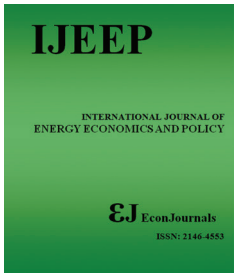

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An Empirical Analysis of Trade Market Dynamics on CO_2 Emissions: A Study of GCC Economies

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ABSTRACT

This study aims to conduct a comprehensive investigation into the impact of macro trade determinants on carbon dioxide emissions within Gulf Cooperation Council (GCC) economies spanning from 1995 to 2022. Specifically, it explores this influence through the theoretical frameworks of the Pollution Haven Hypothesis (PHH) and the Environmental Kuznets Curve (EKC). Advanced econometric methods, including stepwise regression employing the fully modified least square method and Pool ordinary least square method, are utilized in this research. Granger causality and Johnson cointegration tests are employed to assess both long- and short-term dynamics. The findings reveal that macro trade factors such as total investment, trade reserves, per capita income, and net inflow of foreign direct investment exhibit significant associations with carbon dioxide emissions across both short and long-term timeframes. Particularly noteworthy is the positive and statistically significant impact of per capita income, total investment, foreign direct investment, and gross national savings on CO_2 emissions. In contrast, trade reserves demonstrate a significant and negative impact on greenhouse gas emissions.

Keywords: Gulf Cooperation Council, Trade Openness, Drivers, Cointegration, Granger Causality
JEL Classifications: F1, Q5

1. INTRODUCTION

The post-World War II surge in global trade has been a catalyst for economic advancement worldwide. However, it has also precipitated a pressing issue: The escalation of carbon dioxide emissions. Against the backdrop of climate change, the equitable allocation of emission responsibilities among nations has gained paramount importance. Consequently, the study of carbon embodied in trade has garnered considerable scholarly attention (Bhatti et al., 2021a; Bhatti et al., 2022; Bai et al. 2023; Wang et al., 2024). Debone et al., (2022) scrutinized Brazil's economic structural transformations regarding carbon emissions, uncovering a noteworthy correlation between these variables. Furthermore, the unsettling reality emerges that nearly half of the world's most polluted cities are concentrated in India and China, comprising a collective majority of 48 out of the top 50 (Zmami and Ben-Salha, 2020).

Examining the determinants of trade openness within Gulf Cooperation Council (GCC) countries is crucial for understanding the elements influencing their trade policies and assimilation into the world economy. This investigation holds significant importance as trade openness is closely connected to development and economic growth (Hashim et al., 2024; Huchet-Bourdon et al., 2018; Hye & Lau, 2015; Idris et al., 2016; Lee & Rabago, 2024; Seyfullayev, 2022; Martins et al., 2023; Sanusi and Dickason-Koekemoer, 2024; Husnain et al., 2024). It is evident that nations embracing greater trade openness typically achieve

higher income levels and demonstrate superior economic and financial performance (Ali et al., 2022; Ju et al., 2010; Keho, 2017; Kouwoaye, 2021). Addressing pollution as a negative externality threatening environmental sustainability is imperative, particularly in GCC economies (Dauda et al., 2021). Numerous investigations have looked into the potential effects of foreign direct investment and global trade on environmental damage. The increased economic activity and the introduction of new industrial techniques could make environmental degradation worse as a result of international commerce. International trade does contribute to its emergence (Lee et al., 2019).

This study endeavors to pinpoint the key trade determinants accountable for the deterioration of environmental conditions, gauged primarily through carbon dioxide (CO_2) emissions, within the GCC countries. The choice to focus on this regional bloc stems from its adoption of economic reforms designed to expedite economic progress in recent years. While these reforms have potentially bolstered economic growth, they may also entail detrimental impacts on the environment. The increasing deterioration of the environment in GCC nations observed particularly in recent years, is likely attributed to heightened industrialization, dependence on fossil fuels, and accelerated urban development.

Trade engagement within GCC countries stands out as a pivotal driver behind the surge in CO_2 emissions. The region's economic expansion, propelled by trade agreements and globalization, has spurred demand in energy-intensive sectors like manufacturing, transportation, and construction (Haider et al., 2024). Consequently, heightened economic activity has led to increased utilization of fossil fuels, notably oil and natural gas, which serve as the primary energy sources in the GCC region. Moreover, the prioritization of carbon-intensive industries for export-oriented production has further amplified the carbon footprint of GCC nations. Processes such as oil and gas extraction, processing, and transportation, alongside the production of petrochemicals and other energy-intensive commodities, play a significant role in CO_2 emissions. Among the top 10 most polluted countries in the world in 2018, Bahrain, Kuwait, and the United Arab Emirates are three of the GCC's uncomfortably high-ranking countries. In addition, other cities, including Dubai, Kuwait City, and Manama, are above the WHO's air pollution threshold by over 500% (IQAir AirVisual, 2019). The GCC's nexus between environmental degradation and business has to be thoroughly investigated and addressed, as these findings demonstrate.

Several investigations have been carried out the literature has provided a majority of theoretical explorations of the relationship, known as the Environmental Kuznets Curve (EKC), between economic expansion and environmental degradation in response to these challenges (Akbar et al., 2024). Moreover, a large body of empirical research examining the connection between these variables has been carried out (Cialani, 2017; Mele and Randazzo, 2019). In response to these concerns, a large number of studies have been carried out, most of them theoretical and focusing on the association between economic growth and environmental degradation (Nasim et al., 2023). Moreover, a substantial amount of empirical research has been done to examine the relationship between these variables (Mele and Randazzo, 2019). Energy consumption has a major role in increasing greenhouse gas emissions, according to empirical studies on the variables causing environmental degradation (Kaygusuz, 2007; Magazzino and Cerulli, 2019; El-Montasser and BenSalha, 2019). Additionally, it has been determined that some open-minded economic policies—like the rise of foreign industries with high pollution and the importation of goods with high carbon content—are aggravating environmental deterioration (Haug and Ucal, 2019; Choudhury et al., 2023).

This research adds a great deal of originality and significance to the body of knowledge on sustainable environmental practices and international trade. To do this, it examines the trade factors that affect carbon dioxide emissions in the economies of the GCC. A wide range of variables affect a nation's trade dynamics and are referred to be trade determinants. Although much previous research in this field has concentrated on empirical data, insights from a variety of theoretical viewpoints have been conspicuously absent. By investigating the theoretical foundations of trade drivers' effects on CO_2 emissions in GCC economies, this work contributes to the current understanding of the subject.

This study also represents a significant contribution to the existing literature, notable for its utilization of an extensive dataset spanning economies over 26 years. Diverging from mere relationships, the research aims to establish a robust foundation for a long and short-term causal relationship. The initial phase involves identifying five key trade determinants linked to carbon dioxide emissions, employing stringent model fitness assessments through stepwise AIC selection and advanced panel regression techniques. Reliable research links trade openness to carbon dioxide emissions and five other economic variables in GCC countries: trade reserves, per capita income, total investment, gross national savings, and foreign direct net flow investment. Cointegration tests using the Johansen approach then show linkages between short- and long-term integration. The findings of this study suggest that there is more going on here than merely surface-level relationships between trade factors and CO_2 emissions.

There are five primary sections to the study's structure. The relevant literature is summarized in the section that follows. The study approach used to ascertain the theoretical drivers' coefficients and look into how trade determinants affect CO_2 emissions is described in Section 3. Section 4 examines the findings, and Section 5 presents the conclusion.

2. LITERATURE REVIEW

2.1. Environmental Kuznets Curve Theory

In the context of Gulf Cooperation Council (GCC) countries, the application of the Environmental Kuznets Curve theory to understand the impact of trade drivers on CO_2 emissions can be particularly insightful. Historically, GCC countries have experienced rapid economic growth driven by factors such as oil and gas exports, foreign investment, and infrastructure development. This economic expansion has been accompanied by

a surge in industrialization, urbanization, and energy consumption, leading to significant CO_2 emissions. Economic growth during this early phase has been fueled in large part by trade drivers, such as imports of products and services and exports of oil and gas resources. But the high per capita CO_2 emissions are a result of using fossil fuels for both transportation and energy generation.

As GCC countries continue to develop, there is a growing recognition of the environmental challenges associated with rapid economic growth, including air pollution, water scarcity, and climate change. Governments in the region are increasingly investing in renewable energy projects, implementing environmental regulations, and diversifying their economies away from fossil fuels. Cleaner technology and sustainable development techniques are gaining popularity, even if commerce continues to be a major driver of economic growth. Investments in renewable energy sources, such as wind and solar power, the adoption of energy-efficient technology, and initiatives to improve energy efficiency in the transportation and industrial sectors all contribute to the decoupling of economic growth from CO_2 emissions. Consequently, there is a probability that the relationship between trade drivers and CO_2 emissions will start to decline In the long run, GCC countries may reach a stage of high-income and advanced economic development where environmental considerations become more prominent. At this point, the EKC hypothesis indicates that when governments enact tougher environmental laws, make investments in environmentally friendly infrastructure, and support green technologies, there may be a decrease in CO_2 emissions per person as a result of continued economic growth. Economic activity is still largely driven by trade factors, but sustainable development and lowering carbon intensity are receiving more attention.

2.2. The Pollution Haven Hypothesis (PHH) Theory

According to the Pollution Haven Hypothesis (PHH), a theory in environmental economics, companies may relocate from countries with rigorous environmental regulations to those with fewer restrictions as a result of international trade. This move might be made to benefit from reduced manufacturing costs brought about by fewer environmental regulations, resulting in the creation of pollution "havens" in areas with laxer regulations. The theory posits that this phenomenon could cause an increase in pollutants in the host countries where industries relocate, while potentially reducing pollution levels in the countries where industries originated due to a decline in industrial activity. Overall, the PHH raises questions about the environmental implications of globalization and international trade, highlighting potential trade-offs between economic growth and environmental protection.

The Pollution Haven theory can be applied to determine the impact of trade drivers on CO_2 emission in GCCcountries. According to this argument, industries may shift from nations with severe environmental restrictions to those with fewer regulations, thereby increasing pollution in the latter. GCC countries, endowed with abundant oil and gas resources, have experienced rapid industrialization and economic growth, fueled by exports of these resources. However, this growth has often been accompanied by environmental challenges, including high levels of CO_2 emissions. According to the PHH theory, trade drivers like imports and exports may encourage businesses to move to GCC nations in order to benefit from cheaper manufacturing costs and laxer environmental rules. This move may cause an increase in CO_2 emissions in GCC countries as firms develop and operate with fewer environmental restraints. The reliance on oil and gas exports as primary sources of revenue in GCC countries has significant implications for CO_2 emissions. Trade drivers, particularly the export of fossil fuels, contribute to the extraction, processing, and transportation of these resources, which are associated with substantial CO_2 emissions. Furthermore, the revenues generated from oil and gas exports often support industrial development and infrastructure projects, further contributing to emissions growth.

In addition to direct emissions from domestic industries, trade drivers also influence CO_2 emissions through imported goods and services. GCC countries often import a significant portion of their consumer goods, machinery, and equipment, which may be produced in countries with lower environmental standards. As a result, the carbon footprint associated with imported goods can contribute to overall CO_2 emissions in GCC countries, even if the production occurs elsewhere. The PHH theory highlights the importance of environmental regulations and policies in mitigating emissions from industrial activities driven by trade. GCC countries are increasingly recognizing the need to address environmental sustainability and climate change concerns, leading to the implementation of policies aimed at diversifying their economies, promoting renewable energy sources, and reducing carbon intensity.

2.3. Review of Empirical Studies

A substantial amount of research has examined the fundamental causes of environmental deterioration in recent decades. Here, we examine the key variables found in earlier research, such as urbanization, financial development, energy use, and economic growth. Next, we summarize research results from observational studies aimed at clarifying the factors contributing to environmental deterioration in Gulf Cooperation Council (GCC) nations. According to a recent study by Chien et al. (2023), there is a negative association between CO_2 emissions and foreign direct investment (FDI) in the G7 countries, implying that higher FDI leads to lower CO_2 emissions in these cases.

Research on the effects of GDP, inward FDI, and urban growth on Canada's CO_2 levels was carried out by Rahman and Vu (2020). Their research showed a correlation between rising FDI inflows and higher CO_2 emissions as well as a positive relationship between GDP growth and carbon emissions. Similarly, Ulucak et al. (2020) explored the causal links among natural resource depletion, economic growth, foreign direct investment (FDI), and environmental sustainability in the BRICS countries. Their findings revealed a positive correlation between environmental pollution indicators and economic development. Thus, as noted by Abdouli et al. (2017) and Sapkota et al. (2017), investment inflow becomes a significant factor affecting CO2 emissions. It is also noteworthy that there is a connection between gross capital formation and CO2 emissions. Researchers Sadiq et al. (2023) investigated how CO2 emissions in a group of countries

that comprised Brazil, Russia, India, and China (BRICS-1) were affected by policy uncertainty, corruption, and the use of renewable energy. Their results suggest that persistent emissions reductions over an extended period of time are linked to increased use of renewable energy and successful anti-corruption initiatives. However, the study also highlights that policy uncertainty poses a significant threat to environmental sustainability (Afshan et al., 2023b). This study focuses on how trade determinants affect CO2 emissions in GCC nations to fill in any gaps in the literature (Figure 1)

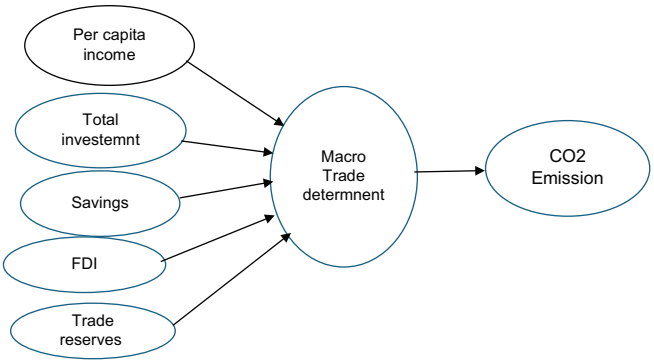
3. METHODOLOGY

3.1. Conceptual Framework

This study aims to assess how macro trade factors affect trade openness and how that affects CO_2 emissions in the economies of the GCC. Numerous macro variables are taken into account, such as trade reserves (TR), FDI, gross national savings (GNS), per capita income (PCI), and total investment (IN). These variables were selected based on their theoretical ability to forecast trade openness, which affects CO_2 emissions. The study uses a panel data approach with data gathered from 1995 to 2022 to accomplish this purpose. Through the use of panel data, the research takes into account both cross-sectional and temporal fluctuations, allowing for a more thorough and sophisticated comprehension of the intricate connection between trade openness macro factors and CO_2 emissions.

This study focuses on GCC nations for several reasons. Firstly, these countries possess distinctive trade drivers that set them apart from other regions, largely due to their varied political and economic structures. Secondly, concentrating the sample on this specific group of economies minimizes heterogeneity within the dataset. Thirdly, only nations with reliable data available from reputable sources were included in the sample, as the number of countries was constrained by data availability regarding the variables of interest. Access to data concerning the factors influencing trade openness and CO_2 emission within the GCC nations is pivotal to this study. The initial step of the study involved verifying the availability of data for the relevant variables. It was determined that data has been accessible since 1995, prompting the commencement of analysis from this year onwards. The World Development Indicators (WDI) is utilized as credible sources of panel data for the GCC countries included in the sample.

Figure 1: Macro trade determinants and CO_2 emission



3.2. Estimation Procedure

This study evaluated the model and determined the statistical significance of the results using different validation processes to guarantee the validity and reliability of the analysis. Initially, the model's specification, involving ten independent variables, underwent an evaluation to identify potential over- or under-specification using the Akaike Information Criterion (AIC). Then, to ascertain which independent factors had the greatest impact on trade openness prediction, Stepwise Regression (SR) was utilized. Through this process, five variables—FDI, TR, TIN, GNS, and PCI—were selected, all of which exhibited statistical significance.

Furthermore, to increase the model's robustness, a variety of estimating approaches were used, including FMOL and POLS. To ascertain the statistical significance of the model's fit, F-statistics were employed. With the help of these validation techniques, the study's conclusions were confirmed to be precise, reliable, and statistically significant, resulting in a thorough comprehension of how macro trade openness determinants affect CO_2 emissions in GCC countries. To evaluate parameter causation and cointegration, this study employed four factors selected using stepwise regression and proposed by theoretical literature. The investigation of causality employed Granger's causality framework, a method widely used in previous research (Greene, 2003; Wooldridge, 2002). Additionally, the Pedroni and Johnson Cointegration test was applied. The Engle-Granger Cointegration test, which assesses the residuals of a spurious regression performed with I(1) variables, was also used to determine if the variables are co-integrated.

3.3. Econometric Model

This work introduces two models. The first model aims to assess the impact of macroeconomic trade variables on trade openness. The second model examines how the determinants of trade openness influence CO_2 emissions within the economies of the Gulf Cooperation Council (GCC). In this context, the primary dependent variables are CO_2 emissions and trade openness (TO). The five principal trade drivers influencing trade openness are listed on the left-hand side of Equation 1. Trade openness is defined as the ratio of a nation's GDP to its trade, represented as TO_jt, where "j" denotes a specific nation (ranging from 1 to N) and "t" denotes the years. Carbon dioxide emissions are measured in metric tons per capita, represented as CO_2_jt, where "j" stands for a particular country (ranging from 1 to N) and "t" for the current year. X_jt, a collection of X components with "I" values ranging from 1 to K, represents the independent variables driving this relationship. Observed within nation "j," these variables span the years 1995-2020 and have a range of 1 to N. Consequently, the following is a quick description of the test models:

$$TOP_{jt} = \theta_{jt} + \theta_{jt1}(GNS_{jt}) + \theta_{jt2} + (FDI_{jt}) + \theta_{jt3} + (TR_{jt}) + \theta_{jt4} + (PCI_{jt}) + \theta_{jt5}(TIN_{jt}) + \theta_{jt9} + \eta_{jt} \quad (1)$$

$$CO2_{jt} = \theta_{jt} + \theta_{jt1}(GNS_{jt}) + \theta_{jt2} + (FDI_{jt}) + \theta_{jt3} + (TR_{jt}) + \theta_{jt4} + (PCI_{jt}) + \theta_{jt5}(TIN_{jt}) + \eta_{jt} \quad (2)$$

Additionally, the study considers variables such as gross national savings, foreign direct net flow investment, trade reserves,

total investment, and per capita income. These variables are incorporated into a multiple-regression model using panel regression techniques. Here, "t" stands for the selected annual period, while "j" stands for various nations. It is anticipated that trade openness and CO_2 emissions will be significantly impacted by the variables in Equations (1) and (2). The goal of each X factor is to reach predetermined statistical significance thresholds (P = 0.05, P = 0.10, or P = 0.01). A comprehensive summary of each of the various criteria used in this investigation is given in Table 1.

4. RESULTS AND DISCUSSION

Table 2 shows descriptive statistics for both dependent and independent variables in GCC nations from 1995 to 2020. On average, trade openness stands at 107.06, reflecting a notable level of trade activity among GCC nations, with values ranging from 191.87 to 49.71. The average CO_2 emissions for GCC countries are recorded at 23.09, with values ranging from 96.20 to 5.68. Net foreign direct investments have an average of 2.49, varying from 15.75 to −2.76. The average trade reserve for GCC nations is 827.47, fluctuating between 4719 and 5.68. Trade balance ranges from 48.45 to −4.38, with an average of 20.67. Total investment varies from 36.47 to 12.83, averaging at 24.62. Per capita income is recorded at an average of 66.17, with values ranging from 4.86 to 3.92. Gross national savings vary from 75.54 to 7.43, with an average of 42.39. These mean values, which are consistent with ranges seen in earlier studies, suggest that these factors accurately describe the dynamics of trade openness in GCC nations.

Table 3 presents the findings of the variance inflation factor (VIF) test, which was employed to determine multicollinearity. The mean VIF ratio was used for this assessment. All relevant variables were included in the analysis to perform the multicollinearity assessment using mean-variance factor analysis. All of the variables' VIF values were found to be ≤10, which suggests that the models do not contain multicollinearity.

Table 4 displays the results of the unit root test for the individual intercepts of the factors' level and first differences series. According to the test statistics, all variables in models 1 and 2 are non-stationary at their level but become stationary when examined at their first differences. I(1) indicates that there is first-order integration for these variables. Finding the optimal lag time for the GCC economy comes next after these variables are first-difference stationary. This result is critical for using sophisticated econometric approaches such as Granger causality tests and Johnson cointegration tests. Table 4 outlines the best lag selection criteria.

4.1. Lag Selection and Cointegration Test

Table 5 presents the results of the lag order selection experiments conducted for the GCC nations. The study used five different lag selection criteria to determine the most appropriate lag durations: Likelihood ratio (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion. According to these criteria, Lag 1 was selected as the lag order for both Model 1 and Model 2 in the GCC economies, based on the minimum observed value.

Various testing approaches have been proposed for panel integration, including Fisher-type tests utilizing the Johansen methodology (Maddala and Wu, 1999) and tests by Pedroni (1999, 2004). In panel data analysis, Johansen tests are incorporated into the Fisher test. Table 6 provides an overview of the Pedroni panel cointegration test findings, focusing on the economies of the GCC. To assess cointegration in panel data, Maddala and Wu's (1999) alternative approach pools tests from separate cross-sections to

Table 1: Variables computation

Variables	Measurement	Sign	Sources	Impact
Trade openness	Export+import/GDP	TOP	WDI	Dependent variable
Carbon dioxide emission	Carbon dioxide/per capita income	CO_2	WDI	Dependent variable
Savings	Gross national savings/GDP	GNS	IMF/WDI	X1 factor effect "+"
Foreign direct net flow investment	FDI net inflow/GDP	FDI	WDI	X2 factor effect "+"
Trade reserve	Total reserve minus gold/GDP	TR	WDI	X3 factor effect "+"
GDP per capita incomes	Total GDP/total population	PCI	WDI	X5 factor effect "+"
Total investment	Gross capital formation/GDP	TIN	IMF/WDI	X7 factor effect "+"

TOP: Trade openness, WDI: World development indicators, GNS: Gross national savings, FDI: Foreign direct investment, TR: Trade reserves, PCI: Per capita income, TIN: Total investment, CO_2: Carbon dioxide

Table 2: Descriptive statistics of gulf cooperation council economies

Variables	Mean	Median	Maximum	Minimum	SD	J-B
TOP	107.06	95.88	191.87	49.71	31.63	15.18****
CO2	23.09	21.71	47.66	11.50	8.46	22.01***
TR	25.15	18.25	96.20	5.68	21.83	146.29***
TIN	24.62	24.89	36.47	12.83	5.05	0.34***
PCI	4.45	4.37	4.86	3.92	0.24	6.06***
GNS	42.39	39.72	75.54	7.43	15.66	2.81***
FDI	2.49	1.66	15.75	−2.76	2.85	86.73***

TOP, TR, TIN, PCI, GNS, and FDI represent the trade openness, trade reserves, total investment, trade balance, per capita income, and gross national savings, respectively. While J-B represents the Jerqu Bera normality test. TOP: Trade openness, WDI: World development indicators, GNS: Gross national savings, FDI: Foreign direct investment, TR: Trade reserves, PCI: Per capita income, TIN: Total investment, SD: Standrad deviation

generate a test statistic for the full panel. Fisher's method combines the results of several independent tests. The table also presents data from the Johansen-Fisher cointegration test (Johansen, 1988, 1991; Johansen & Juselius, 1990).

Two variables' associations with one another were predicted using Granger causality. The cointegration test does not consider how one variable's past value affects another's current value. These hypothetical situations were examined with the Granger causality test.

Table 7's analysis reveals that the trace test finds many cointegration relationships between the variables, indicating significance at the 1% and 5% levels. In addition, the Granger causality test is utilized to examine the relationship between two variables in order to make forecasts. It's crucial to note that while the cointegration test identifies relationships between variables, it doesn't elucidate how the historical values of one variable may impact the current values of another. Consequently, to scrutinize these potential relationships, the Granger causality test is deployed.

Two variables' associations with one another were predicted using Granger causality. The cointegration test does not consider how one variable's past value affects another's current value. These hypothetical situations were examined with the Granger causality test.

Table 8 presents the Granger causality statistics for the GCC region and offers significant insights. The P-value for the null hypothesis, which indicates unidirectional causal relationships between TOP and TR, suggests that TR affects TOP. This result is corroborated by a prior study (Hailat et al., 2023), which investigated the influence of trade openness on the foreign currency reserves (FCRs) of BRICKS countries, assessing both the magnitude of trade openness and its impact on FCRs. Furthermore, it evaluated the sustainability of FCRs, revealing varying relationships between economic openness and FCRs across member nations, indicative of the role trade openness has played in the accumulation of FCRs.

The results indicate that Total Investment (TIN) Granger Causes Trade Openness (TOP) with a P = 0.00, suggesting a unidirectional relationship between TIN and TOP. This result is consistent with earlier research conducted by (Nelson et al., 2018; Chiappini, 2011) on the subject, which found a unidirectional causal link between trade openness and investment in Egypt. Furthermore, the study shows a unidirectional relationship between TOP and PCI, suggesting that higher trade openness in GCC nations is a direct result of rising PCI. This finding is supported by earlier studies by (Afzal et al., 2012; Zaman, 2012), which found that PCI and TOP were causally related in a unidirectional manner.

Table 3: Multicollinearity test variance inflation factor

Variables	T	VIF
Model I		
TIN	0.68	1.64
PCI	0.47	2.10
GNS	0.23	4.27
FDI	0.82	1.21
TR	0.22	4.27
Model II		
TIN	0.813	1.230
PCI	0.210	4.771
GNS	0.210	4.771
FDI	0.929	1.077
TR	0.588	1.702

A VIF value of 10 or less indicates no multicollinearity. VIF: Variance inflation factor, TIN: Total investment, PCI: Per capita income, GNS: Gross national savings, FDI: Foreign direct investment, TR: Trade reserves

Table 4: Panel unit root results

	ADF-Fisher Chi-square		PP-Fisher Chi-square		Im, Pesaran, Shin		Levin, Lin and Chu	
	Intercept		Intercept		Intercept		Intercept	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
TOP	32.27***	41.62***	25.27**	48.17***	−3.03***	−4.40***	−3.22**	−5.17***
TR	11.30	30.48***	11.19	51.16***	−0.42	−3.51***	−0.97***	−3.33***
TIN	16.49	33.54***	18.45	61.74***	−1.33*	−3.54***	−0.68***	−2.30***
PCI	19.49**	24.56***	19.82*	40.69***	−2.46***	−2.04***	−3.73***	−1.68***
GNS	9.68	29.32***	7.35***	47.97***	−0.12	−2.99***	−0.06	−1.94***
FDI	17.58***	30.56***	15.33***	63.34***	−1.2	−3.16***	−05.1***	−7.54***
CO_2	12.31	29.63***	16.06	40.90***	−045	−2.48***	−1.42***	−2.66***

The notation ***P<0.01; **P<0.05; *P<0.1 represents the corresponding significance levels. TOP: Trade openness, WDI: World development indicators, GNS: Gross national savings, FDI: Foreign direct investment, TR: Trade reserves, PCI: Per capita income, TIN: Total investment

Table 5: Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SIC	HQ
Model I						
0	−1781.854	NA	8.97e+12	49.69040	49.91174	49.77
1	−1351.414	765.22	2.26e+08	39.09484*	40.86558*	39.79*
2	−1320.302	49.26188	3.85e+08	39.59171	42.91185	40.913
Model II						
0	−2267.70	NA	6.52e+18	63.18	63.40	63.27
1	−1846.14	749.43	2.10e+14	52.83	54.60*	53.54
2	−1814.44	50.19	3.52e+14	53.31	56.63	54.63

LR: Likelihood, FPE: Final prediction error, AIC: Akaike information criterion, SIC: Schwarz information criterion, NA: Not available

Table 7: Johansen panel co-integration results

Hypothesesnumber of integration	With trend				Without trend			
	Fisher statistic* (from trace test)	P	Fisher statistic* (from the maximum eign test)	P	Fisher statistic* (from trace test)	P	Fisher statistic* (from the maximum eign test)	P
Mosel I								
None	1505	0.00	2296	0.00	1850	0.00	1206	0.00
At most 1	1490	0.00	786.1	0.00	1452	0.00	731.20	0.00
At most 2	938.50	0.00	56.65	0.00	56.65	0.00	460.20	0.00
At most 3	73.68	0.00	73.68	0.00	120.5	0.00	82.33	0.00
At most 4	95.63	0.00	59.71	0.00	70.18	0.00	49.29	0.00
At most 5	65.13	0.00	49.74	0.00	33.53	0.00	32.27	0.00
Model II								
None	118.31	0.00	45.31	0.00	57.31	0.00	113.31	0.00
At most 1	64.93	0.00	25.35	0.00	49.15	0.00	59.42	0.00
At most 2	112.77	0.00	76.46	0.00	110.5	0.00	110.5	0.00
At most 3	110.5	0.00	110.5	0.00	112.3	0.00	77.03	0.00
At most 4	122.5	0.00	77.30	0.00	52.77	0.00	40.45	0.00
At most 5	65.92	0.00	49.70	0.00	25.51	0.00	28.11	0.00

The notation ***P<0.01; ** P<0.05; *P<0.1 represents the corresponding significance levels

Table 8: Granger causality test

Null hypotheses	W-statistic	Zbar-statistic	P
TR does not granger cause TOP	2.06	−0.25	0.79
TOP does not granger cause TR	5.74	2.91	0.00
TIN does not granger cause TOP	6.21	−0.27	0.00
TOP does not granger cause TIN	2.74	0.32	0.74
PCI does not granger cause TOP	2.27	−0.07	0.93
TOP does not granger cause PCI	3.23	0.74	0.45
GNS does not granger cause TOP	1.41	−0.81	0.41
TOP does not granger cause GNS	5.08	2.34	0.01
FDI does not granger cause TOP	0.95	−1.21	0.22
TOP does not granger cause FDI	6.46	3.53	0.00
Model II			
TR does not granger cause CO_2	2.57	0.18	0.86
CO_2 does not granger cause TR	5.73	2.91	0.00
TIN does not granger cause CO_2	5.01	2.36	0.02
CO_2 does not granger cause TIN	3.72	1.17	0.24
PCI does not granger cause CO_2	4.49	1.84	0.07
CO_2 does not granger cause PCI	3.19	0.71	0.48
GNS does not granger cause CO_2	4.13	1.52	0.13
CO_2 does not granger cause GNS	4.45	1.82	0.06
FDI does not granger cause CO_2	5.11	2.37	0.02
CO_2 does not granger cause FDI	3.00	0.55	0.58

The notation *** P<0.01; **P<0.05; *P<0.1 represents the corresponding significance levels at 1%, 5% and 10%, respectively. TOP: Trade openness, TIN: Total investment, CO2: Carbon dioxide, GNS: Gross national savings, FDI: Foreign direct investment, PCI: Per capita income

Moreover, GNS and TOP exhibit a causal relationship in this study, with GNS Granger causing TOP at a significant level of 1%. According to the findings, an increase in GNS leads to growth in trade openness, and vice versa, implying that trade openness expands as GNS rises across GCC economies. This result resonates with earlier research, such as that of Suleman et al. (2023), whose studies also identified a unidirectional link between GNS and savings in emerging economies. Furthermore, the study's findings reveal a unidirectional causal link between TOP and FDI at a significance level of 1%, with TOP Granger causing FDI. This observation supports previous studies conducted by Bunnag (2023), which demonstrated a unidirectional relationship where FDI affects CO_2 emissions.

The Granger causality findings for the second model are reported in Table 8. yielding noteworthy insights into GCC economies. Notably, we discovered a unidirectional association between CO_2 emissions and trade reserves in these economies, indicating a direct impact of CO_2 emissions on trade reserves. This finding is supported by the recent study by Suleman et al. (2023, 2024), which unveiled a complex interplay between TR and CO_2 emissions in emerging countries. Their research demonstrated both short-term and long-term associations between trade reserves and CO_2 emissions.

Furthermore, our research showed a unidirectional causal relationship between total investment and CO_2 emissions, suggesting that rising total investment in GCC nations is associated with rising CO_2 emissions. This result is consistent with research by Sun et al. (2023), which found a two-way causal relationship between China's carbon emissions and green total investment. Additionally, at a 10% significance level, our investigation demonstrates established, a one-way causal relationship between CO_2 emissions and PCI, demonstrating that rising per capita income significantly Granger causes rising CO_2 emissions. This result is consistent with Suhrab et al.'s (2023) investigation into the association between GDP and CO_2 emissions in Pakistan. It indicates that higher per capita wealth is linked to higher CO_2 emissions in GCC economies.

Additionally, our analysis results show a one-way causative link between Gross National Savings (GNS) and CO_2 emissions, with GNS Granger driving CO_2 emissions at a 1% level of significance. This demonstrates that rising GNS causes CO_2 emissions in GCC economies, which is in line with other studies like Raihan's (2023) conclusion that rising CO_2 emissions from energy use and economic growth promote environmental degradation. As a component of GDP, gross national savings may have an indirect effect on emissions, according to these studies that examine unidirectional Granger correlations between GDP growth and CO_2 emissions. The study's conclusions indicate a unidirectional relationship between FDI and CO_2 emissions, showing that FDI strongly Granger influences CO_2 emissions at a significance threshold of 1%. One explanation for this relationship is the rise

in production capacities in emerging economies brought about by FDI and industrial growth. If this form of industrial growth relies on energy-intensive processes driven by fossil fuels, it may result in increased emissions of carbon dioxide.

Furthermore, a major factor in deciding emission levels in FDI projects is the selection of energy sources. More specifically, emissions can be made worse by relying too much on foreign investments in energy sources with high emissions, such as coal. This finding contradicts previous research by Apergis et al. (2023), which found that FDI flows from the UK and Denmark to BRICS countries increase carbon emissions, lending credence to the pollution haven idea. On the other hand, it was revealed that FDI from France, Germany, and Italy reduced carbon emissions in the BRICS countries, hence strengthening the pollution halo effect. Furthermore, foreign direct investment (FDI) from Austria, Finland, Japan, the Netherlands, Portugal, and Switzerland had no discernible impact on carbon emissions in the BRICS countries.

Table 9 provides a comprehensive overview of the key discoveries obtained from the panel pooled data regression analysis, categorizing the results into three distinct groups. Notably, the stepwise regression (SR) model emerges as the most robust explanatory framework. The F-test value of 9.01, coupled with a P-value below 0.01 for the SR model, underscores its strong statistical fit to the data. Furthermore, the model's adjusted R-squared value of 44% suggests a moderate degree of explained variance. Through the stepwise regression (SR) model selection process, it becomes evident that only five variables exhibit estimated coefficients that are statistically significant. These variables—foreign direct investment (FDI), trade reserves (TR), total investment (TIN), gross national savings (GNS), and per capita income (PCI)—emerge as the main causes of TOP within the GCC economies. This groundbreaking revelation significantly enhances our understanding of the key macro factors shaping trade openness in the region.

The analysis uncovered a statistically significant positive impact of GNS on TOP. This implies that nations with higher levels of GNS are more inclined towards trade openness. As GNS rises, there is a corresponding propensity for trade openness to rise in GCC economies. This discovery suggests that countries with substantial savings are more predisposed to participate in global trade, potentially leveraging their financial resources to foster greater openness in trade relations. Furthermore, this finding is consistent with prior research. For instance, Dirir and Aden (2023) found a positive relationship between gross national savings and significant components of financial sector development, indicating a propensity for increased savings to drive economic growth. Similarly, Ula (2023) identified a unidirectional relationship between savings and trade activity, reinforcing the notion that higher savings levels may facilitate the adoption of open trade policies, thereby stimulating economic growth and trade activity. This study's findings also show the significant and positive impact of trade openness on foreign direct investment. This implies that rising FDI rising trade openness. Thus, it follows that GCC nations with more liberal trade policies are probably going to draw more foreign direct investment from businesses, which will boost global trade in the end. This outcome is consistent with a previous study undertaken by (Lien, 2021) his findings show that trade openness has a positive significant impact on FDI inflow in Vietnam.

Three different types of test outcomes are displayed in Table 9 presents the panel data regression analysis results for model 2. The FEM is a highly effective interpretive model as evidenced by its remarkable. The F-test value is 57.52.05, indicating that the model is significantly fitted, with a $P < 0.01$. Additionally, The model exhibits an adjusted R-squared statistic of 75%., which suggests that a significant amount of variability is explained by the model. We used stepwise regression in our approach for selecting the model, and the results showed that only five factors had estimated coefficients that were statistically significant. Thus, these variables are recognized as the primary macro trade

Table 9: Panel regression results

Variables	SR	POLS	FMOLS
Dependent variable TOP			
Constant	−140.92*** (−1.88)	−140.92*** (−1.88)	
TR	0.05** (2.04)	0.05** (2.04)	0.18*** (2.62)
TIN	1.44** (2.25)	1.44** (2.25)	0.73*** (6.32)
PCI	55.35*** (3.35)	55.35*** (3.35)	25.07*** (5973)
GNS	1.71*** (5.23)	1.71*** (5.23)	1.29*** (114.59)
FDI	2.74*** (2.90)	2.74*** (2.90)	(5973) ***
Adjusted R^2	0.44	0.44	0.39
F-test	9.01***	9.01***	
Model II DV CO_2			
Constant	6.730*** (4.271)	6.732*** (4.217)	
TR	−0.00 (−0.05)	−0.05*** (−2.22)	−0.05** (−2.227)
TIN	0.23*** (7.23)	0.146*** (3.980)	0.146*** (3.986)
PCI	0.00*** (8.69)	0.00*** (8.097)	0.00*** (8.097)
GNS	0.19*** (3.29)	0.154*** (2.754)	0.154*** (2.574)
FDI	0.147** (2.33)	0.109*** (1.847)	0.109*** (1.847
Adjusted R^2	71	75	69
F-test	57.52***	57.54***	57.53

The values in parentheses represent t-statistics. While the notation ***P<0.01; **P<0.05; * P<0.1 represents the corresponding significance levels. While SR, POLS, and FMOLS represent stepwise regression, pooled OLS, and fully modified OLS, respectively. SR: stepwise regression, FMOLS: Fully modified ordinary least squares, TOP: Trade openness, TIN: Total investment, CO_2: Carbon dioxide, GNS: Gross national savings, FDI: Foreign direct investment, PCI: Per capita income

determinants impacting CO_2 emissions in the economies of the GCC economies. With a coefficient of $\theta = 0.05$ ($P < 0.05$) at a significance level of 5%, the current research highlights the noteworthy positive impact of trade reserves on trade openness within GCC economies. This outcome aligns with earlier research, such as the study conducted by Rahmawati and Suriani (2022), which revealed that exports influence Indonesia's foreign currency reserves positively. Their findings indicate that future exports exert a beneficial effect on Indonesia's foreign exchange reserves.

Moreover, per capita income (PCI) exhibits a positive influence on TOP at the 1% significance level. These findings highlight the substantial influence of PCI on trade openness in GCC countries, challenging the conventional notion that trade openness is primarily determined by per capita income. This observation echoes previous investigations, such as the study by Jošić (2023), which explored the connection between GDP growth in OECD nations and trade openness. Their research aimed to elucidate how trade openness influences economic expansion, and the results affirmed that increased trade openness contributes to economic growth. The results of this research also show that trade reserves have a considerable negative influence on carbon dioxide emissions in GCC economies. A rise in GCC economies' trade reserves leads to a significant decrease in CO_2 emissions (coefficient $\beta = -0.05$, $P < 0.05$). This discovery stands in contrast to prior research, such as the study conducted by Mohammed Idris et al. (2023) on OECD countries, which found evidence of a long-run and short-run cointegrating relationship. They discovered that while renewable energy use improves the trade balance in the long run, it has a negative impact in the short term.

Furthermore, the analysis identifies a significant positive impact of gross national savings (GNS) on carbon dioxide emissions. With a $P < 0.01$, the coefficient for GNS is 0.154. This trend indicates that rising GCC economies' gross national savings are frequently associated with rising CO_2 emissions. This issue can be explained by the fact that higher savings rates in these economies are linked to higher investment, which raises energy consumption and, in turn, increases CO_2 emissions. This result aligns with the research conducted by Suleman et al. (2024), which showed that gross national savings had a large and favorable effect on CO_2 emissions in emerging economies. They underlined the necessity of policies that encourage investment to take into account the possibility of an increase in CO_2 emissions and investigate mitigating options. Additionally, this study discovered a statistically significant positive correlation between per capita income (PCI) and CO_2 emissions in the GCC nations, with a $P < 0.01$ and a coefficient of $\beta = 0.00$. Remarkably, this implies that within the GCC environment, fluctuations in per capita income do not significantly affect CO_2 emissions. This outcome is consistent with past research by Jiang et al. (2023), which discovered a comparable positive correlation between CO_2 emissions and per capita income in the BRICS nations.

Furthermore, FDI significantly reduced CO_2 emissions, according to our research, which found a coefficient of 0.109 and a $P < 0.01$. This suggests that there is a tendency for CO_2 emissions to rise in GCC economies with more FDI. This association can be explained by the concentration of FDI investments in energy-intensive industries like mining and manufacturing, which frequently use energy sources based on fossil fuels and hence increase emissions. This observation aligns with prior findings, such as those by Shah et al. (2023), which identified FDI as a primary driver of environmental degradation. Furthermore, our study identifies a significant positive impact of total investment (IN) on carbon dioxide emissions. With a P-value below 0.01, the coefficient for IN is 0.146, indicating that higher levels of total investment in GCC countries have also a positive impact on CO_2 emissions. This association may stem from the fact that elevated levels of total investment correspond to increased economic activity and energy consumption, resulting in greater emissions. This result supports earlier research by Li et al. (2022), which discovered that higher expenditure and economic expansion are linked to higher CO_2 emissions in MINT nations.

4.2. Testing the Estimated Results Using Alternative Techniques

This study used a range of alternative estimation methods, such as stepwise regression (SR), OLS, and FMOLS, to strengthen the robustness of our research findings. The fundamental work by Phillips and Hansen (1990) serves as the theoretical basis for FMOLS, which presents it as a source of reliable and effective estimates for short-term coefficients while resolving endogeneity issues. Their asymptotic property validation of FMOLS highlighted its efficiency and dependability in certain scenarios. Table 8 explains the outcomes produced by these various estimation techniques. The pattern that is consistent across SR, Pooled OLS, and FMOLS is noteworthy as it indicates that TR, GNS, FDI, PCI, and TIN possess an effect on TOP that is positive and statistically significant. This consistency shown across several estimating techniques supports the validity of our preliminary results.

In Model 2, one striking finding is that the coefficient associated with per capita income (PCI) was consistently found as zero across all three estimate approaches (SR, Pooled OLS, and FMOLS). This implies that PCI does not have a substantial economic impact on CO_2 emissions in GCC economies. Moreover, our analysis of Model 2 highlights the consistently positive impacts of total investment (IN), FDI, and GNS on CO_2 emissions for all three estimating techniques. This demonstrates how important these trade-related issues are as CO_2 emissions drivers in the economies of the GCC. Furthermore, the coefficient linked to TR consistently shows a negative value across all approaches, suggesting that TR significantly reduces the amount of CO_2 emissions. To sum up, the utilization of different estimating techniques adds more support to the validity and consistency of our main conclusions, which are painstakingly detailed in Table 9.

4.3. Implications for Policy

The discovery that trade openness macrofactors exert a positive influence on CO_2 emissions in Gulf Cooperation Council economies presents policymakers with a complex challenge,

necessitating carefully crafted policy responses to harmonize economic development with environmental sustainability. In addressing this finding, policymakers must prioritize the integration of environmental considerations into trade policies, ensuring that trade efforts align openness with emissions reduction goals. This entails incorporating sustainability criteria into trade agreements and fostering environmentally responsible trade practices. Moreover, strategic investment in clean technologies and sustainable infrastructure is imperative to mitigate the environmental repercussions of heightened trade activity. By developing renewable energy sources, implementing energy-efficient transportation systems, and promoting sustainable urban planning, GCC countries can minimize their carbon footprint while facilitating trade. Additionally, promoting sustainable practices among businesses and consumers engaged in trade activities is essential, with policies incentivizing the adoption of eco-friendly production methods and consumption habits. Implementation of carbon pricing mechanisms and emissions trading schemes can further incentivize emissions reduction, while capacity building and technology transfer initiatives can enable GCC economies to adopt cleaner production methods. Collaboration with international partners is paramount, as addressing emissions from trade requires coordinated efforts on a global scale. Through these comprehensive policy responses, GCC economies can leverage trade openness to drive economic growth while mitigating CO_2 emissions and advancing environmental sustainability.

The revelation that Gross National Savings (GNS) exerts a positive influence on CO_2 emissions within Gulf Cooperation Council (GCC) economies carries profound policy implications for regional sustainability endeavors. Policymakers are urged to prioritize the redirection of GNS towards investments in green technologies and renewable energy sources, thereby mitigating carbon emissions. This necessitates the implementation of stringent regulatory measures to ensure that GNS is channeled into environmentally beneficial projects. Governments should consider implementing carbon pricing mechanisms or emissions trading schemes to incentivize sustainable practices and internalize the environmental costs of CO_2 emissions. Moreover, there is an urgent need for GCC economies, heavily reliant on fossil fuels, to expedite efforts to diversify their economic portfolios. By investing GNS in non-oil sectors such as renewable energy, tourism, and technology, these economies can reduce dependency on carbon-intensive industries and foster long-term sustainability. Concurrently, public awareness and education campaigns should be employed to enlighten citizens about responsible resource management and the benefits of transitioning towards a low-carbon economy. Furthermore, fostering international collaboration through participation in multilateral agreements and sharing best practices is essential for addressing climate change effectively on a global scale. In essence, aligning economic policies with environmental imperatives is paramount to achieving sustainable development in GCC economies amidst the positive relationship observed between GNS and CO_2 emissions.

The discovery of a positive impact of per capita income on CO_2 emissions in GCC economies necessitates strategic policy interventions to reconcile economic prosperity with environmental sustainability. Policymakers must prioritize investments in sustainable technologies and renewable energy sources to mitigate the carbon intensity associated with rising incomes. Carbon pricing systems and rigorous environmental laws can motivate firms and individuals to use cleaner manufacturing methods and lower their carbon footprint. Promoting sustainable consumption patterns, investing in public transportation infrastructure, and integrating climate considerations into economic policies are essential steps to curb the environmental impact of increasing incomes. By adopting targeted policies that address the nexus between income growth and CO_2 emissions, GCC economies can foster sustainable development trajectories while reducing the negative consequences of climate change.

The revelation that FDI has a positive impact on CO_2 emissions in GCC economies necessitates a strategic approach to policy-making that harmonizes economic growth with environmental sustainability goals. To achieve this, policymakers should consider implementing incentives to encourage FDI in environmentally sustainable projects and industries, such as renewable energy and energy efficiency initiatives. Strengthening environmental regulations and oversight mechanisms is vital to ensure that FDI contributes to sustainable development objectives while minimizing its carbon footprint. Additionally, facilitating technology transfer and knowledge sharing between foreign investors and local industries can accelerate the adoption of clean technologies and best practices. The developing countries are aiming to become technologically advanced countries and to achieve the swift and speedy industrialization (Aysan et al., 2020; Kayani, 2021). FDI can be considered as one of the major driving forces behind GDP growth, and it also acts as a means for transferring latest technologies to the host countries (Kayani and Sadiq, 2022; Kayani et al., 2024). Governments should also direct FDI towards developing clean infrastructure projects and invest in capacity building and skills development to support sustainable development initiatives. By integrating FDI policies with national climate plans and strategies, GCC economies can leverage foreign investment to drive sustainable development, reduce CO_2 emissions, and promote economic prosperity in the region.

The revelation that trade reserves negative impact on CO_2 emissions in GCC economies presents a pivotal opportunity for policy interventions aimed at fostering environmental sustainability while bolstering economic resilience. Policymakers must prioritize initiatives that promote trade integration within the region and with global partners, reducing trade barriers and optimizing resource allocation to diminish the need for energy-intensive domestic production, thus lowering CO_2 emissions. Additionally, diversifying economic activities beyond carbon-intensive sectors can further mitigate emissions associated with industrial production and trade, with governments supporting the growth of sustainable industries such as renewable energy and eco-tourism. Investment in sustainable transportation infrastructure, coupled with the integration of environmental standards into trade agreements, can ensure that trade

liberalization efforts align with sustainability goals. Furthermore, implementing carbon pricing mechanisms and environmental taxes on carbon-intensive goods can incentivize businesses to reduce their carbon footprint, while capacity building and technology transfer initiatives enable industries to adopt cleaner production methods and technologies (Kayani et al., 2023). By leveraging trade reserves as a catalyst for sustainable development, GCC economies can simultaneously reduce CO_2 emissions and enhance economic growth, competitiveness, and resilience in the face of global environmental challenges.

5. CONCLUSION

The five main macro trade factors that were the subject of this study were TR, TIN, PCI, FDI, and GNS. Examining the dynamic relationships between factors influencing trade openness and carbon dioxide emissions was its main objective. The study sought to identify unidirectional Granger causal linkages between carbon dioxide emissions and important trade parameters, by theoretical frameworks that suggest causal relationships. Initially, the most important characteristics influencing trade openness were determined using a stepwise regression technique.

Different statistical techniques were then applied to confirm the results. In addition to the fully modified least squares (FMOLS) approach, the findings were validated using sophisticated panel regression techniques, including Fully Modified Ordinary Least Squares (FMOLS) and Ordinary Least Squares (OLS). Pedroni and Johansson's cointegration techniques were employed to examine long-term dynamics and validate persistent relationships. Granger causality tests were conducted to determine the direction of causality between trade openness, CO_2 emissions, and the identified trade variables. The data analysis for this study spans the years from 1995 to 2022. The outcomes provide further evidence supporting existing scholarly research, highlighting the intricate relationship between key trade-related factors and CO_2 emissions over various time scales. This research underscores the critical role of macroeconomic trade determinants—such as total investment, per capita income, FDI, gross national savings, and trade reserves—in influencing environmental outcomes within GCC economies by elucidating the interactions between drivers of trade openness and CO_2 emissions.The first model identifies FDI as the primary factor influencing trade openness in the GCC countries. On the other hand, per capita income in Model 2 shows very little impact on CO_2 emissions.

Additionally, the analysis of the second model shows that the GDP per capita, gross national savings, total investment, and foreign direct investment all positively and statistically significantly affect CO_2 emissions in the GCC countries. Additionally, the study reveals a noteworthy negative impact of trade reserves on CO_2 emissions. While the research also identifies a positive impact of per capita income on CO_2 emission levels, the magnitude of this effect is relatively small when considering the size of the coefficient. Moreover, further analysis indicates that trade reserves have a negative influence on CO_2 emissions in GCC countries.

As with any scholarly endeavor, our study is subject to certain limitations that could inspire future research inquiries. The conclusions drawn in this study rely heavily on the accuracy and reliability of the data utilized. The validity of our research hinges on factors such as data availability, scope, and the timeframe covered. Therefore, ensuring precision, dependability, and authenticity in both data collection and analysis processes is crucial, as these aspects form the foundation for the success, productivity, and relevance of any research endeavor. One notable limitation lies in the scarcity and incompleteness of macroeconomic data preceding 1995, which restricts a comprehensive examination of trade openness determinants within the context of GCC countries. The study's sample period spans from 1995 to 2020, and while it offers valuable insights, it also presents challenges in capturing long-term trends and dynamics.

This multi-country study employs various testing techniques to analyze trade openness statistics, potential trade determinants, and their impact on CO_2 emissions within a sample of GCC economies. However, there are numerous avenues for future research. For example, assessing the efficacy, validity, and reliability of the proposed multi-model testing approach across different geographical regions, such as those within the South Asian Association for Regional Cooperation (SAARC), could offer intriguing insights. Additionally, researchers could explore alternative proxies for trade openness, such as the composite trade share or the generalized trade openness index, which present promising opportunities for further investigation. By addressing these limitations and exploring these avenues, future research can build upon the foundation laid by this study and contribute to a deeper understanding of the complex relationship between trade openness factors and CO_2 emissions.

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