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# Assessing Environmental Sustainability in Top Middle East Travel Destinations: Insights on the Multifaceted Roles of Air Transport Amidst Other Energy Indicators

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## Abstract

The Middle Eastern region is well-known for its flourishing tourism industry as the aviation sector contributes over US$213 billion to the regional GDP while air transport-related activities account for over 3.3 million jobs. Howbeit, the environmental impacts of this flourishing industry remain questionable. Hence, this study examines the tourism-emissions nexus in the Middle Eastern region from the perspective of air transportation while underscoring the multifaceted roles of major indicators like globalization, income, and energy use in the region. The empirical analysis of data spanning from 1975 to 2018 was conducted with advanced panel data analytical approach using the CS-ARDL technique. The sample selection was guided by available statistics on international tourist arrivals from the United Nations World Tourism Organization (UNWTO, 2020), with a focus on the case of the five leading travel destinations in the region including Saudi Arabia, United Arab Emirates (UAE), Egypt, Oman, and Qatar. The robustness of the evaluated outputs was checked after which result-based policy suggestions were enunciated for authorities and other regional stakeholders. The analysis indicated that air transportation although boosting tourism has constituted significant detrimental environmental impacts on the reviewed destinations with an estimated long-run elasticity of ~1.03. Additionally, while the trio of globalization, energy utilization, and income expansion exacerbate environmental degradation, the lowest carbon-triggering magnitude was observed from the regional income expansion. Thus, while the aviation sector facilitates the growing quest to diversify from a primary sector-based economy (mainly resources exploitation) to other prospective service industries like tourism, the study posits the need for authorities to put measures in place to address the environmental side effect of air transportation.

**Keywords:** Air Transport; Tourism; Environment; Energy consumption; Globalization; the Middle East

# 1 INTRODUCTION

Tourism has witnessed tremendous growth in the last couple of decades on a global scale and the destinations whose earnings reach or exceed US$ 1 billion have been noted to have approximately doubled from the year 1998 (UNWTO, 2020). Also, there was about 54% real growth in international tourism in the years between 2009 and 2019 with a record 3% rise in international tourism receipts representing about US$ 1.48 billion in the year 2019 (UNWTO, 2020). On a regional basis, a region like the Middles East is rapidly gaining more popularity in the tourism world as many countries in the region are well-known for their flourishing tourism industry. As of 2019, the highest growth in both arrivals and receipts was recorded in the Middle East on a regional basis (UNWTO, 2020).

International tourist arrivals in the Middle East grew by about 8.32% year-on-year basis between 2018 and 2019. More than 65 million people visited the region in 2019 with a country like Saudi Arabia and the United Arab Emirates (UAE) welcoming 17.52 million and 16.73 million people respectively. Other countries in the region like Egypt, Jordan, and Bahrain among others also welcomed millions of arrivals as seen in Table 1. The Middle East region offers touristic destinations for various kinds of tourism including being the host to some of the world's largest religious sites (Olsen, 2018; Timothy, 2020).

The economic benefits of the tourism industry in many of these Middle Eastern countries cannot be overemphasized especially in terms of tourism revenue as seen in Table 1. Several studies have thus been devoted to addressing issues relating to the development, growth, and stability of the tourism industry considering the contributions of the sector to countries in the region and most of the studies have addressed the inherent economic and socio-political challenges (Hopfinger & Scharfenort, 2020; Timothy, 2018). Others also try to address some challenges confronting the sector such as fears and psychological orientation of tourists about the Middle East due to issues like terrorism and political tensions in the region (Butler, 2018; Göktuğ Kaya et al. 2022).

**Table 1**: **International tourist arrivals and tourism revenues in the Middle East (2010/2019)**

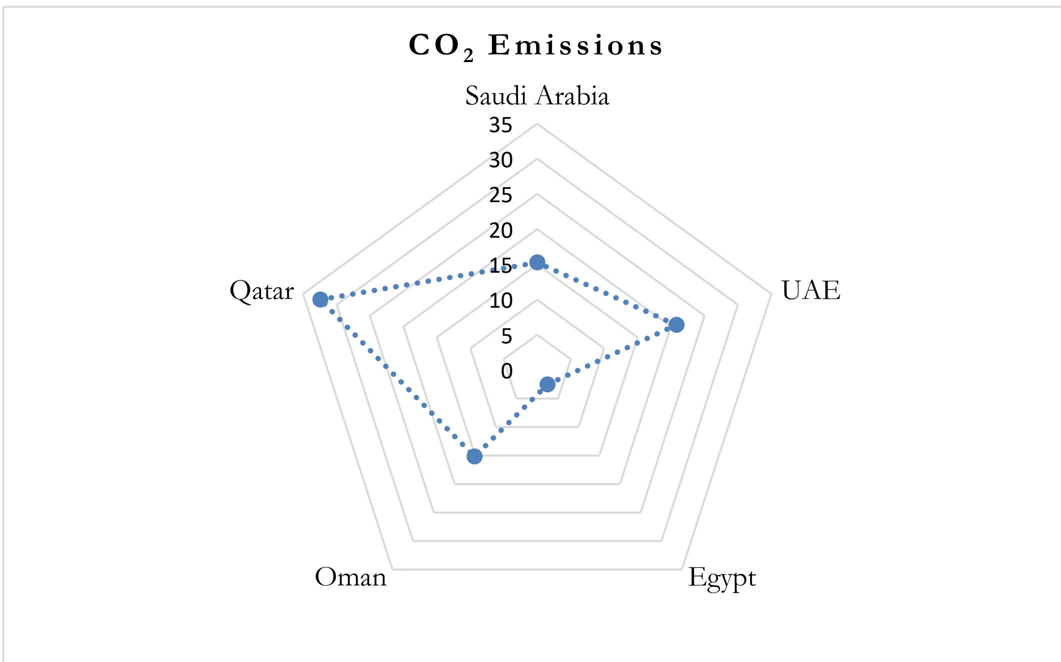
| | Tourist arrivals (in thousands) | | Tourism revenues (in US$ million) | |
|---|---|---|---|---|
| | ***YEARS*** | | | |
| ***Countries*** | ***2010*** | ***2019*** | ***2010*** | ***2019*** |
| Saudi Arabia | 10,850 | 17,526 | 6,712 | 16,382 |
| UAE | 7,432 | 16,730 | 8,577 | 21,800 |
| Egypt | 14,731 | 13,026 | 12,528 | 13,030 |
| Jordan | 4,207 | 4,488 | 3,585 | 5,786 |
| Bahrain | 995 | 3,849 | 1,362 | 3,681 |
| Oman | 1,441 | 2,500 | 783 | 1,811 |

| | | | | |
|---|---|---|---|---|
| Qatar | 1,700 | 2,137 | 584 | 5,442 |
| Lebanon | 2,168 | 1,936 | 7,995 | 8,593 |

**Note:** Data obtained from UNWTO (2020) countries excluded due to missing data include Iraq, Libya, Yemen, Palestine, and Syria

However, sufficient attention is yet to be paid to the environmental impacts of this booming sector in the region at large, or at least on an individual country level. Meanwhile, the available statistics show that matters of environmental degradation are rising in the region even as CO2 emissions continue to grow among other prominent greenhouse gas (GHG) emissions in the region over the last couple of decades (WDI, 2021). As of the end of 2018, as seen in Figure 1, among some of the top tourist destinations in the region, Qatar leads in carbon emission levels followed by the UEA and Saudi Arabia respectively.

**Figure 1**: $CO_2$ Emissions in Selected Middle Eastern countries (End of 2018)




**Note:** $CO_2$ emissions data in metric tons per capita were obtained from the WDI (2021).

Meanwhile, the compelling evidence on the possible consequences of the growing GHG emissions like $CO_2$ emissions among others has increasingly resonated in the literature including droughts, extreme temperatures, floods, and agricultural activities distortions among other reported dangers of climate change (IPCC, 2021; Lee et al., 2021; Onifade, 2023). Furthermore, there are reported dangers of low adaptability to climate variability in the Middle East region with many countries risking various degrees of economic loss if necessary environmental actions are not taken within the ideal period (Waha et al. 2017; Kousky, 2014; Sowers et al. 2011). Thus, addressing the tourism-emission dynamics in the Middle East is essentially a beneficial task considering that many countries in this region are at the forefront of the growth in the global tourism industry.

Therefore, in view of the foregoing issues, this study makes contributions to the literature by providing a critical analysis of the tourism-emissions nexus from the perspective of air transportation using the leading touristic countries in the Middle East while underscoring the multifaceted roles of globalization, income expansion, and energy use among these countries. The current study significantly helps to extend the frontiers of knowledge on some considerations and most especially when considering the direct focus on air transport. The tourism industry in the middle east has recorded tremendous progress in the last couple of years and the successes of this booming industry cannot be separated from the growth and progress witnessed in the global aviation industry over the years. In fact, as of 2011 according to the Air Transport Action Group, the aviation industry account for 51% of the total international tourist movements and this figure has grown to about 58% as of 2019 in the years preceding the COVID-19 outbreak (ATAG, 2020). Aside from the tourism benefits of this prospering industry, the economic benefits cannot be overlooked too as air transportation represents about 4.1% of global GDP as of 2018 with approximately 35% of the global trade values carried out via air transport up to the tune of about US$6.5 trillion. Furthermore, air transport-related jobs account for over 3.3 million jobs in the Middle East with over US$213 billion contribution to the GDP of the region (ATAG, 2020). However, the attention of most researchers is disproportionately directed toward addressing the economic facets of the booming air transport industry vis-à-vis how to ensure sustainable and more robust tourism growth in the region. Hence, the current study focuses on the environmental facets of the development by addressing the tourism-emission nexus for the region from an air transport perspective. Furthermore, as the literature on the middle east continues to evolve, other merits of the present study can be seen from the adopted methodological framework in the empirical analysis. The utilized approaches essentially cater to some pitfalls that often mar panel data empirical analysis of this sort to include issues of common factors in data observation that often create the problem of cross-sectional dependency among others.

Following the introduction in Section 1, the rest of the chapter is grouped into 4 Sections. Section 2 contains the literature review while Section 3 contains the explanation of the methodologies for the empirical analysis. The results analyses were provided in Section 4 while the conclusions and policy recommendations were given in the last section (Section 5).

## 2 LITERATURE REVIEW

The literature on the roles of air transport in environmental degradation is gradually rising but still falls short in terms of the required attention in comparison to the quantum of available studies that have generally addressed environmental challenges, especially from the perspective of energy consumption and carbon emission (Shahbaz et al., 2020; Destek & Sinha, 2020; Leitão & Balsalobre-Lorente, 2021; Dingru et al. 2023; Godil et al. 2021; Bozkaya et al. 2022). Some studies have attempted to establish a link between air transport and the environment in terms of carbon emission levels (Lo et al. 2020; Chatti, 2021; Habib et al., 2022; Song et al., 2022). Some researchers have also individually focused on some other factors in establishing the tourism-environmental degradation links including factors like trade, financial development, urbanization, and foreign direct investment (Khan et al. 2019; Eichner & Pethig, 2009; You & Lv, 2018; Sinha & Shahbaz, 2018). However, the current study addresses some pertinent gaps. Firstly, most of the existing studies have only provided empirical analysis that does not include the middle eastern region despite the regions' increasing roles in the global tourism industry. Secondly, the importance of globalization is often excluded in the empirical scope of the related works. Meanwhile, the inherent roles of this factor should not be overlooked. The present study essentially benefited from the use of the KOF globalization index – a comprehensive index that provides a view of globalization from the broader perspectives of cultural, economic, and financial indices all of which are central factors to global tourism development. Thirdly, the present study also fills the gap in the literature on methodological pitfalls of some of the extant works, by essentially addressing the issues of common factors in data observations that usually lead to the problem of cross-sectional dependency which often mars panel data empirical analysis of this sort. In table 2, a comprehensive summary of some findings from existing studies has been provided including their scope, the approaches adopted, and the general findings and overall conclusions.

**Table 2: A Summary of Relevant Extant Studies**

| Contributors(s) | Sample Data Evaluated | Sample Countries Evaluated | Empirical Approaches | Findings |
|---|---|---|---|---|
| | | | | |
| **Air Transportation and the Environment in view** | | | | |
| Hassan et al. (2022) | 1985 to 2018 | China | Dynamic ARDL | Public transportation (including air transport) increases environmental pollution through $CO_2$ emissions. |
| Lee et al., (2021) | 2000 to 2018 | Global Aviation | Multiple approaches including ESM, SCM, and IRF models | International air transportation increases the earth's surface temperature through $CO_2$ and net non-$CO_2$ contributions. |
| Lo et al. (2020) | 1997 to 2011 | Lombardy-Italy | Panel Econometric Analysis | Air transport (size of aircraft and route distance) increases $CO_2$ emissions. |
| Chatti (2021) | 2002 to 2014 | 43 countries | System GMM | Air transport increases $CO_2$ emissions but the internet help in increasing the desired sustainability. |
| Adedoyin et al. (2021) | 1995 to 2018 | 26 EU member states | System GMM | Increase in tourism raises $CO_2$ emissions. |
| Gyamfi et al. (2022b) | 1995–2016 | E7 economies | AMG & CCEMG | Air transport increases environmental damage through $CO_2$ emissions. |

| | | | | |
|---|---|---|---|---|
| Habib et al. (2022) | 1990 - 2016 | G20 Countries | Fixed-effect panel quantile regression | Air transport increases emissions in the G20 using different indicators. |
| Song et al., (2022) | 2010–2018 | Korea | DOLS, VECM & FMOLS | Established a positive relationship between CO2 emission and air transport |
| Bekun et al. (2022a) | 1995–2016 | E7 economies | Driscoll-Kraay & AMG | Tourism demand increases $CO_2$ emission. |
| Hassan et al., (2021) | 1985 to 2018 | China | NARDL method | Negative or positive shocks in operational mileage per capita of Air transport increases emission in China |
| Mehmood (2021) | 1996 to 2015 | SAARC countries | PMG method | Air transportation increases environmental damage through $CO_2$ emissions. |
| **Globalization, Income, Energy Use, and the Environment in view** | | | | |
| Le & Ozturk (2020) | 1990 – 2014 | 47 Emerging economies | CCEMG, AMG, and DCCE | $CO_2$ emissions levels in the 47 emerging economies are induced by globalization. |
| Zaidi et al. (2019) | 1990 – 2016 | APEC countries | CUP-BC & CUP-FM methods | $CO_2$ emissions are reduced by globalization in these economies. |
| Shahbaz et al., (2019) | 1970 – 2012 | 87 economies | Cross-correlation Method | Globalization only lowers $CO_2$ emissions in high and middle-income economies. |
| Saint Akadiri et al., (2020) | 1970 to 2014 | Turkey | ARDL method | They concluded that globalization has no impact on $CO_2$ emissions. |

| | | | | |
|---|---|---|---|---|
| Sharif et al. (2020) | First Quarter 1978 to fourth quarter 2017 | China | QARDL | Globalization mainly has a negative influence on environmental quality. |
| Destek (2020) | 1995 to 2015 | The Central and Eastern European Economies | Granger Causality and AMG approach | Globalization rates increase $CO_2$ emissions in the CEECs. |
| Adebayo et al., (2021) | 1980 to 2018 | Korea (South) | ARDL Method | $CO_2$ emissions levels in Korea are induced by globalization. |
| Farooq et al. (2022) | 1980 – 2016 | For 180 economies | Panel QR | $CO_2$ emissions are reduced by globalization in these economies. |
| Balsalobre-Lorente et al (2020a) | 1994 to 2014 | OECD nations | FMOLS method | Globalization helps to reduce $CO_2$ emissions. |
| Destek & Sinha, (2020) | 1980 – 2014 | 24 OECD economies | MG, FMOLS, & DOLS | Non-renewable energy use increases degradation contrary to the impacts of renewables. |
| Apergis & Payne (2014) | 1980 – 2011 | 25 OECD countries | FMOLS method | Income growth increases carbon emissions |
| Shahbaz et al., (2021) | 1980 – 2019 | India | Nonlinear ARDL approach | Income expansion increases environmental degradation |
| Ozturk and Acaravci, (2016) | 1980 to 2006 | Island of Malta and Cyprus | Causality and ARDL approaches | $CO_2$ emissions and energy use increase economic growth. |
| Leitão & Balsalobre-Lorente (2021) | 1990 to 2018 | 28 EU members | Causality and DOLS | Renewable energy usage dampens $CO_2$ emissions |

| | | | | |
|---|---|---|---|---|
| Asumadu-Sarkodie and Owusu, (2017) | 1971 to 2013 | For Ghana | Regression methods | An increase in energy use & growth increases $CO_2$ emissions. |
| Shahbaz et al., (2020) | 1870 to 2017 | For the UK | Bootstrapping bounds test method | Energy utilization increases $CO_2$ emissions |
| Ozturk & Acaravci (2010) | 1968 to 2005 | Analysis for Turkey | Causality and ARDL approaches | There is no causal nexus between energy use, $CO_2$ emission, and economic growth. |
| Alola (2019) | First Quarter (1990)-second quarter (2018) | The USA | ARDL (The Dynamic approach) | Income growth & energy use increase $CO_2$ emission |

**Note:** See Appendix Table 8 for more information on the full meaning of all abbreviations.

# 3 METHODOLOGY

## 3.1 Data and Country Selection

The country selection process for the study is guided by data availability vis-à-vis the report of the global tourism statistics of the United Nations World Tourism Organization (UNWTO, 2020). From Table 1 in the introduction, the WTO reported the international tourist arrivals and tourism revenues in categories and the report for those in the MENA region shows the countries' tourism performances. The data obtained for the region excluded some countries due to missing data including Iraq, Libya, Yemen, Palestine, and Syria. Issues of political crisis and wars may have created irregularities in data accessibility in some of these countries. Some of the leading performing countries in the region include Saudi Arabia, Egypt, UAE, Jordan, Iran, Qatar, Lebanon, and Kuwait. However, due to data irregularities and insufficient data for some of the important proxies of the study, five of these leading countries were covered in the current study namely Saudi Arabia, Qatar, Egypt, Oman, and the United Arab Emirates (UAE). The author thus compiled the data used for the study from three major sources between 1975 and 2018 including the World Development Indicator (WDI), British Petroleum (BP), and the KOF Swiss Economic Institute data source. The KOF index covers various dimensions of globalization ranging from the economic perspectives to the financial, political, and sociocultural aspects. The variable notations and summary of proxies are given in Table 3.

**Table 3. Variables' Information**

| Proxies | Notations | Summary and Sources of proxies |
|---|---|---|

| | | |
|---|---|---|
| **Carbon emission levels** | $CO_2$ | CO2 emissions (metric tons per capita) from the WDI (2021). |
| **Air Transportation** | LnAT | Proxied as numbers of air passengers carried. From the WDI (2021). |
| **Globalization** | LnGZ | The globalization index of the KOF Swiss Economic Institute (Gygli et al. 2019). |
| **Economic Growth** | LnPY | Measured by the gross domestic product per capita (current US$) from the WDI (2021). |
| **Energy Consumption** | LnPEC | Primary energy consumption per capita. From the BP (2021) |
| **Interaction** | LnAT*G | The interaction of air transportation and globalization |

### 3.2 Baseline Model and the Theoretical Underpinnings

The initial baseline model representing the targeted interaction between environmental quality level and tourism growth from the perspective of air transportation is captured in equation 1. However, it can be observed that beyond the air transport component, other factors are incorporated into this baseline model based on certain theoretical considerations and given the conducted review of extant empirical studies.

$$Ln\mathrm{CO}_{2it} = \beta_0 + \beta_1 Ln\mathrm{AT}_{it} + \beta_2 Ln\mathrm{GZ}_{it} + \beta_3 Ln\mathrm{PEC}_{it} + \beta_4 Ln\mathrm{PY}_{it} + \beta_5 Ln\mathrm{AT} * \mathrm{G}_{it} + \varepsilon_{it} \qquad (1)$$

The beta ($\beta_0$) component represents the intercept term in equation (1), while the corresponding betas ($\beta_1$) $to$ ($\beta_5$) captures the environmental impacts of the variables that are being assessed. All variables' definitions have been previously outlined in Table 2.

The theoretical underpinning of the present study is rooted in the environmental facets of the globalization arguments given the trend of globalization in the last couple of years that is characterized by wider integration and rapid expansion of different economic sectors including but not limited to the aviation and tourism industries in several economies across the globe. Several theories in the vast literature have rationalized the link between environmental degradation and globalization and a couple of extant studies have examined the validness of the tenets of some of these theories (Terzi & Pata, 2019; Sadik-Zada & Ferrari, 2020; Khan et al. 2020).

The pollution haven hypothesis and the pollution halo hypothesis stand out among these theories. The arguments for the pollution haven hypothesis increased by the late 1970s when Walter & Ugelow, (1979) asserted that globalization paves the way for transferring pollution-intensive production abroad. The pollution haven hypothesis has since then stand as a major argument against globalization with respect to its impacts on environmental degradation around the globe and the discussion on its validity or relevance is still subject to research in the growing literature (Terzi & Pata, 2019).

However, as the increasing arguments for the pollution haven hypothesis ranges, a contrary argument to the supposed detrimental environmental effects of globalization also surfaced. This is widely tagged as the pollution halo hypothesis in the literature (Birdsall & Wheeler, 1993). The argument in the latter hypothesis is diametrical to the pollution haven hypothesis as far as the impacts of globalization on the environment are concerned. The conjecture argues that globalization is an avenue by which a desirable cross-country transfer of environmentally beneficial technology is achievable among countries across the globe. In essence, it is believed that developing economies would gain from technology acquisition from the developed economies and these gains can then be metamorphosized into bigger environmental benefits as there will be lower environmental degradation. Nevertheless, a major sector that has experienced tremendous benefits from technological improvement is the air transport sector and the overall economic benefit in terms of tourism development cannot be overemphasized in our globalized world. Nevertheless, as tourism continues to spur in the middle east, the environmental facets of the inherent increasing globalization trends still require some attention. As such, considering the mix evidence in extant studies (Terzi & Pata, 2019; Sadik-Zada & Ferrari, 2020; Khan et al. 2020), the validity of the pollution halo hypothesis is still open for more research just as in the case of the pollution haven hypothesis. Therefore, while examining the environmental aspect of air transport and globalization separately, we also investigate the possible impacts of the interaction between these two major components. Lastly, in our ever-increasingly globalized world, economic expansion and primary energy consumption have been identified as parts of the main drivers of $CO_2$ based on the review of extant empirical studies (Farooq et al. 2022; Onifade & Alola, 2022). As such, to ensure a more reliable estimation without being confronted with variable omissions, the baseline model also makes room to control for the underlying roles of these crucial components.

### 3.3. Empirical Procedures

To ensure the choice of the most appropriate empirical techniques for postulating well-informed recommendations, the empirical analytical aspect began with an overall sample features examination beginning with a cross-sectional analysis. The cruciality of checking the cross-sectional status of the data in terms of whether there is a dependency (CD) in errors among the heterogeneous dataset cannot be ignored. This is pertinent as the world is increasingly becoming more and more integrated into different ramifications as travel desires are rising among people with fewer trade restrictions characterizing the increasing economic integration among nations.

As such, to ensure guaranteed robust findings via the selection of the most appropriate heterogeneous panel data technique of estimation, the importance of taking cognizance of the CD test has been highlighted in the work of Chudik and Pesaran (2015). Therefore, three (3) different techniques to check the CD status were employed in the study including the recent Pesaran (2015) LM techniques and the duo of Breusch and Pagan (1980) LM techniques, and the Pesaran (2007) test of CD. There is a full discussion of the results confirming the presence of CD in the panel structure as shown in the subsequent section of the study. Moving on, following the CD status confirmation, it was determined that the corresponding test of variables' stationarity levels and subsequent checks to be conducted for cointegration analysis must be strong enough to address the inherent CD issues in the panel structure. Therefore, the current study opted for the CIPS and IPS approaches to confirm the individual panel variables' stationarity conditions. In a normal panel setting assessment, these adopted unit root approaches are very efficient in assessing the variation within panels as well as offering the necessary qualities to observe second-order generation. The CIPS approach follows the operational procedure depicted in equation (2) alongside equation (3) showing the estimator for the subsequent test statistics.

$$\Delta CM_{i,t} = \psi_i + \psi_i Z_{i,t-1} + \psi_i CM^{*}_{it-1} + \sum_{1=0}^{p} \psi il \Delta CM_{it-1} + \sum_{i=0}^{p} \psi il \Delta CM_{i,t1} + \mu_{it} \quad (2)$$

$$CIPS_{2007} = N^{-1} \sum_{i=0}^{n} CDFi \quad (3)$$

The cross-sectional dependent augmented Dickey-Fuller (*CADF*) is denoted by the *CDF* in Equation (3). On the other hand, $CM^{*}_{it-1}$ and $\Delta CM_{i,t1}$ captures the cross-section averages. As for the cointegration analysis, the technique to adopt must take cognizance of the *CD* matter. Hence, applying the common first-generation level relationship procedures would eventually produce biased results that can suggest turning down the null hypothesis when in fact the opposite ought to be the real situation. Therefore, the current study makes use of the Westerland (2007) second-generation panel cointegration procedures to circumvent the underlying CD problems and as such make sure that the final decision about the null hypothesis of the absence of level relationship among the sample is correctly taken. An estimated panel statistics (Pt, Pα) and group statistics (Gt, Gα,) are used to determine the status of the cointegrating relationship in line with the error correction process in Equation (4).

$$\Delta Z_{it} = \zeta_i D_t + \Phi_i Z_{it-1} + \lambda_i Y_{it-1} + \sum_{j=1}^{pi} \Phi_{ij} \Delta Z_{i,t-j} + \sum_{j=0}^{pi} \gamma_{ij} \Delta Y_{i,t-j} + \mu_{it} \quad (4)$$

Given a typical panel setting with variables Z and Y, the $\zeta_t$ represents the vector of parameters in Equation (4) while the ($\Phi_i$) denotes the error correction process. Furthermore, there are chances of changing the panel setting deterministic ($D_t$) components such that we can estimate varying degrees of models. For example, there can be specifications of models that include just a constant term whereby $D_t = 1$, or specification of model that contains the duo of trends and constant whereby $D_t = (1, t)$. Although the latter specification is used in the current study, it's also possible to have a model specification with neither the constant nor trend whereby $D_t = 0$. Overall, the Westerlund (2007) technique helps circumvent the CD limitations.

### 3.4. Panel Long-run Coefficient Evaluations

Chudik and Pesaran (2015) panel Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) estimator was utilized to obtain the panel long-run coefficients following the detection of CD vis-à-vis the conducted panel preliminary tests. The popular Pesaran et al., (1999) panel ARDL technique would have been an alternative approach for the long-run estimation given mix order in panel variable integration, however, this approach would fail to account for the CD limitations thereby yielding misleading results. As such, Chudik and Pesaran (2015) designed the CS-ARDL that is efficient for obtaining reliable and robust estimates while circumventing the CD pitfalls. Besides, the method is also compatible with the situation of mixtures in panel integration order and useful even if the sample has a relatively small *T* (Chudik et al. 2016). The technique essentially combines the duo of mean group (MG) estimator and pooled mean group (PMG) estimator to assess long-run and short-run coefficients while accounting for the long-term correlations from heterogeneous effects in panel observations.

$$\Delta Z_{it} = \delta_i \{Z_{i(t-1)} - \vartheta_i Y_{it}\} + \sum_{j=1}^{p-1} \beta_{ij} \Delta Z_{i(t-j)} + \sum_{j=0}^{q-1} \pi_{ij} \Delta Y_{i(t-j)} + \varphi_i + \varepsilon_{it} \quad (5)$$

$\vartheta_i$ denotes the long-run relationship vector in the traditional ARDL model as seen in Equation (5) while the correction term is represented by $\{Z_{i(t-1)} - \vartheta_i Y_{it}\}$. The subsequent short-run coefficients are represented with the $\beta_{ij}$ and $\pi_{ij}$ parameters while the $\delta_i$ captures the group-specific speed of correction that must be negative and significant. In the case of cross-sectionally correlated errors, the estimates from this traditional panel ARDL approach will be biased and unreliable. As seen in Equation (6), the CS-ARDL technique thus creates an augmentation to the specification by including the cross-sectional averages of the explained and explanatory variables alongside the combination of their lag values to correct the pitfall.

$$\Delta Z_{it} = \delta_i\{Z_{i(t-1)} - \vartheta_i Y_{it} + \alpha_i^{-1} n_i \bar{Z}_t + \alpha_i^{-1} Z_i \bar{Y}_t\} + \sum_{j=1}^{p-1} \beta_{ij} \Delta Z_{i(t-j)} + \sum_{j=0}^{q-1} \pi_{ij} \Delta Y_{i(t-j)} + \sum_{j=0}^{p-1} \lambda_{ik} \Delta \bar{Z}_{i(t-j)} + \sum_{j=0}^{q-1} Z_{ik} \Delta \bar{Y}_{i(t-j)} + \varphi_i + \varepsilon_{it} \quad (6)$$

$\bar{Z}_t$ and $\bar{Y}_t$ denote the panel cross-sectional averages of variables $Z_{it}$ and $Y_{it}$ respectively as seen in Equation (6). The $\vartheta_i$ denotes the expected long-run coefficients while the speed of adjustment to equilibrium is represented by $\delta_i$. The long-run equilibrium interactions are obtained from the level components of the cross-section averages in the bracket. Moving on, the estimates from the Augmented Mean Group (AMG) approach were also provided alongside the CS-ARDL results for a sensitivity check and to provide comparative analysis after which the empirical analysis closes with an exploration of the panel Granger causality with the Dumitrescu Hurlin (2012) causality procedures.

# 4 EMPIRICAL RESULTS

## 4.1 The Preliminary Findings

To start the empirical discussion, the common descriptive statistics of each country's data were investigated. Table 4 shows the summary of these statistics. Looking at the statistics in table 4, Saudi Arabia leads in terms of the average number of air transport passengers. The reason is not farfetched as millions of tourists visit this country regularly. Besides, the country is also renowned for hosting some of the notable Islamic holy sites that attract millions of pilgrimages on regular basis. Next in line are the UAE and Egypt respectively. On the other hand, when looking at the carbon emission levels, it can be deduced that the average carbon emission level is highest in Qatar, followed by the UAE and Saudi Arabia respectively. In continuation of the preliminary evaluations, the sample cross-sectional dependence (CD) tests were also conducted alongside the various adopted CD-compliant unit roots test approaches before exploring if there is an overall level relationship among the understudied factors.

**Table 4: Countries' Data Statistics**

| *MENA Countries* | *$CO_2$ emissions* | *Air Transportation* | *Level of Globalization* | *Energy Consumption* | *Economic Growth* |
|---|---|---|---|---|---|
| ***SAUDI ARABIA*** | | | | | |
| *Mean* | 1.133737 | 7.109658 | 1.746270 | 2.363180 | 4.054255 |
| *Maximum* | 1.247770 | 7.599530 | 1.830761 | 2.533493 | 4.402151 |
| *Minimum* | 1.010707 | 6.263802 | 1.637549 | 2.089497 | 3.767629 |
| *Std. Dev.* | 0.064552 | 0.261311 | 0.057543 | 0.114869 | 0.202144 |

| | | | | | |
|---|---|---|---|---|---|
| **_QATAR_** | | | | | |
| *Mean* | 1.578505 | 6.340349 | 1.748147 | 2.878792 | 4.473150 |
| *Maximum* | 1.845036 | 7.494281 | 1.876923 | 3.057744 | 4.929807 |
| *Minimum* | 1.420440 | 5.238046 | 1.658067 | 2.494292 | 4.103953 |
| *Std. Dev.* | 0.104415 | 0.657672 | 0.079326 | 0.112795 | 0.280261 |
| **_EGYPT_** | | | | | |
| *Mean* | 0.212257 | 6.601940 | 1.752572 | 1.429526 | 3.035287 |
| *Maximum* | 0.398295 | 7.092931 | 1.834996 | 1.607891 | 3.551808 |
| *Minimum* | -0.093257 | 5.962322 | 1.638564 | 1.060443 | 2.479646 |
| *Std. Dev.* | 0.140365 | 0.283840 | 0.062269 | 0.142585 | 0.301955 |
| **_OMAN_** | | | | | |
| *Mean* | 0.963641 | 6.175919 | 1.694491 | 2.118051 | 3.904624 |
| *Maximum* | 1.224444 | 7.018627 | 1.804555 | 2.488243 | 4.345173 |
| *Minimum* | 0.647917 | 5.238046 | 1.578352 | 1.721563 | 3.376049 |
| *Std. Dev.* | 0.176868 | 0.431577 | 0.075105 | 0.271516 | 0.269411 |
| **_UNITED ARAB EMIRATES_** | | | | | |
| *Mean* | 1.458752 | 6.678535 | 1.769124 | 2.693274 | 4.515508 |
| *Maximum* | 1.793487 | 7.981177 | 1.877987 | 2.895458 | 4.653092 |
| *Minimum* | 1.269278 | 5.238046 | 1.636049 | 2.194944 | 4.348210 |
| *Std. Dev.* | 0.127127 | 0.834963 | 0.076527 | 0.163633 | 0.088480 |

***Source:*** *Author's calculations with Std Dev. representing the computed standard deviation*

In Table 5, the result of the CD test and the corresponding unit root evaluation were presented. It was observed that the hypothesis arguing for the absence of CD must be turned down as the obtained statistics were significant across the combined techniques. As such, the sample unit root report in table 5 follows the CIPS and IPS methods that are essentially CD-efficient. From the analysis, it was further concluded that both carbon emission and income levels are $I(1)$ meaning that they are differenced stationary while air transportation indices and primary energy utilization are both stationary at a level indicating that they are $I(0)$. There is mixed evidence on the globalization integration order as CIPS revealed that it is $I(0)$ while IPS suggested it is $I(1)$. Whichever is the case, there is sufficient evidence that all the variables are at most $I(1)$ in their integration order. In a nutshell, the subsequent preliminary evaluation step needs to ensure that the detected CD problem does not undermine the final decision regarding the cointegration status of the panel sample series. The reported Westerlund cointegration approach was helpful in this regard as it caters to the CD pitfall. Both the group statistics and the panel statistics were indicative of the validity of a long-run relationship among all variables in the sample series as the null hypothesis of the absence of a level relationship is rejected even at the 5% conventional significance level. Subsequently, the long-run estimates and the causality links were evaluated and presented in Table 6 and Appendix Table 7 respectively.

**Table 5: Results (Cross-sectional dependency, Unit root & Cointegration)**

<table>
<tr><th colspan="2">Technique(s)</th><th colspan="2">Breusch and Pagan (1980) LM Test</th><th colspan="2">Pesaran (2007) CD Test</th><th colspan="2">Pesaran (2015) LM Test</th></tr>
<tr><td colspan="2">Equation (1)</td><td colspan="2">88.095***</td><td colspan="2">3.274***</td><td colspan="2">17.462***</td></tr>
<tr><td colspan="2">Calculated P-value</td><td colspan="2">(0.0000)</td><td colspan="2">(0.0011)</td><td colspan="2">(0.0000)</td></tr>
<tr><td colspan="8">Unit Root Report</td></tr>
<tr><td></td><td colspan="3">CIPS Technique</td><td colspan="4">IPS Technique</td></tr>
<tr><td>Variables</td><td colspan="3">Estimation considering Intercept & trend</td><td colspan="4">Estimation considering Intercept & trend</td></tr>
<tr><td></td><td>At Levels</td><td>At 1st Difference</td><td>Order</td><td colspan="2">At Levels</td><td>At 1st Difference</td><td>Order</td></tr>
<tr><td>LnCO2</td><td>-2.273</td><td>-5.704***</td><td>I(1)</td><td colspan="2">-2.3692</td><td>-6.6804***</td><td>I(1)</td></tr>
<tr><td>LAT</td><td>-3.250***</td><td>-5.783***</td><td>I(0)</td><td colspan="2">-3.7252***</td><td>-7.4281***</td><td>I(0)</td></tr>
<tr><td>LnGZ</td><td>-3.293***</td><td>-6.212***</td><td>I(0)</td><td colspan="2">-2.2671</td><td>-5.9407***</td><td>I(1)</td></tr>
<tr><td>LnPEC</td><td>-2.882*</td><td>-5.900***</td><td>I(1)</td><td colspan="2">-3.3348***</td><td>-6.9326***</td><td>I(0)</td></tr>
<tr><td>LnPY</td><td>-0.846</td><td>-4.113***</td><td>I(1)</td><td colspan="2">-1.6537</td><td>-5.0386***</td><td>I(1)</td></tr>
<tr><td>LnAT*G</td><td>-3.347***</td><td>-5.511***</td><td>I(0)</td><td colspan="2">-3.2541***</td><td>-6.8169***</td><td>I(0)</td></tr>
<tr><td colspan="8">The Cointegration Report</td></tr>
<tr><td colspan="4">Interaction in Equation (1)</td><td colspan="2">Group</td><td colspan="2">Panel</td></tr>
<tr><td colspan="4">LnCO2=f(LnAT), (LnGZ), (LnPEC), (LnPY), (LnAT*G)</td><td>Pτ</td><td>Pα</td><td>Gτ</td><td>Gα</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| **Statistics** | -5.475 *** | -7.214 *** | -2.918 *** | -9.098 *** |
| **P-value** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

***Source:*** *Author's calculations with special characters ***, **, and * showing significance assessment at 1%, 5%, and 10% levels*

## 4.2 Long run Results with Granger Causality Insights

The estimated long-run outcomes are summarized in Table 6. In the current study, the tourism-carbon emission nexus was analyzed from the air transport perspective. Following the outcomes of the CS-ARDL evaluations, it was observed that the growth of air transportation was detrimental to the environmental quality of the reviewed major middle eastern tourist destinations. Precisely, the analyzed data shows a rise in carbon emission to an approximate tune of 1.03% for every 1% growth in the air transport indices. The AMG results also produced complementary evidence of a robustness check as the air transport proxy was found to be inducing carbon emission levels with a much larger magnitude but at a lower level of significance. Moving on to the roles of the control factors, the analysis continues with the influence of energy consumption and globalization on emissions in the middle east as seen in the estimated results in Table 6. It can be seen that these two factors also induce environmental degradation in the middle east as about 0.17% and 4.2% rise in carbon emission levels in the touristic middle east destination can be significantly attributed to a 1% rise in these countries' total energy use and globalization respectively. Furthermore, income level was found to be exacerbating carbon emission levels in these countries given that a 1% rise in income levels in the understudied tourist countries corresponds to about 0.074% expansion in carbon emission.

Furthermore, due to the apriori link between air transport growth and increasing connectivity in our globalized world which was also established in the Granger causality results in Appendix Table 7, the study also explores the interactive influence of globalization and air transport in the tourism-emission nexus model. An interesting outcome was observed as the interaction term exerts cushioning impacts on emission levels. There is about a 0.59% fall in carbon emission levels on an account of a 1% rise in the interaction between globalization and air transportation. More detailed intuition of these results have been provided in the subsequent full discussion subsection 4.3. Lastly, as seen in the CS-ARDL outputs, about 83.9% of the short-run disequilibrium in the system is being reconciled with the long-run equilibrium annually.

**Table 6: Long & short-run coefficient estimates**

| | ***Long-run Estimates*** | | **Robustness Checks** | |
|---|---|---|---|---|
| **List of Variables** **$CO_2$ (Explained)** | **CS-ARDL** Estimates | **P-value** | **AMG** Estimates | **P-value** |
| **LnAT** | 1.0289** | 0.0520 | 1.3436* | 0.0680 |
| **LnGZ** | 4.2340** | 0.0310 | 5.3730** | 0.0280 |

| | | | | |
|---|---|---|---|---|
| **LnPEC** | 0.1740*** | 0.0030 | 0.3836** | 0.0290 |
| **LnPY** | 0.0738*** | 0.0060 | 0.0526 | 0.5550 |
| **LnAT*G** | -0.5917** | 0.0470 | -0.7636** | 0.0480 |
| | ***Short-run Estimates*** | | *Wald test* | 12.84 |
| **ECT** | -0.8395*** | 0.0000 | | |
| **ΔLnAT** | 1.7134* | 0.0550 | | |
| **ΔLnGZ** | 7.1120** | 0.0280 | | |
| **ΔLnPEC** | 0.3299** | 0.0030 | | |
| **ΔLnPY** | 0.1396*** | 0.0100 | | |
| **ΔLnAT*G** | -0.9870** | 0.0500 | | |
| **C** | -1.8395*** | 0.0000 | | |
| **R-squared** | 0.56 | | | |
| **No. Regressors** | 5 | | | |
| **No. Observations** | 220 | | | |
| **No. Group** | 5 | | | |

***Source:*** *Author's calculations with special characters ***, **, and * showing significance assessment at 1%, 5%, and 10% levels*

### 4.3 Further Discussions

It was observed that the growth of air transportation was detrimental to the environmental quality of the reviewed major middle eastern tourist destinations. Although air transport can be said to be very vital for the middle east's booming tourism industry and the overall regional economic development, however, this outcome draws the attention of the authority to the environmental demerits of the aviation industry. These findings support some reported findings relating to the environmental impacts of air transport in the literature (Ozturk et al. 2023; Alonso et al. 2014; Gyamfi et al. 2022a; Godil et al. 2020; Chèze et al. 2013). While the aviation sector facilitates the growing quests and plans by many of the middle eastern countries to diversify from a primary sector-based economy (mainly resources exploitation) to other prospective service industries like tourism, there is a need for the authorities to put measures in place to address the environmental side effect of air transport emission. Considering that air transport accounts for a significant proportion of total global international travel at over 58%, there is a need to address aviation emissions on a global scale. As such, each region in the world has pertinent roles to play and the middle east would do well to contribute its quota. Smith and Rodger (2009) noted that the global community is confronted with an enormous challenge of collective action on the matter of aviation-related carbon emissions. Currently, the economic cost and possibility of incurring economic losses constitute major fears as to whether embarking on emission reduction is worthwhile in the air transport industry. However, some recent studies have suggested the possibility of simultaneously attaining carbon reduction with revenue growth in the aviation industry (Cui et al. 2022).

As for the influence of energy consumption and globalization on emissions, it can be seen that these two factors also induce environmental degradation in the middle east as about 0.17% and 4.2% rise in carbon emission levels in the touristic middle east destination can be significantly attributed to a 1% rise in these countries' total energy use and globalization respectively. This finding speak volumes of the reported demerits of energy consumption and globalization in the growing literature (Le & Ozturk, 2020; Balsalobre-Lorente et al. 2020b; Alola & Onifade, 2022; Bekun et al. 2022b; Destek & Sinha, 2020; Erdoğan et al. 2023). The case of the Middle Eastern countries is quite unique as the region houses some of the largest fossil energy resource reserves on the planet (BP, 2021). Moreover, when looking at the causality scheme pattern in Appendix Table 7, a unique one-way causal nexus is observed from the energy use to the pollution level from carbon emission. Furthermore, income level was found to be exacerbating carbon emission levels in these countries thereby reaffirming the income-emission-inducing stance that some empirical studies have upheld in the extant literature (Shahbaz et al. 2021; Bekun et al. 2021; Kirikkaleli et al. 2022; Onifade & Alola, 2022).

Looking at the interactive influence of globalization and air transport in the tourism-emission nexus of the understudied Middle Eastern bloc, an interesting outcome is seen as the interaction term exerts cushioning impacts on emission levels. Although as unconventional as this may appear, this could imply that while air transport and globalization individually induce emission levels in the region, these two factors can as well serve as media for environmental gains if properly harnessed. In fact, the study of Shahbaz et al. (2019) established an environmental Kuznets impact of globalization on emissions in about sixteen countries. The implications is that the environmental detrimental impacts of globalization may have initially toed the path of the pollution haven conjecture since the increased integration of the middle east region has not only induce tourim growth through travel expansions but has also largely enhanced more investments inflow that have triggered industrialization and production base of the region. In either case, both travel expansion and production expansion would require significant level of energy utilization. Therefore the observed globalization emission evidence can be better understood when considering the causality link between globalization and other major emission inducing forces in the model – mainly energy use and income level as seen in Appendix Table 7. There is a one-way grager causality flow from globalization to energy use. Also, globalization significantly granger cause the level of air transportation in a single direction.

However, globalization can provide an avenue for the acquisition and transfer of environmentally friendly technologies. The studies by Balsalobre-Lorente et al. (2020a), Zaidi et al. (2019), and Xiaoman et al. (2021) have also shown that globalization can cushion carbon emission levels in an economy. As such, the interaction term revealed that the emission levels is expected to be eventually cushioned by the influence of globalization over time. It can be said that globalization has help to boost the level of access to more clean energy technologies in the region. However, on the overall, it is important to note that the magnitude of the detrimental environmental impacts of globalization exceed it observed interactive environmental gains. Incisively, it is arguable that globalization has paved way for more access to the consumption of unconventional energy-intensive commodities in the Middle East on a larger scale compared to the transfer of environmentally beneficial technologies as argued by the Pollution Halo hypothesis. Hence, a possible justification for the larger magnitude observed in the degradation effect of the direct impact of globalization when compared to the relatively smaller magnitude of the cushioning effect of its interactive component on emission level.

Moving on, a detailed causality scheme was provided for the study in Appendix Table 7. There is just a minimal causality from CO2 to the income level and air transport variables but not at the conventional (5%) significance level. Air transportation on the other hand is found to be a significant driver of income level which is a desirable outcome showing that the tourism industry might have richly benefited from the aviation industry over the decades. However, this income growth is observed at the expense of environmental quality as air transport growth significantly granger causes both primary energy consumption and carbon emission in the middle east. The estimated causal nexus from air transport to these variables is one-directional thus revalidating the long-run results and reaffirming the reported environmental demerit of air transportation in some extant studies (Alonso et al. 2014; Gyamfi et al. 2022b; Chèze et al. 2013; Ibrahim et al. 2022).

As for globalization in the region, it was observed that this factor is significantly granger causing the level of air transportation in a single direction. As the world becomes more and more integrated on different ramifications with travel desires growing among people coupled with lesser trade restrictions and higher economic integration, the choice of air transport by tourists has increasingly multiplied over the decades. The one-way causal nexus from globalization to air transport confirms this trend. Furthermore, globalization also granger causes energy consumption, $CO_2$ emission, and the level of income in the region. The causality nexus of globalization with energy consumption in particular is one-directional. Energy consumption often dominates the environmental discussion as the major factor responsible for the largest proportion of $CO_2$ emissions given that all the countries under consideration are developing ones and their economic activity relating to energy intensity is quite high. However, the current results draw our attention to the salient point that the major factors inducing consumption rates should attract more attention from policymakers rather than literarily focusing on the amount of consumption itself. For instance, the high level of energy-intensive commodity consumption in the middle east is mostly made possible and sustained by the ambient of globalization over time as the region continues to open to the outside world. This might as well corroborate the observed overall larger magnitude of the separate impacts of globalization in the region's environmental degradation from carbon emission. Furthermore, globalization may have also contributed to income growth in the region due to the booming tourism industry among other factors like trade and remittances as identified in some recent studies (Khatir et al. 2022; Haouas et al. 2022). Hence, it is not a surprise to see some studies pointing out the environmental demerits of globalization even though it is arguably an important factor for economic prosperity (Erdoğan et al. 2022; Ayobamiji et al. 2022; Onifade et al. 2023a; Ilham et al. 2021).

Furthermore, a unique one-way causal nexus is observed from the energy use to the pollution level from carbon emission. This finding aligns with the stance of some existing studies on the energy use-emission nexus as the general debate on energy consumption, economic growth, and other related issues continue to rise in environmental-related studies (Ali et al. 2022; Onifade et al. 2023b; Adebayo et al. 2022; Duran et al., 2022; Bekun, 2022). With regards to the current study, the observed energy use-emission nexus is attributable to the disproportionate composition of fossil energy in the total energy portfolios of the examined middle eastern countries, and it is known that this region accounts for a lion's share of the global fossil energy resources in terms of the total oil and gas deposit (BP, 2021; Onifade, 2022; Alola et al. 2021). Lastly, income levels granger causes the duo of emissions and globalization levels in the middle east region. This, therefore, implies that there is a dual causal nexus between emission levels and income growth. As such, there is a need for utmost diligence in drafting emission reduction targets and target execution may have to follow carefully designed gradual processes or phases to avoid economic setbacks among these major middle eastern tourist destinations.

## 5 CONCLUSION AND RECOMMENDATIONS

In the current study, the tourism-carbon emission nexus was analyzed from the air transport perspective while essentially incorporating the multifaceted roles of other major factors including globalization, income, and energy utilization. The outputs from the CS-ARDL evaluations using data from 1975 to 2018 indicate that the growth of air transportation was detrimental to the environmental quality of the reviewed major middle eastern tourist destinations. Furthermore, both energy utilization and globalization alongside the level of income expansion also induce environmental degradation in the countries. As such, the overall findings posit salient policy implications for the authorities and stakeholders in the middle eastern countries to take necessary steps toward addressing air transport pollution for regional environmental sustainability.

Even if there is no sufficient clear-cut collective global action to address aviation emissions, the middle eastern authorities can devise region-specific emission compensation laws and schemes while putting in place enforcement taskforces to ensure adequate compliance by commercial transport companies and private aircraft operators alike. Furthermore, the countries also need to encourage research funding for R&D in low-carbon technologies for the aviation industry. In the meantime, while more investment is directed towards low-carbon aviation technologies, the countries can also put in place more regulations like Aviation Fuel Tax to at least discourage the rising trends in private ownership and usage of aircraft as some credible studies have shown that such taxes can be efficient in reducing air transport emission (González & Hosoda, 2016; Fukui & Miyoshi, 2017).

As for the energy consumption component, going by the results, energy use aggravates carbon emissions in the middle east to the detriment of the quality of the environment. This is a sign that the region still needs to work more on diversifying its total energy mix. The majority of these countries are vastly fossil-fuel reliant with fossil energy taking the lion's share of the final primary energy use. Of course, fossil energy resources account for a sizable percentage of these countries' total GDP despite their thriving tourism industry. Hence, it is highly recommended that the countries should come up with a blueprint for the energy transition to renewable start funding and facilitating such an agenda for their environmental protection.

Furthermore, globalization should be exploited for environmental gains rather than allowing external forces to leverage it for the pollution haven agenda in the middle east. Governments need to ensure that they capitalize on the growing level of globalization for the importation of environmentally friendly technologies from abroad. Lastly, even though CO2 is compounding the deteriorating environment in the middle east, authorities must take adequate cautions in drafting and executing emission target plans as there is a minimal indication that carbon emission granger causes income levels. As such, not taking adequate caution in the emission reduction approach may cost the countries some economic losses and perhaps aggravate hardship for the citizenry.

### Limitations and Direction for Future Research

The current study investigates the link between air transportation and the environmental quality level among leading Middle East travel destinations given the booming tourism industry in the region. While conducting the investigation, the study also covered the assessment of the roles of income, energy use, and rising globalization trends in the region. However, future research can build on the established framework in this study in some respects; (i) to begin with, future study can expand the scope considering that the current study is limited to only five of the leading travel destinations. It is also important to note that environmental issues are unfolding matters just as tourism dynamics are continuously revolving. Hence, aside from expansion in data span as time goes by, future research can also incorporate more control factors such as the roles of institutional quality in moderating the established air transport emission nexus in the Middle East region, and similar study can be conducted for other economic blocs around the globe. (ii). In addition, future research can also examing the possibility of exploring the popular Environmental Kuznets Curve (EKC) theory within the developed air transport framework of the study whereby an environmental indicator exist as a function of income mainly alongside other factors.

## Declarations:

**Ethics approval and consent to participate:** NA

**Consent for publication:** NA

**Authors' contributions:** The first author (Stephen Taiwo Onifade) was responsible for the conceptual construction of the study's idea. The first author (Stephen Taiwo Onifade) alongside the second author (Ilham Haouas) handled the introduction and literature sections. Data gathering, preliminary analysis, simulation, interpretation, and policy framework were carried out by the first author, and the general manuscript editing were carried out by both authors.

**Availability of data and materials:** The data for this present study are sourced from the database of the World Development Indicators (WDI, 2021) Available at: https://data.worldbank.org, the KOF Swiss Economic Institute (https://kof.ethz.ch/en/ ), and British petroleum (BP) data available at https://www.bp.com

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# APPENDIX

## Appendix Table 7: Model Causality Exploration

| ***Variables*** | **W-Stat** | | | | | |
|---|---|---|---|---|---|---|
| | ***LnCO₂*** | ***LnAT*** | ***LnGZ*** | ***LnPEC*** | ***LnPY*** | ***Causality Inferences*** |
| ***LnCO₂*** | _ | 3.9327* | 1.3923 | 3.1502 | 3.8123* | $LnCO2 \rightarrow LnAT, LnPY$ |
| ***LnAT*** | 5.3589*** | _ | 2.8742 | 4.1636*** | 4.7600*** | $LnAT \rightarrow LnCO2, LnPEC, LnPY$ |
| **LnGZ** | 5.2682*** | 5.8471*** | _ | 12.062*** | 7.5942*** | $LnGZ \rightarrow LnCO2, LnAT, LnPEC, LnPY$ |
| **LnPEC** | 7.5964*** | 2.5613 | 1.9296 | _ | 3.4021 | $LnPEC \rightarrow LnCO2$ |
| ***LnPY*** | 4.6003** | 2.6061 | 4.2222** | 3.5192 | _ | $LnPY \rightarrow LnCO2, LnGZ$ |

***Source:*** *Author's calculations with special characters ***, **, and * showing significance assessment at 1%, 5%, and 10% levels*

**Appendix Table 8: List of Abbreviations**

| Abbreviations | Full Meanings |
|---|---|
| **APEC countries** | Asia Pacific Economic Cooperation (APEC) countries |
| **OECD countries** | The Organization for Economic Co-operation and Development countries. |
| **CUP-BC and CUP-FM** | Continuously Updated Bias-Corrected (CUP-BC) and Continuously Updated Fully Modified (CUP-FM) methods |
| **AMG** | Augmented Mean Group |
| **ESM** | Earth System Model |
| **SCM** | Simple Climate Model |
| **IRF** | Impulse Response Function |
| **CCEMG** | Common Correlated Effects Mean Group Model |
| **MG** | Mean Group |
| **QARDL** | Quantile Autoregressive Distributed Lag |
| **DCCE** | Dynamic Common Correlated Effect |
| **GMM** | Generalized Method of Moments |
| **ARDL** | Autoregressive Distributed Lag |
| **QR** | Quantile Regression |
| **DOLS** | Dynamic Ordinary Least Squares |
| **VECM** | Vector Error Correction Model |
| **FMOLS** | Fully Modified Ordinary Least Squares |
| **The UK** | The United Kingdom |

| | |
|---|---|
| **The USA** | The United States of America |