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Exploring the Effects of Energy Consumption, Financial Market Development, and Urbanization on CO_2 Emissions in GCC Countries: Cross-Sectional Dependence Analysis

Anass Hamadelneel Adow[1]*, Haider Mahmood[1], Maham Furqan[2]

[1]College of Business Administration, Prince Sattam Bin Abdulaziz University, 173 Alkharj 11942, Saudi Arabia, [2]Oxford Institute for Energy Studies, 57 Woodstock Rd, Oxford OX2 6FA, United Kingdom. *Email: a.adow@psau.edu.sa

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ABSTRACT

Financial Market Development (FMD), energy consumption, and urbanization can have significant effects on carbon emissions in fossil fuels-dependent GCC economies, which can be a hurdle in the way of targets 8 and 13 of the Sustainable Development Goals (SDGs). Thus, the influence of these factors on CO_2 emissions has been tested in six GCC economies in the Environmental Kuznets Curve (EKC) framework. For this purpose, the Cross-Sectional Dependence econometrics has been utilized for the period 1990-2022. The results corroborate the EKC with threshold points of $13867 and $28158 in the long and short run, respectively. In both periods, energy consumption raises emissions. FMD reduces emissions and urbanization raises emissions in the long run. However, their short-run impacts are found insignificant. The study recommends encouraging FMD in the GCC region. However, urbanization and energy consumption should be controlled through policy interventions.

Keywords: SDGs 8 and 13, Financial Market Development, Urbanization, CO_2 Emissions, the EKC
JEL Classifications: Q53, G10, R15

1. INTRODUCTION

The Gulf Cooperation Council (GCC) is carrying the world's highest per capita carbon emissions (World Population Review, 2024) as per their significant reliance on extraction, production, consumption, and exports of oil (Salem et al., 2023). The extraction, refining, and other petrochemical industrial activities related to hydrocarbon are carbon-intensive (Griffiths et al., 2022). Moreover, high energy consumption in transportation, construction, and desalination sectors are also contributing significantly to carbon emissions. In addition, GCC environmental policies like subsidized energy prices are another reason (Malik et al, 2019), which is accelerating their energy consumption and responsible for energy inefficiency and carbon emissions. Moreover, GCC countries are expanding in terms of urbanization and infrastructure projects (Zaidan and Abulibdeh, 2021), which include the construction of smart cities and mega-events. Some GCC countries are transitioning toward clean energy projects. However, this transition is slow due to structural dependencies on fossil fuels and energy-intensive industries.

Some GCC economies are transiting toward Financial Market Development (FMD) to reduce dependence on the oil sector. However, FMD could have environmental problems as well. For instance, FMD is channeling investments in the oil and gas industries (Adow, 2024), which are carbon-intensive. Further, FMD can also support the exploration, extraction, and refining of hydrocarbons, which can further enhance carbon emissions. Moreover, FMD can provide finance for infrastructure and real estate development (Sanfelici and Halbert, 2019), which has given rise to energy and carbon-intensive cement and steel industries. Besides, FMD may provide finance for energy-intensive automobiles and air-conditioning products in the hot climate GCC region. Conversely, FMD may also help in mitigating carbon emissions. For instance, FMD may increase investments in sustainable and low-carbon projects (Al Mamun et al., 2018). Moreover, FMD can attract green financing instruments to provide capital for clean projects as per renewable energy transition targets of some GCC countries. Besides, FMD can provide funds for R&D for clean technologies like carbon capture and storage (Al Mamun et al., 2018). Furthermore, FMD could finance the GCC economies to diversify from the oil sector to cleaner economic sectors. So, FMD may contribute to reducing carbon emissions in GCC economies.

Another challenge faced by the GCC economies is a positive trend in urbanization. Urbanization in the GCC region can increase CO_2 emissions due to the energy-intensive urban development (Belloumi and Alshehry, 2016). For instance, the GCC economies are heavily investing in construction and infrastructure sectors nowadays including residential and commercial buildings and transportation networks in urban areas (Asif, 2016), which need cement, steel, lighting, and cooling and heating systems. The production of these inputs is energy-intensive. Moreover, electricity generation in the GCC region majorly depends on fossil fuels, and increasing urbanization can give rise to electricity consumption and carbon emissions from the electricity sector. Furthermore, rising urbanization is expanding the transportation sector in this region (Rahman et al., 2017), which contributes to emissions. Contrarily, the environmental consequences of urbanization can be reduced with renewable energy adoption in urban areas, public transportation, and energy-efficient urban planning. For instance, Saudi Arabia is working on an NEOM project to develop a smart city with sustainability and innovation infrastructure. However, the majority of activities in urban areas of the GCC region are energy and carbon-intensive.

The above discussions highlight the environmental pros and cons of urbanization and FMD in the GCC region. The GCC literature scrutinizes the nexus between FMD and emissions, which has corroborated the positive effects of FMD (Hamed and Ozatac, 2023) and the negative effects of FMD (Mahmood, 2022) on emissions. Both studies ignore the possible cross-sectional dependence (CSD) in analysis, which is highly expected due to the similar economic structure and geographical location of GCC economies. Thus, we apply CSD-based techniques in the model of GCC countries. Moreover, urbanization and energy usage can affect this relationship. Thus, the effects of FMD, urbanization, and energy consumption on emissions are tested in the environmental Kuznets curve (EKC) framework.

2. LITERATURE REVIEW

The relationship between FMD and environmental sustainability is uncertain in literature. Sadorsky (2010) argued that deeper financial markets tend to increase energy usage, which may lead to emissions. Thus, FMD without environmental regulation can have negative ecological impacts (Omri et al., 2015). Likewise, Khan et al. (2020) explained that increasing access to capital might raise emissions. Conversely, Zhang (2011) argued that FMD can offer greater opportunities for renewable investments. Moreover, Shahbaz et al. (2013) argued that FMD can support clean technologies and environmentally friendly practices. Besides, efficient financial markets are essential for the optimal allocation of resources, which would promote environmental sustainability (Amir et al., 2019). Alternatively, financial inefficiencies can finance industries with harmful environmental effects (Acheampong, 2019).

Yu et al. (2024) explored a panel of 57 economies from 2000 to 2017 and found that financial depth reduced emissions in rich nations and increased emissions in developing economies. Nevertheless, financial access reduced emissions. Moreover, financial depth reduced emissions in the developing world and increased them in the developed world. Inward FDI increased CO_2 emissions in poor nations and reduced them in rich economies. Furthermore, carbon pricing mitigated the negative environmental effects of inward FDI. Dong et al. (2024) scrutinized Chinese provinces from 2005 to 2021 and stated that FMD reduced emissions by facilitating economic transformation. Yiadom et al. (2024) investigated 97 countries from 1991 to 2019 and found the finance-led EKC. FMD and economic progress mitigated emissions. However, the effectiveness of these factors varies by income level where high-income countries had more significant environmental effects.

Bekun et al. (2024) examined E7 countries and found that FMD dampened environmental pollution. However, economic growth worsened environmental quality, and institutional quality had also a negative effect on the environment. Elmonshid et al. (2024) focused on GCC countries from 2001 to 2021 and found that financial efficiency reduced emissions at both lower and higher quantiles, which corroborated that efficient financial systems mitigated emissions with different income levels. Moreover, Renewable Energy Consumption (REC) reduced emissions at higher quantiles. Ngcobo and De Wet (2024) examined South Africa from 1990 to 2021 and stated that FMD elevated the renewable energy supply, which could alleviate emissions. Basheer et al. (2024) explored the N-11 countries from 1995 to 2019 and corroborated the EKC hypothesis. The FMD accelerated emissions. However, REC mitigated the negative ecological effects of FMD.

Hussain et al. (2024) investigated 26 Asian countries and found a positive long-run connection between FMD and emissions in poor nations. The short-run effect was negative and the long-run effect was positive in developed countries. Moreover, feedback between financial inclusion and emissions was also reported. Wang et al. (2024) investigated China's carbon emissions from 2005 to 2020 and found that energy structure and carbon intensity raised CO_2 emissions. Moreover, financial mechanisms to promote energy saving mitigated carbon emissions. Raggad et al. (2024) examined Saudi Arabia from 1981 to 2018 and found that FMD was associated with improvements in the ecological footprint. However, financial institution development mitigated environmental degradation. However, the expansion of financial markets increased the ecological footprint. Xiong et al. (2023) examined Chinese provinces and found that FMD significantly reduced emissions.

Shahzadi et al. (2023) explored G-7 nations from 1997 to 2021 and found that green investment reduced emissions in the long run. However, it increased emissions in the short run. This result highlighted that initial investments in green technologies would increase emissions in the short term due to their costs of transitioning. However, the positive environmental effects can be achieved in the long run. Xie et al. (2024) investigated the top twenty carbon-emitting nations from 2003 to 2019 and found that the digital economy increased emissions through direct effect. However, it improved economic growth and environmental quality in the indirect effects. Moreover, financial expansion decreased CO_2 emissions in all quantiles. Solaymani and Montes (2024) analyzed New Zealand from 1990 to 2020 and found that REC, non-REC, FDI, and governance stimulated economic growth. However, REC reduced CO_2 emissions. But, non-REC raised CO_2 emissions. Moreover, FMD, exchange rate, and governance significantly reduced CO_2 emissions.

Saadaoui et al. (2024) examined Turkey from 1985 to 2021 and found that hydroelectric energy, geopolitical risk, and FDI mitigated emissions. However, income and FMD increased CO_2 emissions. Moreover, feedback between hydroelectricity and emissions was also reported. Işık et al. (2024) investigated 27 OECD nations from 2001 to 2020 and corroborated the EKC in the lower CO_2 emissions quantiles. Moreover, REC and internet usage reduced CO_2 emissions. However, mineral rents raised environmental degradation. Yadav et al. (2024) examined BRICS nations and found that clean investments complemented by governance mitigated emissions. Adams and Fotio (2024) investigated Africa from 1990 to 2018 and found that economic integration improved the environment directly by reducing CO_2 emissions. However, it had an indirect negative effect of urbanization, FMD, and industrialization. Usman et al. (2024) analyzed the influence of disaggregated FMD in the N-11 nations from 1995 to 2019 and substantiated the EKC hypothesis. Besides, the stock market and banking sector reduced ecological footprints. However, urbanization raised environmental degradation.

Saqib et al. (2024) explored polluted nations from 1993 to 2020 and found bidirectional causality between REC and carbon footprints. Moreover, affluence and FMD influenced carbon footprints. The findings highlighted that eco-friendly technology and REC could alleviate pollution. Özkan et al. (2024) investigated Turkey from 2000 to 2019 and found that energy vulnerability reduced environmental quality. Additionally, FMD also reduced environmental quality at lower quantiles of environmental quality. However, political globalization raised environmental sustainability in all quantiles. Ozturk et al. (2024) examined South Asia from 1971 to 2018 and found the EKC. FMD helped to contribute to environmental conservation. However, fossil fuels disrupt environmental quality. Moreover, FMD and energy usage caused the ecological footprints.

Dhahri et al. (2024) scrutinized Africa and stated that mobile phone usage and internet access raised economic, social, and environmental sustainability. Moreover, FMD with information technologies reduced emissions. Liu et al. (2024) inspected China from 2011 to 2019 and substantiated an EKC between financial agglomeration and emissions. Adebayo et al. (2023) analyzed MINT countries from 1969 to 2019 and stated a mixed connection between FMD and emissions. FMD reduced emissions in some periods and raised them in other periods. Tsimisaraka et al. (2023) investigated One Belt One Road nations from 2004 to 2019 and found that financial inclusion reduced emissions. Besides, REC and globalization also condensed CO_2 emissions. Sadiq et al. (2024) analyzed BRICS from 2001 to 2020 and found that green finance, REC, and eco-taxation mitigated emissions.

The reviewed literature signified that FMD could have a different type of relationship with emissions. Moreover, urbanization and energy usage increased emissions. Thus, the present research aims to investigate the environmental effects of FMD, energy usage, and urbanization in the GCC region.

3. METHODOLOGY

In the theoretical discussion, Grossman and Krueger (1991) recommended testing the nonlinear effect of economic expansion on pollution, which is an EKC hypothesis. Increasing economic growth can increase aggregate demand and energy consumption in the fossil-fuel-dependent GCC economies. However, economic growth could help generate pleasant environmental effects at a later stage by adopting energy-efficient technologies, REC, and tight environmental regulations. These efforts could have technique and composition effects on the economies to reduce the environmental problems associated with economic growth. Literature has suggested testing the EKC hypothesis in the FMD model (Basheer et al., 2024; Işık et al., 2024; Usman et al., 2024; Ozturk et al., 2024). In the GCC economies, FMD, energy usage, and urbanization could have a significant contribution to the EKC. As, FMD can promote the investments in oil and gas industries (Adow, 2024). Thus, FMD can promote activities related to the exploration, extraction, and refining of hydrocarbons, which are highly pollution-oriented. Moreover, FMD can finance the housing sector (Sanfelici and Halbert, 2019), which can promote pollution-oriented cement and steel industries. FMD can also provide consumer loans to buy automobiles and other energy-intensive household products. On the other hand, FMD can also support a clean environment by providing loans for sustainable industries and by providing loans to renewable energy projects (Al Mamun et al., 2018). This region is targeting to diversify their economies from the oil and gas sectors. Thus, FMD can provide loans for clean sectors. Moreover, urbanization can also contribute to the environment. For instance, urbanization can promote the construction of residential and commercial buildings. Moreover, urbanization needs infrastructure development and electrification (Belloumi and Alshehry, 2016), which may increase the industrial activities in cement, steel, and electricity generation. Due to fossil fuel dependence, these industrial activities can raise pollution in GCC economies. Thus, FMD, energy usage, and urbanization can contribute to the environment in the GCC region and are incorporated into the EKC framework as follows:

$$CE_{it} = f\,(YPC_{it}, YPC_{it}^{2}, FMD_{it}, URB_{it}, EC_{it}) \quad (1)$$

All series in equation 1 are taken in their natural logarithm forms. CE_{it} is CO_2 emissions per capita. YPC_{it} is per capita Gross Domestic Product (GDP) and YPC_{it}^2 is a square term of YPC_{it}. EC_{it} is energy consumption per capita. FMD_{it} is the credit by the financial sector percentage of GDP. URB_{it} is the urban residents percentage of the total population. All data is taken from the World Bank (2024) for the period 1990-2022 for 6 GCC economies.

In the panel of GCC economies, the CSD is anticipated owing to their shared geographical proximity and similar economic structures carrying regional trade and common energy dependencies. To examine the CSD in individual series and the hypothesized relationship, the CSD test of Breusch and Pagan (1980) is applied with the following statistic:

$$LM = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} tm_{ij}^2 \tag{2}$$

m_{ij}^2 is a coefficient, which may compute the degree of CSD between the series in the GCC economies. Equation 2 can be tested assuming no CSD. Later, we may apply an alternative CSD test proposed by Pesaran et al. (2008), which can be used for further validation carrying the following CSD statistic:

$$CSD = \sqrt{\frac{2}{n(n-1)}}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} m_{ij} \tag{3}$$

Equation 3 can be tested with the same procedure of Breusch and Pagan (1980) to verify the CSD in the panel series and the hypothesized relationship. Later, we apply the adjusted CSD test proposed by Pesaran (2021) with the following test statistic by caring about the potential heterogeneity across GCC economies:

$$CSD_{adj} = \left[\sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} m_{ij} - q\right] / \sigma \tag{4}$$

After testing the CSD issue comprehensively, we test the existence of Slope Heterogeneity (SH) across the countries' relationships as per Pesaran and Yamagata's (2008) procedure:

$$\Delta = \sqrt{n}\left(\frac{v_n - k}{\sqrt{2k}}\right) \tag{5}$$

$$\Delta_{adj} = \sqrt{N}\left(\frac{v_n - E(v_n)}{\sqrt{Var(v_n)}}\right) \tag{6}$$

v_n captures the mean of the slope from each GCC country's relationship in the Δ and Δ_{adj} tests with a null hypothesis of homogenous slopes. After confirming the CSD and SH, Pesaran's (2007) framework is applied, which cares for the CSD in analysis. The test equation is as follows:

$$\Delta z_{it} = b_0 + b_{1i} z_{it-1} + b_{2i}\overline{z_{t-1}} + b_{3i}\overline{\Delta z_t} + \sum_{j=1}^{k} b_{4ij}\Delta z_{it-j} + e_{1it} \tag{7}$$

z_{it} could be tested with the null hypothesis ($b_{1i} = 1$). By testing it, we ensure that the series does not exhibit random walks. Afterward, we can further validate the findings by using the CIPS statistic by considering both the individual series' characteristics and the CSD:

$$CIPS = \frac{1}{n}\sum_{i=1}^{n} CADF_i \tag{8}$$

Equation 8 will be tested assuming all countries in the panel with a unit root. Otherwise, the panel series is stationary. Later, Kao's (1999) technique will be utilized to confirm the cointegration by confirming the stationary residual of equation 1. It can be confirmed by significant ADF statistics with the following equation:

$$\Delta u_{it} = ae_{it-1} + \sum_{j=1}^{k} b_j \Delta u_{it-1} + v_{it} \tag{9}$$

The stationarity of u_{it} can be evidence for cointegration. To further verify the results obtained from Kao's (1999) technique, we apply Pedroni's (2004) approach, which cares about the possibility of the relationships differing across countries with the help of the following seven test statistics:

$$T^2 n\sqrt{n}\, x_{\hat{v}\, n,T} = T^2 n\sqrt{n} \,/\, \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{e}_{i,t-1}^2\right) \tag{10}$$

$$T\sqrt{n}\, x_{\hat{\rho} n,T-1} = T^2\sqrt{n}\left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{e}_{i,t-1}\Delta e_{i,t} - \hat{\lambda}_i\right) \Big/ \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 e_{i,t-1}^2\right) \tag{11}$$

$$x_{t\, n,T} = \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right) \Big/ \sqrt{\left(\tilde{\sigma}_{N,T}^2 \sum_{i=1}^{n}\sum_{t=1}^{T} \hat{L}_{11i}^{-2}\hat{e}_{i,t-1}^2\right)} \tag{12}$$

$$x_{t\, n,T}^* = \left(\sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{e}_{i,t-1}^* \Delta\hat{e}_{i,t}^*\right) \Big/ \sqrt{\left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^{n}\sum_{t=1}^{T} 1/\hat{L}_{11i}^2 \hat{e}_{i,t-1}^{*2}\right)} \tag{13}$$

$$T\sqrt{n}\, \tilde{x}_{\hat{\rho} N,T-1} = T.1/\sqrt{n}\left(\sum_{t=1}^{T}\hat{e}_{i,t-1}\Delta e_{i,t} - \hat{\lambda}_i\right) \sum_{i=1}^{n}\left[\frac{1}{\sum_{t=1}^{T}\hat{e}_{i,t-1}^2})\right] \tag{14}$$

$$1/\tilde{x}_{t\, n,T} = \frac{1}{\sqrt{N}\left(\sum_{t=1}^{T}\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right)}.1 \Big/ \left[\sum_{i=1}^{n}\left(\hat{\sigma}_i^2 \sum_{t=1}^{T}\hat{e}_{i,t-1}^{2}\right)\right] \tag{15}$$

$$1/\sqrt{n}\,\tilde{x}_{t\, n,T}^* = \frac{1}{\sqrt{n}\left(\sum_{t=1}^{T}\hat{e}_{i,t-1}^*\Delta\hat{e}_{i,t}^*\right)}.\; 1\Big/\sqrt{\sum_{i=1}^{n}\left(\sum_{t=1}^{T}\hat{s}_i^{*2}\hat{e}_{i,t-1}^{*2}\right)} \tag{16}$$

The above equations could not care about the CSD in analysis. Thus, Westerlund's (2007) methodology is applied, which covers both the CSD and SH. Thus, it provides a more comprehensive assessment of cointegration with the following statistics:

$$G_t = N^{-1}\sum_{i=1}^{N}\frac{\widehat{\Omega}_i}{\widehat{s}_i} \tag{17}$$

$$G_a = N^{-1}\sum_{i=1}^{N}T\widehat{\Omega}_i \tag{18}$$

$$P_t = \frac{\sum_{i=1}^{N}\widehat{\Omega}_i}{\sqrt{\sum_{i=1}^{N}\widehat{s}_{i\,i}^{2}}} \tag{19}$$

$$P_a = \sum_{i=1}^{N}T\widehat{\Omega}_i \tag{20}$$

After conducting the cointegration, the CSD-based Auto-Regressive Distributive Lag (ARDL) of Chudik et al. (2017) is applied to find the long and short estimated in the following way:

$$\Delta z_{it} = g_{1i}z_{it-1} + g_{2i}^{'}x_{it-1} + c_1\overline{z_{t-1}} + c_2\overline{x_{t-1}} + \sum_{j=1}^{k}g_{3ij}\Delta z_{it-j} + \sum_{j=0}^{k}g_{4ij}^{'}\Delta x_{it-j} + u_{2it} \tag{21}$$

z_{it} shows CO_2 emissions and x_{it} carries all independent variables. Moreover, the long-run effects will be estimated by applying the normalization procedure. To obtain the short-run effects, an error correction term (ECT_{t-1}) will be incorporated in equation 21.

4. EMPIRICAL RESULTS AND DISCUSSION

The findings of CSD and SH tests are presented in Table 1. The significant CSD for CE_{it} highlights the regional interdependence of carbon emissions. It can be claimed due to the common reliance on oil trade in the GCC. Thus, it makes CO_2 emissions in one GCC economy associated with other GCC economies. The CSD is also observed in YPC_{it} and YPC_{it}^2, which underscores the economic interlinkages among GCC countries. For instance, collective dependence on the oil industry is the major reason behind the movement of GDP in the same direction in the GCC economies. Moreover, fluctuations in oil prices can uniformly affect the income of all GCC economies due to their same economic structure. Similarly, the CSD is also corroborated in FMD_{it}, which explains a strong regional integration in financial markets. The flow of investments in the energy and infrastructure sectors could develop this interdependence. There is also the presence of CSD in EC_{it}, which indicates a common pattern of high energy use in GCC countries. For instance, similar energy-intensive industries, urbanization trends, and subsidized energy prices can determine the energy consumption ties in these economies. The URB_{it} variable has also CSD across GCC economies. Lastly, the SH test also corroborates the SH across GCC economies, which explains a varying relationship across GCC countries.

Table 2 shows the CADF and CIPS tests. At their levels, all variables have unit roots as per positive or low negative test statistics, which could not exceed the critical values and indicate that the variables are non-stationary. Nevertheless, all variables are stationary after taking the first differences with high negative test statistics. Thus, the integration level is one.

Table 3 confirms the long-term relationship in the hypothesized model with the Kao test, which shows that the ADF statistic is significant ($P < 0.01$) and confirms the stationarity of the residual of the model. Moreover, the Pedroni test results also support the cointegration as the panel-v, panel-ADF, and group-ADF statistics are significant ($P < 0.01$), which corroborates the cointegration. However, the Pedroni test does not care about CSD, and the Kao test does not care the CSD and SH. Thus, the Westerlund test is applied, which cares about both issues and offers robust estimates in the presence of SH and CSD. The Gt, Pt, and Pa statistics are significant ($P < 0.01$), which again confirms the cointegration in the presence of both SH and CSD.

Table 4 reveals CSD-based ARDL results. In the long run, the parameter of YPC_{it} is positive (11.769), which indicates that economic growth is accelerating emissions. Nevertheless, the coefficient of YPC_{it}^2 is negative (−0.617). Thus, the square of YPC_{it} is reducing emissions, which substantiates the EKC hypothesis. So, GCC economies are growing without environmental problems

Table 1: CSD and SH estimates

Series	CSD tests			Pesaran and Yamagata's (2008) SH test	
	Breusch and Pagan (1980)	Pesaran et al. (2008)	Pesaran (2021)	Δ	Δadj
CE_{it}	78.524	42.584	31.587		
	(0.000)	(0.000)	(0.000)		
YPC_{it}	206.324	64.385	59.319		
	(0.000)	(0.000)	(0.000)		
YPC_{it}^2	219.574	40.625	35.652		
	(0.000)	(0.000)	(0.000)		
FMD_{it}	186.354	63.659	51.638		
	(0.000)	(0.000)	(0.000)		
URB_{it}	263.521	44.967	38.651		
	(0.000)	(0.000)	(0.000)		
EC_{it}	269.854	43.622	26.325		
	(0.000)	(0.000)	(0.000)		
Residual	365.251	79.365	33.542	29.652	26.854
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 2: Stationarity tests

Series	Leveled series		Differenced series	
	C	C&T	C	C&T
CADF test				
CE_{it}	0.563	0.862	−3.521***	−3.982***
YPC_{it}	0.452	0.963	−3.952***	−3.854***
YPC_{it}^2	0.532	0.841	−4.325***	−4.632***
FMD_{it}	0.635	−0.125	−3.816***	−3.943***
URB_{it}	−0.563	−0.985	−3.635***	−3.722***
EC_{it}	0.352	0.254	−3.541***	−3.962***
CIPS test				
CE_{it}	0.296	0.541	−3.667***	−3.967***
YPC_{it}	0.364	0.495	−3.259***	−3.641***
YPC_{it}^2	0.496	0.517	−4.020***	−3.892***
URB_{it}	0.684	0.152	−3.835***	−3.965***
FDI_{it}	−0.596	−0.695	−3.952***	−4.021***
EC_{it}	0.365	0.826	−3.651***	−3.963***

*** show stationarity. C is intercept and T is trend

Table 3: Cointegration analyses

Cointegration test	Statistics	P-value	Weighed Statistics	P-value
Pedroni (2004)				
Panel statistics				
Panel-v	−5.633	0.000	−4.521	0.000
Panel-rho	−0.496	0.416	−0.758	0.296
Panel-PP	−0.856	0.269	−0.962	0.225
Panel-ADF	−5.295	0.000	−4.963	0.000
Group statistics				
Group-rho	−4.625	0.000		
Group-PP	−0.763	0.226		
Group-ADF	−4.695	0.000		
Kao et al. (1999)				
ADF	−4.632	0.000		
Westerlund (2007)				
Statistic	Value	P-value		
Gt	−5.362	0.000		
Ga	−2.632	0.296		
Pt	−4.625	0.000		
Pa	−1.526	0.364		

Table 4: Long and short-run estimates

Variable	Coefficient	Standard error	t-value	P-value
Long run				
YPC_{it}	11.769	2.835	4.151	0.000
YPC_{it}^2	−0.617	0.189	−3.264	0.000
FMD_{it}	−0.963	0.273	−3.527	0.000
URB_{it}	0.632	0.213	2.965	0.000
EC_{it}	0.862	0.203	4.247	0.000
Short run				
YPC_{it}	8.176	1.586	5.155	0.000
YPC_{it}^2	−0.399	0.086	−4.639	0.000
FMD_{it}	−0.852	0.644	−1.323	0.199
URB_{it}	0.264	0.279	0.946	0.345
EC_{it}	0.735	0.201	3.657	0.000
ECT_{t-1}	−0.632	0.149	−4.242	0.000

after a threshold of $13867. However, income before this point can increase emissions. Moreover, the coefficient of EC_{it} is positive (0.862), which indicates that energy consumption is accelerating emissions. A 1% increasing energy consumption could raise emissions by 0.862%. Thus, higher energy consumption increases emissions due to dependence on the oil sector. So, energy production and consumption are raising emissions. The coefficient of URB_{it} is also positive (0.632), which indicates that higher levels of urbanization contribute to emissions. A 1% increasing urbanization could raise emissions by 0.632%. It is possible due to increasing industrialization, transportation, and construction sector activities in response to higher urbanization, which is pollution intensive. Moreover, the demand for infrastructure with urbanization also increases, which drives emissions from the cement and steel sectors. Lastly, the coefficient of FMD_{it} is negative (−0.963), which indicates that FMD helps reduce CO_2 emissions. A 1% increasing FMD could mitigate emissions by 0.963%. Thus, FMD with efficient financial markets facilitates investments in cleaner technologies and energy-efficient projects in the GCC region. Moreover, FMD could facilitate the transition of GCC economies from oil and gas sectors to sustainable clean sectors.

In the short run, the parameter of ECT_{t-1} is negative (−0.632), which indicates that the model adjusts to long-run equilibrium at 0.632% annually. Further, income and its squared term have positive (8.176) and negative (−0.399) effects, respectively. The EKC hypothesis is substantiated with a threshold of $28158. Moreover, the coefficient of EC_{it} is positive (0.735), which shows that energy consumption raises emissions. A 1% increasing energy consumption could raise emissions by 0.735%. However, the effects of urbanization and FMD are insignificant.

The results confirm the EKC in the GCC region. Similarly, the FMD literature has reported the validity of the EKC (Basheer et al., 2024; Işık et al., 2024; Usman et al., 2024; Ozturk et al., 2024). As per our results, growing GCC economies can cause environmental degradation in the first phase. This is possible due to their energy-intensive industries. However, emissions can decline after a threshold of $13,867. It shows that raising income after $13,867 is associated with economic diversification from the oil and gas industries to some cleaner sectors like the recently booming tourism and recreation industries in GCC economies. Moreover, income has also been invested in cleaner technologies, which could reduce carbon intensity and improve energy efficiency. Moreover, some GCC economies have recently invested in renewable energies to reduce dependence on the oil industry.

FMD mitigates emissions. Similarly, some literature reported the negative effect of FMD on emissions (Dong et al., 2024; Yiadom et al., 2024; Bekun et al., 2024; Dhahri et al., 2024; Xiong et al., 2023). However, a few studies also found a positive effect of FMD on emissions (Basheer et al., 2024; Saadaoui et al., 2024; Özkan et al., 2024). Nevertheless, the negative effect of FMD in the GCC region reflects that FMD provides funds for investments in clean technologies. Moreover, FMD also promotes green bonds and sustainability loans to facilitate investment in eco-friendly projects and sectors. Moreover, FMD could finance energy-efficient technologies and infrastructure, which would reduce energy intensity in the GCC region. Furthermore, FMD could help in reducing dependence on the oil industry and transit GCC economies to cleaner sectors as per their Vision 2030.

Urbanization is also found a major driver of environmental degradation. Accordingly, few studies reported the positive effect of urbanization on emissions (Usman et al., 2024; Adams and Fotio, 2024). Thus, a rapid expansion of urban areas in the GCC is involved with energy-intensive activities like construction, industrial development, and infrastructure projects in the GCC region. These sectors can increase demand from the cement and steel sectors, which rely heavily on fossil fuels. Moreover, urbanization also expands the transportation sector, which is consuming fossil fuels for energy needs and polluting the environment. Moreover, urbanization can raise energy consumption in residential, commercial, and industrial buildings. Lastly, energy consumption also increases emissions. Thus, it reflects the dependence of energy consumption on fossil fuels in the GCC region.

5. CONCLUSION

FMD, urbanization, and energy consumption can determine carbon emissions in GCC economies. Moreover, the CSD is expected in the GCC economies due to their common economic and energy structures. Thus, we estimate their effect on CO_2 emissions in GCC economies from 1990 to 2022 by using CSD-based econometrics. The results corroborate with the EKC with a turning point of \$13,867 in the long run and \$28158 in the short run. In addition, FMD helps reduce emissions in the long term but not in the short term. Thus, FMD promotes investments in clean and renewable energy technologies, green bonds, and other eco-friendly projects and sectors. However, energy usage and urbanization raise emissions in the long term. Thus, urbanization accelerates emissions with energy-intensive activities like construction and infrastructure projects in the GCC region. Moreover, it expands transportation, which is majorly fossil fuel-based in these economies. However, urbanization has insignificant effects in the short run.

The results suggest that FMD has great potential to mitigate emissions in the GCC region. Thus, GCC governments should further promote green funding from FMD to support a clean environment. For this purpose, regulatory frameworks should be revised to promote green bonds and sustainable investments. Moreover, GCC governments should provide subsidies to promote funding for renewable energy projects and sustainable business practices. So, renewable infrastructure should be financed by financial markets. However, urbanization and energy usage raise emissions. So, GCC governments should introduce strict regulations for the construction of buildings in urban areas. Moreover, financial benefits should be introduced to develop energy-efficient buildings. Moreover, the transport sector in urban areas is also fossil fuel-based in GCC economies. Thus, energy subsidies should be removed for fossil fuel consumption and these subsidies should be provided for renewable energy consumption in the urban transport sector. Moreover, the concept of public transportation should be enhanced to reduce the overuse of private vehicles. In addition, energy-efficient vehicles should be promoted by subsidies in urban areas.

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