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Investigating the role of export product diversification for renewable, and non-renewable energy consumption in GCC (gulf cooperation council) countries: does the Kuznets hypothesis exist?

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Abstract
This study explores the effects of renewable and nonrenewable energy demand on export product diversification, economic growth, natural resources, human capital, and trade in GCC (Gulf Cooperation Council) countries using data of six countries from 1990 to 2019. The empirical analysis integrates the panel unit root tests (IPS and CIPS), panel quantile regression, and fully modified OLS models. The empirical results confirm that there exists a significant negative relationship between renewable energy and export diversification; signifying that diversification of products will reduce renewable energy. Similarly, when compared to the square of export product diversification, it shows a positive and significant correlation. The empirical findings highlighted the presence of Kuznets's hypothesis between export product diversification, renewable, and non-renewable energy consumption. Furthermore, the findings suggest that natural resources and economic growth may increase overall energy consumption in GCC countries. It implies an important policy suggestion that encouraging export diversification will reduce GCC countries' reliance on oil to meet energy demand.

Keywords Export product diversification · Renewable energy · Kuznets hypothesis · GCC countries · Panel cointegration analysis

JEL Classifications · C32 · F1 · F12 · Q56

1 Introduction

The economies of the Gulf Cooperation Council (GCC) countries have increased dramatically in recent decades. For instance, Saudi Arabia and the UAE constitute two of the GCC's main economies, together accounting for around two-thirds of global GDP. Saudi Arabia accounted for 47% of GDP in the country, while UAE accounted for 26%, and

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Qatar and Kuwait accounted for 11% and 9%, respectively (EIU, 2010). The GCC countries account for about a quarter of the world's crude oil production, mostly from Saudi Arabia, the UAE, and Kuwait, and the three countries are among the ten largest crude oil producers in the world in 2018 (BP, 2019). The GCC countries have increased their energy consumption by 74% since 2000 and are expected to double by 2020. Notably, the surge in overall energy demand has led to the rise of the use of non-renewable and fossil fuel energy sources. The sudden flow in the market for energy and power is in line with the high global demand for carbon emissions and climate change issues (Al-Maamary et al., 2017b). Both the rising level of population and consumption risk the exports of GCC economies, further harming the sustainable development issues. For instance, Saudi Arabia's current demand growth is huge and if persisted, the oil exports could be reduced much earlier than expected by the end of the decade (Simiak & Fesheraki, 2011).

Because of the continued reliance on the oil and gas sectors as major contributors to GDP, the GCC economy places an increasing emphasis on diversification. Diversifications could lead to several factors, the main factor of which is to reduce the risk associated with dependence on oil revenues, such as varying oil prices and changes in the structure of the global market. The other benefit is to create jobs and the third point is that diversification is in the process of planning for the post-oil age, when demand for fossil fuels is expected to be subsidizing (IRENA, 2019). Although, GCC countries are economically stable in terms of inflation and exchange rates. The level of education, trade, and FDI has been improved. More interestingly, these economies have also increased their GDP share of non-oil production, but it remains largely dependent on global oil prices (Callen, et al., 2014; IMF 2014). A decline in oil prices also reduces the economic activities in the non-oil sector. It shows the diversification of these economies is not good.

The GCC has implemented a wide range of policy areas, including business-climate reforms, infrastructure growth, and huge financial support for the industry (Callen et al., 2014). The Gulf economies have made a strategic decision to expand renewable energy, as they are more stable than other energy importing countries due to the region's oil and gas reserves.

Nonetheless, the GCC countries remain vulnerable to certain issues, such as harsh climate, security infrastructure, and, in particular, a high reliance on oil and gas exports and heavily subsidized domestic consumption rates (Abdmouleh et al., 2015). Despite financial prosperity and relative economic and political stability in the majority of GCC countries, the economic downturn exposed the Gulf economy's structural vulnerabilities because of its heavy reliance on oil and gas. In GCC countries, for electricity generation, the energy mix uses 75% of natural gas, while the other 25% is from crude oil. It is expected to increase the export potential of hydrocarbons by 437 million barrels by 2025 (IEO, 2010). During the past two decades, one of the GCC's highest levels of economic and energy use in the world is expected to occur (Ebinger et al., 2011). It is important to understand for the GCC countries that they will not be able to depend forever on a petroleum economy and that diversification of energy is crucial. The GCC countries are best placed to generate more hydrocarbon fuel for export by integrating renewable energy. It is also an important chance to foster economic growth while improving access to safe, affordable energy (Abdmouleh et al., 2015; Malik et al., 2019).

Moreover, renewable policy guidelines for GCC countries were widely reflected in the international literature (Abdmouleh et al., 2015; Al-Maamary et al., 2017a; Atalay et al., 2016; Ferroukhi et al., 2013; Malik et al., 2019). The GCC's investment in renewable energy development has several important advantages. For example, it promotes energy diversification, arguing that the combination of reliance on conventional fossil fuels and the expropriation of renewable energy resources will increase long-term energy security. By reducing fossil fuel consumption will increase potential revenue for oil and gas export (Bhutto et al., 2014; Can et al., 2020; Liu et al., 2018). The integration of different literature on export product diversification has concentrated on the effects of diversification on economic growth, energy demand, economic benefits, and CO_2 emissions (Djimeu & Omgba, 2019; Mania, 2020; Dogan et al., 2020a; Shahzad et al., 2021a, 2021b; Wang et al, 2021; Rafique et al. 2021). While there has been less discussion in previous literature about the link between diversification and renewable energy consumption, there is a requirement in existing research that should fill a gap in the literature by focusing on how export diversification can help GCC countries transition from fossil fuel to renewable energy.

1.1 Contribution of the study

The main contribution of the study is to examine the effects of export product diversification on renewable and non-renewable energy consumption in GCC countries. In the same line, the study further investigated the heterogeneous effects of natural resources, energy consumption, economic growth, and human capital on overall energy consumption. The present research mainly reports three contributions. First, this is probably the first research to account for the role of export diversification impacts on the energy consumption of GCC countries. This is due to the reason that the studied GCC economies heavily rely on the generation and consumption of gas, natural resources, and oil, while the share of renewable energy in the total energy mix is very limited.

On the other side, the studied countries have climate change issues and pressure of environmental regulations e.g., SDGs, etc. It is worthwhile to mention here that the implications and conclusions of this work might be fruitful to reduce the oil and fossil fuel dependence of GCC countries. Export product diversification presents overall economic complexity, structural change, and manufacturing systems, as it affects the energy mix structure in the host country (Dogan et al., 2020b; Rafique et al., 2021). Hence, studying the role of export diversification is logical and in line with the existing research work (Can et al., 2020; Shahbaz et al., 2019). Second, this paper is the first empirical work that explores the Kuznets hypothesis for the role of export product diversification, renewable, and non-renewable energy consumption to unveil new findings. Notably, the study argues that after a certain threshold point of export diversification; it might have different effects and shocks on the economy, and overall energy usage. Lastly, based on the detailed empirical findings the current research reports new solutions and implications for alternative energy sources and to meet energy security issues. The policy implications of this study are in line with the sustainable development goals (SDG-7: clean and affordable energy, SDG-8: sustainable economic growth, and SDG-13: Climate Action) and overall cleaner production objectives.

2 Overview of diversification and energy in GCC countries

The Gulf Cooperation countries (GCC) are highly dependent on their oil and natural gas sector, not only for their economic growth but also for their revenue. However, their existing economic model is not stable due to many reasons. Firstly, oil prices are inherently unstable mainly influenced by any sudden change in the global economy and geopolitical factors.

Secondly, their growth is highly dependent on government spending which is only possible when these governments earn an increasing amount of oil and gas revenue. The third challenge of this model includes the emergence of shale gas as a new source, increased demand for renewable energy in terms of climate change, technological advancement that increases fuel efficiency, and a rise in transportation electricity as an alternative to fossil fuels. There are more internal factors that also pushing for reforms in the GCC region. First, the instability in government revenue collection due to the unstable oil market. The reason behind this is that the state expenditure model is pro-cyclical in these economies. If oil prices rise, governments spend more on rising the number of economic productions. However, when prices decline, these governments cannot maintain their spending level. Due to which economic activities come down. Further, the GCC countries in particular, because of price subsidies, are highly energy intensive. The GCC has the lowest energy intensity in the United Arab Emirates (UAE). However, even here, the UAE needs about 10% more fuel to produce a one-dollar economic operation than the world average (IEA, 2019). All these above factors call for some economic reforms, which promote economic and export diversification, to increase the proportion of output other than oil in the overall economy. Figure 1 explains the outlook of primary energy consumption and trade openness situation in GCC countries. From the data plot in Fig. 1, we observe that energy consumption and trade are continuously rising in the GCC region. Undeniably, for the GCC zone, diversification is not a new concept. It has been planned by the governments in this area since 1970 (Callen et al., 2014). For instance, a motive to diversify the Saudi economy is well mentioned in the first National development plan of Saudi Arabia in 1970. However, the Saudi economy is still reliant on oil rents. The demand for electricity in the region has increased by around 5.7% annually almost twice the global average since the year 2000. This demand is met by electricity produced by oil and natural gas. If we look at the consumption side, we can see that space cooling by air conditioners is the main cause of this increase in electricity demand and is expected to continue to increase in the coming years (IEA, 2019). Using renewable energy sources such as solar energy can significantly reduce this dependence on hydrocarbon fuels. Interestingly, the political leaders in GCC countries also realize this potential and are making such policies that can promote renewable energy production as a tool of diversification.

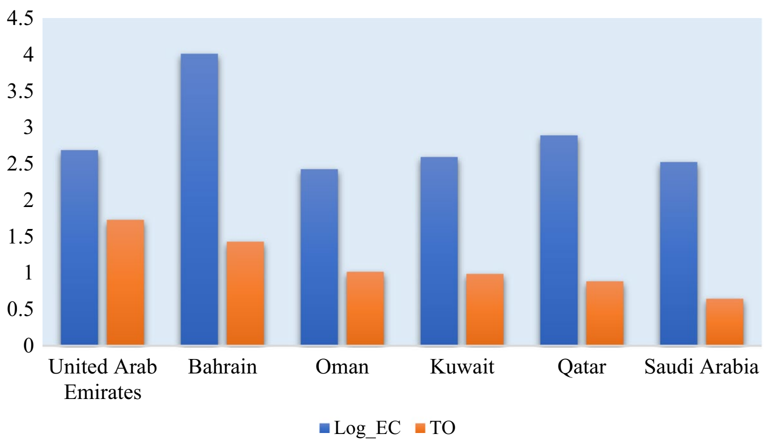

Fig. 1 Primary energy consumption and trade in GCC countries (2018)

For example, the UAE has a strategy to increase the share of renewable energy in total electricity generation to twenty-five percent by 2030. Surprisingly, these countries have also received encouraging offers at the lowest rate internationally from international investors. However, the current level of output of renewable energy is therefore just below 0.5% of the net power generation. The main cause of this is higher levels of energy subsidies. This high level of subsidies does not only promote inefficient energy consumption but also discouraging the development of renewable energy sources.

3 Literature review

The key policy goal in oil-exporting economies was economic diversification to reduce exposure to fluctuating oil prices. Many oil-exporting economies have long argued that economic diversification is necessary for addition to crude oil, but no industry can compete with hydrocarbon capacity to generate large and relatively quick incomes. Oil exporters in the Gulf Cooperation Council (GCC) and the Middle East and North Africa (MENA) have become an urgent priority for economic and fiscal reform, driving structural changes, and accelerating diversification away from the oil sector (Shehabi, 2019; Mania and Rieber 2019; Mania & Rieber, 2019).

The literature on export product diversification primarily discussed export product diversification and growth by export (Aditya & Acharyya, 2013; Mudenda et al., 2014; Sannassee et al., 2014; Gozgor & Can, 2016; Liu et al., 2018, 2019; Dogan et al., 2021).

According to studies, diversification of export products emerges during the early stages of development efforts and continues until the country reaches a certain income level. Few studies discover an inverted U-shaped relationship between export products, diversification, and income. Many recent studies emphasize the importance of renewable energy, as Ponce and Khan (2021) suggest that increasing renewable energy and energy efficiency deteriorated CO_2 emissions in nine developed countries from 1995 to 2019. Khan et al. (2020a) revealed that renewable energy was strongly and positively associated with international trade. Furthermore, the results show that renewable energy consumption improved environmental quality in Nordic countries. According to Ponce and Oliveira (2021) investigated increase in renewable energy consumption in high, middle, and low-income countries is one of the primary drivers for forest preservation. Khan et al. (2020b) highlighted renewable energy, regulatory pressure, and environmentally friendly policies in South Asian countries. Meanwhile, Fatima et al. (2021) observed the effects of higher income and renewable energy on environmental quality and found that increasing the use of renewable energy reduces CO_2 emissions in high-emitting countries. However, in the GCC countries, the link between diversification and renewable energy is not well understood. While policy-based myths are enveloping the GCC region's suggestion for renewable energy. Abdmouleh et al. (2015) highlighted the key gaps in renewable implementation while discussing the GCC region's fiscal, financial, political, environmental, and technological aspects. Based on the results, they proposed a set of policies to aid in the achievement of specific targets in the renewable energy and electricity sectors.

Ferroukhi et al. (2013) investigated the factors that influence and obstruct the diffusion of renewable energy technologies. The study examined the state of renewable energy in the GCC countries, including projects, capacity, and policy frameworks, utilizing literature. Griffiths (2017) investigated current trends in renewable energy policy to identify the most efficient and feasible renewable energy sources in GCC countries. The findings indicate that pragmatic auctions on renewable energy are the primary means of stimulating energy development globally.

Similarly, other studies discuss renewable energy consumption policy recommendations for GCC countries (Alnaser & Alnaser, 2019; Atalay et al., 2016). However, renewable energy (RE) implementations in the GCC region remain limited because renewable energy costs are still very high in comparison to traditional electricity expenses in these countries (Bachellerie, 2012).

The Gulf energy sector is increasingly dependent on oil and natural gas production to meet regional demand (Al-Maamary et al., 2017b). More recently, Shahzad et al. (2021a) investigated the effects of export diversified activities on renewable energy. According to the findings, product diversification policies have a positive impact on renewable energy demand in both developed and emerging economies. Thus, according to Bashir et al. (2020), export diversification helps to reduce energy intensity and could be used as a policy factor in improving energy efficiency and environmental sustainability in 29 OECD countries. In the same line, Wang et al. (2020) expressed the strong support for policies of ecological innovation and export diversification to reduce carbon emissions. Study findings supported diversifying export products and using renewable energy help G-7 countries to reduce CO_2 emissions.

Further, Table 1 also shows the relevance of studies on export diversification, economic growth, and the existence of the EKC. Khan et al. (2021) also noted that in RCEP countries, the role of export diversification and composite risk in mitigating carbon emissions was lower between 1987 and 2017. In addition, it is suggested that the export diversification scheme for these countries be restructured. To summarize, the development of renewable energy and the benefits of export product diversification has been studied in both developed and emerging markets, while less research conducted in GCC countries. However, to the best of our knowledge, previous literature has ignored the role of export diversification and renewable energy in GCC countries.

4 Materials and methods

4.1 Data specification

Our empirical analyses utilize panel data of six GCC countries over the period 1990–2019. The studied countries include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. Data collected from multiple sources are as follows: natural resource revenues, economic growth, and international trade are collected by World Bank database (World Development Indicators, 2020). The data of renewable and non-renewable energy consumption are taken in kg of oil equivalent and accessed from Energy Information Administration, the most reliable database in the energy economics literature (EIA, 2020). Human capital data in human capital index growth collect from the Penn World Table (version 9.1).

The human capital index mentions the overall education capacity in years of schooling and returns to education in the world. During recent years, the governments of GCC economies have been struggling to improve education quality and reduce the economy's energy dependence. Hence, a higher level of human capital might be a relevant factor for higher energy efficiency and therefore education can be a significant determinant of renewable and non-renewable energy consumption (Sharma et al., 2021). The export product diversification data are

Table 1 Literature summary on export Product diversification, energy and growth

Authors	Countries (year)	Variables	Method	Outcomes	EKC
Munemo (2011)	69 Developing countries (1983–2003)	Foreign aid, Export diversification	Fixed effects-instrumental technique	Foreign aid not exceeding 20% of a country's GDP significantly promotes export diversification	No
Aditya and Acharyya, (2013)	65 countries (1965–2005)	Export diversification, growth	Dynamic panel estimation	Exports Diversification affects GDP	No
Mudenda et al. (2014)	South Africa (1980–2010)	Product diversification, capital formation, human capital, real effective exchange rate, Trade openness	Cointegrating vector autoregressive (CVAR)	Export diversification affects economic growth	Yes
Gozgor and Can (2017)	Turkey (1971–2010)	Product diversification, Energy consumption, CO_2 emissions	Cointegration analysis with multiple endogenous structural breaks	increase in export product diversification yields higher CO_2 emissions in the long run	Yes
Liu et al. (2018)	Japan, Korea, China (1990–2013)	GDP, Export product diversification, export market diversification, ecological footprint	Augmented Dickey-Fuller test, Vector Auto –Regression (VAR), Error Correction Model	The positive relationship between GDP, diversification with Ecological footprint	Yes
Alvarado et al. (2018)	151 countries as a global study (1980–2016)	Energy use, GDP, CO_2	Fixed effects and random effects	Energy consumption and manufacturing contribute to increasing CO_2 emissions	No
Liu et al. (2019)	125 OECD countries (2000–2014)	Export Product diversification International trade, CO_2 emissions,	Driscoll and Kraay standard errors	Export Product diversification increase CO_2 emissions	Yes
Lv et al. (2019)	Chinese cities (2005–2016)	Urbanization, Growth, energy intensity	Spatial Durbin models	Urbanization increase energy intensity	No
Shahbaz et al. (2019)	United States (1975–2016)	Export Product diversification Real GDP, Energy use, education, oil prices	Bootstrapping autoregressive-distributed lag (ARDL)	Education economic growth increased export Diversification Consumption while oil prices decrease energy demand	No

Table 1 (continued)

Authors	Countries (year)	Variables	Method	Outcomes	EKC
Arminen and Menegaki (2019)	Middle- and high-income countries (1985–2011)	Institutional quality, income, growth changes	System GMM methods	Institutional changes affect energy and environment	No
Dogan et al. (2019)	55 Countries (1971–2014)	Urbanization, Energy Consumption, Economic complexity, Trade Openness	Quantile Regression	The results show that economic complexity has significant impacts on the environment	Yes
Le et al. (2020)	90 countries (2002–2014)	Export product diversification, Human capital, globalization, industrial value-added	Panel Corrected Standard Errors model (PCSE)	The long-run relationship between export diversification, factors, and income inequality	Yes
Dogan et al. (2020a)	63 developed and developing countries (1971–2014)	Trade openness, Export quality, economic growth, urbanization, and total energy, CO_2 emissions	Panel quantile estimators	Economic growth and total energy and Urbanization increase CO_2 emissions	Yes
Gnangnon (2020)	109 developing countries (1981–2014)	Diversification, income, industry, tax performance	Panel regression (Feasible Generalized Least Squares)	Export diversifications induce tax performance	No
Mania, (2020)	98 developed and developing countries (1995–2013)	Export diversification CO_2 emissions	Generalized Method of Moments) and long-run Pooled Mean Group (PMG)	Effects of export diversification on CO_2 emissions is positive	Yes
Can et al. (2020)	84 Developing countries (1971–2014)	Export Product Diversification, Population, CO_2 emissions, GDP, Foreign Direct Investment, Energy Consumption	Autoregressive distributed lag method (ARDL)	Export diversification, extensive margin, and intensive margin have a positive effect on CO_2 emissions	Yes

considered from the Theil index developed by the International Monetary Fund, (2020). Notably, the higher values of export diversification indicate export concentration, while the lower values mention large product diversification of exports. The lower export diversification figures suggest that more types of products are available to export (Shahbaz et al., 2019). For the resource proxy, we employ oil rents as a share of GDP as a measure of resource dependence.

4.2 Estimation strategy

By applying first and second-generation root tests, we start our empirical study. We use the IPS root test unit developed by Im et al. (2003) and the Pesaran (2007) root test unit panel CIPS. The main objective of the root test unit is to verify the stationary properties of the variables. The results of the integration order are more accurate (i.e., I (0) or I (1) in the IPS and CIPS tests (Mrabet et al., 2019). In the case of a mixed integration (level and first difference) or I (1) all variables, the long-term relationship between the studied variables can be evaluated by the use of a cointegration analysis (Ganda, 2018). The root of the CIPS unit is discussed here for certain variables;

$$\mathrm{CIPS}(n, t) = n^{-1} \sum_{i=1}^{n} t_i(n, t) \tag{1}$$

Next, the authors investigate the relationship of balance between variables through Pedroni's (1999) co-integration test in combination with Kao for robustness. The co-integration test first developed by Pedroni (1999) is used for heterogenous panel cointegration. This test allows for the interdependence of the cross section with different effects.

Pedroni (1999) suggests two types of residual-based experiments. Following the first type, four measures are distributed as normal asymptotically, based on groupings and regression residuals within the group, namely (panel V statistics, panel r statistics, panel PP statistics, and panel ADF statistics) with the second type (sampler statistics, sample PP statistics and group ADF statistics). These statistics are founded on estimators that simply average each participant calculating the individual coefficient, and each test can take into account individual short-term dynamics, similar fixed effects, deterministic trends, and individual similar slope coefficients. (Pedroni, 2004). The main goal is to determine whether the econometric specification has a long-term relationship by checking the cointegration variables.

With the discovery of simulation experiments in Monte Carlo, The ADF-Statistical Panel and the ADF Group Studies (Pedroni, 1999, 2004) have shown that they are much more accurate in smaller samples than the other ones. Also, Kao (1999) has been studying residual cointegration regression tests in panel results, using the Kao residual congregation test to analyze the null of no contest in vibrating panels. In this study, we are using Pedroni (1999) method to check for co-integration into heterogeneous panel data. More recently, Rahman and Velayutham (2020) also employed a similar empirical strategy for renewable energy detailed analysis.

More precisely, the authors use two empirical models for renewable and non-renewable energy demand. Whereas the models are given as;

Model-1;

$$\mathrm{Lnec}_{\mathrm{it}} = \alpha_i + \delta_{\mathrm{it}} + \beta_1 \mathrm{div}_{\mathrm{it}} + \beta_2 \mathrm{LnGdp}_{\mathrm{it}} + \beta_3 \mathrm{Nres}_{\mathrm{it}} + \beta_4 \mathrm{Hc}_{\mathrm{it}} + \beta_5 \mathrm{trade}_{\mathrm{it}} + \mu_{\mathrm{it}} \tag{2}$$

Model-2;

$$\text{Lnec}_{\text{it}} = \alpha_i + \delta_{\text{it}} + \beta_1 \text{div}_{\text{it}} + \beta_2 \text{div}_{\text{it}}^2 + \beta_3 \text{LnGdp}_{\text{it}} + \beta_4 \text{Nres}_{\text{it}} + \beta_5 \text{Hc}_{\text{it}} + \beta_6 \text{trade}_{\text{it}} + \mu_{\text{it}}$$
$$i = 1 \dots N;\ t = 1, \dots, T \tag{3}$$

The above equations Lnec_{it} refers to renewable and non-renewable energy consumption in different estimates. Notably, the first model estimates the role of export diversification with income, natural resources, human capital, and trade as controlling factors. However, model-2 is mainly utilized for the estimation of the Kuznets hypothesis between export diversification and energy consumption. Whereas, $\beta_2 \text{div}_{\text{it}}^2$ shows the coefficient values for diversification square, which can also indicates the threshold in the magnitude effects.

Where i is the country-specific intercept and t is the panel-specific deterministic time pattern. The slopes of $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6 can differ for each variable (measured in quantitative figures as renewable and non-renewable energy), indicates divergent exports and energy use. This reflects natural resources, human capital, and trade.

The $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6 are the coefficient of renewable energy, export diversification economic growth, natural resource, human capital, and trade. Lastly, μ_{it} indicates the error term in model specification.

4.3 Panel Quantile regression (QR)

To transform the conditional distribution function into pieces, the quantile regression (Koenker & Bassett, 1978) is used. Such sections define a conditional-dependent variable Y_i cumulative distribution given the explanatory variable X_i using conditional quantiles. Notably, the panel quantile regression is a widely used technique in the energy economics literature, as it provides consistent and robust outcomes by avoiding endogeneity issues (Farooq et al., 2019; Sarwar et al., 2019).

More precisely there are two important reasons to choose this methodology in this study. First, the authors choose panel quantile regression approaches based on the qualities and properties of the data. As a consequence, we can obtain more robust and valid results. Second, this method is used in only a few existing studies that incorporate long-term data to different countries (Alvarado et al. 2018; Halliru et al., 2020; Akram et al., 2021). Furthermore, this method is considered to be a valid approach for energy- environmental related issues.

Assuming that the upper limit of conditional distribution is linear, where Quantum X_i is the following:

$$Y_i = x_i' \cdot \beta + u_{\theta i} \tag{4}$$

$$\text{Quant}_\theta(Y_i / X_i) = \inf\{Y : F_i(Y/X)\theta\} = x' \cdot \beta_\theta$$
$$\text{Quant}_\theta(u_\theta / x_i) = 0$$

where $\text{Quant}_\theta(u_\theta / x_i)$ represents the θ conditional quantile of Y_i on regressor vector x', while β_θ is the unknown vector of parameters to be estimated different values of θ in (0, 1); u_{θ_i} is the error term assumed to be continuously differentiable c.d.f (cumulative density function) $F_i(y/x)\theta$ The value $F_i(y/x)\theta$ shows the conditional distribution of Y_i condition x_i. Varying the value of u from 0 to 1 shows the entire distribution of Y_i conditional on x_i. and the estimator for β and u_{θ_i} achieved from

Table 2 Descriptive statistics

Variables	Obs	Mean	SD	Min	Max	p1	p99	Skew	Kurt
Renewable energy	168	8.182	10.472	0	23.079	0	23.052	.497	1.256
Non-renewable	168	23.861	1.022	21.276	26.35	22.163	26.267	.414	2.565
Diversification	168	4.573	.839	2.691	5.82	2.809	5.814	-.617	2.301
Economic growth	168	25.15	1.123	22.909	27.26	23.015	27.253	.171	2.021
Natural resources	168	1.683	1.667	.052	8.426	.124	8.421	1.888	6.832
Human capital	168	2.29	.249	1.964	3.092	1.986	3.016	1.005	3.066
Trade	168	1.021	.336	.426	2.102	.516	1.919	1.02	3.331
Diversification^2	168	21.614	7.268	7.243	33.87	7.889	33.807	-.349	2.082

Table 3 Panel unit root tests

Variables	CIPS unit root test		IPS unit root test	
	Level	First difference	Level	First difference
Renewable energy	−4.498	−1.951***	−2.181	−493***
Non-renewable	−2.363	6.027***	−0.543	−6.679***
Diversification	−2.294	−5.275***	−2.23	−5.45***
Economic growth	−1.614	−4.674***	−1.386	−4.161***
Natural resources	−2.226	−4.804***	−1.49	−4.655***
Human capital	−2.405	−2.770*	−1.022	−2.078***
Trade	−3.139	−5.347***	−2.303	−5.401***
Diversification^2	−2.403	−5.410***	−2.334**	−5.4831***

Superscripts ***, **, *denote statistical significance at the 1 and 5% and 10% levels, respectively

$$\min \sum\nolimits_{i:u\theta>=o}^{n} \theta^{\times}|u\theta| + \sum\nolimits_{i:u\theta<=0}^{n} 1-\theta^{\times}|u\theta i| = \sum\nolimits_{i:y_i - x' i \cdot \mathrm{B}\theta>=0} \theta^{\times} \quad \left|yi - x' i \cdot \beta\theta\right| \tag{5}$$

5 Empirical analysis and results

Table 2 reports a descriptive statistical summary. Table 2 illustrates the standard deviation, mean minimum, maximum variables. The economic method usually promotes the testing of stationary properties between variables before the model is estimated. This is critical to avoid integrated variables of I (2). And a spurious analysis that influences the formulation of policies at large. It is in this light that the root unit test panel (CIPS and IPS) for the GCC countries presented in Table 3 was conducted. The test was conducted both at the level and 1st difference for both CIPS and IPS unit root. At the level of unit-root, all the variables under review statistically significant at 1st difference except the diversification^2 are significant at the level.

The next step is to investigate a long-run relationship between the variable to determine the existence of convergence. To this end, the authors apply the Pedroni co-integration test advanced by Pedroni (1999) in conjunction with the Kao co-integration test to investigate the balanced relationship presented in Table 4. Both the Pedroni test and the Kao cointegration test were used to investigate the relationship between renewable energy, non-renewable energy, economic growth, natural resources, human capital, and diversification over 1990–2019 for six GCC countries. The null hypothesis assumes that there is no cointegration in the model specification. The cointegration tests are employed as renewable energy and non-renewable consumption in two model specifications, without considering the role of diversification^2. These cointegration tests reveal the existence of a long-run relationship between the variables. In a more recent study, Gozgor and Can (2016) also reported strong cointegration between export diversification and carbon emissions for the case of Turkey.

Table 5 summarizes the quantile regression model's estimation results. The outcome of Eq. (1) shows that export diversification has a negative significant relationship with renewable energy. Suggesting that product diversification will reduce renewable energy. Similarly, when we checked the square of diversification, we found a positive and significant result. It was stated that after a certain level of product diversification, renewable energy could be increased. Similar findings are supported by Shahzad et al. (2021a) for G-7 and E-7 countries. Both findings are extraordinary and support the energy structure, which can help to further promote the achievement of sustainable development goals. When using the (FMOLS) model, similar results were obtained. Our findings show that promoting product diversification initially reduces renewable energy in GCC countries, but after gaining a competitive advantage in product diversification, renewable energy can increase. The average rise of 1 percent in export diversification would reduce the demand for energy by 3.34 percent, all in the same way. It shows that if GCC countries are focused on manufacturing products, the resulting product diversification will increase energy efficiency which in turn reduces renewable energies. While economic growth and human capital have positive relationship and natural resources have a negative and significant relationship with renewable energy. While trade shows an insignificant relationship with renewable energy for GCC countries, the empirical results

Table 4 Panel cointegration analysis

	Model 1		Model 2	
	t-statistics	*P*-value	*t*-statistics	*P*-value
Pedroni cointegration				
Panel modified phillips-perron statistics	1.492*	0.06	0.697	0.243
Panel phillips-perron statistics	−1.7068***	0.04	−3.297	0.000***
Panel ADF-statistic	−3.098***	0.001	−3.421	0.000***
Kao cointegration				
Modified Dickey-fuller *t*-statistic	−3.73***	0.000	−1.304*	0.09
Dickey-fuller *t*-statistic	−2.79***	0.002	−4.066***	0.000
Augmented dickey-fuller *t*-statistic	−1.34***	0.008	−0.495	0.310
Unadjusted modified dickey Fuller *t*-statistic	−3.72***	0.000	−5.122***	0.000
Unadjusted Dickey-Fuller *t*-statistic	−2.792***	0.002	−5.831***	0.000

Model 1 shows the cointegration of renewable energy and model-2 illustrates non-renewable energy. Cointegration is checked without the square of export diversification. *** Significant value at 5% level

Table 5 Quantile regression and FMOLS empirics for renewable energy

Variables	Quantile regression		FMOLS	
	Eq-1	Eq-2	Eq-1	Eq-2
Diversification	−3.34***	12.106***	−2.461***	16.89*
	(0.58)	(5.720)	(0.985)	(9.05)
Economic growth	7.253***	7.239***	6.884***	6.952***
	(0.483)	(0.606)	(0.825)	(0.957)
Natural resources	−1.65***	−1.523***	−1.945***	−2.209***
	(0.257)	(0.327)	(0.439)	(0.516)
Human capital	5.46***	3.137	4.91***	4.451
	(2.08)	(2.637)	(3.557)	(4.159)
Trade	−1.53	−1.348	1.914	1.818
	(1.33)	(1.737)	(2.345)	(2.82)
$Diversification^2$	–	12.11***	–	2.298
Constant	−167.08***	−192.14***	−164.06***	−203***
	(9.344)	(16.08)	(15.966)	(25.32)
Observations	168	168	168	168
R^2	0.5626	0.5706	0.425	0.475
Neweywest test	–	–	51.023	14.635
Standard error (Long run)	–	–	7.013	8.121

Standard errors shown in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$

support the conclusions and narrative of Ghazouani et al. (2020); Shahbaz et al. (2019) and Can et al. (2020).

Moreover, GCC economies are largely dependent on the production and export of oil and countries in the region. Due to the recent COVID-19 crisis, it is an idea by the International Energy Agency (IEA) that global oil demand will fall to 99.9 million barrels per day (bpd) in 2020. Also, there exists a negative relationship between non-renewable energy and export diversification in Table 6. It shows overall, diversification discourages non-renewable energy for GCC countries. With a square of diversification, it shows a positive and significant relationship with non-renewable energy consumption in the case of GCC countries. Notably, the empirical results argue that there exist inverted U-shape relationships between export diversification, diversification threshold, and energy consumption in GCC countries. In this study, the authors only checked the EKC hypothesis between the export product diversification and renewable energy and non-renewable energy demand in GCC countries (Ghazouani et al., 2021; Guo et al., 2021).

We explored that the first EKC trend for non-renewable energy consumption reduces the energy demand, but after a certain threshold, it increases energy demand. It means with the increase in diversification energy demand will also increase. Such novel findings can be regarded as a contribution to the literature and can be used to draw new implications for a sustainable environment and cleaner production. While natural resources have a significant and positive relationship, Shahbaz et al. (2019), added that natural resources contribute to increasing non-renewable energy demand.

Table 6 Quantile regression and FMOLS empirics for non-renewable energy

Variables	Quantile regression		FMOLS	
	Eq-1	Eq-2	Eq-1	Eq-2
Diversification	−0.096	−2.115***	−0.09	−2.537***
	(0.08)	(0.564)	(0.06)	(0.654)
Economic growth	0.970***	0.945***	0.930***	0.995***
	(0.07)	(0.060)	(0.05)	(0.06)
Natural resources	0.119***	0.185***	0.148***	0.187***
	(0.03)	(0.032)	(0.03)	(0.037)
Human capital	0.119*	−0.321	0.03*	0.107*
	(0.302)	(0.260)	(0.25)	(0.301)
Trade	0.272	0.015***	0.01	−0.267
	(0.193)	(0.171)	(0.16)	(0.204)
Diversification^2	–	0.229***	–	0.273***
Constant	−.8071	5.201	0.519	4.237***
	(1.356)	(1.585)	(1.122)	(1.833)
Observations	168	168	168	168
R^2	0.6966	0.7313	0.446	0.74
Neweywest test	–	–	56.389	14.350
standard error (Long run)	–	–	1.188	0.589

Standard errors shown in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

6 Discussion of findings

The empirical findings of export product diversification, the square of diversification vary among two model specifications for renewable and non-renewable energy. According to the quantile regressions and FMOLS empirics, product diversification might increase renewable energy consumption, and then after a certain threshold, it might tend to reduce it. The present study is the first to report on the role of product diversification, its threshold, human capital, and natural resources for overall energy consumption patterns in GCC countries. More specifically, the results argue that along with the diversification strategies the human capital (education quality), income, and natural resources are key variables to induce energy efficiency and overall energy demand. This is due to the reason that the education quality and income level will affect the will and wisdom to use more clean and renewable sources, which can be useful for sustainable development. In the same line, the human capital will have positive effects to use less non-renewable sources for environmental protection and health purposes; because the greenhouse gas emissions and use of fossil fuels will affect human health. Our findings are also in line with (Farooq et al., 2019; Sarwar et al., 2019 and Can et al., 2020) for China and developing countries, respectively. Overall, the current study argues that natural resources, trade, and income may be important factors in influencing nonrenewable energy consumption, which may pose a concern for current and future climate change issues. Such findings can be explained by the new products, new markets, and green investments created by renewable energy in GCC and few developed economies. The empirical findings are consistent with the findings of Shahzad et al. (2021a). They also investigate the effect of export diversifications on renewable energy consumption using a panel data set of (G-7 and E-7) countries from 1990 to 2017. Overall, the findings show that product diversification policies benefit both developed and emerging economies' renewable energy demand. Based on the detailed findings, the present study argues that policymakers in GCC countries must think beyond their income, revenue, and economic complexity improvements. For instance, the GCC countries can struggle for innovative technologies, new machines that generate fewer pollutant emissions.

7 Concluding remarks and policy implications

This paper investigates the effects of export product diversification on renewable and non-renewable energy demand for the GCC countries throughout 1990–2019. Panel unit root tests, cointegration analysis, quantile regression, and fully modified OLS estimation techniques have been used for empirical analysis. The results show that export diversification has a negative significant relationship with renewable energy. Suggesting that product diversification will reduce renewable energy. Equally, when we checked with the square of diversification it shows a positive and significant. It mentioned that after a certain threshold in product diversification the renewable energy can be increased. The same results showed while applying the fully modified OLS (FMOLS), model. Our results demonstrated that by promoting product diversification initially reducing the renewable energy in GCC countries, while after getting the certain edge of product diversification renewable energy could increase.

The empirical findings highlighted the presence of Kuznets's hypothesis between export product diversification, renewable, and non-renewable energy consumption. The findings argue that at first, product diversification reduces renewable energy but after a certain threshold, it shows the increasing trend. Similarly, natural resource and economic growth also show a positive and significant effect on renewable and non-renewable energy demand. Notably, the empirical findings of this work highlight that human capital, trade, and natural resources significantly affect renewable energy and non-renewable energy consumption in GCC countries. The results imply that investments in natural resources, income, and international trade might influence renewable energy investments.

One of the important contributions of this research is to unveil the role of the diversification threshold at which it affects renewable and non-renewable energy consumption. In the overall, empirical analysis, the findings suggested that there is an inverted U-shape relationship between product diversification and energy consumption in GCC countries. The results imply that if the diversification process continues, it can reduce oil and fossil fuel dependence. This is due to the reason that GCC economies heavily rely on the export of oil and non-renewable products. Hence, if these countries diversify their export portfolio, it can enhance renewable energy consumption and new types of cleaner energy sources in the region. Such an approach can be further helpful in achieving a few of the relevant sustainable development goals, sustainability, and cleaner production objectives.

The diversification policies and regulations might be helpful for the following sustainable development goals; SDG-7: clean and affordable energy, SDG-8: sustainable economic growth, and SDG-13: Climate Action. This is justified from the reason the diversification of products might bring more foreign direct investments, the latest technologies for industry, and manufacturing processing. On the same line, the new industries would create jobs and might be helpful to overcome energy security and energy poverty issues in the region. In the context of policy implication, the authors observe that increasing export product diversification could help GCC countries to increase renewable energy. During recent years, Arab Energy Conferences, the diversification of Arab oil-producing countries was a constant and key subject. However, the issue has an additional dimension in the current sense of structural changes in the global energy scene.

The policymakers should realize that rapid growth in GCC economies will result in higher energy demand. Therefore, promoting export diversification will reduce the oil dependency to fulfill energy demand. The shift from the major Arab exporters of oil for a table economy has certain short-term economic repercussions but it might influence the transition toward greener energy. As per this study, if GCC countries fulfill their diversification goals, it will have a beneficial impact on the speed and long-term demand for the global energy transition. If they accomplish their diversification targets, it might have an impact on global energy transition rates, long-term oil demand, making oil policy more flexible and pragmatic and pursuing the longer-term plan. National and regional policies can play an important role in assisting GCC countries not only in identifying renewable energy market priorities and avenues but also in expanding the road map to include other policies and measures aimed at predicting problems caused by a high share of renewable energy in the power mix and appropriate solutions. Eventually, the implications of this study contribute to the objectives of sustainable development and cleaner production. Policymakers have also recommended some regulations and administrative policies in the pursuit of a sustainable environment, such as reduced tariffs, target prices, quota obligations, reduced value-added-tax for specific technologies, and a carbon tax, among others. In developing, emerging, and developed economies, the export product basket is extremely important for overall growth and sustainable development goals. Japan, Brazil, India, China, and Bangladesh, for example, export a wide range of agricultural and industrial products, demonstrating their diverse economic structures with high-tech industries (Ikram et al., 2021).

While, in the case of the GCC economies, diversification is slow, and these countries lack high-tech new products due to their narrower focus or lower economic complexity. Notably, existing research has shown that the export-led growth theory is valid for a variety of developing and developed economies, and product diversification may help overcome a variety of environmental issues. Furthermore, GCC countries with high solar incidence, such as Saudi Arabia, may struggle to improve economic complexity and reduce greenhouse gas emissions by creating incentives for manufacturing, industrialization, and urbanization. For future research there is a need to investigate the role of institutional quality and governance for overall energy structure and renewable energy. This is due to the reason that in the case of GCC countries, most of the economic and industrial decisions are centralized based on the government structure and policies.

Finally, future research can investigate the EKC validity of export diversification and import diversification. To this end, the researchers and policymakers can extend this framework by incorporating economic complexity, and for leading exporting economies, leading polluting economies, or OECD countries.

Availability of data and materials The datasets used during the current study are available from the corresponding or first author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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