Düzce Üniversitesi
Bilim ve Teknoloji Dergisi

Research Article

Can Economic and Financial Development Curb CO_2 Emissions in Qatar

Ibrahim ARI [a,*]

[a] *Bilgisayar Mühendisliği Bölümü, Mühendislik ve Doğa Bilimleri Fakültesi, İstanbul Medeniyet Üniversitesi, İstanbul, TÜRKİYE*
* *Sorumlu yazarın e-posta adresi: ibrahim.ari@medeniyet.edu.tr*
DOI: https://doi.org/10.29130/dubited.1168280

ABSTRACT

This study investigates the impacts of economic and financial development on carbon emissions in Qatar between 1975 and 2018 by analyzing the results of the ARDL and VECM tests. We do so by considering two model specifications, Model 1 and 2, considering CO_2 emission is a dependent variable. In Model 1, economic growth and its square are considered as independent variables to test the basic Environmental Kuznets Curve (EKC) hypothesis. The results provide evidence to confirm the EKC hypothesis for Qatar. In Model 2, various economic and financial variables are specified as regressors, and all the independent variables have a statistically significant impact on CO_2 emissions at a 1% level. The coefficient of real income per capita implies that an increase in income will increase carbon emissions by 72%. On the other hand, financial development's carbon elasticity indicates that an increase in financial development will decrease CO_2 emissions by 32%. The carbon elasticity of foreign trade signifies that an increase in trade will decrease CO_2 emissions by 33%.
Keywords: *EKC hypothesis, Economic growth, Financial development, Environment-growth-finance nexus, CO_2 emissions.*

Ekonomik ve Finansal Gelişme Katar'daki CO2 Emisyonlarını Azaltabilir Mi?

ÖZET

Bu çalışma, ARDL ve VECM testlerinin sonuçlarını analiz ederek Katar'da 1975 ve 2018 yılları arasında ekonomik ve finansal gelişmenin karbon emisyonları üzerindeki etkilerini araştırmaktadır. Bunu, CO2 emisyonunun bağımlı bir değişken olduğunu göz önünde bulundurarak, Model 1 ve 2 olmak üzere iki model spesifikasyonunu dikkate alarak yapıyoruz. Model 1'de, temel Çevresel Kuznets Eğrisi (EKC) hipotezini test etmek için ekonomik büyüme ve karesi bağımsız değişkenler olarak ele alınmıştır. Sonuçlar, Katar için EKC hipotezini doğrulamaktadır. Model 2'de çeşitli ekonomik ve finansal değişkenler regresör olarak belirtilir ve tüm bağımsız değişkenler CO2 emisyonları üzerinde %1 düzeyinde istatistiksel olarak anlamlı bir etkiye sahiptir. Kişi başına reel gelir katsayısı, gelirdeki artışın karbon emisyonlarını %72 oranında artıracağını ima eder. Öte yandan, finansal gelişmenin karbon esnekliği, finansal gelişmedeki artışın CO2 emisyonlarını %32 oranında azaltacağını göstermektedir. Dış ticaretin karbon esnekliği, ticaretteki artışın CO2 emisyonlarını %33 oranında azaltacağını ifade etmektedir.

Anahtar Kelimeler: *EKC hipotezi, Ekonomik büyüme, Karbon emisyonu, Finansal gelişme*

Geliş: 29/08/2022, Düzeltme: 01/05/2023, Kabul: 28/05/2023

I.INTRODUCTION

Global warming and climate change have been recognized the facts that adversely impact lives, health, food, agriculture, resource allocations, and many other explicit and hidden sustainability problems. Greenhouse gas (GHG) emissions that have been amplified about 50 fold since the mid-1800s are also now considered as the primary reason for various natural hazards such as heat waves, rain flooding, sea level rises with an ever increasing magnitudes and severity [1]. Anthropogenic GHG emissions became significantly and adversely effective at the time of the industrial revolution because energy use was a crucial input factor of growth in manufacturing commodities and transportation, and the primary sources of energy have been fossil fuels releasing millions of tons of GHGs. A significant portion of worldwide GHG emissions is originated from energy use that is reported between 80 [1] and 90% [2]. In 2017, CO_2 emissions were reported as about three-quarters (74.32%) of total GHG emissions, followed by methane, N2O, and other emissions (HFCs, CFCs, SF6) contributed 17.26%, 6.22%, and 2.19%, respectively [1]. In short, as a result of humankind's caseless and relentless exploitation of nature, we are at the edge of future catastrophic natural events, and most of them would be irreversible.

Research and policy circles have expanded their agenda into the causality relationship between air pollution due to CO_2 emissions, economic growth, and financial development. In this regard, the Environmental Kuznets Curve (EKC) has attracted an ever-increasing attention since the 1990s because it has revealed an important statistical understanding and implications for countries' economic progress impact on the environment. The EKC hypothesis states that economic growth initially deteriorates environment up to a tipping point, and then it mitigates, even cures, environmental degradation. However, not all countries satisfy the EKC hypothesis, and some show discrepant behavior from the hypothesis. This is because the EKC considerably depends on countries' development status (i.e., developing and developed countries), drivers for economic growth (i.e., manufacturing, service sector, natural resources, and so on), and policy framework.

Qatar has shifted from a pearl, fishing, and agricultural-based economy to a hydrocarbon-based economy since the first oil extraction in the late 1940s. Qatar is blessed with an abundant amount of natural gas resource and ranked third worldwide after Russia and Iran in terms of proven natural gas reserves [3], [4]. Its purchasing power parity (PPP) per capita was US$142,000 in 2012 when Qatar was on top of the list. However, it went down to fourth rank with around US$94,000 in 2019 [5] mainly because of its high dependence on fluctuating oil and natural gas revenues, which constitutes more than 50% of GDP, 85% of export earnings, and 70% of government revenues [6].

Policymakers and academics propose alternative economic pathways for Qatar to escape being an oil and gas-powered rentier state [7]–[9]. This struggle is because economic diversification is one of the primary objectives in Qatar's development agenda, Qatar National Vision (QNV) 2030, and the other objective is to prevent excessive CO2 emissions for sustainable development. In line with these objectives, Qatar almost eliminated all financial household subsidies for electricity and water, which is about 0.6% of GDP since 2016 and reduced by 77% [10]. This initial step was essential to lower energy and water use waste. In Qatar and many other rich Gulf countries, water implies intensive energy because they desalinate seawater to obtain clean water for 100% of household needs. Besides, Qatar's water consumption is 557 liters/day/inhabitant, which is considerably high and far from global averages [11]. The desalination process requires substantial energy sources, and they use fossil fuels to meet the requirement because they are oil and gas-abundant countries. Furthermore, Qatar has severely hot weather and uses air conditioning (AC) pervasively, consuming 30-40% of the total electricity capacity in summers [12]. As a result of these challenges, Qatar consumes 11-fold higher energy than the global average 18 thousand MWh [3]. Extreme energy-water consumption has significant and adverse effects on air quality and places Qatar in the first rank worldwide for CO2 emissions per capita with approximately 39 tones, which is more than eightfold the global average [3].

Qatar's objectives towards reducing CO_2 emissions in the short term put significant pressure on the economy because of upcoming mega-events, such as the 2022 FIFA World Cup, Qatar's first large scale (800MWp) solar farm construction by 2022 [13], and the 2030 national vision manifestation's finale date. Policymakers in Qatar define a general framework for economic development while drawing people's attention to the environment, but it needs to be tailored specific policy and regulations under this framework. Therefore, economic and financial development impact on CO_2 emissions and testing EKC hypothesis become one of the most attractive empirical topics in the literature, and also motivate this study. We attempted to answer the fundamental question in this field: Can economic and financial development curb CO_2 emissions in Qatar?

The rest of this paper is organized as follows: Section 2 provides an overview of the Environmental Kuznets Curve and reviews the previous work on the causal relations on CO_2 emissions for different countries, mainly Qatar. Section 3 explains the data including descriptive statistics and defines two model specifications for ARDL and VECM tests. Section 4 presents our findings from the short long causality effects and reveals the EKC validity. Section 5 demonstrates the conclusions and policy implications.

II. LITERATURE REVIEW

Simon Kuznets [14] illustrated in his seminal study entitled “Economic Growth and Income Inequality” that an increase in income per capita leads to rising income inequality initially up to a certain threshold, and then the inequality begins to decrease. In a similar methodology, Grossman and Krueger (1991) analyzed relationship between various environmental parameters and income, and reported that CO_2 and "smoke" rise by the GDP at low levels, but decreasing when GDP reaches to high levels [15]. This type of relations implies the inverted U-shaped behavior between the tested variables. In line with this, the Environmental Kuznets Curve (EKC) hypothesis fundamentally explains that income per capita deteriorates environment first, and then it starts to improve environmental conditions after a high level of income, as represented in the inverted-U shape relation. In this context, Panayotou (1993) first defines the EKC hypothesis between environmental pollutants and income regarding the similarities with findings of Kuznets (1955). Afterwards, the EKC has become a popular approach in ecological economics following many excellent research and review papers, such as [17]–[20].

Stern (2004) pointed out that the literature accommodates plenty of mixed results even for the same country because of the employed methodology, time span, structural breaks, noise within and across the variables, and sometimes weaknesses associated with econometric analyses such as omitting heteroskedasticity and serial correlations. In this context, Table 1 summarizes the studies in the literature on the EKC hypothesis for different countries, but mainly for the countries including Qatar, for various policy implications in Section 5 according to their focus, variables, period, methodology, and the EKC result.

Table 1. *EKC hypotheses' results reported for Qatar, and those including it.*

Author	Country	Variables[a]	Period	Methodology[b]	EKC result
Arouri et al. (2012)	MENA	$CO_2 \| f(Y, Y^2, E)$	1981-2005	CCE-MG	Inverted-U
Omri et al. (2015)	MENA	$CO_2 \| f(Y, Y^2, E, TR, U, FD)$	1990-2011	GMM	Inverted-U
Jammazi & Aloui (2015)	Qatar	CO_2 - Y	1980–2013	WWCC	Inverted-U
Mrabet & Alsamara (2017)	Qatar	$CO_2 \| f(Y, Y^2, E, EX, U, FD)$	1980-2011	ARDL	U-shaped
Mrabet et al. (2017)	Qatar	$EF \| f(Y, T, EX), EF \| Y$	1980-2011	ARDL	M-increase[c]
Charfeddine (2017)	Qatar	$CO_2 \| f(Y, Y^2, E, TR, U, FD)$	1970-2015	MS-VECM	Inverted-U
	Qatar	$EF \| f(Y, Y^2, E, TR, U, FD)$	1970-2015	MS-VECM	U-shaped
Ansari et al. (2020)	GCC[d]	$EF \| f(Y, Y^2, E, TR)$	1991-2017	DOLS, FMOLS	U-shaped
Bulut (2020)	Turkey	$EF \| f(Y, Y^2, FDI, RE, I)$	1970-2016	ARDL, DOLS	Inverted-U
Ben Cheikh et al. (2021)	MENA[d]	$CO_2 \| f(Y, Y^2, E)$	1980-2015	PSTR	Inverted-U
Ma et al. (2021)	Germany France	$CO_2 \| f(Y, Y^2, RE, NRE, TU, L)$	1995-2015	Panel VECM	Inverted-U
Abulibdeh (2022)	Qatar	$CO_2 \| f(Y, Y^2, E, CP)$	1990-2019	ARDL	Inverted-U
Mahmood (2022)	GCC	$CO_2 \| f(Y, Y^2, OC, NG)$	1975-2019	NARLD	U-Shaped
Sheikhzeinoddin et al. (2022)	MENA	$CIE \| f(Y, Y^2, Y^3, EI, POP)$	2000-2015	Panel ARDL	N-Shaped

Notes:(a) EF: Ecological footprint, Y: GDP, Y^2: GDP-squared, Y^3: GDP-cubed, E: Energy use, TR: Foreign trade (openness and globalization), U: Urbanization, FD: Financial development, EX: Exports, CP: Crop production, POP: Population, EI: Energy Intensity, CIE: Composite index of environment, FDI: Foreign direct investment, TU: Truism development, L: Labor force, RE: Renewable energy use, NRE: Nonrenewable energy use, OC: Oil consumption, NG: Natural gas consumption, I: Industrialization. (b) CCE-MG, GMM, WWCC, MS-VECM, PSTR, DOLS, and FMOLS stand for common correlated effects mean group, the generalized method of moments, wavelet windowed cross correlations, Markov switching vector error correction model, panel smooth transition regression respectively, dynamic ordinary least square, and fully modified ordinary least square. (c) M-increase represents monotonic increase. (d) The GCC and MENA stand for the Gulf Cooperation Council and Middle East and North Africa, respectively.

Comparing the impact of economic and financial development on carbon emissions in developed countries versus emerging countries is a topic that has received a great deal of attention in the literature. Developed countries tend to have higher levels of carbon emissions per capita than emerging countries, but this is partly due to historical emissions [28]. A study by Wei et al. (2010) found that the cumulative CO2 emissions of developed countries were responsible for 60-80% of the increase in global temperature since the preindustrial era [29]. However, when looking at current emissions, emerging countries such as China and India have surpassed developed countries in terms of total emissions [1]. Economic growth in emerging countries is often accompanied by a significant increase in carbon emissions, but this relationship can be moderated by environmental policies and technological innovation. For example, a study by Zhao et al. (2022) found that environmental regulations can help to reduce the carbon intensity of economic growth in China [30]. Similarly, a study by Zhang et al. (2020) found that renewable energy technology can help to decouple economic growth from carbon emissions in Southeast Asian countries [31].

The financial sector can play an important role in promoting low-carbon development in both developed and emerging countries [32]. Khan and Ozturk (2021) found that financial development can help to reduce carbon emissions in 88 developing countries, including Qatar [33]. Sun et al., (2022) showed that the most carbon-emitting country, currently, China as a developing country can benefit from financial development to reach a low-carbon economy [34]. However, there are controversial studies demonstrating that financial development should be under control to curb carbon emissions and find alternative ways to decrease carbon emissions such as in the United States, a developed country [35]. Overall, the impact of economic and financial development on carbon emissions is complex and context-specific [36], [37]. However, both developed and emerging countries can take steps to promote low-carbon development through financial policies and technological innovation.

Low-income countries tend to have lower levels of carbon emissions per capita consumption than developed countries because they export carbon emissions to the developed, namely rich, countries, but this relationship can be moderated by economic growth and industrialization [38], [39]. For example, Hundie (2021) found that carbon emissions in poor Sub-Saharan Africa countries such as Ethiopia are likely to increase as these countries undergo industrialization and economic growth [40]. Similarly, Avenyo and Tregenna (2022) found that carbon emissions in low-income countries are likely to increase as these countries adopt more energy-intensive technologies [41]. They also illustrated that as long as rising economic growth and financial development in developing countries, they will adopt more technology-intensive manufacturing processes and thus will decrease carbon emissions. Environmental policies and renewable energy can help to reduce carbon emissions in low-income countries. For example, Edziah et al. (2022) found that renewable energy can help to reduce carbon emissions in low-income countries such as Burkina Faso, Gambia, and Zimbabwe [42]. In line with that, environmental policies can help to reduce emissions in developing countries [43]. Overall, the literature suggests that poor countries face unique challenges in addressing carbon emissions due to their lower levels of economic and financial development. However, these countries can still take steps to reduce their emissions through environmental policies, renewable energy, and access to financial resources and technology transfer.

The relationship between economic and financial development and carbon emissions is also relevant for countries with different levels of energy resources. Energy resource-rich countries tend to have higher levels of carbon emissions per capita, but this relationship can be moderated by environmental policies and technological innovation. For example, Usman et al. (2022) found that carbon emissions in energy resource-rich countries can be reduced by promoting the development of renewable energy, financial development, and implementing carbon pricing policies [44]. Bekhet et al. (2017) demonstrated that financial development can help to reduce carbon emissions in energy resource-rich countries such as Saudi Arabia [45]. In contrast, economic growth up to a certain threshold increases carbon emissions in resource-rich countries [46].

This manuscript contributes to the literature from the perspective of an energy resource-rich and high-income level country, Qatar, by differing from existing studies as follows. First, all the variables were scaled with the population data and employed as per capita macroeconomic and environmental data to be consistent in the model specifications and remove potential noise. This approach also distinguishes our study from the literature by differentiating datasets. Second, CO_2 was treated as a dependent variable instead of an independent as in many studies, particularly related to Qatar. Third, Model 1 focused on the fundamental EKC hypothesis by including only GDP and its square as independent variables to remove possible noise that might be incurred by other variables such as energy use.

III. METHODOLOGY

This study first investigates whether all the variables are stationary by analyzing their integration number with the unit root tests, Augmented Dickey-Fuller (ADF) [47] and Philips and Perron [48]. Then, according to these pretests, we employed the Autoregressive Distributed Lag (ARDL) [49] cointegration test to examine two model specifications: basic EKC and CO2 emission specifications, to reveal short and long-term relations among CO2 emissions, economic and financial development. The ARDL provides whether there is a relationship between dependent and independent variables. We further investigate the causality direction by changing dependent and independent variables in Vector Error Correction Model (VECM) to demonstrate short- and long-run directional impacts for each possible combination and justify the ARDL results.

A. DATA AND DESCRIPTIVE STATISTICS

This study employs various financial and economic variables to investigate their impacts on CO_2 emissions. We assume that some of the variables proxy to the certain variables and used them. The annual data are: (i) CO_2 emissions, (ii) real GDP as a proxy for economic development, (iii) domestic credit to private sector as a proxy for financial development, (iv) foreign trade (the sum of exports and imports) as a proxy for openness and financial development, (v) gross fixed capital formation, which is considered as the total investment. All the data are collected from World Development Indicators of the World Bank for the period of 1975-2018 [50]. It is worth noting that the COVID-19 pandemic has heavily affected macroeconomic and environmental datasets and induced potential structural time breaks, thereby we selected the datasets in the pre-COVID-19 era. The domestic credit, foreign trade, and gross fixed capital formation are normalized with the real GDP shares (2010 US dollars) per capita and population data to eliminate potential noise and make these data consistent with the remaining data in the units. The natural logarithms of all the data are used to reduce heteroscedasticity. Table 2 shows descriptive statistics for the data and variables employed in levels and log-levels.

Table 2. *Descriptive statistics.*

Variable	**Definition**	**Mean**	**Min**	**Max**	**St. dev.**
	Levels				
CO_2	CO_2 emissions (metric tons per capita)	49.43	35.69	110.95	17.24
GDP	Real GDP (2010 US dollars per capita)	60421.46	39051.91	91455.24	14546.83
FD	Financial development (2010 US dollars per capita)	21854.44	9632.40	52804.29	11085.43
T	Foreign trade (2010 US dollars per capita)	29045.34	7408.30	77622.05	20260.80
INV	Investment (2010 US dollars per capita)	13326.25	2795.09	29566.82	8790.527
	Log Levels				
LCO_2	Log of CO_2 emissions (metric tons per capita)	1.67	1.55	2.05	0.12
LGDP	Log of Real GDP (2010 US dollars per capita)	4.77	4.59	4.96	0.11
LFD	Log of Financial dev. (2010 US dollars per capita)	1.52	1.06	1.90	0.21
LT	Log of Foreign trade (2010 US dollars per capita)	4.36	3.87	4.89	0.30
LINV	Log of Investment (2010 US dollars per capita)	4.01	3.45	4.47	0.32

Notes: 1. The FD, FT, and INV are, first, gathered as a percentage of GDP, and then they are calculated as per capita measurements by the authors.

B. THE ARDL MODELS

The literature has many studies utilizing bivariate cointegration tests for a long-run relationship among two variables. This methodology has advantages such as a deep understanding of the interrelations between them and potential noise reduction. But, on the other hand, it may induce a shallow understanding of a system that is affected by multivariable, and thereby it incurs biased relations and misses underlying mechanism for the complex systems. In this respect, this study follows the ARDL bounds test proposed by

Pesaran and Shin [49], which is a multivariate cointegration test, to obtain robust and unbiased insights into financial and economic development effects on CO2 emissions. The ARDL test contains several benefits against other cointegration techniques such as Engle and Granger [51], Johansen and Juselius [52], and Johansen [53] methods. Some of the advantages can be listed as follows: the ARDL models (i) permit mixed integration numbers in the order of zero and one, whereas other cointegration methods allow only the same integration number for all variables, (ii) provide unbiased estimates of whether explanatory variables are endogenous or not [49], and (iii) employ a single reduced-form equation for estimating the long-run relations. The ARDL methodology comprises two consecutive stages to test the long- and short-run estimates. If there is a long-run cointegration—Error Correction Term should be negative and statistically significant—, then the short-run equation is estimated. In line with this procedure, we formulated two log-linear functional models for the basic EKC and CO2 emissions specifications.

B.1. Model 1: Basic EKC specification

First, this study investigates the EKC hypothesis in a fundamental model (hereafter, called both the basic EKC, and Model 1, interchangeably) by considering only CO2 emissions and GDP to confirm whether the inverted U-shaped relationship exists between them (see Eq.(1-2)). The model also includes real GDP squared to embed the nonlinearity into the relationship. We exclude financial development, foreign trade, and investment to avoid potential noise and overfitting. The basic EKC model also analyses the short-run estimates (see Eq.(3)) and error correction term showing convergence to the long-run (see Eq.(4)), if there exists the long-run relationship.

$$\begin{aligned}\Delta(LCO2_t) = \alpha_{11} + \sum_{i=1}^{a_{11}} \beta_{11i}\Delta(LCO2_{t-i}) + \sum_{j=1}^{b_{11}} \gamma_{11j}\Delta\left(LGDP_{t-j}\right) + \sum_{k=1}^{c_{11}} \theta_{11k}\Delta(LGDP_{t-k})^2 \\ + \ \delta_{11}LCO2_{t-1} + \delta_{12}LGDP_{t-1} + \delta_{13}LGDP_{t-1}^2 + \epsilon_{11t}\end{aligned} \tag{1}$$

where Δ denotes the first difference operator, and ϵ_{11t} represents the white noise at time t. The common lag order is selected based on Akaike Information Criterion (AIC) because it has superiority over the Schwartz Bayesian criterion (SBC) in small samples by performing consistent and better results [54]. Next, the ARDL bounds test is conducted based on the joint F-statistic whether there is a long-tun relation by testing the null hypothesis of no cointegration, H_0: $\delta_{1x} = 0$, against the alternative of H_1: $\delta_{1x} \neq 0, x = 1,2,3$.

ARDL test holds two critical values, called bounds, published by Pesaran et al. (2001) for analyzing the cointegration of regressors. The results are interpreted according to the inconclusiveness band with the upper I(1) and bottom I(0) levels. In this regard, the null hypothesis of no cointegration is rejected if the resulting F-statistics is greater than the upper limit of I(1). The null hypothesis is accepted if the resulting F-statistics is smaller than the bottom threshold of I(0). In the case of falling F-statistics inside the band, the outcome becomes inconclusive. These band levels change with sample sizes, and the first reported critical values are based on large sample sizes. Therefore, Narayan (2005) recalculated critical values for the bounds test in discrete steps of small sample sizes ranging from thirty to eighty observations by employing a similar methodology with Pesaran et al. (2001). In this respect, this study uses Narayan's critical values as we have 44 observations for all the variables.

In case of the existence of a long-run relationship as a result of the first step (see Eq.(1)), the next step is to examine the long and short-run models represented in Eq.(2) and Eq.(3).

$$LCO2_t = \alpha_{12} + \sum_{i=1}^{a_{12}} \beta_{12i}(LCO2_{t-i}) + \sum_{j=1}^{b_{12}} \gamma_{12j}\left(LGDP_{t-j}\right) + \sum_{j=1}^{c_{12}} \theta_{12k}(LGDP_{t-k})^2 + \epsilon_{12t} \quad (2)$$

$$\Delta(LCO2_t) = \alpha_{13} + \sum_{i=1}^{a_{13}} \beta_{13i}\Delta(LCO2_{t-i}) + \sum_{j=1}^{b_{13}} \gamma_{13j}\Delta\left(LGDP_{t-j}\right) + \sum_{k=1}^{c_{13}} \theta_{13k}\Delta(LGDP_{t-k})^2 + \psi_1 ECT[1]_{t-1} + \epsilon_{13t} \quad (3)$$

where ϵ_{12t} and ϵ_{13t} are the errors, called white noise, and $ECT[1]$ is the Error Correction Term at the first model specification, the basic EKC hypothesis. ECT indicates convergence velocity to equilibrium state from the short-run to the long-run (see Eq.(4)). In other words, it functions as the speed of adjustment to bring the variables back to the long-run equilibrium following a short-run shock There has to be a statistically significant coefficient ψ_1 with a negative sign for the convergence.

$$ECT[1]_t = LCO2_t - \left(\alpha_{12} + \sum_{i=1}^{a_{12}} \beta_{12i}(LCO2_{t-i}) + \sum_{j=1}^{b_{12}} \gamma_{12j}\left(LGDP_{t-j}\right) + \sum_{j=1}^{c_{12}} \theta_{12k}(LGDP_{t-k})^2\right) \quad (4)$$

B.2. Model 2: CO_2 specification

The basic EKC hypothesis examines only the real GDP effect on CO2 emissions without involving other economic and financial explanatory variables. This model specification focuses on the relation of integrated economic and financial development indicators with CO2 emissions by including various regressors, namely domestic credit to the private sector, foreign trade, and investment, along with real GDP. The model equations for the ARDL bounds test, long-run and short-run relations, and ECT equation are given in Eq.(5-8), respectively.

$$\begin{aligned}\Delta(LCO2_t) = \alpha_{21} &+ \sum_{i=1}^{a_{21}} \beta_{21i}\Delta(LCO2_{t-i}) + \sum_{j=1}^{b_{21}} \gamma_{21j}\Delta\left(LGDP_{t-j}\right) + \sum_{k=1}^{c_{21}} \theta_{21k}\Delta(LFD_{t-k}) \\ &+ \sum_{l=1}^{d_{21}} \eta_{21l}\,\Delta(LT_{t-l}) + \sum_{m=1}^{e_{21}} \zeta_{21m}\Delta(LINV_{t-m}) + \delta_{21}LCO2_{t-1} + \delta_{22}LGDP_{t-1} \\ &+ \delta_{23}LFD_{t-1} + \delta_{24}LT_{t-1} + \delta_{25}LINV_{t-1} + \epsilon_{21t}\end{aligned} \quad (5)$$

$$\begin{aligned}LCO2_t = \alpha_{22} &+ \sum_{i=1}^{a_{22}} \beta_{22i}(LCO2_{t-i}) + \sum_{j=1}^{b_{22}} \gamma_{22j}\left(LGDP_{t-j}\right) + \sum_{k=1}^{c_{22}} \theta_{22k}(LFD_{t-k}) + \sum_{l=1}^{d_{22}} \eta_{22l}\,(LT_{t-l}) \\ &+ \sum_{m=1}^{e_{22}} \zeta_{22m}(LINV_{t-m}) + \epsilon_{22t}\end{aligned} \quad (6)$$

$$\begin{aligned}\Delta(LCO2_t) = \alpha_{23} &+ \sum_{i=1}^{a_{23}} \beta_{23i}\Delta(LCO2_{t-i}) + \sum_{j=1}^{b_{23}} \gamma_{23j}\Delta\left(LGDP_{t-j}\right) + \sum_{k=1}^{c_{23}} \theta_{23k}\Delta(LFD_{t-k}) \\ &+ \sum_{l=1}^{d_{23}} \eta_{23l}\,\Delta(LT_{t-l}) + \sum_{m=1}^{e_{23}} \zeta_{23m}\Delta(LINV_{t-m}) + \psi_2 ECT[2]_{t-1} + \epsilon_{23t}\end{aligned} \quad (7)$$

where ϵ_{2xt} values correspond to the white noises at time t, and ψ_2 shows the convergence velocity for the long-run equilibrium.

$$ECT[2]_t = LCO2_t - \left(\alpha_{22} + \sum_{i=1}^{a_{22}} \beta_{22i}(LCO2_{t-i}) + \sum_{j=1}^{b_{22}} \gamma_{22j}(LGDP_{t-j}) + \sum_{k=1}^{c_{22}} \theta_{22k}(LFD_{t-k}) + \sum_{l=1}^{d_{22}} \eta_{22l}(LT_{t-l}) + \sum_{m=1}^{e_{22}} \zeta_{22m}(LINV_{t-m}) \right) \quad (8)$$

C. THE VECM FOR SHORT AND LONG RUN CAUSALITY

This study further analyzes the short and long-run causality relationship and impacts of financial and economic developments on CO2 emissions by utilizing the Engle and Granger methodology [51]. First, we estimate residuals from the results of the long-run model for CO2 specification. The next is to examine Granger causality with vector-error-correction models (VECM) by combining the long-run model's residuals into the equation. The VECM is superior to standard Granger causality when there is cointegration. The VECM equations for CO2 specification model are given in Eq.(9),

$$\begin{pmatrix} \Delta LCO2_t \\ \Delta LGDP_t \\ \Delta LFD_t \\ \Delta LT_t \\ \Delta LINV_t \end{pmatrix} = \begin{pmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \\ \tau_5 \end{pmatrix} + \begin{pmatrix} \upsilon_{11,1} & \upsilon_{12,1} & \upsilon_{13,1} & \upsilon_{14,1} & \upsilon_{15,1} \\ \upsilon_{21,1} & \upsilon_{22,1} & \upsilon_{23,1} & \upsilon_{24,1} & \upsilon_{25,1} \\ \upsilon_{31,1} & \upsilon_{32,1} & \upsilon_{33,1} & \upsilon_{34,1} & \upsilon_{35,1} \\ \upsilon_{41,1} & \upsilon_{42,1} & \upsilon_{43,1} & \upsilon_{44,1} & \upsilon_{45,1} \\ \upsilon_{51,1} & \upsilon_{52,1} & \upsilon_{53,1} & \upsilon_{54,1} & \upsilon_{55,1} \end{pmatrix} \begin{pmatrix} \Delta LCO2_{t-1} \\ \Delta LGDP_{t-1} \\ \Delta LFD_{t-1} \\ \Delta LT_{t-1} \\ \Delta LINV_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \upsilon_{11,p} & \upsilon_{12,p} & \upsilon_{13,p} & \upsilon_{14,p} & \upsilon_{15,p} \\ \upsilon_{21,p} & \upsilon_{22,p} & \upsilon_{23,p} & \upsilon_{24,p} & \upsilon_{25,p} \\ \upsilon_{31,p} & \upsilon_{32,p} & \upsilon_{33,p} & \upsilon_{34,p} & \upsilon_{35,p} \\ \upsilon_{41,p} & \upsilon_{42,p} & \upsilon_{43,p} & \upsilon_{44,p} & \upsilon_{45,p} \\ \upsilon_{51,p} & \upsilon_{52,p} & \upsilon_{53,p} & \upsilon_{54,p} & \upsilon_{55,p} \end{pmatrix} \begin{pmatrix} \Delta LCO2_{t-p} \\ \Delta LGDP_{t-p} \\ \Delta LFD_{t-p} \\ \Delta LT_{t-p} \\ \Delta LINV_{t-p} \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ \epsilon_5 \end{pmatrix} \quad (9)$$

where $\epsilon_x, (x = 1, \ldots, 5)$, denotes independent normally distributed residuals. The lag order p is selected based on AIC criterion. The null hypotheses for bivariate short-run and multivariate long-run VECM Granger causalities are given in

Table ***3***.

Table 3. *The null hypotheses of VECM causality tests for CO_2 specification.*

		Short-run ($i = 1, \ldots, p$)					Long-run
		ΔLCO_2	$\Delta LGDP$	ΔLFD	ΔLT	$\Delta LINV$	ψ_j
CO_2 specification	ΔLCO_2	$-$	$\upsilon_{12,i} = 0$	$\upsilon_{13,i} = 0$	$\upsilon_{14,i} = 0$	$\upsilon_{15,i} = 0$	$\psi_1 = 0$
	$\Delta LGDP$	$\upsilon_{21,i} = 0$	$-$	$\upsilon_{23,i} = 0$	$\upsilon_{24,i} = 0$	$\upsilon_{25,i} = 0$	$\psi_2 = 0$
	ΔLFD	$\upsilon_{31,i} = 0$	$\upsilon_{32,i} = 0$	$-$	$\upsilon_{34,i} = 0$	$\upsilon_{35,i} = 0$	$\psi_3 = 0$
	ΔL	$\upsilon_{41,i} = 0$	$\upsilon_{42,i} = 0$	$\upsilon_{43,i} = 0$	$-$	$\upsilon_{45,i} = 0$	$\psi_4 = 0$
	$\Delta LINV$	$\upsilon_{51,i} = 0$	$\upsilon_{52,i} = 0$	$\upsilon_{53,i} = 0$	$\upsilon_{54,i} = 0$	$-$	$\psi_5 = 0$

IV. RESULTS AND DISCUSSION

The Augmented-Dickey-Fuller (ADF), and Phillips and Perron (PP) unit root tests [47], [48] are performed to investigate whether all the variables are stationary. The unit root pretests are mandatory to continue the following tests without statistical flaws. The ARDL critical bounds are documented in Pesaran et al. (2001) and Narayan (2005), and their validity depends on the integration orders of the variables in the equation. The integration numbers obtained from the unit root tests should be less than or equal to the first order, I(0) and I(1). Table 4 demonstrates that both ADF and PP findings that CO2 emission is stationary in levels, I(0), whereas others have a unit root in levels but are stationary in the first integration order, I(1). The result shows that the equations contain mixed integration orders in I(0) and I(1). This finding enables performing the ARDL test for further investigations.

Table 4. *Unit root test results.*

Variables	Levels		1st Difference		Conclusion
	ADF	PP	ADF	PP	I(order)
LCO2	-2.8603 [5]*	-3.3471 (2)**	-5.5540 [0]***	-5.6017 (2)***	I(0)
LGDP	-1.6877 [0]	-1.8469 (4)	-4.5245 [0]***	-4.7813 (4)***	I(1)
LFD	-1.7856 [0]	-1.7738 (2)	-6.0131 [0]***	-6.0308 (6)***	I(1)
LT	-0.9349 [0]	-1.1494 (3)	-5.0397 [0]***	-5.0397 (0)***	I(1)
LINV	-0.5363 [0]	-0.6839 (3)	-5.8063 [0]***	-5.8171 (3)***	I(1)

*Notes:1. *, ** and *** indicate significance level at the 10%, 5% and 1%, respectively. 2. The numbers in parentheses are the lag orders in ADF tests that are selected based on the AIC, and square brackets shows the optimal bandwidths for PP tests.*

Table 5 portrays diagnostic test results for the basic EKC and CO2 emissions model specifications. The results validate that these two models are consistent in following the ARDL and VECM tests to estimate reliable and unbiased policy recommendations. The diagnostic tests show that the variables maintain the following requirements. First, they do not have serial correlation and heteroskedasticity problems. Besides, there is zero mean and constant variance, which are implied by a normal distribution. Next, misspecification does not exist in the models according to the Ramsey Regression Equation Specification Error Test (RESET) [56]. Last, real-life time series such as economic and environmental datasets contain structural time breaks in general due to various crises such as the 1973 oil crisis worldwide. Thus, this study examines the structural time stability of the two model specifications by performing the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests (Brown, Durbin, & Evans, 1975). Figure 1 demonstrates the CUSUM and CUSUMSQ graphics that are confined in the critical bounds of 5% significance. These findings imply that the models are stable in the period 1975-2018.

Table 5. *Model diagnostic test results.*

Test	Basic EKC spec. Stat. (probability)	CO_2 specification Stat. (probability)
Breusch-Godfrey serial corr. LM test (F-statistic)	0.2725 (0.8925)	1.1214 (0.3707)
Heteroskedasticity: Breusch-Pagan-Godfrey (F)	1.5006 (0.1867)	0.5194 (0.9135)
Heteroskedasticity test: ARCH (F-statistic)	2.3700 (0.1087)	0.0973 (0.7567)
Normality test: Jarque-Bera test	0.4481 (0.7993)	1.2473 (0.5360)
Ramsey RESET test (F-statistics)	2.5671 (0.1217)	1.8382 (0.1672)
CUSUM	Stable	Stable
CUSUMsq	Stable	Stable

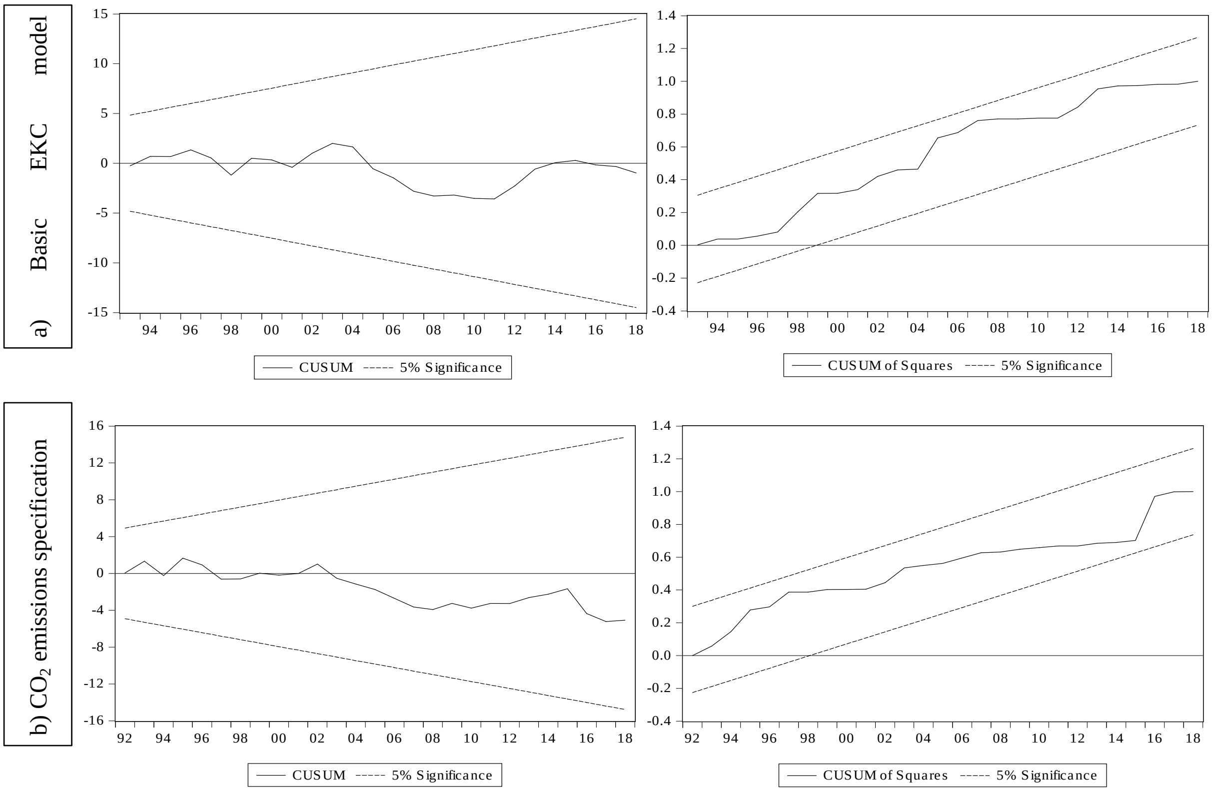

Figure 1. The CUSUM and CUSUM of squares for the three model specifications, (a) the basic EKC, and (b) CO_2 emissions.

This study was carried out with a relatively small time series (N=44 sample size) in the period 1975-2018. Burnham and Anderson (2004) demonstrated that the AIC method in the lag selection outperforms the alternative techniques (such as the SCB approach) that imply unbiased estimates. Thus, this study followed the AIC technique in the ARDL and VECM models. Table 6 shows the estimated F-statistics from the ARDL models for (LCO2|LGDP, LGDP2) and (LCO2|LGDP, LFD, LT, LINV) and the corresponding critical bounds at both 1% and 5% significance levels. The results provide evidence that two model specifications (Model 1 and 2) maintain long-run relationships between the dependent variables and regressors at a 1% significance level. These findings enable us to resume the ARDL long-run estimation for two model specifications to propose policy recommendations.

Table 6. *Estimated ARDL models and bounds F-tests for cointegrations.*

ARDL model	Model spe.	F-statistics	CV 1%		CV 5%	
			I(0)	I(1)	I(0)	I(1)
(LCO2|LGDP, LGDP^2)	(2,4,4)	8.5579	5.920	7.197	4.083	5.207
(LCO2|LGDP,LFD,LT, LINV)	(4,1,4,3,0)	7.1321	4.394	5.914	3.178	4.45

Notes:1. The optimal lag orders in the model specification are selected based on the AIC. 2. The CV represents the critical values for the lower I(0) and upper I(1) bounds that are obtained from the table of Case III in Narayan (2005).

Table 7 illustrates the results of the long-run cointegration estimates for the specifications of Model 1 and Model 2 and demonstrate a strong and statistically significant long-run relationship between the dependent variables and regressors at a 1% significance level. In Model 1, the real GDP per capita has a positive and significant cointegration coefficient, whereas its square is negatively and strongly cointegrated with carbon emissions. This result indicates that income per capita and CO2 emissions move to a higher or lower level together up to a certain threshold in the long-run, and then carbon emissions turn the opposite direction. In Qatar, carbon emissions rise by an increase in the income before an upper limit in which CO2 emissions begin to diminish with rising income. This confirms the presence of inverted-U shaped relationship that holds the EKC hypothesis. This result aligns with [21]–[23], [26], [27], [57], but differs from [24], [25], [58], [59] (see Table 1).

Table 7. *ARDL long run estimates for Model 1 and 2.*

Variables	Basic EKC specification		CO_2 specification	
	Coefficient	t-Statistics	Coefficient	t-Statistics
LGDP	112.9403***	3.3062	0.7185***	7.8889
$LGDP^2$	-11.9597***	-3.3054	–	–
LFD	–	–	-0.3217***	-8.7450
LT	–	–	-0.3339***	-13.3623
LINV	–	–	0.1645***	4.9824
ECT_{t-1}	-0.2996***	-6.1791	-1.3785***	-6.3987
R^2	0.9247		0.9760	
Adjusted R^2	0.8899		0.9617	

*Notes:1. *, ** and *** indicate significance level at the 10%, 5% and 1%, respectively.*

Model 2 estimates the change in CO_2 emissions per capita depending on financial and economic development regressors that are statistically significant at a 1% significance level (see Table 7). The estimated log-linear long-run coefficients of real income per capita for the impact on the CO2 emissions is 0.718, implying that an increase in the income will increase the carbon emissions by 72%. Financial development's carbon elasticity indicates that an increase in financial development will decrease CO2 emissions by 32%. The carbon elasticity of foreign trade signifies that an increase in the trade will decrease CO2 emissions by 33%. The carbon elasticity of investment designates that raising gross fixed capital formation a unit will increase CO2 emissions by 16%.

The ECT coefficients of Model 1 and Model 2 are estimated at -30% and -138%, respectively, which are negative and statistically significant at a 1% significance level. These findings provide evidence that the basic EKC and CO2 specifications follow a short-run adjustment to adjust the long-run stability in potential shocks during the period. The adjustment speed is calculated by inversing the absolute ECT values. In this respect, the speeds of adjustment are 3.33 years and less than a year in Model 1 and Model 2, respectively. In other words, these adjustment speeds imply that Model 1 restores the long-run relationship around every 3.5 years, and no shock appears for more than a year in Model 2. In the meantime, the adjusted R2 value is large enough, ranging from 0.92 to 0.98, confirming that Models 1 and 2 statistically satisfy the goodness of fit.

Table 8 demonstrates the VECM Granger causality test results, along with their directions, for short and long-run relations between the given variables for the CO2 specification. This study focuses on the shaded area highlighted in the table, and the remaining results are out of the scope. In this regard, we interpret the findings considering two conditions of CO2 functioning (i) dependent and (ii) independent variable. First, in the shaded row, the real GDP and foreign trade lead to carbon emissions in the short run at a 1% significance level. Besides, the domestic credit to the private sector also drives CO2 emissions at a 5% confidence level. Due to the short-run dynamics on carbon emissions, the model converges to the long-run equilibrium at a 10% significance level. Second, in the shaded column considering CO2 as the independent variable, there is no short-run causality running from carbon emissions to real income, financial development, foreign development, and investment. In other words, the change in carbon emissions has no impact on other variables in the short run. However, policymakers should concern and give attention to long-run relations for curbing CO_2 emissions given in both Table 7 and Table 8.

Table 8. *The short and long run VECM Granger causality analysis for CO_2 specification.*

	Short-run					Long-run
	$\Delta LCO2_t$	$\Delta LGDP_t$	ΔLFD_t	ΔLT_t	$\Delta LINV_t$	ECM_{t-1}
Dependent variable	χ^2 statistics [p-value]					Coefficient [t-statistics]
$\Delta LCO2_t$	–	12.271*** [0.0065]	10.099** [0.0177]	14.670*** [0.0021]	0.8117 [0.8467]	-0.1051* [-1.7900]
$\Delta LGDP_t$	0.5319 [0.9118]	–	11.651*** [0.0087]	6.7522* [0.0802]	1.2162 [0.7491]	-0.0985** [2.4128]
ΔLFD_t	0.9920 [0.8032]	6.9328* [0.0741]	–	2.8755 [0.4112]	5.7259 [0.1257]	0.0902 [0.5436]
ΔLT_t	1.0212 [0.7961]	12.612*** [0.0056]	4.0721 [0.2538]	–	9.6092** [0.0222]	0.4216*** [-2.6760]
$\Delta LINV_t$	1.8211 [0.6104]	3.1357 [0.3712]	3.7989 [0.2840]	2.2143 [0.5291]	–	0.1325 [0.8316]

*Notes: 1. The null hypothesis is that there is no causal relationship between variables. 2. Δ is the first difference operator. 3. *, ** and *** indicate significance level at the 10%, 5% and 1%, respectively.*

V. CONCLUSION AND POLICY IMPLICATIONS

This study investigates the impacts of economic and financial development on carbon emissions in Qatar between 1975 and 2018 by analyzing the results of the ARDL and VECM tests. In this regard, we define two model specifications, Model 1 and 2, considering CO_2 emission is a dependent variable. In Model 1, economic growth and its square are considered as independent variables to test the basic Environmental Kuznets Curve (EKC) hypothesis. The results provide evidence to confirm the EKC hypothesis for Qatar. In Model 2, various economic and financial variables are specified as regressors, and all the independent variables have a statistically significant impact on CO_2 emissions at a 1% level. The coefficient of real income per capita and investment imply that an increase in both will increase carbon emissions by 72% and 16%, respectively. On the other hand, financial development's carbon elasticity indicates that an increase in financial development will decrease CO_2 emissions by 32%. The carbon elasticity of foreign trade signifies that an increase in trade will decrease CO_2 emissions by 33%.

This study gives some insights into potential reasons for the validity of the EKC hypothesis in Qatar as follows. First, the abundance of natural gas gives Qatar an advantage in generating less polluting energy over other fossil fuels such as oil and coal. As an evidence on that, Mahmood (2022) examined the impacts of oil and natural gas consumption on the environment in the GCC countries and illustrated that natural gas consumption has a less adverse effect on CO2 emissions than oil consumption [59]. It is worth noting that Qatar and other countries with desert climate endure water scarcity and obtain almost all the clean water by distilling sea water with large desalination plants requiring massive energy. Thus, Qatar may have been releasing relatively less carbon than its counterparts while increasing its GDP by using natural gas-powered plants. Second, the literature provides evidence on curbing carbon emissions by increasing service sector's share in the GDP while rising economic growth, such as in the case of Turkey [60]. This is because the service sector is generally cleaner than the manufacturing sector. In Qatar, while the shares of the manufacturing and service sector were 9% and 28.6% in 2011, respectively, these ratios changed to 8% and 52.7% in 2020, respectively [61]. This dramatic shift may have been helping Qatar to mitigate the carbon emissions while increasing the GDP.

Qatar must pay attention to keep sustainable economic development by gradually reducing carbon emissions and protecting the environment. This warning is crucial for not only Qatar but also the GCC and MENA countries. This is because the recent literature shows that the MENA countries demonstrate a second turning point for those showing the inverted-U shape behavior between environmental degradation and the GDP [62]. This point reveals an N-shaped pattern implying that environmental degradation has a tendency to rise in the first and last phases of economic growth, and it reduces in the middle phase. Therefore, Qatar should avoid falling into this trap in the last stage and carry on holding the EKC hypothesis. To this end, we provide the following policy recommendations.

This study illustrated that financial development and trade openness mitigate the CO2 emissions in the long-run, same as the other studies in the literature [22], [57]. In fact, Qatar realized this relationship while preparing its promising national roadmap before 2008, Qatar National Vision 2030 [63]. This document states that "coordination with Gulf Cooperation Council states and with Arab and regional economic organizations to establish trade, investment and financial ties." However, Qatar experienced a diplomatic crisis with the neighboring and other Middle East countries and they severed financial and trade activities between 2017 and 2021. Qatar should avoid this kind of crisis as much as possible to sustain its financial and trade development, and thus carbon reduction. Moreover, economic policies should focus on financial development and trade openness to continue curbing CO2 emissions.

Energy use, which commonly accompanies environment-growth studies, was omitted in the model specifications to eliminate potential noise between carbon emissions and energy consumption because Qatar generates electricity and distills water in the plants powered by only fossil fuels. Moreover, economic and financial development's impact on energy consumption in Qatar was also studied in different studies [23], [26], [45], [64], [65]. In this regard, to keep emissions under control, our recommendation is to implement policies that reduce energy intensity and increase efficiency not only on the supply side but also demand side by eliminating all the energy subsidies and even putting carbon taxes. This may prevent people and industries to waste energy (i.e., electricity) and encourage them to seek alternative ways. The government should give incentives to households and industry is to produce their own electricity from the sun by installing solar PV panels. This is because Qatar has high irradiation and a convenient environment suited for solar energy. Furthermore, the literature demonstrated that renewable energy consumption, such as solar, significantly decreases carbon emissions in the countries demonstrating the validity of EKC hypothesis [66]. Therefore, Qatar should also accelerate its solar farm projects.

Qatar captured an exceptional opportunity in branding and advertising the country's name worldwide by hosting the FIFA 2022 World Cup. This event may help Qatar to develop foreign trade and financial ties globally, and attract more tourists to explore the distinctive features of both Qatari environment and hospitality. One of the reasons on a dramatic increase in service sector recently is the tourist attraction due to the FIFA organization. As can be seen that tourism development helps carbon reduction with many paths, and there are studies in the literature aligning with this view [66]. Therefore, Qatari policymakers should have the intention of keeping Qatar an attractive tourist destination and even implement acceleration programs for this purpose. In this way, Qatar might have essential leverage for curbing carbon emissions.

VI.REFERENCES

[1] WRI, "Historical GHG Emissions: CAIT Data Source," *Available online at: https://www.climatewatchdata.org*, 2021.

[2] J. Gütschow, L. Jeffery, R. Gieseke, and A. Günther, "The PRIMAP-hist national historical emissions time series (1850-2017)," *GFZ Data Services*. 2019. doi: 10.5880/pik.2019.018.

[3] BP, "Statistical Review of World Energy, 2020 | 69th Edition," 2020. [Online]. Available: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

[4] A. Meza, I. Ari, M. S. Al-sada, and M. Koç, "Future LNG competition and trade using an agent-based predictive model," *Energy Strateg. Rev.*, vol. 38, no. August, p. 100734, 2021, doi: 10.1016/j.esr.2021.100734.

[5] The World Bank, "World Development Indicators. GDP per capita PPP (current international $)," *[Data]*, 2020. https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?most_recent_value_desc=true&sort=desc&start=1990&view=chart (accessed Jan. 10, 2021).

[6] MDPS, "Qatar Economic Outlook," *Minist. Dev. Plan. Stat.*, no. August, pp. 1–50, 2020, [Online]. Available: http://www.mdps.gov.qa/en/knowledge/Doc/QEO/Qatar_Economic_Outlook_2016_2018_EN.pdf

[7] A. M. Jolo, I. Ari, and M. Koç, "Driving Factors of Economic Diversification in Resource-Rich Countries via Panel Data Evidence," *Sustainability*, vol. 14, no. 5, p. 2797, Feb. 2022, doi: 10.3390/su14052797.

[8] B. H. Mohamed, I. Ari, M. S. Al-sada, and M. Koç, "Strategizing Human Development for a Country in Transition from a Resource-Based to a Knowledge-Based Economy," *Sustainability*, vol. 13, no. 13750, 2021.

[9] A. Al-mulla, I. Ari, and M. Koç, "Sustainable financing for entrepreneurs : Case study in designing a crowdfunding platform tailored for Qatar," *Digit. Bus.*, vol. 2, no. 2, p. 100032, 2022, doi: 10.1016/j.digbus.2022.100032.

[10] M. Al-Saidi, "Instruments of energy subsidy reforms in Arab countries — The case of the Gulf Cooperation Council (GCC) countries," *Energy Reports*, vol. 6, pp. 68–73, 2020, doi: 10.1016/j.egyr.2019.08.020.

[11] H. Hussein and L. A. Lambert, "A Rentier state under blockade: Qatar's water-energy-food predicament from energy abundance and food insecurity to a silent water crisis," *Water (Switzerland)*, vol. 12, no. 4, 2020, doi: 10.3390/W12041051.

[12] I. Ş. Bayram, O. Alrawi, H. Al-Naimi, and M. Koç, "Direct load control of air conditioners in Qatar: An empirical study," *2017 6th Int. Conf. Renew. Energy Res. Appl. ICRERA 2017*, vol. 2017-Janua, pp. 1007–1012, 2017, doi: 10.1109/ICRERA.2017.8191209.

[13] Total, "Al-Kharsaah Solar PV IPP Project," 2020.

[14] S. Kuznets, "Economic Growth and Income Inequality," *Am. Econ. Rev.*, vol. 45, no. 1, pp. 1–28, 1955.

[15] G. Grossman and A. Krueger, "Environmental Impacts of a North American Free

Trade Agreement," *Natl. Bur. Econ. Res.*, no. 3914, 1991, doi: 10.3386/w3914.
[16] T. Panayotou, *Empirical tests and policy analysis of environmental degradation at different stages of economic development*, vol. 4, no. WP. 238. 1993.
[17] G. M. Grossman and A. B. Krueger, "Economic Growth and the Environment," *Q. J. Econ.*, vol. 110, no. 2, pp. 353–377, 1995.
[18] S. Dinda, "Environmental Kuznets Curve hypothesis: A survey," *Ecol. Econ.*, vol. 49, no. 4, pp. 431–455, 2004, doi: 10.1016/j.ecolecon.2004.02.011.
[19] D. I. Stern, "The Rise and Fall of the Environmental Kuznets Curve," *World Dev.*, vol. 32, no. 8, pp. 1419–1439, 2004, doi: 10.1016/j.worlddev.2004.03.004.
[20] S. A. Sarkodie and V. Strezov, "A review on Environmental Kuznets Curve hypothesis using bibliometric and meta-analysis," *Sci. Total Environ.*, vol. 649, pp. 128–145, 2019, doi: 10.1016/j.scitotenv.2018.08.276.
[21] M. E. H. Arouri, A. Ben Youssef, H. M'henni, and C. Rault, "Energy consumption, economic growth and CO 2 emissions in Middle East and North African countries," *Energy Policy*, vol. 45, pp. 342–349, 2012, doi: 10.1016/j.enpol.2012.02.042.
[22] A. Omri, S. Daly, C. Rault, and A. Chaibi, "Financial development, environmental quality, trade and economic growth: What causes what in MENA countries," *Energy Econ.*, vol. 48, pp. 242–252, 2015, doi: 10.1016/j.eneco.2015.01.008.
[23] R. Jammazi and C. Aloui, "On the interplay between energy consumption, economic growth and CO2 emission nexus in the GCC countries: A comparative analysis through wavelet approaches," *Renew. Sustain. Energy Rev.*, vol. 51, pp. 1737–1751, 2015, doi: 10.1016/j.rser.2015.07.073.
[24] Z. Mrabet and M. Alsamara, "Testing the Kuznets Curve hypothesis for Qatar: A comparison between carbon dioxide and ecological footprint," *Renew. Sustain. Energy Rev.*, vol. 70, no. December 2015, pp. 1366–1375, 2017, doi: 10.1016/j.rser.2016.12.039.
[25] Z. Mrabet, M. AlSamara, and S. Hezam Jarallah, "The impact of economic development on environmental degradation in Qatar," *Environ. Ecol. Stat.*, vol. 24, no. 1, pp. 7–38, 2017, doi: 10.1007/s10651-016-0359-6.
[26] L. Charfeddine, "The impact of energy consumption and economic development on Ecological Footprint and CO2 emissions: Evidence from a Markov Switching Equilibrium Correction Model," *Energy Econ.*, vol. 65, pp. 355–374, 2017, doi: 10.1016/j.eneco.2017.05.009.
[27] N. Ben Cheikh, Y. Ben Zaied, and J. Chevallier, "On the nonlinear relationship between energy use and CO2 emissions within an EKC framework: Evidence from panel smooth transition regression in the MENA region," *Res. Int. Bus. Financ.*, vol. 55, no. May, p. 101331, 2021, doi: 10.1016/j.ribaf.2020.101331.
[28] T. Herzog, J. Pershing, and K. A. Baumert, "Navigating the numbers: greenhouse gas data and international climate policy," WRI: World Resources Institute, Washington, 2005.
[29] T. Wei *et al.*, "Developed and developing world responsibilities for historical climate change and CO2 mitigation," *Proc. Natl. Acad. Sci.*, vol. 109, no. 32, pp. 12911–12915, 2012.
[30] Y. Zhao, L. Zheng, and J. Zhu, "Could environmental courts reduce carbon intensity? Evidence from cities of China," *J. Clean. Prod.*, vol. 377, p. 134444, 2022.
[31] J. Zhang, Z. Fan, Y. Chen, J. Gao, and W. Liu, "Decomposition and decoupling analysis of carbon dioxide emissions from economic growth in the context of China and the ASEAN countries," *Sci. Total Environ.*, vol. 714, p. 136649, 2020.
[32] A. O. Acheampong, M. Amponsah, and E. Boateng, "Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies,"

Energy Econ., vol. 88, p. 104768, 2020.
[33] M. Khan and I. Ozturk, “Examining the direct and indirect effects of financial development on CO2 emissions for 88 developing countries,” *J. Environ. Manage.*, vol. 293, p. 112812, 2021.
[34] Y. Sun, W. Guan, Y. Cao, and Q. Bao, “Role of green finance policy in renewable energy deployment for carbon neutrality: Evidence from China,” *Renew. Energy*, vol. 197, pp. 643–653, 2022.
[35] E. Dogan and B. Turkekul, “CO 2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA,” *Environ. Sci. Pollut. Res.*, vol. 23, pp. 1203–1213, 2016.
[36] M. Shahbaz, M. A. Nasir, E. Hille, and M. K. Mahalik, “UK’s net-zero carbon emissions target: Investigating the potential role of economic growth, financial development, and R\&D expenditures based on historical data (1870--2017),” *Technol. Forecast. Soc. Change*, vol. 161, p. 120255, 2020.
[37] M. Shahbaz, M. A. Destek, K. Dong, and Z. Jiao, “Time-varying impact of financial development on carbon emissions in G-7 countries: Evidence from the long history,” *Technol. Forecast. Soc. Change*, vol. 171, p. 120966, 2021.
[38] The World Bank, “World Development Indicators 2010,” Washington D.C., 2010.
[39] G. P. Peters, J. C. Minx, C. L. Weber, and O. Edenhofer, “Growth in emission transfers via international trade from 1990 to 2008,” *Proc. Natl. Acad. Sci. U. S. A.*, vol. 108, no. 21, pp. 8903–8908, 2011, doi: 10.1073/pnas.1006388108.
[40] S. K. Hundie, “Income inequality, economic growth and carbon dioxide emissions nexus: empirical evidence from Ethiopia,” *Environ. Sci. Pollut. Res.*, vol. 28, no. 32, pp. 43579–43598, 2021.
[41] E. K. Avenyo and F. Tregenna, “Greening manufacturing: Technology intensity and carbon dioxide emissions in developing countries,” *Appl. Energy*, vol. 324, p. 119726, 2022.
[42] B. K. Edziah, H. Sun, P. K. Adom, F. Wang, and A. O. Agyemang, “The role of exogenous technological factors and renewable energy in carbon dioxide emission reduction in Sub-Saharan Africa,” *Renew. Energy*, vol. 196, pp. 1418–1428, 2022.
[43] R. G. Bell and C. Russell, “Environmental policy for developing countries,” *Issues Sci. Technol.*, vol. 18, no. 3, pp. 63–70, 2002.
[44] M. Usman, D. Balsalobre-Lorente, A. Jahanger, and P. Ahmad, “Pollution concern during globalization mode in financially resource-rich countries: do financial development, natural resources, and renewable energy consumption matter?,” *Renew. Energy*, vol. 183, pp. 90–102, 2022.
[45] H. A. Bekhet, A. Matar, and T. Yasmin, “CO2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models,” *Renew. Sustain. Energy Rev.*, vol. 70, no. 2017, pp. 117–132, 2017, doi: 10.1016/j.rser.2016.11.089.
[46] S. Adams, F. Adedoyin, E. Olaniran, and F. V. Bekun, “Energy consumption, economic policy uncertainty and carbon emissions; causality evidence from resource rich economies,” *Econ. Anal. Policy*, vol. 68, pp. 179–190, 2020.
[47] D. A. Dickey and W. A. Fuller, “Distribution of the Estimators for Autoregressive Time Series With a Unit Root,” *J. Am. Stat. Assoc.*, vol. 74, no. 366, p. 427, 1979, doi: 10.2307/2286348.
[48] P. C. B. Phillips and P. Perron, “Testing for a unit root in time series regression,” *Biometrika*, vol. 75, no. 2, pp. 335–346, 1988, doi: 10.1093/biomet/75.2.335.
[49] M. H. Pesaran, Y. Shin, and R. J. Smith, “Bounds testing approaches to the analysis of level relationships,” *J. Appl. Econom.*, vol. 16, no. 3, pp. 289–326, 2001, doi:

10.1002/jae.616.
[50] The World Bank, “World Development Indicators,” *[Data]*, 2020. https://databank.worldbank.org/source/world-development-indicators (accessed Jan. 10, 2021).
[51] R. F. Engle and C. W. J. Granger, “Co-Integration and Error Correction : Representation , Estimation , and Testing,” *Econometrica*, vol. 55, no. 2, pp. 251–276, 1987.
[52] S. Johansen and K. Juselius, “Maximum likelihood estimation and inference on cointegration - with applications to the demand for money,” *Oxf. Bull. Econ. Stat.*, vol. 52, no. 2, pp. 169–210, 1990, doi: 10.1111/j.1468-0084.1990.mp52002003.x.
[53] S. Johansen, “Testing weak exogeneity and the order of cointegration in UK money demand data,” *J. Policy Model.*, vol. 14, no. 3, pp. 313–334, 1992, doi: 10.1016/0161-8938(92)90003-U.
[54] K. P. Burnham and D. R. Anderson, “Multimodel Inference: Understanding AIC and BIC in Model Selection,” *Sociol. Methods Res.*, vol. 33, no. 2, pp. 261–304, Nov. 2004, doi: 10.1177/0049124104268644.
[55] P. K. Narayan, “The saving and investment nexus for China: Evidence from cointegration tests,” *Appl. Econ.*, vol. 37, no. 17, pp. 1979–1990, 2005, doi: 10.1080/00036840500278103.
[56] J. B. Ramsey, “Tests for Specification Errors in Classical Linear Least-Squares Regression Analysis,” *J. R. Stat. Soc. Ser. B*, vol. 31, no. 2, pp. 350–371, 1969.
[57] A. Abulibdeh, “Time series analysis of environmental quality in the state of Qatar,” *Energy Policy*, vol. 168, no. May, p. 113089, 2022, doi: 10.1016/j.enpol.2022.113089.
[58] M. A. Ansari, M. R. Ahmad, S. Siddique, and K. Mansoor, “An environment Kuznets curve for ecological footprint: Evidence from GCC countries,” *Carbon Manag.*, vol. 11, no. 4, pp. 355–368, 2020, doi: 10.1080/17583004.2020.1790242.
[59] H. Mahmood, “The effects of natural gas and oil consumption on CO2 emissions in GCC countries: asymmetry analysis,” *Environ. Sci. Pollut. Res.*, vol. 29, no. 38, pp. 57980–57996, 2022, doi: 10.1007/s11356-022-19851-2.
[60] U. Bulut, “Environmental sustainability in Turkey: an environmental Kuznets curve estimation for ecological footprint,” *Int. J. Sustain. Dev. World Ecol.*, vol. 00, no. 00, pp. 1–11, 2020, doi: 10.1080/13504509.2020.1793425.
[61] World Bank, “World bank open data.” https://data.worldbank.org/indicator/ (accessed Feb. 20, 2023).
[62] A. Sheikhzeinoddin, M. H. Tarazkar, A. Behjat, U. Al-mulali, and I. Ozturk, “The nexus between environmental performance and economic growth: New evidence from the Middle East and North Africa region,” *J. Clean. Prod.*, vol. 331, no. July 2021, p. 129892, 2022, doi: 10.1016/j.jclepro.2021.129892.
[63] QNV 2030, “Qatar National Vision 2030,” *Ministry of Development Planning and Statistics of Qatar*, 2008. https://www.mdps.gov.qa/en/qnv1/Documents/QNV2030_English_v2.pdf (accessed Feb. 15, 2019).
[64] I. Ari and M. Koc, “Economic and Financial Development Impacts on Energy Consumption and Air Quality in Qatar,” *J. Manag. Econ. Res.*, vol. 20, no. 1, pp. 313–330, 2022, doi: http://dx.doi.org/10.11611/yead.1061317.
[65] M. Kahia, M. S. Ben Aïssa, and L. Charfeddine, “Impact of renewable and non-renewable energy consumption on economic growth: New evidence from the MENA Net Oil Exporting Countries (NOECs),” *Energy*, vol. 116, pp. 102–115, 2016, doi: 10.1016/j.energy.2016.07.126.
[66] X. Ma, N. Ahmad, and P. Y. Oei, “Environmental Kuznets curve in France and

Germany: Role of renewable and nonrenewable energy," *Renew. Energy*, vol. 172, pp. 88–99, 2021, doi: 10.1016/j.renene.2021.03.014.