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# The Impact of Green Finance, FinTech and Digital Economy on Environmental Sustainability: Evidence from Advanced Panel Techniques

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**ABSTRACT**

Improving environmental sustainability is a crucial priority for economies to further global progress. The United Nations General Assembly has proposed enhancing environmental sustainability by adopting the SDG-7 recommendations. This study investigates the effect of green finance, fintech and digital economy on environmental sustainability utilizing panel data between 2013 and 2023 in Middle Eastern countries: Saudi Arabia, Turkey, Kuwait, United Arab Emirates and Qatar. For the analysis, panel unit root test, panel cointegration test and Pairwise Dumitrescu-Hurlin panel Causality tests were done. Our empirical results show that cointegration is among the variables that were analyzed. Green finance, digital economy, and FinTech are closely interrelated. The outcomes may provide helpful knowledge regarding the development of environmental sustainability. Policymakers are recommended to formulate feasible and energy system-compatible policies to provide green funding to the energy systems of Middle Eastern countries with maximum convenience.

**Keywords:** Digital Economy, FinTech, Environmental Sustainability, Middle East
**JEL Classifications:** F1, F13, O13, Q56

## 1. INTRODUCTION

Recently, environmental sustainability has garnered significant attention from governments and researchers in the financial sector (Guang-Wen and Siddik, 2023). As a result, the Paris Climate Change Deal was established to acknowledge climate change as a potential threat to ecological and social well-being. Most economies worldwide are legally obligated to implement strategies for reducing greenhouse gas emissions to restrict global warming to <2°C (Al-Kasasbeh et al., 2023; Udeagha and Ngepah, 2022).

Moreover, Middle Eastern countries exhibit higher energy consumption than other industrialized nations, which poses significant challenges for Middle Eastern countries (Al-kasasbeh, 2023; Alquliti, 2022). These countries are often characterized as emerging economies with restricted technological progress and heavily depend on domestic and imported fossil fuels for energy production. This has contributed significantly to their economic growth and threatened the ecological balance in their diverse power sectors. However, in the present era, it is no longer feasible to stimulate economic growth without ensuring environmental balance, specifically by regulating the rise in carbon dioxide ($CO_2$) emissions.

Consequently, reducing $CO_2$ emissions has become a commendable objective for contemporary researchers in pursuing a sustainable and eco-friendly world. This endeavor encompasses various significant factors, including green finance (GF), digital economy

(Digi), and financial technologies (fintech) (Almasria et al., 2024; Naser et al., 2024; Alhanatleh et al., 2024; Al_Kasasbeh et al., 2024a; Mpofu, 2024; Udeagha and Ngepah, 2022).

Recently, green finance has been introduced to save the environment and has made substantial advancements. Green finance facilitates the alignment of public interests with sustainable development goals by integrating financial decisions with environmental preservation. It supports explicitly environmentally friendly business models, focusing on renewable energy and related sectors. Green finance bridges the barriers between consumers, producers, investors, and lenders and highlights the role of money in promoting environmental conservation (Wang and Zhi, 2016). The expense of that will amount to trillions. To pursue the UN Sustainable Development Goals regarding climate change, an annual investment of around 5-7 trillion dollars is required to develop environmentally friendly industries (Kharas and McArthur, 2016). Nevertheless, the current green financial channel is inadequate, and it is imperative to harness the potential of fintech to enhance green financing promptly. Nonetheless, the precise mechanism by which fintech and green finance expedite the attainment of sustainable development for organizations remains ambiguous. Hence, examining the interplay between fintech, green finance, sustainable development, digital economy, and environmental sustainability holds theoretical and practical importance.

The reason for preferring Middle Eastern economies for the analysis is that they provide substantial pathway for developing countries to achieve environmental sustainability. Numerous developing countries encounter significant economic, social, and environmental vulnerabilities due to insufficient energy resources and their susceptibility to environmental change and severe climatic hazards, thereby reducing their environmental sustainability. The primary contributions of this article are as follows: We extend the related research on the determining factors of environmental sustainability. The current study has investigated the influence of various factors, including industrial structure (Xiong et al., 2019), technological innovation (Wang and Wang, 2020), energy consumption structure (Sineviciene et al., 2017), environmental regulation (Song et al., 2022), and urbanization (Lv et al., 2020), on environmental sustainability. However, there has been a lack of examination regarding the impact of finance, digital economy, and fintech on environmental sustainability. This study breaks new ground by delving into the impact of finance, digital economy, and fintech on environmental sustainability, filling the gaps in the existing literature. Finally, based on our research findings, we propose several significant policy implications for regulators to further improve environmental sustainability through managing green finance, digital economy, and fintech.

## 2. LITERATURE REVIEW

### 2.1. Green Finance and Environmental Sustainability

The British Petroleum's World Energy Outlook report discusses the difficulty of meeting the increasing energy demand while reducing carbon emissions. According to the International Energy Agency (Liu et al., 2022) the primary energy consumers are the household, transportation, and industrial sectors. Hence, environmental sustainability is a matter of great importance, as enhancements in this area hold the potential to reduce energy consumption and $CO_2$ emissions substantially. Furthermore, several countries have enacted legislation to enhance environmental sustainability (Gillingham et al., 2009).

Green financing is a matter of great concern in boosting energy efficiency. Finance is commonly acknowledged as the main motivator for energy projects, with financial institutions showing a strong interest in them as well. Many academic research papers have pointed out the lack of effectiveness of green funding in different nations because of fundamental problems. Hafner et al. (2020) highlighted that green finance instruments, like green bonds, are not effective in emerging economies because of insufficient private sector participation and inadequate financial infrastructure. Charles and Philip (2020) discovered that there was no connection between green bonds and Sustainable Development Goals (SDGs) in India. They claimed that this was due to financial deficiencies in the private sector and the lack of clear directives in India's climate action plan. Hammoudeh et al. (2020) also did not succeed in confirming a direct connection between green bonds and economic or environmental indicators.

In contrast, Pavlyk (2020) carried out a bibliometric study showing a favorable influence of green investment on the advancement of renewable energy and energy efficiency. The writer observed an increasing pattern in literature that centers on environmental sustainability and environmentally-friendly financing. Raberto et al. (2019) highlighted that green investment opportunities can help in the shift towards a more energy-efficient sector. Azhgaliyeva et al. (2020) investigated the issuance of green bonds in the Association of Southeast Asian Nations (ASEAN) and related policies. They discovered that a large percentage of these bonds were allocated to projects in renewable energy and environmental sustainability to improve environmental sustainability and address the region's energy demands.

### 2.2. FinTech and Environmental Sustainability

Lately, there has been a notable surge in research studying the use of contemporary FinTech. Studies performed by Teng and Shen (2023) and Shkodina et al. (2018) have contributed to this research field's growth. Al-Kasasbeh et al. (2023) describe FinTech as creative concepts that enhance financial services using technology-based strategies customized for individual company requirements. FinTech encompasses various financial technologies like mobile payment systems, high-frequency trading, crowd funding, virtual currencies, and blockchains (Aldboush et al., 2023; Vives, 2017; Adaba et al., 2019; Arner et al., 2020).

The rising interest in fintech among specialists results from the growing demand for environmentally friendly, easy-to-use financial products and services. Fintech uses technological progress to speed up the delivery of financial services, benefiting financial institutions. Online banking has been recognized as an effective element in promoting socioeconomic resilience, as highlighted by Karaki and Al-Kasasbeh (2024) and Dwivedi et al. (2021). The progress of ICT has revolutionized financial enterprises, improving service efficiency and environmental sustainability, as noted by Yan et al. (2021). Furthermore, Li et al. (2022) emphasized the importance of expanding the scope of financial depth to achieve environmental sustainability. Previous research has also established the crucial role of technological innovation in determining EP, as confirmed by Awawdeh et al. (2022).

The advancement of creative financing methods in different sectors, such as energy, can be enhanced by digital technologies. Fintech's innovative and impactful nature has been acknowledged as a disruptive force in the energy sector. Promoting the use of funds for energy efficiency leads to significant social, environmental, and ecological benefits (Deng et al., 2019). According to Puschmann et al. (2020), the importance of green finance and fintech is emphasized in achieving clean energy goals necessary for sustainable development. Moreover, Kim (2018) highlights the importance of banks getting involved in backing low-carbon energy projects. Vogel et al. (2019) argue that blockchain technology has created environmentally and economically viable goods, thereby enhancing the circular economy.

### 2.3. Digital Economy and Environmental Sustainability

Su et al. (2021) conducted an empirical study to examine the influence of the digital economy on the enhancement of industrial systems, utilizing data at the province level in China. Their findings demonstrated that the process of enhancing the industrial structure was closely linked to actively advancing the digital economy. Zhou et al. (2022) demonstrated that the digital economy facilitates the worldwide value chain of Chinese manufacturing. Liu et al. (2023) discovered that the digital economy serves as a catalyst for innovation in total factor productivity (TFP). Prior research has examined the influence of the digital economy on energy consumption and pollution levels. These studies have uncovered a connection between the digital economy and total factor productivity, suggesting a strong correlation between the digital economy and gross total factor energy efficiency (GTFEE). Consequently, there has been a greater emphasis on examining the influence of the digital economy on GTFEE. The advancement of the Internet greatly enhances energy conservation and emission reduction efficiency by leveraging technical advancements and optimizing energy structures.

Chen et al. (2023) employed data, Tobit, and GMM empirical regression techniques to examine the mechanism and pathway via which the digital economy impacts energy efficiency. Their findings demonstrated that the digital economy enhanced the effectiveness of all components in the region, with market trade serving as the primary conduit for real estate transactions. Wang et al. (2022) conducted a study that demonstrated an inverse U-shaped correlation between the digital economy and carbon emissions. Initially, carbon emissions increased, but eventually decreased.

## 3. MATERIALS AND METHODS

### 3.1. Data and Description of Variables

This research aims to investigate the influence of Green Finance, Digital Economy, and FinTech on Environmental Sustainability. Data has been gathered from 2013 to 2023 for five Middle Eastern countries, chosen based on data availability. Due to the limited data accessibility, especially in the fintech sector, and the relatively new nature of this industry with a lack of historical data, the study focused on the 5 Middle Eastern nations and a shorter time period. The data covers the years 2013-2023 for the following Middle Eastern countries: Turkey, Saudi Arabia, Kuwait, Qatar, and the United Arab Emirates. Previous research has shown that green finance, digital economy, and FinTech have significant impacts on improving environmental sustainability (Cen and He, 2018; Alquliti, 2022; Karaki et al., 2023a). However, it is crucial to acknowledge the various constraints that must be addressed. The analysis is constrained by data availability, particularly in the fintech field, which is still new and lacks historical data. The study's green finance concept mainly focuses on investments in pollution control technology, potentially limiting the scope of environmentally friendly investments while excluding others. While using data sources like the World Bank ensures reliability, it may also lead to variations in data quality and consistency among different countries. Nonetheless, the study provides valuable insights into how fintech, green financing, and the Digital Economy can boost Environmental Sustainability. It also promotes transparency by revealing the data sources and variables utilized. In the study. Table 1 provides information about the model variables.

### 3.2. Model Developed

The current paper examines the effect of green finance, digital economy, and finTech on environmental sustainability; the regression equation of the model is as follows:

$$ES_{it} = GF_{it}.FT_{it}.Digi_{it}.\varepsilon_{it} \quad (1)$$

The estimated model's econometric form is as follows:

$$ES_{it} = \beta_0 + \beta_1\, GF_{it} + \beta_2\, FT_{it} + \beta_3\, Digi_{it} + \varepsilon_{it} \quad (2)$$

Where, *ES* denotes environmental sustainability, *GF* represents green finance, *Digi* represents the digital economy, *FT* represents the fintech, as defined by the number of authorized invention patents in each area, and $\varepsilon_{it}$ represents the random disturbance item, the cross-sectional units are represented by *i*, and *t* captures time dimension of the panel. Regression line coefficients - $\beta_0$ and $\beta_3$. The paper proposes a model with one dependent variable and three independent variables.

### 3.3. Econometric Techniques

#### *3.3.1. Cross-sectional dependence test*

The panel exhibits variations in slope and interdependence among its cross-sections. The initial step in our inquiry is examining and

**Table 1: Variables description and data source**

| Variable | Abb. | Period | Source |
|---|---|---|---|
| Green finance | GF | 2013-2023 | OECD |
| FinTech | FT | 2013-2023 | FD, WDI |
| Environmental sustainability | ES | 2013-2023 | SDG, WDI |
| Digital economy | Digi | 2013-2023 | WB |

OECD: Organization for economic co-operation and development, and corporate governance, SDG: Sustainable development goals, FD: Fintech district, WDI: World development indicators assessing the attributes of our panel dataset to determine if there is any cross-section dependence and variation in slopes. Member countries on the panel may exhibit similarities in certain aspects while diverging in others. Therefore, neglecting to consider the potential diverse characteristics in an empirical model might lead to biased analysis, particularly in the case of panel analysis. Given the potential heterogeneity across the cross-sectional units, the second-generation techniques are utilized in this context. The following equation represents Pesaran (2004) cross-section dependence (CSD) test employed to analyze the presence of cross-section dependence:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} pij\right)} \quad (3)$$

Where $N$ is the sample size, $j$ countries, $T$ indicates the period and $pij$ denotes the correlation of errors of $i$.

Breusch and Pagan (1980) developed the Lagrange multiplier (LM) test for assessing cross-sectional dependence. To demonstrate this test, we can use the following equation:

$$y_{it} = a_i + \beta_i x_{it} + \varepsilon_{it} \quad (4)$$

In this case, i represents the proportions of the cross-section, while t signifies the length of time." The null hypothesis suggests independence of cross-sections, while the alternative hypothesis suggests interdependence of cross-sections.

### *3.3.2. Unit root*

The second step entails doing a stationarity analysis in the chosen panel, which encompasses both cross-sectional and time series dimensions. This analysis is aimed at effectively addressing the issue of heterogeneous panel and resolving the problem of cross-section dependence among the cross-sectional components. In this analysis, the panel unit root tests used are IPS, developed by Im et al. (2003), and CIPS, established by Pesaran (2007). The null hypothesis posits the presence of a unit root in the data.

### *3.3.3. Panel cointegration test*

Once the cross-sectional dependence and unit roots in the panel data have been confirmed, it is imperative to determine if the variables are cointegrated. The third technique examines the panel cointegration using the Westerlund (2007) error correction model (ECM), which specifically deals with the problems of heterogeneous slope parameters and cross section dependence. To establish the enduring relationship between variables, we employed the Kao residual cointegration test developed by Kao et al. (1999).

### *3.3.4. Dumitrescu and Hurlin causality tests*

The link between dependent and independent variables is illustrated through the utilization of long-term estimate methodologies. However, it is crucial to determine the direction of the short-term causal relationship between the variables for effective policymaking. In order to achieve this, we utilize a causality check devised by Dumitrescu and Hurlin (2012) to ascertain the causal connection between the variables. The stationary findings are accounted for using the vector autoregressive (VAR) technique, which takes into consideration the unobserved heterogeneity in the data. This test conducts separate regressions for each cross-section in order to establish the causal relationship between variables.

## 4. EMPIRICAL RESULTS AND DISCUSSION

The CD in the model is initially examined in the empirical evaluation. The evaluation of CD has emerged as the primary emphasis of the present literature. Failure management of the CD may result in outcomes that are influenced by bias (Ahmed et al., 2022). The results of the CD and LM investigations are succinctly presented in Table 2. The data are statistically significant at the 1% significance level and support the rejection of the null hypothesis. The results shown in Table 2 confirm the presence of CD. The CD's presence enables the utilization of second-generation unit root evaluations for analyzing the integration order of the variables.

The panel unit root tests are a statistical method used to determine if a time series variable exhibits a unit root when analyzed in panel data tests. IPS and CIPS technologies are utilized for this purpose. The outcomes of both tests are summarized in Table 3. The empirical findings of the IPS test suggest that green finance, FinTech, the digital economy, and environmental sustainability exhibit a unit root at the level. These variables exhibit no unit root in their first difference and are integrated at 1(1). The CIPS panel unit root test outcomes exhibit a unit root at the level for all variables except for FinTech. However, when taking the first difference, all variables become stationary.

Utilizes the residual cointegration test devised by Kao et al. (1999) and Westerlund (2007) to present statistical results on cointegration. The conditional panel ECM provides error correction estimates for both the mean group and the panel. Moreover, (Gτ and Gα) and (Pτ and Pα). According to Table 4, the Kao-residual cointegration test demonstrates a statistically significant long-term association between GF, FT, EE, and Digi, with a significance level of 5%. The null hypothesis was refuted, which posits the absence of cointegration between the variables. These findings indicate the presence of cointegration among the variables examined.

**Table 2: Cross-sectional dependence tests results**

| Variable | Breusch-Pagan LM | Pesaran scaled LM | Pesaran CD |
|---|---|---|---|
| GF | 97.74* | 20.61* | 14.64* |
| FT | 204. 85* | 48.13* | 16.62* |
| ES | 215.85* | 45.11* | 14.21* |
| Digi | 143.78* | 28.67* | 8.72* |

***, ** and * is for the significance level of 10%, 5% and 1%

**Table 3: Panel unit root test**

| Variables | IPS | | CIPS | |
|---|---|---|---|---|
| | Level | Fist-difference | Level | Fist-difference |
| GF | −2.027 | −3.321* | −2.334 | −3.495* |
| FT | −2.059 | −3.689* | −4.455* | −5.019* |
| ES | −2.675 | −4.396* | −2.068 | −4.873* |
| Digi | −1.728 | −3.396* | −1.728 | −4.833* |

*, ** and *** Denotes rejection of the null hypothesis at 1% and 5% and 10% significance level

**Table 4: Kao and Westerlund cointegration test**

| Westerlund (2007) | | | | | |
|---|---|---|---|---|---|
| **Model** | | $G_t$ | $G_a$ | $P_t$ | $P_a$ |
| $ES_{it}=GF_{it}.FT_{it}.Digi_{it}.\varepsilon_{it}$ | | −6.084* | −37.015* | −18.621* | −39.416* |
| Kao residual cointegration test | | | | | |
| ADF | t-statistics−1.425** | | | | Prob. 0.0211 |

***, ** and * is for the significance level of 10%, 5% and 1%

**Table 5: Pairwise Dumitrescu-Hurlin panel causality analysis**

| Null hypothesis | W-stat. | Zbar-stat. | Prob. |
|---|---|---|---|
| ES does not homogeneously cause GF | 3.410* | 4.260 | 0.000 |
| GF does not homogeneously cause ES | 4.853* | 3.090 | 0.000 |
| ES does not homogeneously cause FT | 3.921* | 4.016 | 0.000 |
| FT does not homogeneously cause ES | 4.362* | 4.710 | 0.000 |
| ES does not homogeneously cause Digi | 1.061 | 0.319 | 0.613 |
| Digi does not homogeneously cause ES | 4.662* | 3.072 | 0.000 |

***, ** and * is for the significance level of 10%, 5% and 1%

The estimates obtained from paired panel causality tests are presented in Table 5. Dumitrescu and Hurlin (2012) have established unidirectional and bidirectional causation between the variables being studied. A bidirectional causal relationship between green finance and environmental sustainability, and FinTech and environmental sustainability is confirmed by the test below. The findings also reveal a one-way causal relationship between digital economy and environmental sustainability.

The statistics indicate a positive correlation between FinTech events and energy conservation utilization, as reported by Anh Tu et al. (2021). The emergence of FinTech is a direct response to the growing adoption of energy saving practices in the energy sector (Iqbal et al., 2021). The FinTech industry also enables the focus and spread of information. The cumulative benefits have been demonstrated to facilitate the development of the renewable energy sector (Alemzero et al., 2021). The statistics indicate a positive correlation between FinTech events and the utilization of energy conservation, as reported by Anh Tu et al. (2021).

Green financing has a substantial influence on environmental sustainability. Enhancing environmental sustainability can be achieved by establishing specialized policy groups that focus on attaining energy poverty objectives (Liu et al., 2022). Governments and politicians should enact legislation to reduce domestic energy consumption and greenhouse gas emissions and enforce them to alleviate the effects of energy poverty on low-income families. The digital economy provides more efficient methods for energy consumption, innovative solutions to manage intricate electrical systems created by a wide range of small clients, and new investment opportunities (Karaki et al., 2023b).

## 5. CONCLUSION

This paper examined the relationship between green finance, digital economy, finTech and environmental sustainability. This paper empirically evaluates the impact of green finance, digital economy and finTech on environmental sustainability in Middle Eastern countries from 2013 to 2023. To achieve this goal, the study initiated the empirical analysis by ascertaining the presence of a CD in the data. Upon detecting the presence of CD in the series, we performed the IPS and CIPS second-generation unit root tests. The results of these tests indicated that all variables exhibit first-order stationarity. Given the diverse nature of the five countries examined, we utilized the Westerlund (2007) technique. To achieve the objectives outlined in the Paris Climate Agreement, we suggest implementing strategies that promote the utilization of renewable energy sources, encourage environmental innovation, and enhance energy generation. Green finance, digital economy, and finTech are closely interrelated. The initial stages of developing renewable energy can be both precarious and costly. Policy support is essential for creating a conducive climate to enhance this industry.

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