IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(6), 56-66.

EJ EconJournals

The Effect of ICT on CO_2 Emissions in the GCC Countries: Does Globalization Matter?

Ebaidalla M. Ebaidalla[1]*, Sana Abusin[2]

[1]Ibn Khaldon Center for Humanities and Social Sciences, Qatar University, P.O. Box. 2713, Doha, Qatar, [2]The Social and Economic Survey Research Institute, Qatar University, P.O. Box 2713, Doha, Qatar. *Email: ebaidalla@qu.edu.qa

Received: 14 July 2022 **Accepted:** 18 October 2022 **DOI:**https://doi.org/10.32479/ijeep.13499

ABSTRACT

Despite the significant impact of information and communication technologies (ICTs) on environment, whether globalization enhances the role of ICT in environmental quality is a question that received limited research attention. This paper examines the impact of ICTs on carbon dioxide (CO_2) emissions in the presence of globalization in the Gulf Cooperation Council (GCC) countries for the period of 1995–2018. The study adopted the mean group (MG) and augmented mean group (AMG) estimation methods to address the problems of cross-sectional dependence and heterogeneity. Unexpectedly, the results of both MG and AMG revealed that the spread of ICT exerts positive and significant impact on CO_2 emissions, implying that ICTs worsening the environment in GCC countries. However, the adverse impact of ICTs on CO_2 emissions can be mitigated through globalization process. Therefore, policy makers in GCC countries should utilize globalization process, adopting advanced energy-saving technologies that reduce energy consumption and improve environmental quality.

Keywords: ICT, Globalization, CO_2 Emissions, MG, AMG, GCC Countries
JEL Classifications: C33, D83, F64, Q43

1. INTRODUCTION

Greenhouse gas (GHG) emissions and climate change are among the most global challenges facing both developing and developed countries. Based on the Kyoto climate protocol in 1997, Paris climate agreement in 2015, and lately the 2021 Glasgow climate conference, governments are exerting tremendous efforts to lessen the carbon dioxide (CO_2) emissions through investment in climate-friendly energy resources. In the light of rapid globalization process and diffusion of information and communication technologies (ICTs) in recent years, a substantial debate has emerged concerning the role of ICT and globalization in reducing energy consumption, and hence mitigating greenhouse gas emissions (Shahbaz et al. 2017; Shahnazi and Shabani 2019; Usman et al. 2021).

The relationship between ICTs and environment quality has been studied extensively in the last decade, although, the empirical findings have been mixed. Some empirical studies documented that information and communication technology can play important role in reducing energy consumption and pollution intensities in production process, leading to more efficient economic growth (Toffel and Horvath 2004; Wang et al. 2015). In addition, ICT application may help in mitigating CO_2 emissions through utilization of energy-efficient technology across economic sectors (Usman et al. 2021; Godil et al 2020). However, some researchers argue that technology may hamper environmental quality through several channels. For instance, the adoption of ICT applications can reduce the prices of goods and services produced, therefore promotes economic activities, and industrialization, which may increase energy consumption and carbon emissions (Haftu 2019; Raheem et al. 2020; Ulucak et al. 2020).

Incidentally, the expansion of globalization activities in recent decades has stimulated the role of ICT in all economic activities

(Ulucak et al. 2020; Ahmed et al. 2021). For example, the integration in international markets as well as trade cooperation encourage ICT adoption in developing regions via technology transfer (Ulucak et al. 2020). However, despite the favorable influence of globalization on ICT penetration (Shahbaz et al. 2017; Haseeb et al. 2018), there is a vast debate about the harmful and beneficial environmental effects of globalization through ICT development, a matter should be considered as a double-edged axe (Shahbaz et al. 2017; Wang et al. 2020). From optimistic side, globalization can mitigate CO_2 emissions through adoption of advanced energy-saving technology, which reduces energy consumption and improves environmental quality (Shahbaz et al., 2015). Whereas, another group of researchers argued that globalization may stimulate adoption of ICT equipment, which in turn stimulates energy usage, e-waste and then greenhouse gas emissions (Salahuddin et al. 2016; Danish et al. 2018). Therefore, a wise management of global market integration can lead to better utilization of energy efficient ICT equipment for the benefit of environment.

Against the above backdrop, this paper aims to examine the nexus between ICT and CO_2 emissions in the Gulf Cooperation Council (GCC) countries, namely, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The study also investigates whether globalization process enhances or depresses the impact of ICT on CO_2 emissions, using the mean group (MG) and augmented mean group (AMG) long-run estimators. In other words, we examine the impact of interaction between ICT and globalization on CO_2 emissions.

The novelty of this study is three-fold. First, to the best of our knowledge, this study is the first attempt to examine the impact of ICTs and globalization on CO_2 emissions in GCC countries. This would reveal important policy implications, as GCC countries is an oil abundant region, with increasing trend of carbon dioxide emissions, originated primarily form intensive energy consumption (Bekhet et al. 2017). In addition, the GCC countries experienced a high trend of ICT penetration with remarkable economic growth during the last three decades (Wiseman and Anderson 2012). Second, the study examines the interaction impacts between each globalization dimension and ICT on CO_2 emissions. Thus, we estimated four specifications to reflect the main dimensions of globalization, namely, economic, social, political, and overall globalization, to assess their effects on the link between ICT and CO_2 emissions in GCC countries. This would be important theoretical contribution from this study to literature on nexus between ICT and carbon dioxin emissions. Third, unlike most of the prior research in GCC countries, this study addresses the issues of cross-sectional dependence and heterogeneity in the panel data, using mean group (MG) and augmented mean group (AMG) methods of long-run estimates.

The remainder of this paper is structured as follows. Section 2 outlines the state of ICT and CO_2 emissions in GCC countries. Section 3 reviews the literature about the nexus between ICT, globalization and CO_2 emissions. While sections 4 describes methodology and data sources, Section 5 presents the empirical results and discussions. Finally, sections 6 concludes with some policy recommendations and area for future research.

2. ICT PENETRATION AND CO_2 EMISSIONS IN GCC COUNTRIES: AN OVERVIEW

The Gulf states are among the most energy suppliers in the world, possessing about one third of the proven world crude oil reserves and about one fifth of the world natural gas reserves (BP 2020). The recent statistics indicate that the total oil exports of GCC countries in 2020 was about 13 million barrels per day, representing approximately 18% of total world production (BP 2020). The huge volume of oil exports is reflected in the high per capita GDP and demand for technology and luxury goods. The region also benefitted from the rapid process of global market integration and use of information and communication technology (ICT). GCC ranks among the top regions in terms of using ICT facilitates in the world (Wiseman and Anderson 2012). Figure 1 shows that during the last three decades, GCC countries have witnessed a remarkable expansion in the number of mobile subscribers and internet users.

Figure 1 also points out that the mobile subscriptions in all GCC countries have increased sharply after 2000s, benefited from the global communication revolution. As can be read from the figure, the number of mobile cellular subscribers in GCC increased from about six subscribers in 1995 to more than 200 per each 100 persons in 2015, meaning that each person holds more than two mobile lines on average, particularly in Bahrain, Kuwait and the United Arab Emirates (UAE). In the same vein, the percentage of internet users out of the total population increased sharply in all GCC countries. The figure shows that about 100% of population uses internet, indicating that all inhabitants of GCC utilized the internet facilities in the recent years. The figure also shows that the rate of using ICT in GCC countries is higher than the world average, which is about 60% in 2020 (World Bank, 2020).

Regarding the environment quality, Figure 2 presents the trend of carbon dioxide emissions measured by the metric tons per capita. The figure shows that the level of CO_2 emissions in GCC courtiers is very high compared to the world average (World Bank, 2020). The Figure shows that the level of emissions vary obviously across countries. Qatar ranks first in terms of CO_2 emissions in GCC countries, followed by Kuwait, Bahrain and UAE, respectively. However, Saudi Arabia and Oman have the lowest level of CO_2 emissions in the region. This can be justified by the big number of population in Saudi Arabia and the low amount of oil production in Oman, compared to other GCC states. The high level of emissions in GCC can be attributed to the high gross domestic product (GDP) per capita, which creates an intensive demand for energy, particularly fossil fuel (Bekhet et al., 2017). Indeed, the intensive use of domestic fossil fuels in transportation, electricity generation and industrial sector is the main driver of carbon dioxide emissions in the Arab Gulf countries. Moreover, the region lacks an efficient carbon-reduction technologies as well as substitute sources of energy, rendering GCC countries expose to high CO_2 emissions (Bekhet et al., 2017).

In the light of intensive use of non-renewable energy and ICT facilities in the context of rapid globalization process as well as high per capita income, the link between ICT, globalization

Figure 1: Trends of mobile phone and broadband subscriptions in GCC countries (1995-2018)

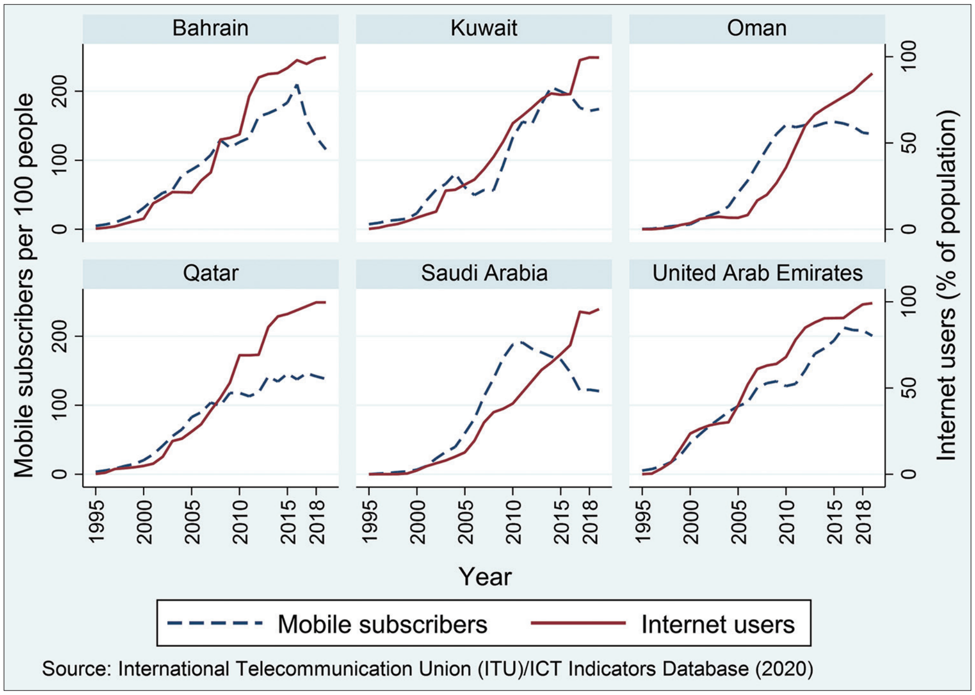
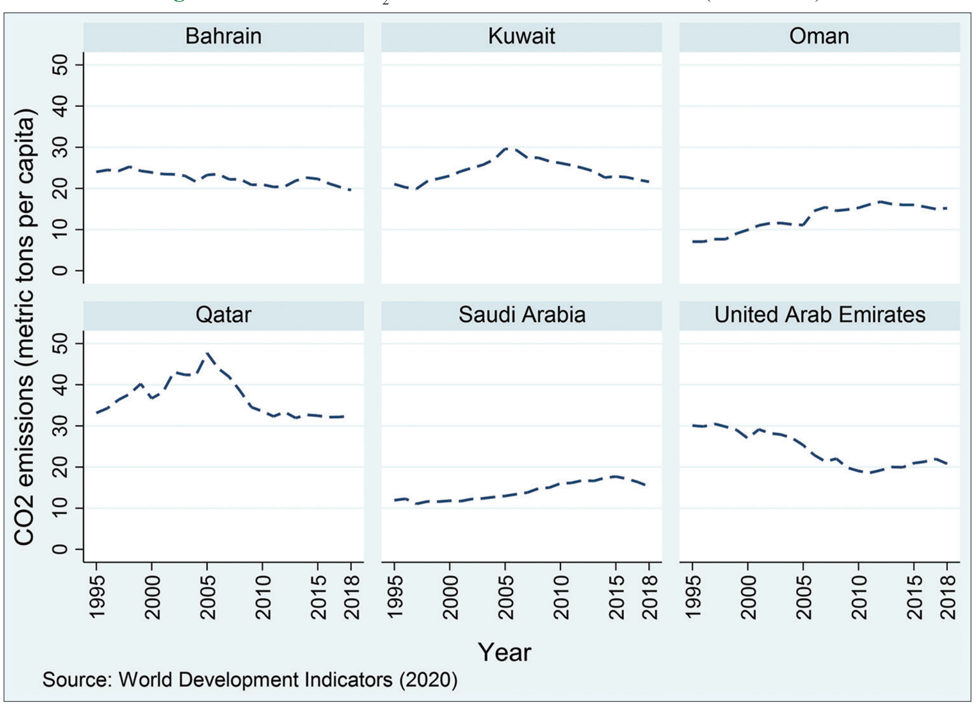


Figure 2: Trends of CO_2 emissions in the GCC countries (1995-2018)



and environmental degradation would be interesting, relevant and timely research question for GCC countries. Therefore, this study fills an important gap in literature on ICT-CO2 emissions nexus, using MG and AMG techniques robust to heterogeneity and cross-sectional dependence

3. A BRIEF LITERATURE REVIEW

Due to rapid increase in globalization process, information technologies and global carbon emissions across regions, the nexus between ICTs, globalization and CO_2 emissions has gained a considerable attention from researchers in recent years. In this section, we briefly review the exiting literature related to (1) the link between ICT and CO_2 emissions and (2) the impact of globalization on CO_2 emissions.

3.1. ICT and CO_2 Emissions

Despite the sizable research attention concerning the link between ICT and carbon dioxide emissions, the evidence on this issue is inconclusive and varies across countries and regions. A large body of research documented that ICT development can play a potential role in mitigating CO_2 emissions via several channels. First, adoption of ICT in production field can improve energy performance, hence reducing energy consumption and carbon dioxide emissions (Shahnazi and Shabani, 2019; Godil et al., 2020). Second, ICTs forms, such as mobile phones, Internet and satellites can improve household energy use decision and individual environmental conservation behavior (Bastida et al., 2019). Third, ICTs facilities like internet and mobile phone applications can enhance the dissemination of knowledge regarding the environmental pollution and strengthen people's environmental awareness, which is in turn promotes their knowledge regarding the environmental protection (Chen et al., 2019). Fourth, the spread of ICT promotes trade of goods and services, hence enhances enterprise's productivity and creates new jobs (Cardona et al., 2013; Niebel, 2018).

Most of existing empirical studies support the claim that ICT significantly reduces CO_2 emissions (Baptista et al., 2012; Wang et al., 2015; Zhang and Liu, 2015; Ahmed et al., 2021). For instance, Monzon et al. (2017) examined the impact of ICT on greenhouse gas emissions generated by the road transportation sectors in Madrid, Spain; found that ICT mitigates CO_2 emissions. Asongu (2018) investigated the role of ICT and globalization in reducing CO_2 emissions in 44 Sub-Saharan African countries over the period of 2000–2012. The study revealed that ICT plays a significant role in reducing carbon emissions. Likewise, Chen et al. (2019) examined the impact of ICT on CO_2 emission using the Chinese provincial panel data, covering the period (2001–2016). The paper found that the impact of both internet and mobile phone have negative and significant impact on CO_2 emission intensity over all quantiles, particularly at the national level. Recently, Ulucak et al. (2020) examined the link between ICT diffusion and CO_2 emissions for the BRICS economies (Brazil, Russia, India, China, and South Africa), during the period of 1990-2015. The results revealed that ICT has negative and significant impact on CO_2 emissions in BRICS countries.

In contrast, a another group of empirical studies reported that ICT penetration increases energy consumption, particularly electricity, and then degrades environment, since a sizable amount of electricity generation relies on non-renewable sources such as fossil oil and coal, which increases the emission of polluting gases (Lee and Brahmasrene, 2014; Chen et al. 2019). In this regard, Lee and Brahmasrene 2014 examined the link between ICT, CO_2 emissions and economic growth, using a panel annual data for nine ASEAN countries, over the period from 1991 to 2009. The results revealed that ICT has positive and significant effects on CO_2 emissions. Salahuddin et al. (2016) also investigated the effect of ICT on CO_2 emissions in OECD countries for the period (1991–2012). The study found that ICT has positive and significant impact on CO_2 emissions. Likewise, Danish et al. (2018) examined the effects of ICTs on environmental quality in the Next Eleven (N-11) countries for the period (1990-2015). Using MG and AMG estimation techniques their results revealed that ICT has positive and significant effect on CO_2 emissions.

3.2. Globalization and CO_2 Emissions

Despite the growing attention among researchers toward the effect of globalization process on environment quality, the interaction effect of ICT and globalization (i.e. interaction between ICT and globalization) has received limited attention. However, most of the existing research focuses on the link between globalization and CO_2 emissions, with inconclusive evidence. A growing body of empirical studies indicates that globalization destroy the natural resources and escalate carbon dioxide emissions (Shahbaz et al., 2018; Wang et al., 2020). For instance, Shahbaz et al. (2018) examined the link between globalization and CO_2 emissions over the period (1970–2014) in Japan. Their study found that globalization process increases carbon emissions. Likewise, Kalayci and Hayaloğlu (2019) investigated the impact of globalization on CO_2 emissions in the NAFTA countries using panel data for the period (1990–2015). Their findings revealed a positive and significant association between economic globalization and CO_2 emissions. Wang et al. (2020) examined the impact of economic globalization on CO_2 emissions for G7 countries over the period of 1996–2017, found that economic globalization increases carbon emissions. Recently, Pata (2021) studied the link between globalization and carbon emissions in BRIC countries for the period 1971–2016. Using ARDL approach the paper indicated that globalization stimulates CO_2 emissions in BRIC countries.

However, a considerable body of literature found that globalization has beneficial impact on environment quality (Haseeb et al., 2018; Ahmed and Phong, 2021). For instance, Shahbaz et al. (2015) examined the impact of globalization on CO_2 emissions over the period of 1970–2012 in India. The results revealed that the overall index of globalization and sub-indexes (i.e. economic, social, and political globalization) mitigate carbon dioxide emissions in India. In another study, Shahbaz et al. (2017) found that the general index and sub-indices of globalization have negative and significant impact on CO_2 emissions in China. Moreover, Haseeb et al. (2018) examined the nexus between financial development, globalization, economic growth, and energy consumption on CO_2 emissions over the time 1996–2014 in BRICS economies. The paper found that globalization mitigates carbon dioxide emissions. Recently, Ahmed and Phong (2021) examined the link between globalization and CO_2 emissions in the ASEAN-6 countries for the period of 1997–2017. The results revealed that globalization contributes to improving environmental quality by mitigating CO2 emissions.

Despite the growing empirical research that deal with the nexus between ICT and CO_2 emissions, most prior research did not take into account the role of globalization in this association in the long run. Moreover, most of existing research focused on developed and emerging countries with a little attention has been paid to this topic in developing countries, especially GCC countries, a region with abundant non-renewable energy resources and remarkable ICT diffusion. Furthermore, most of prior research do not consider the issue of cross-sectional dependence and heterogeneity in the data, leading to biased and inconclusive evidence. Thus, this study contributes to literature on CO_2 emissions-ICT nexus, emphasizing on whether globalization enhances the effect of ICTs on CO_2 emissions in GCC countries in the long-run.

4. DATA AND METHODOLOGY

4.1. Model Specification and Data Source

To examine the nexus between ICT, globalization and CO_2 emissions, the study adopts econometrics method based on panel data techniques. Following the existing literature on the CO_2 emissions (e.g. Ulucak and Bilgili, 2018; Dkhili, 2022), our econometric model can be specified as follows:

$$CO2_{it} = \alpha_1 X_{it} + \alpha_2 ICT_{it} + \varepsilon_{it} \quad (1)$$

Where CO_2 represents the carbon dioxide emissions metric per capita in country i at time t; X is a vector of the control variables; ICT is the ICT index and ε_{it} is the error term. The control variables include the following: real GDP per capita (GDP), trade openness (TRD) measured by total exports and imports as a percentage of GDP, financial development (FD) measured by domestic credit to private sector as ratio of GDP; and electric power consumption (EC) measured by kWh per capita.

In the second stage, we examine the indirect effect of ICT on environmental degradation through globalization process. We use the interaction terms between ICT and globalization indicators (GLOB ×ICT). Thus, estuation 1 is modified to capture the impact of globalization, which can be expressed as follows:

$$CO2_{it} = \beta_1 X_{it} + \beta_2 GLOB_{it} \times ICT_{it} + \varepsilon_{it} \quad (2)$$

Where GLOB×ICT is the interaction term between ICT and globalization in order to scrutinize whether globalization enhances the effect of ICT on CO_2 emissions. We employ four interactions, reflecting the main globalization indices, namely, overall, economic, social, and political globalization. All variables are used in natural logarithm form.

4.1.1. Key independent variables

4.1.1.1. Information and communication technology (ICT)

This is the key independent variable, which is an index constructed by the principal component analysis (PCA) from three ICT variables, namely, fixed telephone subscriptions, mobile cellular subscriptions, and individual internet users. The data on these three indicators are calculated in terms of per 100 people. The PCA allows us to construct an index by combining the concerned variables (i.e, ICT indicators) into a single index based on their variance (Latif et al., 2018; Ahmed et al., 2021). PCA also is considered an appropriate method and has been used widely in previous empirical studies on ICT-emissions nexus (e.g. Khan et al., 2020; Ulucak et al., 2020; Ahmed and Hong, 2021).

4.1.1.2. Globalization

There are several globalization measures have been used in literature, including international trade, foreign direct investment (FDI) and the constructed indices such as Maastricht Globalisation Index, G-Index and KOF index. However, this study uses the KOF index that introduced by Dreher (2006) at the KOF Swiss Economic Institute and has been updated by Dreher et al. (2008) and Gygli et al. (2018). The KOF globalization index covers 43 variables including, economic, financial, social, cultural, and political globalization aspects, for about 200 countries from 1970 to 2019. This study utilizes four indices, namely, overall, economic, social, and political globalization. The KOF index of globalization has been widely used in literature on ICT-emissions nexus (e.g. Ulucak et al., 2020; Wang et al., 2020).

The study uses annual data over the period (1995-2018) for the six GCC countries, namely, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The data about ICT indicators is sourced from the World Telecommunication/ ICT Indicators Database. While the data about GDP per capita, trade, financial development and electricity consumption are gathered from the World Bank development indicators, the data about CO_2 emissions is sourced from the International Energy Agency (IEA). Finally, the globalization index is gathered from the Swiss Economic Institute database. The descriptive statistics and correlation matrix of the variables used in the analysis are presented in the Appendix.

4.2. Diagnostic Tests

4.2.1. Cross-sectional dependence test

Before proceeding to test the unit root properties of our variables, we check the presence of cross-sectional dependence (CD) in the panel dataset. This is because there is possible of presence of the CD issue among our sample (i.e., GCC countries), since these countries share many common characteristics and are connected through several ways such as, borders, language, technology, investment spillover, and trade agreements. Overlooking interdependence among panel data would leads to misleading and biased results (Pesaran, 2007). Moreover, checking CD in the panel dataset is very crucial to choose appropriate method of the analysis. Therefore, we apply two CD tests namely Breusch-Pagan LM, and Pesaran Scaled LM. These methods have been used intensively in literature to check whether the cross-sectional dependence exists in panel data context. The results of Breusch-Pagan LM and Pesaran Scaled LM test in Table 1 are significant for most variables, implying that there is cross-section dependence among variables understudy. Thus, to avoid inconsistency, methods that are robust to cross-sectional dependence will be employed.

4.2.2. Slope heterogeneity test

It is also important to check the parameter heterogeneity in our data, since ignorance of heterogeneity may results in biased estimation results and leading to misleading test of hypotheses. We test the slope homogeneity by using Pesaran and Yamagata' (2008) test. The results of the slope homogeneity test in Table 2 indicate that the null hypothesis of slope homogeneity is rejected, confirming the presence of heterogeneity.

4.2.3. Unit root test

Having the presence of cross-section dependence among the concerned variables, adopting the first generation unit root tests like ADF, Levin-Lin-Chu (2002) and Im-Pesaran-Shin (2003) test may results in unreliable findings. Therefore, we resort to the second-generation unit root tests such as, augmented cross-sectional IPS (CIPS) and Cross-sectional Augmented Dickey-Fuller (CADF). According to Pesaran (2007), these stationarity test can be specified as follows:

Table 1: Results of cross-sectional dependence test

Variable	$LnCO_2$	lnGDP	LnTR	LnFD	LnEC	LnICT
Breusch-Pagan LM	32.76*** (0.005)	58.04*** (0.000)	34.75*** (0.002)	43.46*** (0.000)	58.35*** (0.000)	29.26** (0.014)
Pesaran Scaled LM	−1.31 (0.191)	−2.03** (0.043)	9.60*** (0.000)	14.83*** (0.000)	3.89*** (0.000)	18.58*** (0.000)

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

$$\Delta y_{it} = \beta_i + \varphi_i y_{i,t-1} + \delta_i \bar{y}_{t-1} + \sum_{j=0}^{n} e_{it} \Delta \bar{y}_{it-1} + \sum_{j=0}^{n} d_{it} \Delta y_{it-1} + \mu_{it} \quad (3)$$

Where Δ represents the difference operator, y_{it} denotes the concerned variable, β refers to individual intercept and μ_{it} denotes the country-specific effects. y is the average of entire observations (N) at time t, while n denotes the lag order. The null hypothesis (H_0) for both CIPS and CADF test is that all individuals in data series are non-stationary, while the alternative hypothesis (H_1) is that all individuals does not have a unit root.

The results of both CIPS and CADF tests presented in Table 3 indicate that all the variables are nonstationary at the level, except globalization indices. However, testing stationary at first difference all variables turn to be stationary. Thus, we conclude that all the variables are integrated of order one I(1).

4.2.4. Panel cointegration test

After determining the integration order of the variables, we implement the cointegration test to check whether the long-run equilibrium relationship exists among the variables under study. Having our model suffers from cross-sectional independence and slope heterogeneity, we relied on the cointegration test developed by Wsterlund (2008). The results of test by bootstrap method are presented in Table 4 below. The results indicate that two groups of Westerlund statistics reject the null hypothesis of no cointegration, supporting the presence of long-run equilibrium relationship between CO_2 emissions and the explanatory variables (i.e., GDP, trade, financial development, electricity consumption and ICT).

For the purpose of robustness check and comparison, we also tested the conitgration among the variables using the Pedroni (1999) test. The results of Pedroni test in Table 5 confirms the cointegration among the variables under study.

Table 2: The Pesaran–Yamagata homogeneity test results

Test	Value	Prob.
Delta tilde	5.159***	0.000
Adjusted Delta tilde	6.384***	0.000

***Indicate significance at the 1% level

Table 3: Results of unit root test

Variable	CIPS		CADF	
	Level	First differences	Level	First differences
CO2	–1.858	–3.509***	–1.463	–4.077***
GDP	–1.271	–2.858***	–1.266	–3.091**
TRD	–1.484	–4.483***	–2.324	–4.697***
FD	–1.900	–2.667***	0.534	–3.702***
EC	–0.367	–3.436***	–2.079	–4.016***
ICT	–1.286	–2.865***	–2.127	–3.298***
Wh_glob	–3.095***	–4.223***	–2.872*	–3.366***
EC_glob	–5.020***	–5.816***	–3.416***	–4.743***
SO_glob	–4.970***	–6.190***	–3.746***	–5.315***
PO_glob	–4.536***	–6.108***	–3.442***	–5.043***

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

Table 4: Results of Westerlund's (2008) cointegration test

Statistic	Value	Z	P-value	Robust P value
G_t	–3.357**	–2.828	0.434	0.053
G_a	–5.877*	2.703	0.997	0.083
P_t	–5.123	0.638	0.738	0.307
P_a	–4.042	2.138	0.984	0.470

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

Table 5: Results of Pedroni cointegration test

	Statistic	P-value
Modified Phillips-Perron t	2.2465**	0.0123
Phillips-Perron t	–2.3383***	0.0097
Augmented Dickey-Fuller t	–3.1063***	0.0009

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

5. EMPIRICAL RESULTS AND DISCUSSION

5.1. The Results of Mean Group Estimation

After confirming the cointegration among the variables understudy, we estimate the long-run parameters. Most of prior studies have adopted the fully modified ordinary least square (FMOLS) and the dynamic ordinary least square (DOLS) methods for long-run estimation. However, these methods does not address the issue of cross-sectional dependence and slope heterogeneity in the data. Moreover, Since our analysis covers only six countries with a relatively long time period, the conventional method of panel data such as the fixed and random effects models may results in biased results (Sarafidis et al., 2009). Having our model suffers from cross-sectional dependence and heterogeneity, therefore, we adopt the MG and AMG techniques. These method accounts for cross-sectional dependence and allows for heterogeneous slope coefficients across panel members. The results of MG and AMG are presented in Table 6.

Table 6 indicates that most of the explanatory variables are statistically significant. Specifically, the coefficient of trade is negative and statistically significant in both MG and AMG model, implying that trade openness mitigate CO_2 emissions in GCC countries. This finding corresponds to many previous studies (e.g. Dogan and Seker, 2016; Sohag et al., 2017). The impact of financial development on CO_2 emissions is negative in MG model, while it is not significant in the AMG model. The results also show that electricity consumption exerts positive and significant impact on CO_2 emissions in GCC countries, supporting the results of Shahbaz et al. (2018), Le and Zaidi et al. (2019) and Ahmed and Phong (2021). This outcome is expected given the high-energy consumption in the GCC countries, as the region relies heavily on non-renewable energy, particularly the fossil fuel (Bekhet et al., 2017). This result also confirms evidence reported by many previous empirical studies in GCC countries such as Salahuddin and Gow (2014) and Jammazi and Aloui (2015).

Regarding the direct environmental impact of ICT, the results in Table 6 reveal that the coefficient of ICT is positive and statistically significant in both MG and AMG model. That is, an increase in ICT index by 1%, the level of CO_2 emissions increases by 0.23% and 21% according to MG and AMG specification, respectively. This suggests that ICT adversely affect environment (increase the level of carbon emissions) in GCC countries. This result can be justified by high and inefficient energy consumption in these countries. In other words, due to high income, there is intensive use of ICT equipment, which may results in high-energy use and e-waste; this is evident by the high rate of e-waste and energy consumption in GCC countries (Bekhet et al., 2017; Rene et al., 2021). This result is consistent with the study of Danish et al. (2018) and Salahuddin et al. (2016), which revealed a positive association between ICTs and CO_2 emissions in the emerging and OECD countries, respectively. However, this finding is inconsistent with the studies of Asongu (2018), Haseeb et al. (2019) and Ahmed and Phong (2021). Thus, having the rapid increase in ICT applications in GCC countries, policy measures that encourage adoption of energy-efficient ICT equipment should be adopted.

Table 6: The direct effects of ICT on CO_2 emissions-MG and AMG estimation results

Variable	MG		AMG	
	Coefficient	Prob.	Coefficient	Prob.
lnGDP	0.0799	0.640	-0.0811	0.717
lnTRD	–0.2384***	0.003	–0.2372***	0.002
lnFD	–0.0833**	0.035	–0.0542	0.390
lnEC	0.4821**	0.042	0.3542*	0.075
lnICT	0.2306**	0.011	0.2139***	0.001
Constant	0.8306	0.835	1.8474	0.689
Wald chi2	19.81		870.03	
Prob > chi2	0.001		0.000	

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

5.2. Effect of Globalization on the Relationship Between ICT and CO_2 Emissions

To examine the association between ICT and CO_2 emissions in the presence of globalization, we estimated equation 2 using the interaction term (GLOB×ICT). The model is estimated for four specifications representing our globalization indices namely, overall, economic, social and political globalization. The results of MG and AMG estimation are presented in Table 7 indicate that the coefficients of interaction terms between each dimension of globalization and ICT (i.e., $GLOB_{econ}$ × ICT, $GLOB_{soc}$ × ICT, $GLOB_{pol}$ × ICT, $GLOB_{overall}$ × ICT) are positive and statistically significant in both MG and AMG model. This implies that in the presence of globalization, ICT positively increases environmental degradation in GCC countries. This finding also support the results of direct effect in Table 6. However, the coefficients of interaction terms are smaller compared to the direct coefficients of ICT reported in the baseline model (i,e., Table 6). This means that the harmful impact of ICT on environment can be mitigated through the expansion of globalization process.

5.3. Dumitrescu and Hurlin Panel Causality Test

Finally, to understand the causal relationships between the study variables, we adopted the Dumitrescu and Hurlin (2012) panel Granger causality test. The DH causality test addresses the heterogeneity in the time series panel data, and estimates distinct regression models for every cross-section dataset to examine causality. The DH causality test also has advantage of producing

Table 7: The indirect effect of ICT on environmental degradation through globalization

Variable	MG				AMG			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
lnGDP	–0.116	–0.0769	–0.0933	–0.0711	–0.115	–0.0822	–0.114	–0.0969
	(0.173)	(0.182)	(0.172)	(0.171)	(0.225)	(0.240)	(0.236)	(0.227)
lnTR	–0.24***	–0.206**	–0.157*	–0.113	–0.245***	–0.197*	–0.151**	–0.132
	(0.0814)	(0.097)	(0.094)	(0.110)	(0.0791)	(0.104)	(0.0720)	(0.0886)
lnFD	–0.093**	–0.0766*	–0.0338	–0.0134	–0.0615	–0.0469	–0.00839	0.000394
	(0.0426)	(0.0454)	(0.0607)	(0.0806)	(0.0665)	(0.0661)	(0.0640)	(0.0735)
lnEC	0.504**	0.459*	0.554***	0.542**	0.370	0.302	0.398*	0.385
	(0.242)	(0.249)	(0.213)	(0.232)	(0.265)	(0.299)	(0.238)	(0.267)
Constant	1.657	0.892	0.292	–0.234	2.657	2.249	1.987	1.705
	(4.053)	(4.000)	(4.259)	(4.378)	(4.725)	(4.692)	(5.134)	(4.760)
$GLOB_{econ}$ × ICT	0.0531**				0.0496***			
	(0.0209)				(0.0150)			
$GLOB_{soc}$ × ICT		0.0487**				0.040***		
		(0.0219)				(0.0132)		
$GLOB_{pol}$ × ICT			0.0344**				0.030***	
			(0.0137)				(0.008)	
$GLOB_{overall}$ × ICT				0.0235*				0.019**
				(0.012)				(0.009)
Wald chi2	18.37	257.07	100.53	470.63	792.34	36.38	162.03	108.7
Prob >chi2	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively reliable results in the presence of CD and is consistent, as can be applied in case of both T >N and N > T samples.

The results of HD causality test are presented in Table 8. The results indicate that all the variables Granger cause CO_2 emissions. This result supports the conintegration test and the long-run estimates of MG and AMG. This also implies that all explanatory variables are associated with CO_2 emissions. In addition, the results show that there is a bidirectional causality between CO_2 emissions and other variables, except electricity consumption and ICT. Moreover, the results indicate a bidirectional causality between per capita GDP on one hand and other variables on the other hand, implying a significant association between income level and macroeconomic variables.

The appropriate lag length is chosen based on Schwarz information criterion.

The causality results also reveal that ICT Granger cause CO_2 emissions, supporting the results of Ahmed et al. (2021). The results show that there is a bidirectional causality between electricity consumption and ICT, suggesting that the diffusion of ICT stimulate energy usage and vice versa in GCC. These results signify the crucial role of ICT on economic variables as well as environmental quality in GCC countries. This result is consistent with the findings of a number of prior research on ICT-emissions nexus (e.g. Ahmed and Phong, 2020; Ulucak et al., 2020; Ahmed et al., 2021).

Table 8: Results of Dumitrescu and Hurlin (2012) heterogeneous panel causality test

Null hypothesis (does not cause)	W-stat	P-value
ln CO_2 does not cause lnGDP	4.458***	(0.000)
lnGDP does not cause ln CO_2	6.501***	(0.000)
ln CO_2 does not cause lnTRD	5.078***	(0.000)
lnTRD does not cause LnCO_2	3.479***	(0.000)
lnCO_2 does not cause lnFD	15.678***	(0.000
lnFD does not cause lnCO_2	3.098***	(0.001)
lnCO_2 does not cause lnEC	1.285	(0.198)
lnEC does not cause lnCO_2	2.334**	(0.019)
lnCO_2 does not cause lnICT	19.541***	(0. 000)
lnICT does not cause lnCO_2	1.689 *	(0.091)
lnGDP does not cause lnTRD	5.242***	(0.000)
lnTRD does not cause lnGDP	5.736**	(0.000)
lnGDP does not cause lnFD	2.607***	(0.009)
lnEC does not cause lnGDP	2.920***	(0.003)
lnGDP does not cause lnEC	1.854**	(0.036)
lnEC does not cause lnGDP	3.590***	(0.000)
lnGDP does not cause lnICT	1.518	(0.128)
lnICT does not cause lnGDP	8.203***	(0.000)
lnTRD does not cause lnFD	4.690***	(0.000)
lnFD does not cause lnTRD	0.693	(0.487)
lnTRD does not cause lnEC	0.284	(0.776)
lnEC does not cause lnTRD	1.66*	(0.096)
lnTRD does not cause lnICT	1.4863	(0.137)
lnICT does not cause lnTRD	3.435***	(0.000)
lnFD does not cause lnEC	2.911***	(0.003)
lnEC does not cause lnFD	3.173***	(0.001)
lnFD does not cause lnICT	2.904 ***	(0.003)
lnICT does not cause lnFD	2.760***	(0.005)
lnEC does not cause lnICT	5.291***	(0.000)
lnICT does not cause lnEC	5.713***	(0.000)

***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

6. CONCLUSION AND POLICY RECOMMENDATIONS

Despite the significant role of ICT in all aspects of modern economies, the environmental impact of ICT and globalization received limited research attention. This study investigates the impact of ICT and globalization on CO_2 emissions in GCC countries, using the data from 1995 to 2018. To address the problems of cross-sectional dependence and heterogeneity, the study adopted the mean groups (MG) and augmented mean group (AMG) estimators of long-run relationship. The analysis used the second-generation unit root and cointegration tests including Westerlund (2008) and Pedroni cointegration tests. To examine the long-run causal effect between the variables, we adopted the Dumitrescu-Hurlin (DH) panel causality test.

The empirical results revealed that there is a long-run relationship between the variables under study. The long-run estimation results of MG and AMG methods indicated that ICT has a positive and significant impact on CO_2 emissions, implying that ICT worsen environmental quality in the GCC countries. Interestingly, the interaction effect of ICT and globalization indices (GLOB×ICT) also is positive and significant across all globalization dimensions (overall, economic, social, political globalization). However, the effect of interaction between ICT and globalization is smaller than the direct impact of ICT, suggesting that the adverse environmental impact of ICT can be mitigated by globalization process. Moreover, the results of causality test indicated that all explanatory variables Granger cause CO_2 emissions. Specifically, the results show that ICT Granger cause CO_2 emissions. In addition, there is unidirectional causality runs from all variables to CO_2 emissions. The presence of causality between the variables confirms the long-run interaction between these variables.

The above findings have many policy implications and relevance for GCC countries. First and foremost, globalization and international market integration can accelerate adoption of and energy-efficient technology, which can lessen the energy consumption and then mitigate the environmental degradation. Therefore, policy makers in GCC countries need to exert more efforts to enhance globalization process through trade integration and technology spillover. Moreover, investment in green ICT projects needs to be encouraged to enhance the efficient use of energy and improving environment quality in GCC. Moreover, extra attention should be given to control the inefficient use of ICT in these countries. Furthermore, regional cooperation in trade and technology within and across the GCC member states need to be strengthened for sustainable environment. Furthermore, globalization and energy consumption should be at the top of policy agenda in GCC countries in order to achieve sustainable environmental quality in the long run.

Finally, to complete the view on the relationship between ICT, globalization and environmental quality, the study suggests several avenues for future research on this issue. First, an empirical study needs to be conducted to examine the channel through which ICT influence environment quality. Second, it would be useful to investigate the environmental impact of ICT, focusing on each ICT facility such as internet and mobile phone applications. Finally, a study to investigate the link between each globalization component (i.e., economic, social and political globalization) and environmental degradation would be useful.

7. DATA AVAILABILITY STATEMENT

The datasets used in this study are available at the following link: https://figshare.com/s/32f3e738612232085d1a

REFERENCES

Ahmed, Z., Nathaniel, S.P., Shahbaz, M. (2021), The criticality of information and communication technology and human capital in environmental sustainability: Evidence from Latin American and Caribbean countries. Journal of Cleaner Production, 286, 125529.

Ahmed, Z., Phong, L. (2021), Linking information communication technology, trade globalization index, and CO 2 emissions: Evidence from advanced panel techniques. Environmental Science and Pollution Research, 28(7), 8770-8781.

Asongu, S.A. (2018), CO_2 emission thresholds for inclusive human development in sub-Saharan Africa. Environmental Science and Pollution Research, 25(26), 26005-26019.

Baptista, P.C., Azevedo, I.L., Farias, T.L. (2012), ICT solutions in transportation systems: Estimating the benefits and environmental impacts in the Lisbon. Procedia-Social and Behavioral Sciences, 54, 716-725.

Bastida, L., Cohen, J.J., Kollmann, A., Moya, A., Reichl, J. (2019), Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming. Renewable and Sustainable Energy Reviews, 103, 455-462.

Bekhet, H.A., Matar, A., Yasmin, T. (2017), CO_2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. Renewable and Sustainable Energy Reviews, 70, 117-132.

BP. (2020), BP Statistical Review of World Energy. 69th ed. London: BP. Available from: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-20209-full-report.pdf

Cardona, M., Kretschmer, T., Strobel, T. (2013), ICT and productivity: Conclusions from the empirical literature. Information Economics and Policy, 25(3), 109-125.

Chen, X., Gong, X., Li, D., Zhang, J. (2019), Can information and communication technology reduce CO_2 emission? A quantile regression analysis. Environmental Science and Pollution Research, 26(32), 32977-32992.

Danish, K., Khan, N., Baloch, M.A., Saud, S., Fatima, T. (2018), The effect of ICT on CO_2 emissions in emerging economies: Does the level of income matters? Environmental Science and Pollution Research, 25(23), 22850-22860.

Dkhili, H. (2022), Investigating the theory of environmental kuznets curve (EKC) in MENA countries. Journal of the Knowledge Economy.

Dogan, E., Seker, F. (2016), An investigation on the determinants of carbon emissions for OECD countries: Empirical evidence from panel models robust to heterogeneity and cross-sectional dependence. Environmental Science and Pollution Research, 23(14), 14646-14655.

Dreher, A. (2006), Does globalization affect growth? Evidence from a new index of globalization. Applied economics, 38(10), 1091-1110.

Dreher, A., Gaston, N., Martens, P. (2008), Measuring Globalization: Gauging its Consequences. New York: Springer.

Dumitrescu, E.I., Hurlin, C. (2012), Testing for Granger non-causality in heterogeneous panels. Economic modelling, 29(4), 1450-1460.

Godil, D.I., Sharif, A., Agha, H., Jermsittiparsert, K. (2020), The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO_2 emission in Pakistan: New insights from QARDL approach. Environmental Science and Pollution Research, 27(19), 24190-24200.

Haftu, G.G. (2019), Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. Telecommunications Policy, 43(1), 88-99.

Haseeb, A., Xia, E., Baloch, M.A., Abbas, K. (2018), Financial development, globalization, and CO_2 emission in the presence of EKC: Evidence from BRICS countries. Environmental Science and Pollution Research, 25(31), 31283-31296.

Haseeb, A., Xia, E., Saud, S., Ahmad, A., Khurshid, H. (2019), Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. Environmental Science and Pollution Research, 26(9), 8594-8608.

Im, K.S., Pesaran, M.H., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. Journal of econometrics, 115(1), 53-74.

Jammazi, R., Aloui, C. (2015), Environment degradation, economic growth and energy consumption nexus: A wavelet-windowed cross correlation approach. Physica A Statistical Mechanics and Its Applications, 436(C), 110-125.

Kalayci, C., Hayaloğlu, P. (2019), The impact of economic globalization on CO_2 emissions: The case of NAFTA countries. International Journal of Energy Economics and Policy, 9(1), 356.

Khan, F.N., Sana, A., Arif, U. (2020), Information and communication technology (ICT) and environmental sustainability: A panel data analysis. Environmental Science and Pollution Research, 27(29), 36718-36731.

Latif, Z., Latif, S., Ximei, L., Pathan, Z.H., Salam, S., Jianqiu, Z. (2018), The dynamics of ICT, foreign direct investment, globalization and economic growth: Panel estimation robust to heterogeneity and cross-sectional dependence. Telematics and Informatics, 35(2), 318-328.

Lee, J.W., Brahmasrene, T. (2014), ICT, CO_2 emissions and economic growth: Evidence from a panel of ASEAN. Global Economic Review, 43(2), 93-109.

Levin, A., Lin, C.F., Chu, C.S.J. (2002), Unit root tests in panel data: Asymptotic and finite-sample properties. Journal of Econometrics, 108(1), 1-24.

Martínez-Zarzoso, I., Bengochea-Morancho, A. (2004), Pooled mean group estimation of an environmental Kuznets curve for CO_2. Economics Letters, 82(1), 121-126.

Monzon, A., Garcia-Castro, Á., Valdes, C. (2017), Methodology to assess the effects of ICT-measures on emissions. The case study of Madrid. Procedia Engineering, 178, 13-23.

Niebel, T. (2018), ICT and economic growth-Comparing developing, emerging and developed countries. World Development, 104, 197-211.

Pata, U.K. (2021), Linking renewable energy, globalization, agriculture, CO_2 emissions and ecological footprint in BRIC countries: A sustainability perspective. Renewable Energy, 173, 197-208.

Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61(S1), 653-670.

Pesaran, M.H. (2007). A simple panel unit root test in the presence of cross-section dependence. Journal of applied econometrics, 22(2), 265-312.

Phong, L.H. (2019), Globalization, financial development, and environmental degradation in the presence of environmental Kuznets curve: Evidence from ASEAN-5 countries. International Journal of Energy Economics and Policy, 9(2), 40-50.

Protocol, K. (1997), United Nations framework convention on climate change. Kyoto Protocol, Kyoto, 19(8), 1-21.

Raheem, I.D., Tiwari, A.K., Balsalobre-Lorente, D. (2020), The role of ICT and financial development in CO_2 emissions and economic growth. Environmental Science and Pollution Research, 27(2), 1912-1922.

Rene, E.R., Sethurajan, M., Ponnusamy, V.K., Kumar, G., Dung, T.N.B., Brindhadevi, K., Pugazhendhi, A. (2021), Electronic waste generation, recycling and resource recovery: Technological perspectives and trends. Journal of Hazardous Materials, 416, 125664.

Salahuddin, M., Alam, K., Ozturk, I. (2016), The effects of internet usage and economic growth on CO_2 emissions in OECD countries: A panel investigation. Renewable and Sustainable Energy Reviews, 62(C), 1226-1235.

Salahuddin, M., Gow, J. (2014), Economic growth, energy consumption and CO_2 emissions in Gulf Cooperation Council countries. Energy, 73, 44-58.

Sarafidis, V., Yamagata, T., Robertson, D. (2009), A test of cross section dependence for a linear dynamic panel model with regressors. Journal of Econometrics, 148(2), 149-161.

Shabani, Z.D., Shahnazi, R. (2019), Energy consumption, carbon dioxide emissions, information and communications technology, and gross domestic product in Iranian economic sectors: A panel causality analysis. Energy, 169(C), 1064-1078.

Shahbaz, M., Khan, S., Ali, A., Bhattacharya, M. (2017), The impact of globalization on CO_2 emissions in China. The Singapore Economic Review, 62(4), 929-957.

Shahbaz, M., Mallick, H., Mahalik, M. K., and Loganathan, N. (2015). Does globalization impede environmental quality in India? *Ecological Indicators*, *52*, 379-393.

Shahbaz, M., Shahzad, S.J.H., Mahalik, M.K. (2018), Is globalization detrimental to CO_2 emissions in Japan? New threshold analysis. Environmental Modeling and Assessment, 23(5), 557-568.

Shahnazi, R., Shabani, Z.D. (2019), The effects of spatial spillover information and communications technology on carbon dioxide emissions in Iran. Environmental Science and Pollution Research, 26(23), 24198-24212.

Sohag, K., Al Mamun, M., Uddin, G.S., and Ahmed, A.M. (2017). Sectoral output, energy use, and CO_2 emission in middle-income countries. Environmental Science and Pollution Research, 24(10), 9754-9764.

Toffel, M.W., Horvath, A. (2004), Environmental implications of wireless technologies: News delivery and business meetings. Environmental Science and Technology, 38(11), 2961-2970.

Ulucak, R., Bilgili, F. (2018), A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. Journal of Cleaner Production, 188, 144-157.

Ulucak, R., Danish, K., Khan, S. (2020), Does information and communication technology affect CO_2 mitigation under the pathway of sustainable development during the mode of globalization? Sustainable Development, 28(4), 857-867.

Usman, A., Ozturk, I., Hassan, A., Zafar, S.M., Ullah, S. (2021), The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis. Telematics and Informatics, 58, 101537.

Wang, L., Vo, X.V., Shahbaz, M., Ak, A. (2020), Globalization and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? Journal of Environmental Management, 268, 110712.

Wang, W.H., Himeda, Y., Muckerman, J.T., Manbeck, G.F., Fujita, E. (2015), CO_2 hydrogenation to formate and methanol as an alternative to photo-and electrochemical CO_2 reduction. Chemical Reviews, 115(23), 12936-12973.

Westerlund, J. (2007), Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics, 69(6), 709-748.

Westerlund, J. (2008), Panel cointegration tests of the Fisher effect. Journal of Applied Econometrics, 23(2), 193-233.

Wiseman, A.W., Anderson, E. (2012), ICT-integrated education and national innovation systems in the Gulf cooperation council (GCC) countries. Computers and Education, 59(2), 607-618.

World Bank. (2020), The World Development Indicators (WDI). Washington, DC: World Bank. Available from: https://databank.worldbank.org/source/world-devel open-indicators [Last accessed on 2021 20 Sep].

Zaidi, S.A.H., Zafar, M.W., Shahbaz, M., Hou, F. (2019), Dynamic linkages between globalization, financial development and carbon emissions: Evidence from Asia Pacific Economic cooperation countries. Journal of Cleaner Production, 228, 533-543.

Zhang, C., Liu, C. (2015), The impact of ICT industry on CO_2 emissions: A regional analysis in China. Renewable and Sustainable Energy Reviews, 44, 12-19.

APPENDIX

Appendix: Descriptive statistics and correlation matrix of variables used in the analysis

Variable	$lnCO_2$	lnGDP	lnTRD	lnFD	lnEC	lnICT	$GLO_{overall}$ × ICT	GLO_{econ} × ICT	GLO_{soc} × ICT	GLO_{pol} × ICT
Mean	3.035525	10.32495	4.595696	3.815924	9.253398	3.583476	5.371299	7.849742	7.771532	7.519115
Std. Dev.	0.402719	0.498562	0.280454	0.354726	0.568161	0.948951	0.433715	0.9740412	0.998002	0.991102
Min	1.956295	9.659229	4.026929	3.03459	7.856071	1.016221	3.846149	5.099207	5.03504	4.663821
Max	3.86493	11.15166	5.256831	4.655741	9.976192	4.704309	5.872602	9.091317	8.984492	8.743041
Correlation Matrix										
$lnCO_2$	1									
lnGDP	0.8339	1								
lnTRD	0.2835	0.008	1							
lnFD	0.2662	0.1274	0.6351	1						
lnELE	0.8335	0.5312	0.5532	0.5105	1					
lnICT	0.4692	0.2735	0.5113	0.5845	0.4677	1				
$GLO_{overall}$ × ICT	0.5544	0.3511	0.5124	0.6071	0.5611	0.9835	1			
GLO_{econ} × ICT	0.5104	0.3043	0.5585	0.5997	0.517	0.9937	0.9843	1		
GLO_{soc} × ICT	0.5095	0.3084	0.5399	0.6002	0.5081	0.9906	0.9807	0.9947		
GLO_{pol} × ICT	0.4813	0.3217	0.4286	0.5496	0.4685	0.9768	0.9703	0.9737	0.9794	1