that there was a positive linkage between FD and CO<sub>2</sub>. In addition, FD Granger caused CO<sub>2</sub>. Likewise, [18] assessed the FD–CO<sub>2</sub> connection in South Africa by utilizing data from 1980 to 2017. The researchers

used ARDL, FMOLS, DOLS, and novel spectral causality approaches. The outcomes from the FMOLS and DOLS disclosed a negative connection between FD and CO<sub>2</sub>, while the causality test revealed a one-way causality from FD to CO<sub>2</sub> in both the short run and the long run. Similarly, [35] scrutinized the FD–CO<sub>2</sub> linkage in Turkey by using FMOLS and DOLS with data stretching from 1960 to 2014. The study outcomes showed a positive connection between FD and CO<sub>2</sub>, while the Granger causality outcome uncovered a unidirectional causality from FD to CO<sub>2</sub> in Turkey. Moreover, using a yearly dataset spanning from 1970 to 2016, [36] assessed the financial development emissions nexus in Thailand using the novel wavelet coherence and ARDL approaches. The findings of the study uncovered that an upsurge in financial development did not have a substantial influence on the level of emissions in Thailand.

### 2.3. Globalization and CO<sub>2</sub> Emissions

Over the years, many studies on the connection between GLO and CO<sub>2</sub> have been conducted; nonetheless, there is no consensus on the influence of GLO on CO<sub>2</sub>. For instance, using the top 10 electricity-consuming nations, [10] assessed the GLO–CO<sub>2</sub> connection using data from 1971 to 2013. The investigators applied both FMOLS and DOLS to explore the linkage between the variables, and the findings indicated that GLO negatively impacted CO<sub>2</sub>, suggesting that an upsurge in GLO improved the quality of the environment. Furthermore, there was a one-way causal linkage from GLO to CO<sub>2</sub>. Likewise, the study of [37] on the GLO–CO<sub>2</sub> association, which was done on 31 developed and 155 developing economies between 1991 and 2018, showed a negative linkage between GLO and CO<sub>2</sub>, which implied that an upsurge in GLO mitigated the degradation of the environment. Ref. [38] examined the GLO–CO<sub>2</sub> connection by employing the Driscoll–Kraay estimator and data pertaining to 23 African countries from 1999 to 2017. The results disclosed a negative GLO–CO<sub>2</sub> association. Similarly, [12] examined the GLO–CO<sub>2</sub> association by utilizing ARDL, dual gap approach, and frequency domain causality, and the outcomes revealed that there was a negative association between GLO and CO<sub>2</sub> and that GLO caused CO<sub>2</sub>. On the contrary, the research of [15] on the dynamics between GLO and CO<sub>2</sub> in Turkey using data from 1971 to 2016 as well as Fourier autoregressive distributed lag (ADL) cointegration and Fourier causality tests found that there was a connection between GLO and CO<sub>2</sub>. Furthermore, the causality test unraveled a unidirectional causal linkage from GLO to CO<sub>2</sub>. This outcome was supported by the study of [6] in West Asia and Middle East (WAME) economies, which used data from 1990 to 2017. The study of [39] on the interrelationship between emissions and globalization using advanced time-series approaches found that an upsurge in globalization aided in mitigating emissions levels in Argentina.

Table 1 presents a synopsis of the seminal studies discussed above.

**Table 1.** Summary of seminal studies.

Author(s)	Nations(s)	Time-Frame	Method(s)	Finding(s)
Effect of EC and GDP on CO <sub>2</sub>				
[21]	Tunisia	1971–2005	Cointegration, impulse response	GDP ⇄ CO <sub>2</sub> (+) EC ⇄ CO <sub>2</sub> (+)
[22]	GCC economies	1980–2012	PMG, causality	GDP ≠ CO <sub>2</sub> EC ⇄ CO <sub>2</sub> (+) EC ⇔ CO <sub>2</sub>
[40]	One hundred and eighty-eight countries	1993–2010	PMG, causality	GDP ⇄ CO <sub>2</sub> (+) GDP ⇄ CO <sub>2</sub> EC ⇄ CO <sub>2</sub> (+) EC ⇔ CO <sub>2</sub>
[23]	India	1971–2011	Toda–Yamamoto causality	EC ⇄ CO <sub>2</sub> GDP ⇄ CO <sub>2</sub> EC ⇔ GDP

Table 1. Cont.

Author(s)	Nations(s)	Time-Frame	Method(s)	Finding(s)
[24]	One hundred and seventy countries	1980–2011	Panel VECM	GDP $\leftrightarrow$ CO <sub>2</sub> (+) GDP $\leftrightarrow$ CO <sub>2</sub> EC $\leftrightarrow$ CO <sub>2</sub> (+) EC $\leftrightarrow$ CO <sub>2</sub>
[20]	ASEAN-5 countries	1980–2016	Panel causality	In Malaysia and Singapore GDP $\leftrightarrow$ CO <sub>2</sub> In Thailand EC $\leftrightarrow$ GDP
[25]	United States	1997–2016	Panel OLS	GDP $\leftrightarrow$ CO <sub>2</sub> (+) EC $\leftrightarrow$ CO <sub>2</sub> (+) GDP <sup>2</sup> $\leftrightarrow$ CO <sub>2</sub> (–)
[26]	Pakistan	1972–2018	Dynamic ARDL, frequency domain causality	GDP $\leftrightarrow$ CO <sub>2</sub> (+) EC $\leftrightarrow$ CO <sub>2</sub> (+) GDP $\leftrightarrow$ CO <sub>2</sub>
[41]	Thirty Chinese provinces	2000–2017	VECM	EC $\leftrightarrow$ CO <sub>2</sub> GDP $\leftrightarrow$ CO <sub>2</sub>
[42]	Spain	1970–2018	Threshold vector autoregression (TVAR)	REC $\leftrightarrow$ CO <sub>2</sub> (–) GDP $\leftrightarrow$ CO <sub>2</sub> (+)
Effect of FD on CO <sub>2</sub>				
[31]	G8 and D8 countries	1999–2013	PMG, Panel ARDL	FD $\leftrightarrow$ CO <sub>2</sub> (+) FD $\leftrightarrow$ CO <sub>2</sub>
[32]	One hundred and eighty-four countries	1990–2017	GMM	FD $\leftrightarrow$ CO <sub>2</sub> (–)
[33]	China	1995–2017	CS-ARDL	FD $\leftrightarrow$ CO <sub>2</sub> (+)
[43]	Bangladesh	1980–2016	ARDL	FD $\leftrightarrow$ CO <sub>2</sub> (–)
[34]	South Asian economies	1990–2014	FMOLS, DOLS, D–H Causality	FD $\leftrightarrow$ CO <sub>2</sub> (+) FD $\leftrightarrow$ CO <sub>2</sub>
[18]	South Africa	1980–2017	ARDL, FMOLS, DOLS	FD $\leftrightarrow$ CO <sub>2</sub> (–) FD $\leftrightarrow$ CO <sub>2</sub>
[35]	Turkey	1960–2014	FMOLS, DOLS	FD $\leftrightarrow$ CO <sub>2</sub> (–) FD $\leftrightarrow$ CO <sub>2</sub>
Effect of GLO on CO <sub>2</sub>				
[10]	Top ten electricity-consuming countries	1971–2013	FMOLS, DOLS	GLO $\leftrightarrow$ CO <sub>2</sub> (–) GLO $\leftrightarrow$ CO <sub>2</sub>
[17]	Thirty-one developed and one hundred and fifty-five developing economies	1991–2018	GMM	GLO $\leftrightarrow$ CO <sub>2</sub> (–)
[11]	Twenty-three African countries	1999–2017	Driscoll–Kraay estimator	PGLO $\leftrightarrow$ CO <sub>2</sub> (–) EGLO $\leftrightarrow$ CO <sub>2</sub> (–)
[44]	Sweden	1990–2018	Quantile-on-quantile	GLO $\leftrightarrow$ CO <sub>2</sub> (–) GLO $\leftrightarrow$ CO <sub>2</sub>
[13]	BRICS	1971–2016	Fourier ADL cointegration, Fourier causality	GLO $\leftrightarrow$ CO <sub>2</sub> (+) GLO $\leftrightarrow$ CO <sub>2</sub>
[45]	Turkey	1971–2016	Dual gap approach, FMOLS	GLO $\leftrightarrow$ CO <sub>2</sub> (+) GLO $\leftrightarrow$ CO <sub>2</sub>
[14]	WAME countries	1990–2017	Panel techniques	GLO $\leftrightarrow$ CO <sub>2</sub> (+) GLO $\leftrightarrow$ CO <sub>2</sub>

### 3. Research Methodology

#### 3.1. Theoretical Underpinning and Model

Economic expansion can impact CO<sub>2</sub> in three different ways: scale, composite, and technique effects. The scale effect states that economic expansion pollutes the environment at first because it necessitates more resources and energy, resulting in greater pollution and waste [46]. The degree of pollution and the materials utilized in the production process, on the other hand, are determined by a nation's sectoral structure. As a result, the composition effect expects the structural transition of countries from the industrial to the service sector to minimize the adverse effects of economic development on the environment. Finally, the technique effect shows that when a country's affluence rises, it adopts new and sophisticated technology that boosts production whilst mitigating emissions [47].

Energy is a critical input in an economy's production process, given the enormous increase in the use of alternative energy sources, because it is the cornerstone of transportation, agricultural production, industry, and homes. Therefore, energy dependency will keep growing as the global population grows, and development and economic growth continue [48]. Urbanization and interconnected global economy will exacerbate energy consumption and reliance as a result of increased telecommunications and mobility. Increasing energy use has a negative impact on the environment, health, safety, lifestyle, and communications, as history has proven.

Furthermore, financial development may contribute to environmental quality through investing in green technology and greener energy products. Financial development, on the other side, may stimulate economic activity, resulting in higher energy consumption and CO<sub>2</sub> emissions [18]. Scholars have disproportionately concentrated on the links between energy utilization or consumption, globalization, and their use in recent years. Theoretically, this relationship is simple; as countries become more international, their energy needs increase as well. It is commonly assumed that as globalization develops, trade barriers will decrease, resulting in increased output and income for a nation. Increases in wealth and output are connected to increases in energy usage [49]. As it is often assumed that growing globalization is related to greater levels of GDP, it is commonly assumed that GLO is a source of rising energy consumption. Based on this debate, the current study investigates the link between EC, GDP, FD, and CO<sub>2</sub> using the following model.

This research also follows what was done by [50] through incorporating GLO into the model.

$$\text{CO}_{2i,t} = \alpha_0 + \theta_1 \text{GDP}_{i,t} + \theta_2 \text{EC}_{i,t} + \theta_3 \text{FD}_{i,t} + \theta_4 \text{GLO}_{i,t} + \varepsilon_{i,t} \quad (1)$$

In the above equation, *i* illustrates the cross-sections, i.e., GCC countries. The period of time (1995–2018) is depicted by *t*. The intercept term is denoted by  $\alpha$ . Moreover,  $\varepsilon$  and  $\theta$ 's stand for parameters and error terms, respectively. Carbon dioxide (CO<sub>2</sub>) emissions are illustrated by CO<sub>2</sub> which is calculated as per capita emissions. Economic growth is measured as GDP per capita (constant USD \$2010), which is utilized in measuring the degradation of the environment. The energy utilization or consumption is represented by EC, and it is calculated as energy use per capita (Kwh). Financial development (FD) is measured as domestic credit to the private sector, and it is depicted by FD. Finally, globalization (GLO) is measured as an index based on foreign direct investment (FDI), trade, and portfolio investment. In this study, both EC and CO<sub>2</sub> are obtained from the database of British petroleum (BP). Furthermore, GDP and FD are gathered from the World Bank database of world development indicators (WDI). Lastly, GLO is gathered from [9].

In terms of the anticipated signs of the indicators' coefficients, it is generally believed that increasing output leads to environmental deterioration via growing resource and energy usage. The continuous growth of GCC economies presents a severe danger to the environment due to unsustainable development practices. Thus, it is predicted that the relationship between GDP and CO<sub>2</sub> is positive ( $\theta_1 = \frac{\delta \text{CO}_2}{\delta \text{GDP}} > 0$ ). A large proportion of energy utilization in GCC countries comes from nonrenewable energy sources. Therefore,

a positive connection is anticipated between EC and CO<sub>2</sub> ( $\theta_2 = \frac{\delta CO_2}{\delta EC} > 0$ ). Besides, a negative association is expected to appear between FD and CO<sub>2</sub> ( $\theta_3 = \frac{\delta CO_2}{\delta FD} < 0$ ); otherwise, it is deemed positive when it is not eco-friendly ( $\theta_3 = \frac{\delta CO_2}{\delta FD} > 0$ ). Lastly, GLO is included in the empirical model of CO<sub>2</sub>. Globalization has boosted competitiveness by expanding the flow of products and services, posing a serious danger on the environment. As a result, GLO is anticipated to positively impact CO<sub>2</sub> ( $\theta_4 = \frac{\delta CO_2}{\delta GLO} > 0$ ); otherwise, it is deemed negative when it is eco-friendly ( $\theta_4 = \frac{\delta CO_2}{\delta GLO} < 0$ ).

### 3.2. Data

The research used panel data for GCC nations from 1995 to 2018 to assess the dynamic connection between CO<sub>2</sub> and the regressors. The variables employed in this empirical analysis are CO<sub>2</sub> emissions (CO<sub>2</sub>), economic growth (GDP), energy consumption (EC), financial development (FD), and globalization (GLO). Table 2 comprises the variables, the signs, the measurements, and the data sources.

**Table 2.** Variables, signs, measurements, and data sources.

Variable	Sign	Measurement	Data Source
CO <sub>2</sub> emissions	CO <sub>2</sub>	Per capita emissions	BP
Economic growth	GDP	Per Capita (constant USD \$2,010)	WDI
Energy consumption	EC	Per capita energy use	BP
Financial development	FD	Domestic credit to the private sector	WDI
Globalization	GLO	Index based on FDI, trade, and portfolio investment	[9]

### 3.3. Estimation Approaches

#### 3.3.1. Cross-Sectional Dependence (CSD) Test

This study commenced by examining cross-sectional dependence (CSD) because the nations are linked via numerous economic, social, and cultural networks that may produce spillover effects. Consequently, this research utilized both the Pesaran Scaled LM and [51] CD tests to ascertain the cross-sectional dependence. The CSD test equation is stipulated as follows:

$$CSD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \tag{2}$$

In this equation, the pairwise correlation is illustrated by  $\hat{\rho}_{ij}$ .

#### 3.3.2. Slope Heterogeneity (SH) Test

The next phase assessed the existence of slope heterogeneity amongst the cross-sectional units. The issue of heterogeneity must be determined because, due to differences in the developing nations’ economic and demographic structure, there is a possibility of slope heterogeneity, which can potentially affect the consistency of panel estimators. For this reason, this study utilized the slope heterogeneity test. The [52] test is illustrated below:

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}} (2k)^{-\frac{1}{2}} \left( \frac{1}{N} \tilde{S} - k \right) \tag{3}$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}} \left( \frac{2k(T-k-1)}{T+1} \right)^{-\frac{1}{2}} \left( \frac{1}{N} \tilde{S} - 2k \right) \tag{4}$$

In the above equation,  $\tilde{\Delta}_{SH}$  and  $\tilde{\Delta}_{ASH}$  stand for delta tilde and adjusted delta tilde, respectively.

### 3.3.3. Stationarity Test

Understanding the stationarity characteristics of a series is critical in empirical analysis. To capture the stationarity features of the series under consideration, we used both cross-sectionally augmented Dicky-Fuller (CADF) the cross-sectionally augmented panel unit root test (CIPS). These methods work well, especially when the slope is heterogeneous, and there is CSD. The equations for these tests are as follows:

$$\Delta Y_{i,t} = \gamma_i + \gamma_i Y_{i,t-1} + \gamma_i \bar{X}_{t-1} + \sum_{l=0}^p \gamma_{il} \Delta \bar{Y}_{t-1} + \sum_{l=1}^p \gamma_{il} \Delta Y_{i,t-1} + \varepsilon_{it} \quad (5)$$

In this equation, the averages of the first differences and the lagged indicators are illustrated by  $\Delta \bar{Y}_{t-1}$  and  $\bar{Y}_{t-1}$ , respectively. Moreover, by taking the average of each CADF, the CIPS is obtained as illustrated in the following equation:

$$\widehat{CIPS} = \frac{1}{N} \sum_{i=1}^n CADF_i \quad (6)$$

### 3.3.4. Cointegration Test

It is critical to capture the long-term relationship between the variables studied. As a result, the cointegration test of [53] was used in this study to capture the long-run relationship between CO<sub>2</sub> and the regressors. Unlike the traditional cointegration tests (e.g., Kao and Pedroni), this test offers impartial outcomes in the presence of CSD and heterogeneity. The cointegration test is presented as follows:

$$\alpha_i(L) \Delta y_{it} = \gamma_{2it} + \beta_i (y_{it} - 1 - \alpha_i x_{it}) + \lambda_i(L) v_{it} + \eta_i \quad (7)$$

where  $\delta_{1i} = \beta_i(1)\hat{\delta}_{21} - \beta_i\lambda_{1i} + \beta_i\hat{\delta}_{2i}$  and  $\gamma_{2i} = -\beta_i\lambda_{2i}$

The Westerlund cointegration statistics are presented as follows:

$$G_t = \frac{1}{N} \sum_{i=1}^N \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (8)$$

$$G_\alpha = \frac{1}{N} \sum_{i=1}^N \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (9)$$

$$P_t = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad (10)$$

$$P_\alpha = T\hat{\alpha} \quad (11)$$

In the above equation,  $G_t$  and  $G_\alpha$  stand for group means statistics, while  $P_t$  and  $P_\alpha$  pertain to panel statistics.

### 3.3.5. Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL)

The CS-ARDL test, developed by [54], was used in this work for both long-run and short-run estimates. This test is more reliable and efficient than other approaches such as mean group (MG), pooled mean group (PMG), augmented mean group (AMG), and common correlated effect mean group (CCMG). The problems of homogeneity slope coefficients, CSD, non-stationarity, unobserved common variables, and endogeneity are all addressed by this technique. This is due to the fact that ignoring unobserved common

variables will result in incorrect estimation results, as stated by Wang et al. (2021). The equation below depicts the CS-ARDL:

$$Y_{it} = \sum_{i=1}^{pY} \pi_{it} Y_{i,t} + \sum_{i=0}^{pZ} \theta_{i1}^t Z_{i,t-1} + \sum_{i=0}^{pT} \phi_{i1}^t Z_{i,t-1} + e_{it} \quad (12)$$

In this equation,  $X_{t-1}^- = (Y_{t-1}^-, Z_{t-1}^-)_t$ ,  $\bar{Y}_t$  and  $\bar{Z}_t$  illustrate average cross-sections. Moreover,  $X_{t-1}^-$  illustrates the averages of both dependent and regressors:

$$\hat{\vartheta}_{\text{CS-ARDL},i} = \frac{\sum_{i=0}^{pZ} \hat{\theta}_{i1}^t}{1 - \sum_{i=1}^{pY} \hat{\pi}_{i1}} \quad (13)$$

$$\hat{\vartheta}_{\text{mean group (MG)}} = \frac{1}{N} \sum_{i=1}^N \hat{\vartheta}_i \quad (14)$$

### 3.3.6. Dumitrescu and Hurlin (DH) Causality

The study used a causality test established by Dumitrescu and Hurlin (2012), to evaluate the causative relationship between CO<sub>2</sub> emissions and each of EC, GDP, FD, and GLO. This test is appropriate if T is larger than or equal to N. This approach is also beneficial for a balanced and diverse panel data collection. This approach can also be used to deal with cross-sectional dependency. Equation (15) depicts the Dumitrescu and Hurlin causality test as follows:

$$z_{i,t} = \alpha_i + \sum_{j=1}^p \beta_i^j z_{i,t-j} + \sum_{j=1}^p \gamma_i^j T_{i,t-j} \quad (15)$$

In the above equation, the lag length is illustrated by j, and the autoregressive parameters are depicted by  $\beta^j$  (j). The alternative and null hypotheses postulate causal association and no causal association, respectively.

## 4. Findings and Discussion

### 4.1. Findings

The empirical analyses of this study are depicted in this section. First, we conducted a CSD test on the variables included in the study. The outcome of the CSD test is presented in Table 3. The findings unveiled that all the series have the issue of CSD. The outcomes demonstrated that we failed to reject the alternative hypothesis. The importance of the CSD is derived from the fact that in today's globalized world, nations are intertwined. This means that any change in one GCC nation's fundamental variable might affect other GCC nations. As a result of spillover effects, the variables are cross-sectionally dependent. Moreover, Table 4 shows that GCC nations have different levels of technological advancement and growth. As a consequence, the findings confirmed the occurrence of heterogeneity slope coefficients. Furthermore, we assessed the stationarity characteristics of the series which are depicted in Table 5, and the outcomes revealed that the series are I (1) variables.

**Table 3.** Cross-sectional dependence (CSD) outcomes.

	CO <sub>2</sub>	GDP	EC	FD	GLO
Breusch–Pagan LM	227.24 *	99.257 *	162.43 *	227.24 *	410.54 *
Pesaran scaled LM	38.749 *	15.383 *	26.918 *	38.749 *	72.216 *
Bias-corrected scaled LM	38.646 *	15.279 *	26.815 *	38.646 *	72.113 *
Pesaran CD	14.512 *	4.3758 *	−1.7779 ***	14.512 *	20.261 *

Note: \* and \*\*\* depict  $p < 1\%$  and  $p < 10\%$ , respectively.

**Table 4.** Slope heterogeneity (SH) outcomes.

	Test Value	<i>p</i> -Value
Delta tilde	4.352	0.000 *
Delta tilde adjusted	4.972	0.000 *

Note: \* depicts  $p < 1\%$ .

**Table 5.** Cross-sectionally augmented panel unit root test (CIPS) outcomes.

	Level	First Difference
CO <sub>2</sub>	-2.103	-5.867 *
GDP	-1.828	-4.474 *
EC	-1.722	-5.234 *
FD	-1.741	-3.527 *
GLO	-2.586	-5.300 *

Note: \* depicts  $p < 1\%$ .

It is crucial to capture the long-run connections between CO<sub>2</sub> and each of EC, GDP, FD, and GLO in GCC economies. In doing so, we applied the cointegration test of [53], and the outcomes are shown in Table 6. Those outcomes unveiled the presence of a long-run association between CO<sub>2</sub> and each of EC, GDP, FD, and GLO. Furthermore, as a robustness check, we employed the Pedroni and Kao cointegration tests, and the results of these tests are presented in Table 7. Those results provided evidence of a long-run connection between CO<sub>2</sub> and each of EC, GDP, FD, and GLO. Thus, the results of the Pedroni and Kao cointegration tests validate the [53] cointegration test.

**Table 6.** Cointegration test outcomes.

Statistic	Value	Z-Value	<i>p</i> -Value
Gt	-3.275 *	-3.087	0.001
Ga	-6.022	1.328	0.908
Pt	-6.423 **	-1.944	0.026
Pa	-6.257	-0.048	0.481

Note: \* and \*\* depict  $p < 1\%$  and  $p < 5\%$ , respectively.

After we affirmed the long-run interrelationship between CO<sub>2</sub> and the regressors, we proceeded to the estimation of the long-run and the short-run connection between CO<sub>2</sub> emissions and the regressors after the long-run cointegration between CO<sub>2</sub> and each of EC, GDP, FD, and GLO has been established. In doing so, we applied the CS-ARDL to capture both the short-run and the long-run connections between CO<sub>2</sub> and the regressors. The outcomes of the long-run CS-ARDL are presented in Table 8. They revealed the following: the influence of CO<sub>2</sub> on GDP growth is positive and significant, suggesting that a 1.829% upsurge in CO<sub>2</sub> is attributed to a 1% upsurge in GDP in GCC economies when other indicators are kept constant. Besides, we also affirmed the EKC hypothesis since the coefficient of GDPSQ is negative (-0.127) and statistically significant. Furthermore, the connection between CO<sub>2</sub> and energy consumption is positive and significant which implies that keeping other factors constant, a 1% upsurge in utilization of energy triggers CO<sub>2</sub> by 0.028%. Moreover, the FD-CO<sub>2</sub> association is positive and insignificant. Lastly, the GLO-CO<sub>2</sub> connection is negative and significant illustrating that a 0.922% decrease in CO<sub>2</sub> is linked with a 1% upsurge in globalization keeping other factors constant.

**Table 7.** Kao and Pedroni outcomes.

<b>Panel A: Kao</b>				
	<b>T-Stat</b>	<b>Prob</b>		
ADF	−4.4890 *	0.0000		
Residual-variance	0.0018			
HAC variance	0.0014			
<b>Panel B: Pedroni</b>				
	<b>Weighted</b>			
	<b>Stat</b>	<b>Prob</b>	<b>Stat</b>	<b>Prob</b>
Panel v-stat	1.1438	0.1263	1.1543	0.1242
Panel rho-stat	0.2267	0.5897	0.2645	0.6043
Panel PP-stat	−2.3354 *	0.0098	−2.0974 **	0.0180
Panel ADF-stat	−2.3855 *	0.0085	−2.1508 **	0.0157
Group rho-stat	1.1387 *	0.8726		
Group PP-stat	−3.1699 *	0.0008		
Group ADF-stat	−4.5722 *	0.0000		

Note: \* and \*\* depict  $p < 1\%$  and  $p < 5\%$ , respectively.

**Table 8.** Cross-sectionally augmented autoregressive distributed lag (CS-ARDL) outcomes.

<b>Panel A: Short-Run Results</b>				
<b>Regressors</b>	<b>Coefficient</b>	<b>StdErr.</b>	<b>Z-Stat.</b>	<b>p-Value</b>
ECM (−1)	−0.801 *	0.2901	−4.017	0.002
GDP	1.080 *	0.362	4.669	0.000
GDPSQ	−0.053 **	0.018	−1.903	0.014
EC	0.038 ***	0.013	1.886	0.064
FD	1.170	0.609	0.727	0.468
GLO	−1.835 *	0.049	−3.929	0.000
<b>Panel B: Long-Run Results</b>				
	<b>Coefficient</b>	<b>StdErr.</b>	<b>Z-Stat.</b>	<b>p-Value</b>
GDP	1.829 ***	0.030	1.886	0.062
GDPSQ	−0.127 *	0.045	−2.784	0.006
EC	0.028 *	0.004	6.252	0.000
FD	−1.679	0.133	−1.480	0.141
GLO	−0.922 *	0.538	−4.699	0.000

Note: \*, \*\*, and \*\*\* depict  $p < 1\%$ ,  $p < 5\%$ , and  $p < 10\%$ , respectively.

After confirming the association between CO<sub>2</sub> and the regressors (EC, GDP, FD, and GLO) in the long run, we also estimated the short-run associations which are represented in Table 8. In the short run, the CS-ARDL showed similar results to those seen in the long-run outcomes. In the short run, the influence of GDP and EC on CO<sub>2</sub> is positive, while GLO impacts CO<sub>2</sub> negatively. As anticipated, the error correction model (ECM) is negative (−0.801), which illustrates that corrections made in past periods can be rectified in succeeding periods.

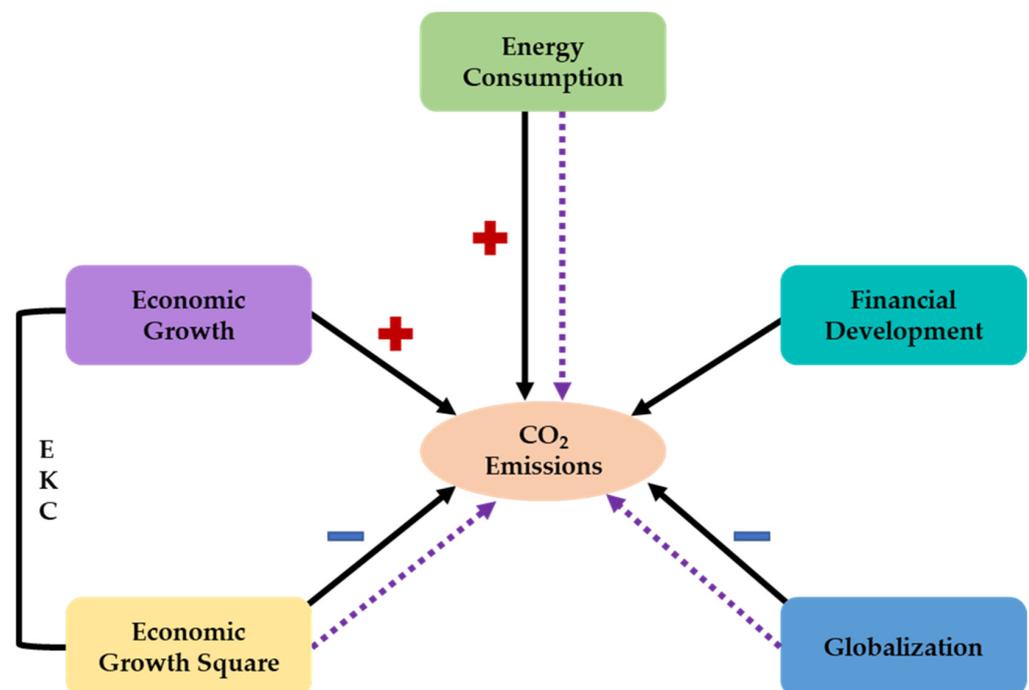
The present study takes a step further by assessing the causal connection between CO<sub>2</sub> and each of EC, GDP, and GLO in GCC countries. The outcomes of the causal association between CO<sub>2</sub> and the regressors are presented in Table 9. The outcomes from the D–H

causality test uncovered a one-way causal linkage from the utilization of energy to CO<sub>2</sub>. This demonstrates that EC can predict CO<sub>2</sub>. Moreover, there is bidirectional causality between FD and CO<sub>2</sub>, which implies that FD can predict CO<sub>2</sub> and vice-versa. Furthermore, there is a feedback causality association between GDP and CO<sub>2</sub>, which implies that both GDP and CO<sub>2</sub> can predict each other. Lastly, there is a unidirectional causal linkage from GLO to CO<sub>2</sub>, which indicates that GLO can predict CO<sub>2</sub> emissions. Figure 1 illustrates the graphical findings of the empirical analysis.

**Table 9.** Dumitrescu and Hurlin (DH) causality outcomes.

Direction of Causality	W-Stat.	Zbar-Stat.	Prob.	Decision
EC → CO <sub>2</sub>	2.78598 **	2.54193	0.0110	One-way causality
CO <sub>2</sub> → EC	0.81241	−0.40790	0.6833	
FD → CO <sub>2</sub>	6.68909 *	8.31375	0.0000	Feedback causality
CO <sub>2</sub> → FD	4.03315 *	4.37064	0.0000	
GDP → CO <sub>2</sub>	4.00496 *	4.38192	0.0000	Feedback causality
CO <sub>2</sub> → GDP	7.64135 *	9.83586	0.0000	
GLO → CO <sub>2</sub>	7.36713 *	9.37155	0.0000	One-way causality
CO <sub>2</sub> → GLO	0.67537	−0.47251	0.5953	

Note: \* and \*\* depict  $p < 1\%$  and  $p < 5\%$ , respectively.



**Figure 1.** Graphical findings.

#### 4.2. Discussion of Findings

This section of the empirical analysis discusses in detail the findings mentioned above. With the aim of investigating the effect of energy consumption (EC), economic growth (GDP), financial development (FD), and globalization (GLO) on CO<sub>2</sub> emissions (CO<sub>2</sub>) in GCC countries, we applied both the CS-ARDL and panel causality techniques. The outcomes from the CS-ARDL revealed that economic growth causes an upsurge in the degradation of the environment in GCC economies. This simply means that GCC nations are majorly pro-growth economies. Thus, they favor economic expansion at the expense of the quality of the environment. As a result, economic growth stimulates the consumption of

energy in GCC countries, which leads to a rise in environmental deterioration. This further implies that, in pursuit of rapid economic expansion, GCC economies' environmental quality has deteriorated. The study also affirmed the EKC hypothesis, which indicates that GCC economies are on the right path towards environmental sustainability. This outcome is consistent with the study of [55] who found that an upsurge in CO<sub>2</sub> in Malaysia is attributed to an upsurge in economic expansion. Moreover, the studies of [28] for Brazil, [16] for highly decentralized economies, and [39] for Argentina comply with this finding by establishing a positive interrelationship between economic growth and CO<sub>2</sub> emissions.

Furthermore, we found that there is a positive interrelationship between energy consumption and CO<sub>2</sub> emissions in both the long run and the short run. This outcome is not surprising given the fact that energy consumption is necessary for economic growth which also triggers the degradation of the environment. Thus, utilization of nonrenewable energy triggers economic expansion which, in turn, mitigates a negative impact on the environment in GCC nations. This finding concurs with the study of [12] for Mexico, which demonstrated that there is a positive interconnection between emissions and energy use. The study of [56] for selected Latin American countries also complies with this finding. Additionally, our finding is consistent with the studies of [45] for India and [57] for Chile.

Moreover, the short-term and the long-term association between financial development and CO<sub>2</sub> emissions is positive and insignificant. This finding is unsurprising given that financial development may not mitigate environmental degradation in emerging countries such as GCC countries, where the structural transition of the financial sector is still in its infant phase. This outcome concurs with the works of [12] for Mexico and [14] for emerging nations; however, it contradicts the outcomes of [18] for South Africa and [58] for Malaysia who established a negative association between FD and CO<sub>2</sub>.

We also found that there is a negative interrelationship between globalization and CO<sub>2</sub> emissions, which implies that globalization plays a vital role in abating emissions levels in GCC economies. One possible reason for the negative connection between globalization and CO<sub>2</sub> is that globalization through trade also enables technical advancement and leads to an increase in economic activity. According to the research of [59] on Andean nations (e.g., Colombia, Peru, Bolivia, and Ecuador), trade openness stimulates industrialization via the capacitive effect, scale effect, comparative advantages effect, and technique effect. It stimulates investment, which, in turn, affects economic activity, energy consumption, and, ultimately, environmental degradation. This outcome conforms with the studies of [37] for Japan, [60] for APEC economies, and [61] for the 15 highest emitting countries. Nonetheless, this outcome contradicts the findings of [62] for South Africa, [63] for Australia, and [15] who found that there is a positive association between globalization and CO<sub>2</sub> emissions.

To capture the causal influence of economic growth, financial development, and globalization on CO<sub>2</sub> in GCC economies, we applied the panel causality approach. The outcomes of this test revealed that energy utilization or consumption, economic growth, and globalization play a vital role in predicting the level of emissions in GCC countries. This outcome infers that any policy directed towards energy consumption, economic growth, and globalization will have a substantial influence on emissions of CO<sub>2</sub> in GCC nations. The above findings have significant policy consequences for GCC countries regarding CO<sub>2</sub> emissions.

## 5. Conclusions and Policy Path

This research study assessed the effect of energy consumption, economic growth, financial development, and globalization on CO<sub>2</sub> emissions in GCC nations by utilizing a dataset stretching between 1995 and 2018. To investigate these connections, the study used cross-sectional dependence, slope heterogeneity, Pesaran unit root, Westerlund cointegration, cross-sectionally augmented autoregressive distributed lag, and Dumitrescu and Hurlin causality approaches. The outcomes of both CSD and SH tests revealed that using the first-generation techniques produces incorrect results. Thus, this study relied on second-generation approaches. Besides, the findings of the panel unit root test unveiled

that the series are I (1). Furthermore, the results of the cointegration test unveiled a long-run association between CO<sub>2</sub> and the regressors, suggesting evidence of cointegration. The outcomes of the CS-ARDL showed that economic growth and energy consumption decrease the sustainability of the environment, while globalization improves it. Moreover, the outcomes of the DH causality test demonstrated feedback causality association between GDP and CO<sub>2</sub> and between FD and CO<sub>2</sub>. In addition, there is a one-way causality from energy use and globalization to CO<sub>2</sub> emissions in GCC economies.

To achieve environmental quality, the current energy regulations must be changed to support green energy sources and other energy-efficient technologies. This research showed that there is a negative link between globalization and CO<sub>2</sub> emissions. As a result, GCC economies should implement the following policy suggestions: Openness to new markets and business partners will aid in the improvement of environmental quality. Environmental deterioration may be reduced by establishing possibilities and flexibility for imports of renewable technology and clear environmental regulations and rules. Policymakers in GCC economies may also strengthen relationships with their foreign commercial partners in order to relieve poverty, create new job opportunities, and increase exports and imports. If these steps are adopted, global trading partners will recognize the value of doing business with GCC countries. Interestingly, financial development has little effect on CO<sub>2</sub> emissions in GCC economies. Financial development may not enhance environmental protection in developing economies, such as GCC nations and other developing countries where the financial sector is still in the early stages of structural transformation. This proposes the need to broaden the financial basis, specifically in terms of public-private partnerships (PPPs) in clean and renewable energy usage to promote clean energy (Sustainable Development Goal-7/SDG-7) and clean environment (SDG-13). In addition, the increase in CO<sub>2</sub> emissions, due to economic expansion, reduces environmental sustainability. This implies that policymakers in GCC economies should exercise caution when enacting policies that promote economic expansion at the price of environmental deterioration. Consequently, there is a need to create effective energy-conserving policies that strike a balance between GCC countries' energy mix, environmental plans, and macroeconomic aims. This will promote long-term economic growth without jeopardizing energy efficiency; instead, a paradigm shift to renewables such as thermal, hydro, wind, and solar energy may be undertaken.

Though this research assessed the association between CO<sub>2</sub> emissions and each of energy consumption, economic growth, financial development, and globalization, further studies should be conducted by using an asymmetric approach and including additional variables. Moreover, other metrics of environmental degradation should be considered in future studies.

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