Harnessing E-commerce and Digital Transformation for Climate Sustainability in Emerging Economies

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Abstract

The aim of this research is to examine the effect of e-commerce, digitalization, and financial market efficiency on climate quality in Middle Eastern economies (2013–2022) using a CUP-FM model. Results show e-commerce reduces carbon emissions, while digital financial inclusion, economic uncertainty, and financial market efficiency worsen environmental quality. A bi-directional causal relationship suggests a feedback loop. Findings highlight the need for eco-friendly policies in e-commerce, digital finance, and green markets to support ICT inclusion, renewable energy, and reduced economic uncertainty.

Keywords: Digitalization; E-commerce; Digital Financial Inclusion; Economic Policy Uncertainty; Financial Market Efficiency

I. Introduction

The tremendous digital revolution in the current era has a crucial impact on economies. E-commerce entails a wide-ranging advantage for developed and developing economies i.e., access to information, more openness to a better-quality environment, and less pollution [1]. [2] argue that the effectiveness of information technology reduces carbon emissions. Information technology has diminished the CO_2 emissions in production processes by cutting energy consumption, hence, enhancing economic efficiency and sustainable climate quality. Many firms and businesses are playing their parts in mitigating climate deterioration and providing incentives to promote the usage of renewable energy in ICT as suggested by [3]. Furthermore, ICT-related carbon emission is projected to decrease by 2.3-1.99% by the end of 2030 [4]. However, the outbreak of the COVID-19 has caused a universal recession because countries have prioritized health over economic development by restricting economic, travel, and tourism activities. However, economic activities resume once societies adapt to the pandemic after the progression of vaccinations [5].

During the height of the pandemic, there was a temporary decrease in the consumption of fossil fuels and the release of carbon dioxide (CO2) [6], [7], [8], [9] discuss the possible emergence of sustainable economic recovery via environmentally friendly conditions. Therefore, the investigation of green environmental quality becomes vital in addressing these challenging issues. Key factors like protecting natural resources and effectively allocating resources across economic sectors are essential to a sustainable economic recovery. The idea that economic affluence depends on extreme consumption of fossil fuels is contested by the rhetoric of sustainable economic recovery, which is grounded in the values of environmental protection. The carbon emissions-economic growth dilemma, which holds that excessive reliance on fossil fuels and conventional energy is the only way to advance the economy, needs to be reconsidered and corrected in light of this paradigm. Hence, the post-COVID-19 economic recovery brings enhanced industrial output, welfare, and global social affluence but also poses climate risks [10], [11], [12]. Therefore, the investigation of sustainable environmental quality becomes progressively necessary and vital. Sustained climate quality is driven by various emerging facets like efficient resource allocation, natural resource preservation, and reduced reliance on fossil fuels in different economic sectors.

Economic digitalization is emerged to improve the efficacy of fossil fuel utilization and to decrease carbon emissions. The digital economic interactions promote the sustainable dissemination of knowledge, minimize urban travel, reduce paper usage, curtail consumption of household energies, and nurture enhanced revenues via the creation of digital initiatives. The most prominently emerged outcome of economic digitalization is "E-commerce" and currently both the developed and emerging economies are planning long-run policies to promote this sector.

The digital transformation journey in the Middle East is uniquely positioned to drive climate sustainability due to its rapid technological adoption, strategic government visions, and innovative spirit. Contrary to other territories, the Middle East is on a fast track for digitalization where major investments with high investments in advancements of technology and associated facilities. Initiatives such as those proposed by governments in Saudi Arabia and the UAE are making connections between digital transformation and sustainability goals that are present in national-level frameworks, such as those of Saudi Vision 2030 and UAE Vision 2021 [13].

Digital solutions that can help in improving resource management and resilience against the climate-specific challenges we face as a region like extreme heat and water scarcity. In addition, start-up trends in the region tend to involve leveraging e-commerce platforms increasing demand for eco-friendly products along with a lesser impact on the environment. Additionally, the use of digital payment solutions and improved logistics help in reducing packaging wastage and cut other costs associated which result in cutting back emissions. The partnership among public and private industries prevails. It builds an environment that enables e-commerce and digital transformation as the ingredients for advancing climate sustainability [14]. As a result, the unique approach to digital transformation in the Middle East focuses on technological advancement and environmental sustainability. This strategy presents a model for linking e-commerce with climate action in other regions.

A. The study significance

This research aims to bridge the gap in prior literature concerning financial inclusion and the environment outcomes in relation to carbon emissions. Although some research has spotlighted the financial implications for environmental degradation, such as how easier access to funding sources can facilitate carbon emissions, the environmental consequences emerging from digital financing are still poorly understood. Several studies indicate that digital financial inclusion can help to decrease carbon emissions by enhancing the effectiveness of resource allocation [15], [16], [17]. While, it could also have the opposite effect by spurring fossil fuel consumption and leading to increased pollution [18], [19]. This creates a gap in knowledge, as it remains unclear whether digital financial inclusion brings more benefits or downsides concerning environmental sustainability. Accordingly, the objective of this research is to explore the association of E-commerce, digital financial inclusion, financial market efficiency, and economic policy uncertainty with climate quality (carbon emissions) by focusing on emerging economies of the Middle Eastern region.

The study provides a contribution by proposing fresh indices for digital financial inclusion and financial market efficiency which enhance the accuracy and comprehensiveness of results as compared to previous studies.

I. Literature Review

Almost all sectors of the economy have gained the advantages of digitalization i.e., a more satisfied customer experience through improved productivity and low costs. However, the natural world is facing unintended consequences due to the rising demands for online goods and services. In this regard, the notion of green e-commerce and green digitalization has emerged, which emphasizes the usage of environmentally friendly technologies. In the most recent literature, the potential of sustainable digitalization has received great attention with reference to lessening CO_2 emissions and focusing on a more sustainable and cleaner economic future. Many studies have investigated different aspects of sustainable environment and green economic recovery using different models.

Over a period from 1991 to 2012, [20] found a strong correlation between e-commerce and carbon emissions. The authors further argue that OECD economies should properly implement digitalized carbon emission policies. [21] explore that short-term investments in E-commerce and ICT do not cause an upsurge in carbon emissions in China while long-term investments do. Moreover, their study finds a weak association between digital technologies and the use of traditional energies. [22] investigated 132 developed and emerging economies and find that e-commerce influences ecological footprints and all economies should introduce eco-friendly connections between technologies and the environment. Over a longer period, [23] found e-commerce and digitalization are negatively associated with environmental quality in Southeast Asian economies. Moreover, the authors find a unidirectional causality between e-commerce, digitalization, and carbon emissions. [24] found that digitalization and ICTs inversely impact pollutant emissions and significantly affect sustainable growth. [25] investigated 29 emerging Asian economies over the period from 2014 to 2018. The authors found that government support, technological diffusion, and financial market participation help to achieve sustainable and green growth. [26] emphasized financial institutions to introduce different financial products and innovative financial instruments to boost sustainable and green projects. Similarly, [27] investigated a longer time period from 1995 to 2018 and examine the different pillars of sustainable recovery in Asian economies. Using quantile regression, the authors find that wide-ranging strategic developments and implementation of green strategies are required to achieve green developments. Green literacy in return enhances sustainable energy conservation, energy consumption, investments in sustainable projects, and waste management.

For the promotion of green e-commerce, [28] proposed that there is a need to incorporate green policies in supply chain e-commerce i.e., SMEs' access to financial markets, sustainable education, and extensive execution of ICT throughout the regional and national economies. On the other hand, [29], [30] find that ecommerce adversely influences environmental quality because of waste generation and power consumption in the supply chain. In order to achieve the favorable outcomes of e-commerce for climate quality, nations should concurrently hunt other green targets, i.e., green logistics, green electricity generation & consumption, and transparent climate tax regulations. [31] examined the association between green growth and digitalization in China over the period from 2006 to 2018. The authors find that digitalization reduces the consumption of resources. [32] argued that e-commerce via ICT expansion and green investments helps economies to achieve carbon neutrality targets. [33] highlighted that e-commerce augments public access to wide-ranging commodities via digital platforms thus contributing to economic advancements. The authors further argue that online shopping lowers the climate impact of human activities. It is argued that e-commerce stimulates trade by driving demand and supply in electronic markets [34], [35]. Additionally, the use of e-commerce lessens the need for commuting to cities in order to access services like banking and insurance and make online purchases of commodities, which minimizes the use of conventional energy sources. This decreases the use of fossil fuel energy, significantly achieves sustainable development goals, and improves the efficiency of natural resources and the natural environment. Similarly, Financial and banking transactions are essential for supporting e-commerce, capital formation, and the realization of several fiscal projects, including those with an environmental focus.

The numerous effects of e-commerce on climate quality highlight how important a role e-commerce could play in promoting environmentally friendly development and sustainable economic growth. The above-mentioned studies explore the valuable aspects of e-commerce in boosting climate quality and delivering guidance to policymakers in the digital economic landscape. However, the role of e-commerce in enhancing climate quality is significantly ignored in early studies [35].

Discussions over carbon emissions are intensifying in light of how important the problem of climate change is [36]. Additionally, a great deal of studies has explored the connections between CO_2 emissions and Digital Financial Inclusion. Fareed et al. (2022), utilize the data from 27 European nations for a longer time period and confirm the deleterious effects of Digital Financial Inclusion on climate quality and further observe the negative effects on CO2 emissions on a worldwide scale. [37] investigated the dynamic association between carbon emissions and digital financial inclusion in G20 countries over a period from 2005 to 2018 and find a positive connectedness between them. From the standpoint of wealthy nations, as well as developing economies, the association between digital financial inclusion and CO_2 emissions has not been adequately explored. [18] for instance, evaluate the impact of digital financial inclusion on the sustainability of climate in 42 emerging economies from 2007 to 2019 and objectively demonstrate that digital financial inclusion lowers climate sustainability by encouraging CO_2 emissions. The above-mentioned studies explore the connectedness between E-commerce, digital financial inclusion, financial market efficiency, economic uncertainty, and climate quality. However, the current study provides evidences in the context of Middle Eastern economies because the literature lacks the impact of e-commerce and digitalization in the context of Middle Eastern economies.

Fig 1 illustrates the fluctuations in the share of natural resources as a percentage of GDP from 2002 to 2022 for several Middle Eastern economies. The economies represented include Bahrain, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

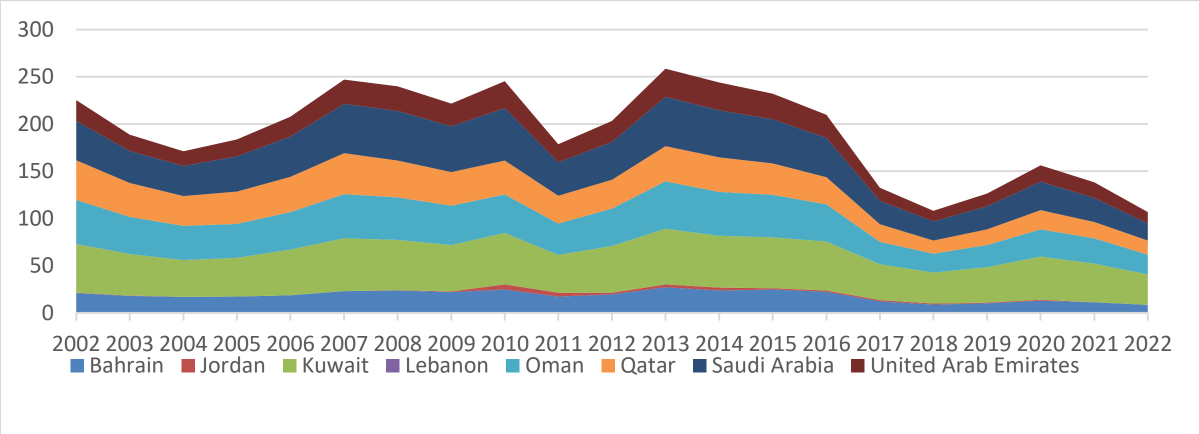

Fig. 1. Volatility of Natural Resources (% of GDP) in Selected Middle Eastern Economies Over Time (World Bank Open Data, 2024.)

Table 1: Variables, short titles, measurements, and sources.

Variable	Short Titles	Measurements	Data Sources
Climate Quality	CQ	Carbon Emissions	WDI
Digital Financial Inclusion	DFI	Index	IMF
"ICT use for business-to-business transactions index"	ECOMR	Index (1–7)	TCdata360 (World Bank)
Financial markets Efficiency index	FME	Index	IMF
Economic uncertainty	EU	Index	https://fred.stlouisfed.org/

Note: WDI indicated World Bank Indicators while IMF presents International Monitory Funds.

II. Theoretical Foundation and Hypotheses Development

Understanding the complex relationships between economic and technological factors and their impacts on carbon emissions and climate quality necessitates integrating several key theories. Each theory provides insights into how different variables interact and influence one another. This section explores the relevant theories and their associated hypotheses.

The Environmental Kuznets Curve (EKC) theory posits an inverted U-shaped relationship between economic development and environmental degradation. Initially, as economies grow, environmental degradation increases, but beyond a certain level of income, further growth leads to improved environmental quality. This theory provides a foundation for examining how economic activities, including e-commerce and digital financial inclusion, affect carbon emissions and climate quality.

The effect of e-commerce on carbon emissions and climate quality may vary based on the level of economic development and regional factors. E-commerce could have different impacts on carbon emissions and climate quality depending on local conditions and technological advancements [38].

Hypothesis (H1): E-commerce use does not homogeneously cause changes in carbon emissions and climate quality in Middle Eastern economies.

Variations in carbon emissions and climate quality may not uniformly influence the level of e-commerce activity. The relationship between environmental conditions and e-commerce adoption might differ across various contexts and economic stages.

Hypothesis (H2): Carbon emissions and climate quality do not homogeneously cause changes in e-commerce use in Middle Eastern economies.

The Technological Innovation and Environmental Impact Theory explores how technological advancements can either improve or worsen environmental outcomes. While technology can enhance efficiency and reduce emissions, it can also lead to increased consumption and resource use. This theory is pertinent for understanding the dual effects of e-commerce and digital financial inclusion on environmental factors.

The impact of digital financial inclusion on carbon emissions and climate quality may differ based on varying degrees of technological integration and financial infrastructure. The relationship between DFI and environmental outcomes may not be consistent across different regions.

Hypothesis (H3): Digital financial inclusion (DFI) does not homogeneously cause changes in carbon emissions and climate quality in Middle Eastern economies.

Differences in carbon emissions and climate quality might not uniformly affect the extent of digital financial inclusion. The influence of environmental conditions on DFI could vary depending on local economic and technological contexts.

Hypothesis 4 (H4): Carbon emissions and climate quality do not homogeneously cause changes in digital financial inclusion (DFI) in Middle Eastern economies.

Financial Market Efficiency and Environmental Sustainability Theory

This theory examines how the efficiency of financial markets can impact environmental sustainability. Efficient financial markets are capable of allocating capital to both green technologies and carbon-intensive industries . This dual potential highlights the complex relationship between financial market efficiency and environmental outcomes.

The relationship between financial market efficiency and environmental outcomes may vary depending on how efficiently markets allocate resources to both sustainable and carbon-intensive investments. The effects on carbon emissions and climate quality might differ across different market conditions.

Hypothesis (H5): Financial market efficiency (FME) does not homogeneously cause changes in carbon emissions and climate quality in Middle Eastern economies.

Variations in carbon emissions and climate quality may not consistently impact financial market efficiency. The influence of environmental conditions on market efficiency might be affected by a range of economic and regulatory factors.

Hypothesis (H6): Carbon emissions and climate quality do not homogeneously cause changes in financial market efficiency (FME) in Middle Eastern economies.

Economic Policy Uncertainty and Environmental Impact Theory

Economic Policy Uncertainty (EPU) theory explores how uncertainty in economic policies can affect environmental outcomes by influencing investment decisions and regulatory environments. Higher uncertainty may lead to reduced investments in green technologies and a focus on short-term gains, impacting carbon emissions and climate quality.

The impact of economic policy uncertainty on carbon emissions and climate quality may vary depending on how uncertainty affects investment in environmental technologies and practices. The relationship might differ based on regional policy environments and economic conditions.

Hypothesis (H7): Economic policy uncertainty (EPU) does not homogeneously cause changes in carbon emissions and climate quality in Middle Eastern economies.

Variations in carbon emissions and climate quality may not consistently influence the level of economic policy uncertainty. The effects of environmental conditions on EPU might be inconsistent across different policy and economic contexts.

Hypothesis (H8): Carbon emissions and climate quality do not homogeneously cause changes in economic policy uncertainty (EPU) in Middle Eastern economies.

III. Methodology and Data Description

The current study explores the association of e-commerce, digital financial inclusion, financial market efficiency, and economic uncertainty with climate quality in 8 Middle Eastern economies from 2013 to 2022. The sample period encompasses the era of COVID-19. Climate quality is measured through carbon emissions in the selected economies which are computed as carbon emissions divided by gross domestic product (GDP). Digital financial inclusion is computed via the transactions of payments, investments, and loans per capita through digital means. Finally, e-commerce is presented through “an ICT use index for business-to-business transactions”. The study also employs economic Risk (economic uncertainty) and the financial market efficiency index (FME) which is measured by (efficiency, access, and assessing depth,) and financial development. The details on variables, their abbreviations, and sources of data are presented in Table 1. Equation 1 depicts the primary econometric models that determine the association between the outcome and independent variables:

$$CQ_{i,t} = \beta_0 + \beta_1 ECOMR_{i,t} + \beta_2 LDFI_{i,t} + \beta_3 LFME_{i,t} + \beta_4 LEU_{i,t} + \varepsilon_{it} \quad (1)$$

The above equation presents the connectedness between Climate quality and e-commerce, digital financial inclusion, economic uncertainty and financial market index. Based on the technique introduced by [39], [40], the study first explores the coefficients of cross-sectional dependency among variables. The approach estimates the cross-section (CD) connectedness between panel units. The confirmation of the presence of CD leads to assessing the stationarity of variables using the cross-sectional augmented Dicky-fuller test (CADF) and Cross-sectionally Augmented Im, Pesaran, and Shin test (CIPS) developed by [41]. The study further employs the panel cointegration technique of the second generation by taking into account the cross-sectional dependencies. In this regard, the study employs a co-integration approach proposed by [42] which is based on four different tests indicated through Equations 2 to 5. These econometric models are very crucial in the determination of co-integration connectedness between the variables.

$$P_r = \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (2)$$

$$P_\alpha = T\hat{\alpha} \quad (3)$$

$$G_r = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (4)$$

$$G_\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (5)$$

Furthermore, the study employs the CUP-FM (continuous-updated modified) technique to determine the coefficients for variables. Bai and Kao (2006) introduced the CUP-FM technique which is preferred over OLS (ordinary Least Square) because CUP-FM infers more accurate results in the existence of cross sectional dependencies in the data series. The causality associations between outcome and independent variables are explored using a model presented by [43]. The said technique aids to comprehend the directional causality among variables. The stability and reliability of empirical outcomes are accessed via robustness checks. Hence, the study ensures the validity of outcomes.

Table 2: The results of CSD checks (cross-sectional dependency).

Variable	Pesaran CD	Breusch-Pagan LM
LCQ	74.14***	134.74***
LECOMR	71.85***	124.94***
LDFI	86.47***	113.02***
LFME	27.59***	95.16***
LEU	98.40***	142.64***

Note: *** checks for confidence interval @ 1%.

IV. Empirical findings and discussion

The section presents the empirical outcomes with the application of econometric methods discussed in the methodological section. The study presents the outcomes of preliminary tests like CD (cross-section dependency), stationarity, and co-integration associations. The outcomes of the CD connectedness test proposed by [39], [40] are shown in Table 3, and the CD model is discussed in the methodological section. Our results indicate the presence of significant CD associations among variables. These results exhibit the interrelations among variables and the presence of cross-section dependencies (CSD) and both are necessary to consider in the next analysis. Subsequently, the presence of CSD leads to exploring the stationarity of variables via panel nit root tests [44]. Non-stationarity is the inherent character of data series, which must be explored before the application of econometric models [45]. According to Ahmad et al. (2018), almost all the data series become stationary at first difference. The outcomes for CIPS ("Cross-Sectionally Augmented Im, Pesaran, & Shin") and CADF ("Cross-Sectionally Augmented Dickey-Fuller") tests are presented in Table 3 it indicates that all the variables under study become stationary when the first difference [I(I)] is taken (see the Panel B of Table 3), however, the variables show non-stationary behavior at level [I (0)] (see the Panel A of Table 3).

Table 3: Outcomes for Stationarity Checks.

Panel A			Panel A		
Variable	CIPS test	CADF	Variable	CIPS test	CADF test
LCQ	- 0.853	- 0.074	LCQ	- 4.843***	- 5.184***
LECOMR	- 0.892	- 0.089	LECOMR	- 5.227***	- 6.552***
LDFI	- 0.021	- 0.086	LDFI	- 8.103***	- 5.041***
LFME	- 0.194	- 0.061	LFME	- 7.49***	- 5.253***
LEU	- 0.106	- 0.082	LEU	- 5.728***	- 5.200***

Note: *** checks for confidence interval @ 1%. Panel A presents the stationarity of variables at level [I(0)] while Panle B presents the same at first difference [I(I)].

Table 4: The outcomes for the panel cointegration association are based on Westerlund's approach.

Statistics	Coefficients	P-value
Pr	- 11.945	0.001
Pα	- 19.194	0.000
Gr	- 10.001	0.011
Gα	- 16.275	0.002

Note: P-value indicated the probability values.

After accounting for the stationarity, the subsequent step is to investigate the co-integration connectedness between the study variables. The strong long-run association among variables is evident from the outcomes of the Westerlund approach presented in Table 4.

Table 5 indicates the parameters of estimations by employing the "CUP-FM" econometric model. The outcomes indicate important acumens about the connectedness between the independent estimators and climate quality in selected Middle Eastern countries. The parameters of the "CUP-FM" econometric model reveal that a significant association between the ECOMR (e-commerce) and CQ (climate quality) exists in Middle Eastern economies. The above table shows that ECOMR has a negative and significant impact on climate quality (measured through Carbon emissions). Table 5 demonstrate that a 1% upsurge in e-commerce ("business to business transaction index") activities brings a 0.1573% reduction in carbon emissions and hence, improves the quality of the environment. The outcomes are consistent with the findings of recent research work [29] [28], [46]. [47], [32], which explore the significant contribution of ecommerce in promotion of environmental quality. The enhanced use of e-commerce cuts the need for the physical existence of both buyer and seller at the time of the transaction, reduces the transaction costs and also reduces the different types of environmental contamination initiated with the physical mode of transaction or buying-selling phenomenon. Hence, e-commerce reduces environmental contamination.

Similarly, digital financial inclusion reduces climate quality as we find a positive association between DFI and CQ. It is clear from Table 5 that a 1% increase in digital financial inclusion activities brings a 0.4194 % upsurge in carbon emissions, hence, deteriorating the environmental quality. This might be because the increased use of technology and digital devices leads to a higher consumption of electricity and enhanced fossil fuel burning in power plants which deteriorate the climate quality. Moreover, there exists a positive association between the financial market index and carbon emissions. The efficiency and access to financial markets enhance financial inclusion, therefore leading to higher consumption of electricity and other natural resources. As a result, the financial market index does not promote climate-conscious behaviors and works away from sustainability. A very determinantal impact of economic uncertainty (risk) on climate quality is observed. The results show that a positive association is present between economic policy uncertainty and carbon emissions. It is inferred from the results that a 1% upsurge in economic uncertainty causes a 0.0538% increase in carbon emissions. Hence, economic policy uncertainty reduces the climate quality and our results highlight the worth of sustainable economic policy to achieve sustainable environmental quality.

Table 5: The coefficients for the CUP-FM test.

Variable	Coefficient	P-Value
LECOMR	- 0.1573	0.000
LDFI	0.4194	0.000
LFME	0.0837	0.041
LEU	0.0538	0.037

Note: P-value indicated the probability values.

To discover the causality connection between outcome and explanatory variables, the study employs the Demitrescu-Hurlin causality approach. The outcomes are presented in Table 6, which indicates a bi-directional causal connectedness between variables. It is clear from the Table that variation in e-commerce activities impacts climate quality and vice versa. The findings indicate that advancements in e-commerce activities enhance climate quality and enhanced climate quality brings advancements in e-commerce practices. Similarly, less uncertain economic policy enhances climate quality and sustainable environmental quality promotes the economic policy. It is also clear from Table 6 that advancements in digital financial inclusion and financial market efficiency have a determinantal impact on climate quality and vice versa. This reciprocal connectedness highlights the worth of considering digital financial inclusion, financial market index, economic policy uncertainty, and e-commerce as potential drivers for promoting sustainable climate quality in Middle Eastern economies.

Table 6: Bi-directional Causality connectedness test.

H0	Statistic	P-Value
E-commerce use does not homogeneously cause Carbon Emissions (CQ)	4.108	0.000
Carbon Emissions (CQ) do not homogeneously cause E-commerce use	5.493	0.000
DFI does not homogeneously cause Carbon Emissions (CQ)	3.703	0.001
Carbon Emissions (CQ) do not homogeneously cause DFI	4.883	0.000
FME does not homogeneously cause Carbon Emissions (CQ)	4.018	0.000
Carbon Emissions (CQ) do not homogeneously cause FME	4.753	0.001
EU does not homogeneously cause Carbon Emissions (CQ)	5.063	0.002
Carbon Emissions (CQ) do not homogeneously cause EU	4.997	0.001

Note: P-value indicated the probability values.

In order to validate the reliability of empirical outcomes, the study employs robustness checks by taking natural resource volatility as the dependent variable. Again, CUP-FM technique is used to re-estimate the panel data and outcomes are exhibited in Table 7. The outcomes of robustness checks backing the estimated results obtained from original CUP-FM estimators in Table 5. The signs of coefficients in Table 8 are similar to the signs obtained and presented in Table 7. This reaffirms that stability and consistency of empirical outcomes and indicates that association of independent variables with dependent variable remains same while employing an alternative outcome variable.

Table 7: Robustness checks.

Variable	coefficient	P-Value
LECOMR	-0.218	0.000
LDFI	0.052	0.000
LFME	0.572	0.039
LEU	0.283	0.013

Note: P-value indicated the probability values.

V. Conclusion

The linkages between green economic recovery and environmental sustainability are of greater concern to emerging and emerged economies after the emergence of novel COVID-19. Countries are aimed to address the critical association between economic advancements and climate quality. This study highlights the significant impact of e-commerce, digitalization, and financial market efficiency on climate quality in Middle Eastern economies from 2013 to 2022. Utilizing a robust CUP-FM econometric model, we found that e-commerce positively influences climate sustainability by reducing carbon emissions. However, digital financial inclusion, economic uncertainty, and financial market efficiency contribute to increased carbon emissions, thus deteriorating environmental quality. The bi-directional causal relationship between the independent and dependent variables suggests a feedback loop, further confirmed by analyzing natural resource volatility. These findings highlight the need for policies promoting green e-commerce and sustainable digital financial practices to improve environmental outcomes.

A. Practical implications

These findings hold global implications, particularly for promoting climate change mitigation and improving environmental quality. A crucial approach to minimize carbon emission operating in Middle Eastern economies is to encourage E-commerce practices to cut around business establishment costs, minimal paper usage, and reduce travel. Green e-commerce initiatives launched by governments and policymakers can leverage these benefits and lead the way for other regions. Further, although financial inclusion implies an increase in electricity and technology consumption resulting in high carbon emissions, this effect can be completely neutralized by promoting green financing for renewable energy projects. Consequently, policymakers need to formulate regulations and incentives to institutionalize these best practices, coupled with awareness and training programs to promote greener decisions by businesses and consumers. Through these measures, the economies of the Middle East can improve environmental conditions while growing economically and technologically, providing lessons for the world in climate action.

B. Limitations and future work

The significant examination of e-commerce, digitalization, and efficiency of financial markets may overlook some other significant determinants of climate quality. Adding more variables such as renewable energy adoption, policy shifts, and technological advancements could yield a more robust understanding of the determinants of climate quality. Finally, investigating how different green policies target e-commerce and digital financial inclusion would bring practical insights to policymakers on how to attain better environmental results.

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