sustainability

Article

Ecological Footprint and Its Determinants in MENA Countries: A Spatial Econometric Approach

Mohammadreza Ramezani [1], Leili Abolhassani [1,2,*], Naser Shahnoushi Foroushani [1], Diane Burgess [2] and Milad Aminizadeh [1]

[1] Department of Agricultural Economics, Ferdowsi University of Mashhad (FUM), Mashhad 9177948978, Iran
[2] Economic Research Branch, Agri-Food & Biosciences Institute (AFBI), Belfast BT9 5PX, UK
* Correspondence: l.abolhasani@um.ac.ir or leili.abolhassani@afbini.gov.uk; Tel.: +98-915-1569429

Abstract: Countries in the Middle East and North Africa (MENA) have been facing serious environmental issues due to over-exploitation of natural resources. This paper analyzes the ecological footprint as a proxy of environmental degradation and determines its influencing factors in 18 MENA countries during 2000–2016. Despite the many studies on the relationship between the ecological footprint and its determinants in the region, the current study use spatial econometric models to take into account spatial dependence in the ecological footprint as well as its determinants. Using a spatial Durbin model, we revealed that neighbors' behavior can significantly affect a country's ecological footprint. Factors such as GDP per capita, trade openness, and financial development were found to increase environmental degradation, while the renewable energy consumption, urbanization, and quality of democracy effectively reduce the ecological footprint. These factors not only affect the ecological footprint in the host country, but also affect it in the adjacent countries in different ways. Due to the interdependence of the countries, we recommend development of a regional vision of the bio-economy such that the scope of the analysis goes beyond the country level to account for territorial effects. Furthermore, considering the great potential for renewable energy consumption in the region, we recommend MENA countries to develop use of renewable energy sources in order to reduce environmental degradation in the region.

Keywords: ecological footprint; spatial Durbin model; urbanization; financial development; MENA region

check for updates

Citation: Ramezani, M.; Abolhassani, L.; Shahnoushi Foroushani, N.; Burgess, D.; Aminizadeh, M. Ecological Footprint and Its Determinants in MENA Countries: A Spatial Econometric Approach. *Sustainability* **2022**, *14*, 11708. https://doi.org/10.3390/su141811708

Academic Editor: Veli Yilanci

Received: 22 July 2022
Accepted: 15 September 2022
Published: 18 September 2022

1. Introduction

The ultimate goal of sustainable development is to improve human well-being and also prevent the deterioration of environmental quality and excessive exploitation and utilization of natural resources [1]. Nonetheless, despite the undeniable contribution of ecological well-being as a vital part of human well-being [2], environmental challenges have been exacerbated by human demands for higher living standards [3–5]. Therefore, there is an urgent need to balance environmental sustainability with economic activities, especially in developing countries where environmental performance has received less attention [6].

The Middle East and North Africa (MENA) countries are among those with the lowest environmental performance. These countries are endowed with abundant natural resources, especially gas and oil reserves, the export of which provides a significant proportion of their budget cash [7]. This makes a high potential for competition among MENA countries to export more of their natural resources in order to manage their economies [8,9]. Hence, environmental degradation in MENA countries has been worsening and alarming that those societies will be facing a severe shortage of environmental resources in the near future if determinants of environmental degradation have not been recognized and managed. Although numerous studies that have been conducted to determine environmental degradation appear to be useful in addressing environmental issues in MENA countries, considerable uncertainty and confusion can still be seen. First, many factors are directly and indirectly involved in environmental conditions. While some of those factors—in particular, economic factors such as GDP—have been well-studied and discussed, some others such as quality of democracy have been little-studied. It is rare to find studies that include variables in different dimensions such as environment and institutional governance in explaining environmental degradation. Therefore, it is necessary to investigate how those factors affect the environment of MENA countries. Second, since various regions have different abundance, pattern, context, and use of natural resources, factors that affect environmental conditions in various countries are different. Third, environmental impacts of the well-defined factors, including trade openness and urbanization, have been differently explored. Therefore, the previous studies cannot be used to clarify how these factors uniquely influence the MENA region.

Furthermore, our research effort is different from the existing studies. First, despite many previous studies, ecological footprint (EF) was used as an indicator of environmental degradation (ED) which is a holistic indicator for measuring the effects of human activities on the environment. The EF measures ecological consumption by calculating the biologically productive land and sea required to produce all of the resources a population demands and to absorb the corresponding wastes in a given year [10,11]; it is commonly measured in global hectare (gha) per capita. EF consists of six important dimensions, namely grazing land, cropland, fishing ground, forestry, carbon, and build-up land footprint [12]. Second, the ED in a country could be potentially related to neighboring countries. For instance, the ecological consumption in different regions interacts spatially through trade and other economic activities. Trading agricultural commodities and energy sources among countries in a specific region are vivid examples of how consumption of natural resources is affected by neighbors. Hence, the econometric model applied in this study accounts for spatial correlations examining if a country's environmental performance can affect other countries. Third, in MENA, because of weak political rights and underperforming civil institutions, democracy and official institutions in the region perform poorly. In addition to the inclusion of most applied factors such as urbanization, GDP per capita, trade openness, and renewable energy consumption, the model examines how institutional performances such as quality of democracy and financial development affect environmental condition.

The next two sections describe economic and environmental conditions of MENA countries and more detailed review of the literature on determinants of environmental degradation. The rest of this paper is structured as follows: Materials and Methods, Results, Discussion, and Conclusion.

1.1. Determinants of Environmental Degradation

Numerous empirical studies on environmental degradation have been conducted in different countries. Table 1 summarized a part of the empirical literature on methodologies used to determine factors affecting environmental degradation and the results. From the table, we can clearly see that empirical studies differ in variables used to describe environmental quality and econometric models applied.

Reviewing the literature from the early studies of 1990s to recent years, studies are divergent regarding proxies used to describe environmental degradation and variables considered as determinants. Most studies from the early years concerned atmospheric emissions such as CO_2, NO_2, $PM_{2.5}$, SO_2, and CH_4, whose levels were used to describe environmental quality. While the challenge of limiting the environment to the climate system in the early years was recognized [13], the recent empirical literature used the ecological footprint (EF) as a multi-dimensional proxy to describe human causes of environmental degradation [14–19]. In the same vein, some MENA studies have proxied ED by EF and analyzed its determinants [11,20–22].

According to the literature, socio-economic factors—including GDP, trade openness, population, urbanization, energy use, and financial development—are prime determinants of environmental problems. Numerous studies illustrate that the economic growth of middle- and low-income countries is attained through exploiting environmental resources [17,20,23]; also, economic development in developed countries were achieved at the cost of over-exploitation of natural resources and pressure on the environment [24,25]. In almost all studies concentrated on the determinants of ecological footprint (e.g., [17,21,24,26,27]), higher economic growth is expected to increase ecological consumption because economic activities are usually accomplished via higher environmental damage. Trade openness was widely regarded as an important factor in environmental degradation; however, mainstream studies found different direction of causality between trade openness and environmental quality. Some studies (e.g., [22,28,29]) illustrate that trade openness could reduce ecological consumption because active international trade allows the transmission of newer technologies that generate less harmful emissions. Some others (e.g., [20,26,30]) argue that trade openness increases the region's tourism level, transportation connectivity, and energy consumption, which in turn might increase the level of environmental degradation (ED). Population pressure is the other key factor that would obviously increase a country's demand for environmental resources causing environmental degradation [31,32]. Urbanization was also considered as the other key factor influencing environmental condition; however, different results of casual direction were reported. Studies conducted by Al-Mulali and Ozturk [20] and Nathaniel et al. [21] suggest that urbanization is associated with a number of harmful environmental impacts, including air pollution, water pollution, anthropogenic greenhouse gas emissions, and biodiversity reduction. On the contrary side, studies such as Charfeddine and Mrabet [11] argue that urbanization is associated with a higher purchasing power of urban inhabitants that may generate demand for clean technologies and more efficient use of natural resources. So, the expected coefficient of urbanization on the ecological footprint may be either positive or negative. Impact of energy use on environmental condition can be different, depending on the type of energy consumed. Unlike non-renewable energy, renewable energy is environmentally friendly in that it does not harm natural ecosystems. Therefore, renewable energy consumption improves environmental quality as it reduces fossil-fuel consumption [10,15,16,24,33,34]. Regarding financial development, mixed results have been reported. For instance, a strong financial system could decrease environmental degradation through enhancing investments in green environmental technologies and shifting towards more efficient production lines [18,30]. On the contrary, many studies argue that financial development may promote living standards and consumer demands on big-luxury items, for example big houses, sport cars, mobile phones, laptops, and computers, resulting in high ecological consumption [17,18,35].

While some variables including GDP, urbanization, energy consumption, trade openness, and financial development have been formerly determined to cause environmental degradation, other variables including quality of democracy (or other equivalent variables like political institutional quality, governance performance, etc.) and a country's biocapacity are seen in the recent literature. Relatively similar results about impacts of newly identified variables on environmental degradation were reported. Most studies [33,34,36,37] demonstrated that quality of democracy plays a significant role in mitigating environmental problems. Only a few studies (e.g., [38]) did not find a fundamental association between quality of democracy and environmental issues. A country's biocapacity was also considered as the main factor of the environmental aspect [26,32,39]. Having a high bio-capacity (BO) in a country indicates an opportunity to use ecosystem resources that most probably lead to environmental degradation [26,39]. The BO measures the maximum capacity of an ecosystem to produce useful biological materials and to absorb waste materials to meet humanity's demands for ecological consumption [10].

The other divergence in the empirical studies is related to econometric model. Maddison [40] argued that ED could be related to neighboring regions and countries as a consequence of their strategic response to transboundary pollution flows. Some other researchers theoretically and empirically supported this argument. Jiang et al. [41], Kang et al. [42], and Wang et al. [39] reported that air pollution, invasive species, and water resources contamination can spread across borders, affecting environmental quality in neighboring regions. The argument was empirically confirmed in subsequent studies [26,39,41,43–48] via spatial econometric models to examine the relationship between ED and explanatory variables. Wang et al. [39] applied a spatial econometric approach to examine the relationship between GDP, BO, and EF at the global scale. The study concluded that GDP and BO increase the EF. Wu [32] assessed the spatial relationship between the EF and its influencing factors in China's provinces during the years 2004–2012 using the Geographically Weighted Regression (GWR) model. The analysis found population size and affluence level as the main driving forces of EF evolution, while technological advancement could effectively constrain EF growth. Zambrano-Monserrate et al. [26] applied a spatial Durbin model to study the determinants of ecological footprint for a sample of 158 countries from 2007 to 2016. Spatial effects were reported, and BO, trade openness, and GDP were detected as the main factors increasing the EF of countries.

Table 1. Determinants of environmental degradation (ED) in different studies.

Authors	Environmental Damage Variable	Countries/Region Period	Method	Environmental Damage Determinants
Selden and Song [49]	SO_2, NO_x, SPM, CO	30 selected countries	Panel estimation	GDP per capita
Cropper and Griffiths [50]	Deforestation	Africa, Latin America, and Asia 1961–1991	Panel estimation	Rural population density, percentage change in population, timber price, GDP per capita, percentage change in GDP per capita
Galeotti and Lanza [51]	CO_2 emissions	110 developing countries 1971–1996	Panel data model	GDP
Maddison [40]	SO_2, NO_x, VOCs, CO emissions	135 selected countries 1990–1995	Spatial econometric approach	GDP per capita
Bagliani et al. [52]	Ecological footprint	141 selected countries 2001	OLS and WLS	GDP, biocapacity
Wang et al. [39]	Ecological footprint	150 countries 2005	Spatial econometric approach	GDP, biocapacity
Shahbaz et al. [35]	CO_2 per capita	India 1970–2012	cointegration test, ARDL bounds test	Total energy consumption intensity per capita, real GDP per capita, globalization, financial development
Al-Mulali and Ozturk [20]	Ecological footprint	14 MENA countries 1996–2012	FMOLS	Urbanization, trade openness, industrial output, political stability
Charfeddine and Mrabet [11]	Ecological footprint	15 MENA countries 1975–2007	Dynamic ordinary least square, fully modified ordinary least square	Real GDP, energy use, urbanization rate, political institution, fertility rate, life expectancy at birth
Effiong [53]	CO_2 and PM_{10} emissions	49 African countries 1990–2010	Fixed effect regression model	Urbanization, technology, population size, GDP
Sarkodie and Adams [34]	CO_2 emissions	South Africa 1971–2017	Surface regressions, recursive residuals, and OLS	Energy and renewable energy consumption, economic development, urbanization, political institutional quality

Table 1. *Cont.*

Authors	Environmental Damage Variable	Countries/Region Period	Method	Environmental Damage Determinants
Jiang et al. [41]	Air quality index	150 Chinese cities 2014	Spatial econometric approach	GDP per capita, foreign direct investment, the share of the tertiary sector, population density, $PM_{2.5}$ concentration, and SO_2 emissions
Rasoulinezhad and Saboori [30]	CO_2 emissions	Commonwealth of Independent States (CIS) region 1992–2015	DOLS and FMOLS	GDP, renewable and non-renewable energy consumption, trade openness, financial development
Alola et al. [24]	Ecological footprint	16 European countries 1997–2014	PMG-ARDL	RGDP, trade openness, fertility rate, renewable energy consumption, non-renewable energy consumption, urbanization
Xu et al. [54]	SO_2, NO_x, and $PM_{2.5}$ emissions	China's provinces 2005–2015	Panel estimation	GDP per capita, population urbanization, population, energy efficiency, industrialization
Nathaniel et al. [17]	Ecological footprint	South Africa 1965–2014	ARDL, DOLS, FMOLS	Energy use, urbanization, financial development, real GDP per capita
Nathaniel et al. [21]	Ecological footprint	13 MENA countries 1990–2016	AMG algorithm	Non-renewable energy, renewable energy, financial development variable, GDP, urbanization
Zhang et al. [10]	Ecological footprint	90 selected countries 1996–2015	OLS	Urbanization, renewable energy consumption, service value added, individuals using the internet, years of schooling, GNI per capita
Moutinho et al. [29]	CO_2 emissions	OPEC countries 1992–2015	Panel corrected standard errors	Energy consumption, trade openness, oil price, gross value added
Haldar and Sethi [33]	CO_2 emissions	39 developing countries 1995–2017	MG, AMG, CCEMG, Dynamic system GMM, FMOLS, quantile regression	Institutional quality, GDP, renewable energy consumption, trade openness, capital formation, FDI, financial development, population
Ahmed et al. [14]	Ecological footprint	G7 countries 1971–2014	CUP-FM and CUP-BC estimators	GDP, energy consumption, urbanization, human capital index, imports of goods and services, export of goods and services, foreign direct investment
Danish et al. [16]	Ecological footprint	BRICS countries 1992–2016	DOLS, FMOLS	Natural resources rent, renewable energy, urbanization, GDP

Table 1. *Cont.*

Authors	Environmental Damage Variable	Countries/Region Period	Method	Environmental Damage Determinants
Zambrano-Monserrate et al. [26]	Ecological footprint	158 countries 2007–2016	Spatial econometric approach	Trade openness, GDP per capita biocapacity per capita
Wu [32]	Ecological footprint	China's 30 provinces 2004 and 2012	GWR	Population size, affluence level, technological advancement
Malik et al. [55]	Carbon emissions	Pakistan 1971–2014	ARDL	Economic growth, foreign direct investment, oil price
Zafar et al. [56]	CO_2 emissions	46 Asian countries 1991–2017	FMOLS	Industrialization, energy consumption, GDP, urbanization
Bulut [15]	Ecological footprint	Turkey 1970–2016	ARDL and DOLS	GDP, foreign direct investments, renewable energy consumption, industrialization
Uddin [57]	CO_2, CH_4 and $PM_{2.5}$ emissions	115 selected countries 1990–2016	FMOLS, GMM estimation	Agriculture and manufacturing GDP growth, energy consumption, urbanization, trade openness, transportation
Tiba and Belaid [58]	CO_2, and NO_x emissions	27 African countries 1990–2013	CCE-MG estimation	GDP, trade openness, foreign direct investment, energy consumption
Saud et al. [18]	Ecological footprint	Selected one-belt-one-road initiative countries 1990–2014	PMG, FMOLS	Financial development, globalization, economic growth, energy use, trade
Mrabet et al. [22]	Ecological footprint	16 MENA countries 1990–2016	PVAR, FMOLS	HDI index, energy consumption, trade openness, urbanization, political unrest
Shahzad et al. [19]	Ecological footprint	United States 1965–2017	QARDL	Economic complexity, fossil fuel energy usage

Note: OLS (ordinary least square), FMOLS (fully modified ordinary least square), DOLS (dynamic ordinary least square), WLS (weighted least square), ARDL (autoregressive distributed lag model), GWR (geographically weighted regression), MG (mean group), AMG (augmented mean group), PMG (pooled mean group), CCEMG (common correlated effects mean group), GMM (generalized method of moments), CUP-FM (continuously updated fully modified), CUP-BC (continuously updated bias corrected), PVAR (panel vector autoregressive), QARDL (quantile autoregressive distributed lag).

1.2. MENA Region and Environmental Issues

The MENA region contains 22 countries [21]. This region is endowed with huge and diverse natural resources including gas and petroleum reserves, various non-oil fuels, and mineral and non-mineral resources [11]. However, the ecological footprints (EF) of those countries have been continuously increasing, mainly due to the fact that almost all of them use their natural resources (in particular energy resources) to develop their economies. EFs of 13 MENA countries in 2016, along with their six dimensions are presented in Figure 1. From the figure, it is evident that the major part of EF in the MNEA region is related to carbon footprint indicating a high impact of MENA countries on global warming. In 2016, the world average ecological footprint per capita was 2.75 global hectares, of which 60% equal to 1.65 hectares was related to carbon footprint, but on average, 4.15 hectare of lands per person—about two times more the global average—are required to remove CO_2 emissions. Cropland footprint, which shows all the area of land required to grow agricultural products, is in second place with an average of 0.60 ha/person. Grazing land, forest products, fishing grounds, and built-up land footprint are in the last places, respectively. To sum up, countries in the MENA region suffer from not only carbon dioxide emissions, but also environmental issues such as deforestation, overfishing, and water shortage [59].

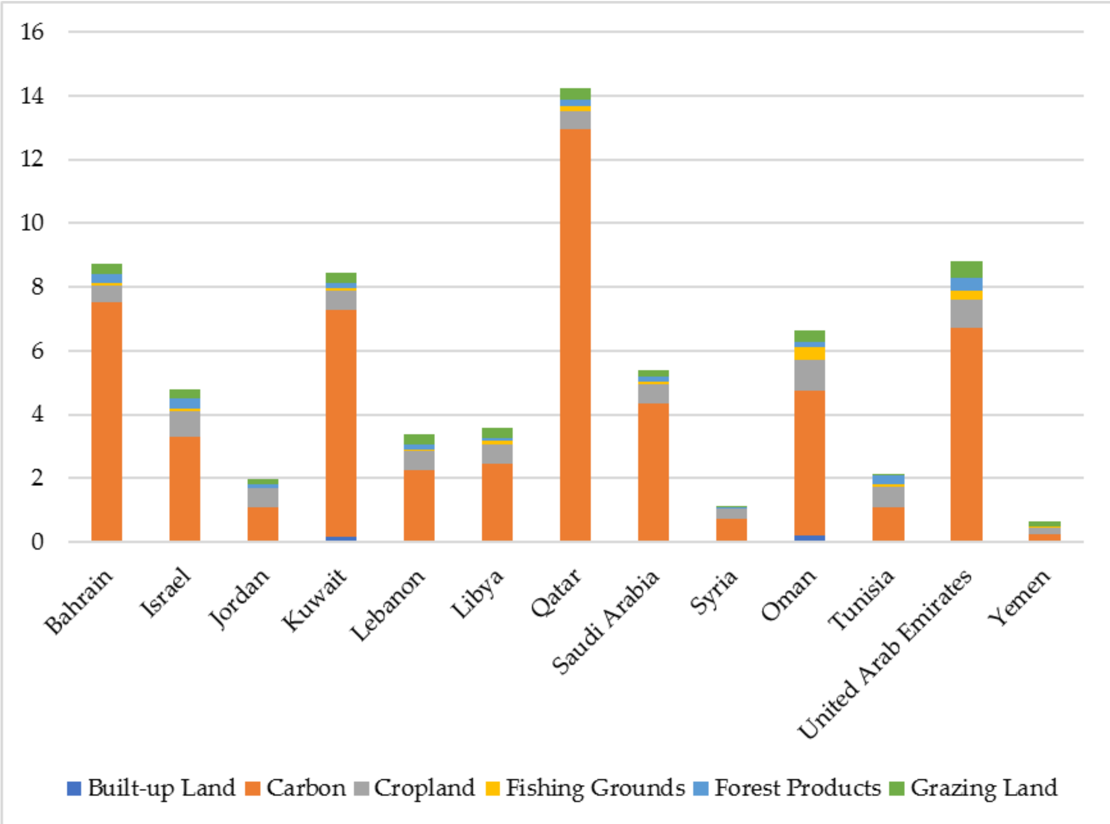

Figure 1. EF of 13 MENA countries in 2016 [12].

The continuous increase in the consumption of ecological resources has led to decreased actual bio-capacity (BO) in the MENA region. Figure 2 presents EF and BO values during 1966–2016. The graphs show that the human demand on nature (EF) has exceeded the regenerative and absorptive capacities of natural capital (BO), showing that the ecological deficit expands rapidly. Six of these countries—Qatar, Kuwait, United Arab Emirates, Bahrain, Oman, and Saudi Arabia—had extremely large EF values and exhibited drastic ecological degradation.

Weak governance performance—political and civil democracy in particular—is another issue in the MENA countries. The region has observed numerous social-political disorders which severely affect environmental quality [60]. Marine ecosystems like mangroves and coral reefs in the Persian Gulf are also endangered and surrounded by biodiversity loss, species extinction, and habitat decline which are mainly caused by accelerated urbanization, climate change, and lack of policies for environmental protection and conservation [61].

Figure 2. Temporal changes in ecological footprint and biocapacity of the MENA countries 1996–2016. Source: National Footprint Account results (2019 Edition) from the Global Footprint Network (GFN).

1.3. Contribution of the Study

This study makes unique contributions to the existing literature on the determinants of environmental degradation in MENA countries. Using spatial econometric approach, we examined empirical evidence on the spatial dependence of environmental degradation in the MENA region. This analysis helps in understanding if a country's environmental performance can affect environmental condition of neighbors. Furthermore, this study examines how recently identified determinants, including quality of democracy and financial development, affect environmental degradation in those countries. Most existing studies did not consider potential effects of these factors on environmental performance, which may result in biased estimates. Moreover, widening the scope of the sample, this study contributes to better insight into the factors associated with environmental quality in the MENA region. This study used the data of 18 MENA countries, while previous studies have been concentrated on fewer countries. The other four MENA countries were excluded from the analysis due to large amounts of missing information.

2. Materials and Methods

A set of annual data of 18 MENA countries—including Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Qatar, Saudi Arabia, Tunisia, United Arab Emirates, Oman, Syria, and Yemen—was used for econometric analysis. Based on the availability of data, we elected to study the two-decade time-period of 2000-2016. All data were collected from the World Development Indicators (WDI), Freedom House website, and the Global Footprint Network (GFN).

2.1. Variables and Data

The ecological footprint (EF) was used to assess environmental degradation (ED) caused by human activities [26]. It has the ability to trace consequences of human activities on the environment. The higher the ecological footprint is, the higher the environmental damage is [20]. Based on the literature reviewed in the previous section, hypothetical influence of explanatory variables including urbanization, GDP per capita, trade openness, renewable energy consumption, financial development, and quality of democracy are shown in Table 2. Indices of financial development and quality of democracy are explained below.

Table 2. Data description, expected signs of variables, and data source.

Variable Name	Symbol	Definition/Units	Expected Impact on EF	Data Source
Ecological footprint per capita	EF	Measured in global hectares		GFN [12]
Urbanization	URB	People living in urban areas as a percentage of total population	−/+	WDI [62]
GDP per capita	GDP	Measured in current USD per capita	+	WDI [62]
Trade openness	TO	Sum of exports and imports of goods and services as a percentage of GDP	−/+	WDI [62]
Renewable energy consumption	RE	Renewable energy consumption as a percentage of total final energy consumption	−	WDI [62]
Financial development index	FDV	-	−/+	WDI [62]
Quality of democracy	QD	-	−	Freedom House [63]

2.1.1. Quality of Democracy

The index of quality of democracy was built by aggregating political rights and civil liberty indices taken from Freedom House data. The "political rights index" was constructed based on 10 different freedom-related indicators which were grouped into three categories. The indicators were constructed by statements about political freedom such as free press and media, independent judiciary system, rule of law, open public discussion, freedom of assembly and democratization, and individual rights. The statements were rated on a scale of 1 to 7, with 7 denoting the least level of political freedom and 1 the highest level of freedom. The average of the ratings from 10 statements were used to construct the political rights index (with values 1–7). Similarly, the "civil liberty index" was constructed based on 15 different individual freedom-related questions, grouped into four categories and rated on a scale of 1 to 7. The civil liberty index (with values 1–7) was obtained by averaging these ratings. Countries with a rating of 7 had the least civil liberties [64,65]. All the indicators were summarized in Table 3. For the full list of questions refer to Freedom House website on https://freedomhouse.org/reports/freedom-world/freedom-world-research-methodology (accessed on 18 January 2021).

Table 3. Indicators used to explain quality of democracy.

<table>
<tr><th colspan="2">Political Rights Index</th><th colspan="2">Civil Liberty Index</th></tr>
<tr><td rowspan="4">Electoral process</td><td>Executive elections</td><td rowspan="4">Freedom of expression and belief</td><td>Media</td></tr>
<tr><td>Legislative elections</td><td>Religious</td></tr>
<tr><td rowspan="2">Electoral framework</td><td>Academic freedoms</td></tr>
<tr><td>Free private discussion</td></tr>
<tr><td rowspan="4">Political pluralism and participation</td><td>Party systems</td><td rowspan="4">Associational and organizational rights</td><td>Free assembly</td></tr>
<tr><td>Political opposition and competition</td><td>Civic groups</td></tr>
<tr><td>Political choices dominated by powerful groups</td><td rowspan="2">Labor union rights</td></tr>
<tr><td>Minority voting rights</td></tr>
<tr><td rowspan="8">Functioning of government</td><td>Corruption</td><td rowspan="4">Rule of law</td><td>Independent judges and prosecutors</td></tr>
<tr><td>Transparency</td><td>Due process</td></tr>
<tr><td rowspan="6">Ability of elected officials to govern in practice</td><td>Crime and disorder</td></tr>
<tr><td>Legal equality for minority and other groups</td></tr>
<tr><td rowspan="4">Personal autonomy and individual rights</td><td>Freedom of movement</td></tr>
<tr><td>Business and property rights</td></tr>
<tr><td>Women's and family rights</td></tr>
<tr><td>Freedom from economic exploitation</td></tr>
</table>

Source: Freedom House [64,65].

To combine the two indices into one score, we followed Charfeddine and Mrabet [11] by summing the two indices and subtracting this sum from 14. The score ranges from 0 to 12. A higher value of this index represents greater freedom and higher democracy.

2.1.2. Financial Development

Following Nathaniel et al. [21], principal component analysis (PCA) was used to create an index for financial development. PCA is a useful statistical technique for simplification and reducing the dimensionality of multivariate datasets [66] and has been widely used in environmental and ecological studies. It employs an orthogonal transformation to transform a large number of variables into a few new variables called principal components [67]. Three variables including domestic credit to the private sector, domestic credit to the private sector by banks, and foreign direct investments were used in PCA. All three variables were measured as a percentage of GDP.

2.2. Model Specification

A spatial econometric model was used to include spatial diffusion of environmental pollution [41]. To ensure that our model was well-specified, we conducted the Global Moran's I test to examine the presence of spatial autocorrelation [68]. The Global Moran's I test can be expressed as follows [46]:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i - \overline{X})(X_j - \overline{X})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}(X_i - \overline{X})^2} \tag{1}$$

where n is the number of countries and X_i and X_j are the EF of country i and j, respectively. W_{ij} represents the spatial weight matrix. In this study, we use rook contiguity to construct a row-standardized spatial weight matrix. Global Moran's I test statistic ranges from −1 to 1. If the test statistic is greater than zero, there is positive spatial correlation between the EF of countries. This correlation turns negative if the Global Moran's I test value is less than zero, and finally, there is no spatial correlation if the test value is equal to zero [46]. To test the significance level of Global Moran's I test, a Z-value is applied, which follows a standard normal distribution and is derived as shown in Equation (2) [46]:

$$Z_I = \frac{I - E[I]}{\sqrt{Var[I]}} \tag{2}$$

where $E[I]$ and $Var[I]$ refer to the expected value and variance of the Global Moran's I, respectively.

The spatial econometrics models can be categorized into the spatial autoregressive model (SAR), the spatial error model (SEM), and spatial autocorrelation model (SAC). The SAR model considers spatial dependence in the dependent variable. This model in matrix form is shown in Equation (3) [68]:

$$y = \rho Wy + \alpha\iota_n + X\beta + \varepsilon \tag{3}$$

where y indicates a vector of $n \times 1$ observations of the dependent variable for every unit in the sample (i = 1, . . . , n), ι_n denotes an $n \times 1$ vector of ones, X denotes a $n \times k$ matrix of independent variables, k is the number of exogenous variables, α and ρ are scalar parameters, β is a vector of parameters, W is the $n \times n$ spatial weight matrix, and ε is a normally distributed error term.

The SEM model takes spatial dependence of the error terms. This model is shown in Equation (4) [68]:

$$\begin{aligned} y &= \alpha\iota_n + X\beta + u \\ u &= \lambda Wu + \varepsilon \end{aligned} \tag{4}$$

where λ is the autoregressive coefficient.

The SAC model contains spatial dependence in both the dependent variable and the error terms. The SAC model is given in Equation (5) [68]:

$$\begin{aligned} y &= \rho W_1 y + \alpha\iota_n + X\beta + u \\ u &= \lambda W_2 u + \varepsilon \end{aligned} \tag{5}$$

where the matrix W_1 may be set equal to W_2.

The Spatial Durbin Model (SDM) was developed to consider the spatially lagged dependent and independent variables. This model is shown in Equation (6) [68]:

$$y = \rho Wy + \alpha\iota_n + X\beta + WX\gamma + \varepsilon \tag{6}$$

In this study, we examined all four types of spatial regression models, including SEM, SAR, SAC, and SDM, and selected the fittest model based on the highest goodness of fit. As the SDM model nests both the SAR and SEM models, and following the strategy proposed by LeSage and Pace [68] and Belotti et al. [69], we assessed the SDM as a starting point and tested for the exclusion of variables from the model using likelihood ratio (LR) tests. To obtain the fittest model, we first tested if $\gamma = 0$ and $\rho \neq 0$, which is the specification test of a SAR. Then, we tested if $\gamma = -\beta\rho$, which implies the specification test of a SEM. We also examined a SAC model. Apart from quality of democracy index and financial development variable, all variables are transformed to their logarithmic forms to moderate sharpness in the time series and achieve consistent empirical evidence. Our empirical model can be written as:

$$\begin{gathered} \ln \text{EF} = \alpha + \rho W \ln \text{EF} + \beta_1 \ln \text{GDP} + \beta_2 \ln \text{URB} + \beta_3 \ln \text{RE} \\ + \beta_4 \ln \text{TO} + \beta_5 \text{FDV} + \beta_6 \text{QD} + \gamma_1 W \ln \text{GDP} + \gamma_2 W \ln \text{URB} \\ + \gamma_3 W \ln \text{RE} + \gamma_4 W \ln \text{TO} + \gamma_5 W\text{FDV} + \gamma_6 W\text{QD} + \varepsilon \end{gathered} \tag{7}$$

where ln is the natural logarithm, EF is ecological footprint, and the independent variables are GDP (gross domestic product per capita), URB (urbanization), RE (renewable energy consumption), TO (trade openness), FDV (financial development index), and QD (quality of democracy) are the set of independent variables.

3. Results

3.1. Descriptive Statistics

Descriptive statistics presented in the Table 4 show that the values of the selected variables can be considerably different over the countries and the years. Over the study years, GDP (with 63%) and domestic credit to private sector (with 57%) have dramatically increased, while renewable energy consumption (with −34%) and foreign direct investment (with −25%) have decreased significantly. The variables associated with institutional governance showed a decline over the 16 years studied.

Table 4. Descriptive statistics of variables.

Variable	Year/Years	Obs.	Mean	Std. Dev.	Min	Max
EF	2000	18	3.914	3.482	0.840	12.350
	2016	18	4.589	3.647	0.670	14.410
	Change (%)		17	5	−20	17
GDP	2000	18	8818.556	10,362.810	554.449	33,291.420
	2016	18	14,399.206	16,201.210	890	57,163.061
	Change (%)		63	56	61	72
RE	2000	18	3.173	4.813	0	15.259
	2016	18	2.088	3.034	0	12.5
	Change (%)		2.088	3	0	13
TO	2000	18	78.049	30.417	40.509	155.509
	2016	18	77.788	35.928	30.246	176.747
	Change (%)		−0.3	18	−25	14
URB	2000	18	70.968	19.268	26.267	99
	2016	18	75.924	18.368	35.394	100
	Change (%)		7	−5	35	1
Civil liberty index	2000	18	5.444	1.149	3	7
	2016	18	5.167	1.295	2	7
	Change (%)		−5	13	−33	0
Political rights index	2000	18	5.667	1.495	1	7
	2016	18	5.444	1.789	2	7
	Change (%)		−4	20	100	0

Table 4. *Cont.*

Variable	Year/Years	Obs.	Mean	Std. Dev.	Min	Max
Domestic credit to private sector	2000	18	38.185	25.698	1.179	87.901
	2016	18	59.951	31.335	5.295	105.187
	Change (%)		57	22	349	20
Domestic credit to private sector by banks	2000	18	36.396	24.550	1.177	85.485
	2016	18	57.363	29.603	5.295	105.187
	Change (%)					
Foreign direct investments, net inflows	2000		58	21	350	23
	2016	18	1.501	2.128	−3.577	5.016
	Change (%)		−25	−28	261	−53

3.2. Financial Development Index

As formerly discussed, three variables including domestic credit to the private sector, domestic credit to the private sector by banks, and foreign direct investments were selected to build up an index of financial development using the principal analysis method. The PCA results are given in Tables 5–7 and Figure 3.

Table 5. Correlation matrix.

	Domestic Credit to the Private Sector	Domestic Credit to the Private Sector by Banks	Foreign Direct Investments
Domestic credit to the private sector	1		
Domestic credit to the private sector by banks	0.987	1	
Foreign direct investments	0.385	0.399	1
Bartlett's test of sphericity	Approx. chi-squared (df): 1451.617 *** (3)		Sig.: 0.000

Note: *** denotes significant level at 1%.

Table 6. Total variance explained by principal components.

Principal Components	Eigenvalue	% Variance	Cumulative Contribution Rate (%)
1	2.235	74.513	74.513
2	0.752	25.056	99.569
3	0.013	0.431	100

Table 7. Component matrix.

	Component 1
Domestic credit to the private sector	0.963
Domestic credit to the private sector by banks	0.967
Foreign direct investments	0.612
Extraction method: Principal Component Analysis	

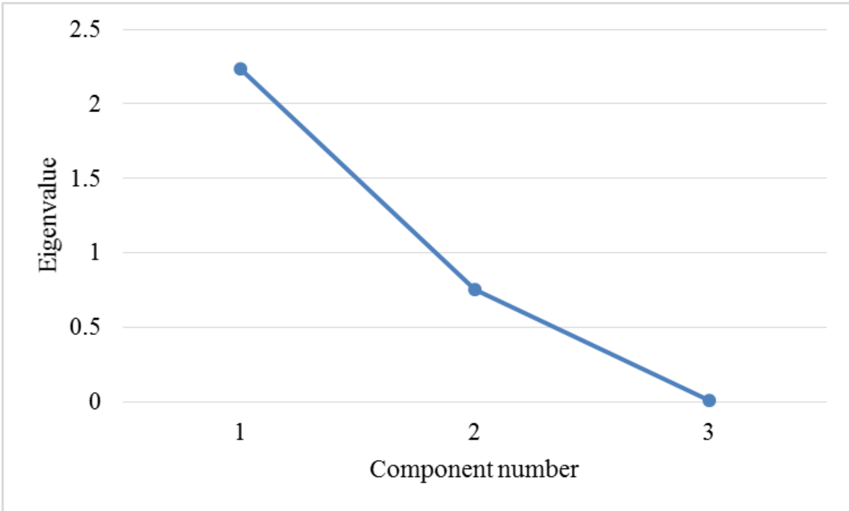

Figure 3. Scree plot.

Table 5 presents correlation among the variables and Bartlett's test to determine whether the data are suitable for factor analysis or not. The Bartlett's statistic is significant at the 1-percent level, rejecting the null hypothesis that the correlation matrix is an identity matrix. Therefore, selected variables can be used to perform PCA.

Table 6 represents eigenvalues and the percentage of variance explained by each principal component. Eigenvalues represent the variances of the principal components. As PCA is conducted on the correlation matrix, the variables are standardized, which means that each variable has a variance of 1 and the total variance is equal to the number of variables used in the analysis: in this case, 3. The scree plot visually represents the eigenvalues against the component number. As seen in Figure 3, only the first factor has an eigenvalue of greater than one, and therefore, it was selected for further analysis.

Table 7 shows component matrix representing correlation between the first PCA factor and three variables. The first factor with eigenvalue higher than one and correlation (loadings) higher than 0.6 can be interpreted as good and fully satisfactory [70].

3.3. Spatial Model Results

The result of Global Moran's I index is presented in the Table 8. Z-scores are positive and highly significant for all years, implying the existence of spatial dependence in ecological footprint and that the spatial regression model has priority over the classic one.

Table 8. The value of the Global Moran's I index of ecological footprint from 2000 to 2016.

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Global Moran's I	0.335 ***	0.328 ***	0.360 ***	0.403 ***	0.361 ***	0.406 ***	0.392 ***	0.412 ***	0.432 ***
Z-value	4.265	4.215	4.504	5.070	4.511	4.883	4.841	5.087	5.238
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Year	2009	2010	2011	2012	2013	2014	2015	2016	
Global Moran's I	0.405 ***	0.429 ***	0.406 ***	0.321 ***	0.248 ***	0.408 ***	0.366 ***	0.382 ***	
Z-value	4.969	5.202	4.983	4.117	3.296	5.055	4.577	4.805	
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Note: *** denotes significant level at 1%.

Table 9 presents regression results for the four spatial models based on the rook contiguity matrix. LR tests and the fit measures indicate that the SDM with the highest adjusted R-squared and the lowest AIC, SC, and HQ is the superior model to explain effects of explanatory variables on environmental degradation. It is worth noting that in order to test the stability of the results, all four spatial models were estimated using other spatial weight matrices including Queen-based contiguity weights matrix, double rook contiguity weights matrix, and K-nearest contiguity weights matrix. On the basis of model fit measures and LR tests, SDM was still the superior model compared to the other three spatial models. However, due to space limits, the regression results are presented only for the selected spatial weight matrix (a summary of regression results can be provided upon request).

Table 9. Estimation of the spatial models.

Variable	SEM	SAR	SAC	SDM
lnGDP	0.579 *** (0.023)	0.497 *** (0.022)	0.582 *** (0.023)	0.573 *** (0.021)
lnRE	−0.014 *** (0.003)	−0.019 *** (0.004)	−0.013 *** (0.003)	−0.020 *** (0.004)
lnTO	0.067 (0.043)	0.020 (0.046)	0.068 (0.043)	0.100 ** (0.043)
lnURB	−0.308 *** (0.104)	0.045 (0.092)	−0323 *** (0.108)	−0.354 *** (0.092)
QD	−0.039 *** (0.005)	−0.032 *** (0.006)	−0.038 *** (0.005)	−0.037 *** (0.006)
FDV	0.129 *** (0.016)	0.102 *** (0.018)	0.132 *** (0.017)	0.132 *** (0.017)
Constant	−2.745 *** (0.286)	−3.431 *** (0.305)	−2.782 *** (0.291)	−5.326 *** (0.995)
Spatial effects				
Rho	-	0.049 (0.042)	0.060 (0.049)	0.218 ** (0.099)
Lambda	0.550 *** (0.064)	-	0.549 *** (0.065)	-
$W \times$ lnGDP	-	-	-	−0.437 *** (0.045)
$W \times$ lnRE	-	-	-	−0.021 * (0.013)
$W \times$ lnTO	-	-	-	−0.099 (0.100)
$W \times$ lnURB	-	-	-	1.545 *** (0.264)
$W \times$ QD	-	-	-	0.019 (0.018)
$W \times$ FDV	-	-	-	−0.103 * (0.060)
Model fit measures				
F-statistic	689.804 ***	788.881 ***	622.288 ***	679.483 ***
p-value (F-statistic)	0.000	0.000	0.000	0.000
R-squared	0.932	0.940	0.926	0.965
Adjusted R-squared	0.927	0.935	0.919	0.961
AIC	0.0427	0.0376	0.0469	0.0228
SC	0.0465	0.0410	0.0511	0.0268
HQ	0.0441	0.0389	0.0486	0.0243
Observations	306	306	306	306

Note: *, **, and *** denote significant level at 10%, 5%, and 1% respectively. Robust standard errors are shown in parenthesis.

The results of SDM shows that the coefficient of the lagged dependent variable, ρ, is significantly positive. The coefficient indicates that a 1% increase in the EF of adjacent countries increases the EF in the own country by 0.218%. Additionally, all the spatially lagged independent variables, except for $W \times$ lnTO and $W \times$ QD, are statistically significant.

4. Discussion

GDP per capita, as expected, can significantly affect the EF. The model estimates show that a one-percent increase in GDP per capita can result in a 0.573% increase in the EF. This result is in line with the findings of many previous studies [14,17,21,26], illustrating that increase in per capita income due to economic activities deteriorates environmental quality via arising human demands on ecological resources. Furthermore, the spatially lagged income variable ($W \times$ lnGDP) has a significantly negative effect on the EF, signifying that an increase in the income level of a neighboring country significantly reduces the EF in the principal country. This results is confirmed by Li and Li [45] in the study of the drivers of carbon emissions in China and the findings of the study conducted by Mahmood [47], who reported that the economic growth of a given country in the North American region encourages its neighboring countries to reduce CO_2 emissions.

The coefficients of both the renewable energy consumption (lnRE) and its spatially lagged variable ($W \times$ lnRE) are negative and significant, showing that switching from fossil fuels to renewable energy not only improves the environmental quality of the home country, but also contributes to the environmental quality in neighboring countries. Kahia et al. [71] and Nathaniel et al. [21] reported that despite enormous potentials of renewable energies, the region has been suffering from serious environmental problems caused by the massive use of fossil fuels. Air pollutants caused by the usage of fossil fuels in a MENA country can spread across the borders and affect environmental quality of neighboring countries.

The coefficient of trade openness is positively significant at 5% level and implies that a one-percent increase in a country's trade flow can cause 0.1% increase in the EF. This result is probably due to the trade character of MENA countries since fossil fuels constitute an important share of their trade with the world. This is confirmed by many previous studies, such as Al-Mulali and Ozturk [20], on MENA countries. Nonetheless, there are a few studies that are in contrast with our findings. For instance, Mrabet et al. [22] reports that trade openness can improve environmental quality because international trade can transfer cleaner technologies from the developed countries, which can reduce ecological consumption. The spatially lagged variable of trade openness ($W \times$ lnTO) is not statistically significant.

The effect of urbanization on the EF is negative at the 1% significance level. However, the spatially lagged coefficient ($W \times$ lnURB) is positive and highly significant. This indicates that urbanization improves the country's environmental condition, while it deteriorates the neighbor's environment. This suggests that increase in demands for environmental resources due to urbanization [20–22] would be achieved through imports from neighbors. The study by Charfeddine and Mrabet [11] on MENA countries supports this finding. Furthermore, urbanization is usually associated with access to cleaner technologies, higher living standards, and increases in a society's desire for environmental protection and sustainability. Both hypotheses point in the same direction: urbanization improves a country's environment, while it worsens the neighbor's environmental condition. This result supports the research of Liu et al. [72] on carbon emissions in China's provinces.

Our result shows the negative effect of quality of democracy on the EF. This result is consistent with studies conducted by Al-Mulali and Ozturk [20] for the MENA region, Haldar and Sethi [33] for 39 developing countries, and You et al. [73] for 41 Belt-and-Road initiative countries, demonstrating that a low quality of democracy negatively affects environmental quality. The spatially lagged variable of quality of democracy ($W \times$ QD) is not significant, demonstrating that improvements in a country's democracy do not have a significant effect on the EF of neighboring countries.

The coefficient estimated for financial development is significantly positive. This implies that financial development reduces environmental quality, probably due to its supporting role in manufacturing activities and infrastructure development. More importantly, the coefficient of the spatially lagged financial development variable ($W \times$ FDV) is negative, implying that financial development in neighboring countries has favorable effects on the local EF. This may be due to the creation of job opportunities and labor force immigration into the industrial region. This conclusion coincides with the study of Samreen and Majeed [74] on the relationship between financial development and carbon emission at a global level.

5. Conclusions

This paper aimed to analyze the ecological footprint and its influential factors in MENA countries. Although several papers focused on the EF and its determinants in the MENA region, to the best of our knowledge, none of them examined whether EFs and their determinants are spatially related. This work may be an initial attempt to explicitly incorporate spatial effects into the analysis. Our results confirm significant spatial dependence in both the dependent variable (EF) and independent variables. In other words, environmental performance and economic conditions in one country significantly affect environmental quality in neighboring countries. Therefore, policymakers need to consider both the benefits of their own countries and the consequences for neighboring countries during policy design and adaption.

Our study shows that most economic actions, except for consuming renewable energy, have different effects on the country and the neighbors' environment. Therefore, economic schemes that have a positive effect on a country's environment may negatively impact the neighbors. For instance, GDP per capita and financial developments were found to worsen a country's environmental quality, while they lessen the ecological footprint of the country's neighbors. Switching from fossil fuels to renewable energy consumption is the only scheme that not only contributes to the environmental quality in the home country, but also reduces the environmental stress in neighboring countries. Despite the undeniable role of renewable energy sources in mitigating environmental issues in the MENA region, its share in regional energy consumption is still very low. Government policies and strategies aimed at developing renewable energy sources is the best way to maintain economic growth of the region as the environment improves.

Furthermore, we found evidence that nations who enjoy freedom and political rights have fewer environmental issues. In this regard, policies aimed at improving judiciary system, freedom of press and media, and protection of human rights could effectively reduce environmental damage in the region. Some countries in the MENA region, however, have faced barriers such as economic sanctions in recent years. Although it is expected that the economic pressure of sanctions lowers the priority of the environmental sector and causes environmental problems [75], further studies about the impact of global governance system on the world's environment is strongly recommended. Our findings reveal that environmental problems in the MENA countries significantly affect environmental quality in neighboring countries, supporting the idea that the environmental problems in the region and potential solutions should be addressed at the territorial scale. To achieve this, it is necessary to establish a trans-territorial organization that assesses strategic plans for synergistic implementation of environmental rules, monitors the implementation of the imposed environmental regulations, and manages inter-country communications.

It should be noted that this paper is an initial attempt to explore factors influencing environmental quality in the region using a spatial econometric approach. Future studies, however, need to include other spatial econometric techniques such as dynamic spatial panel data models and geographically weighted regression. Due to the limitations on the data availability, we included 18 out of 22 MENA countries, covering two decades between 2000 and 2016. We suggest expanding the study by including the other four countries and incorporating more years into the analysis. Finally, we suggest examining the effects of other influential variables such as agricultural policies, research and development, transportation infrastructure, and diversity of renewable energy sources on environmental quality.

Author Contributions: Conceptualization, M.R., L.A., N.S.F. and D.B.; methodology, M.R., L.A. and M.A.; software, M.R. and M.A.; validation, L.A. and N.S.F.; formal analysis, M.R., L.A. and M.A.; investigation, M.R.; resources, M.R.; data curation, M.R. and L.A.; writing—original draft preparation, M.R.; writing—review and editing, M.R. and L.A.; visualization, M.R. and L.A.; supervision, N.S.F.; project administration, N.S.F.; funding acquisition for proofreading and open-access publication, L.A. and D.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available on request due to ethical reasons.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. da Silva, J.M.C.; Li, H.; Barbosa, L.C.F. The ecological intensity of human well-being at the local level. *Environ. Sustain. Indic.* **2020**, *8*, 100061. [CrossRef]
2. Li, J.; Gong, Y.; Jiang, C. Spatio-temporal differentiation and policy optimization of ecological well-being in the Yellow River Delta high-efficiency eco-economic zone. *J. Clean. Prod.* **2022**, *339*, 130717. [CrossRef]
3. Dür, M.; Keller, L. Research Collaboration of Austrian and Indian Teenagers in the Context of Education for Sustainable Development. *Sustainability* **2019**, *11*, 5094. [CrossRef]
4. Wolde, Z.; Wu, W.; Ketema, H.; Karikari, B.; Liu, X. Quantifying Sustainable Land-Water-Energy-Food Nexus: The Case of Sustainable Livelihoods in an East African Rift Valley. *Atmosphere* **2022**, *13*, 638. [CrossRef]
5. Abid, N.; Wu, J.; Ahmad, F.; Draz, M.U.; Chandio, A.A.; Xu, H. Incorporating environmental pollution and human development in the energy-growth nexus: A novel long run investigation for Pakistan. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5154. [CrossRef] [PubMed]
6. Manrique, S.; Martí-Ballester, C.-P. Analyzing the Effect of Corporate Environmental Performance on Corporate Financial Performance in Developed and Developing Countries. *Sustainability* **2017**, *9*, 1957. [CrossRef]
7. Saidin, M.I.; O'Neill, J. Climate Change and the Diversification of Green Social Capital in the International Political Economy of the Middle East and North Africa: A Review Article. *Sustainability* **2022**, *14*, 3756. [CrossRef]
8. Aghahosseini, A.; Bogdanov, D.; Breyer, C. Towards sustainable development in the MENA region: Analysing the feasibility of a 100% renewable electricity system in 2030. *Energy Strateg. Rev.* **2020**, *28*, 100466. [CrossRef]
9. Gorus, M.S.; Aydin, M. The relationship between energy consumption, economic growth, and CO2 emission in MENA countries: Causality analysis in the frequency domain. *Energy* **2019**, *168*, 815–822. [CrossRef]
10. Zhang, S.; Zhu, D.; Zhang, J.; Li, L. Which influencing factors could reduce ecological consumption? Evidence from 90 countries for the time period 1996–2015. *Appl. Sci.* **2020**, *10*, 677. [CrossRef]
11. Charfeddine, L.; Mrabet, Z. The impact of economic development and social-political factors on ecological footprint: A panel data analysis for 15 MENA countries. *Renew. Sustain. Energy Rev.* **2017**, *76*, 138–154. [CrossRef]
12. Global Footprint Network. Available online: https://data.footprintnetwork.org/?_ga=2.169328417.1456014335.1611079047-675422762.1603702175#/countryTrends?type=BCtot,EFCtot&cn=102 (accessed on 19 December 2021).
13. Sarkodie, S.A. Environmental performance, biocapacity, carbon & ecological footprint of nations: Drivers, trends and mitigation options. *Sci. Total Environ.* **2021**, *751*, 141912. [CrossRef]
14. Ahmed, Z.; Zafar, M.W.; Ali, S.; Danish. Linking urbanization, human capital, and the ecological footprint in G7 countries: An empirical analysis. *Sustain. Cities Soc.* **2020**, *55*, 102064. [CrossRef]
15. Bulut, U. Environmental sustainability in Turkey: An environmental Kuznets curve estimation for ecological footprint. *Int. J. Sustain. Dev. World Ecol.* **2020**, *28*, 227–237. [CrossRef]
16. Danish; Ulucak, R.; Khan, S.U.-D. Determinants of the ecological footprint: Role of renewable energy, natural resources, and urbanization. *Sustain. Cities Soc.* **2020**, *54*, 101996. [CrossRef]
17. Nathaniel, S.; Nwodo, O.; Adediran, A.; Sharma, G.; Shah, M.I.; Adeleye, N. Ecological footprint, urbanization, and energy consumption in South Africa: Including the excluded. *Environ. Sci. Pollut. Res.* **2019**, *26*, 27168–27179. [CrossRef]
18. Saud, S.; Chen, S.; Haseeb, A. The role of financial development and globalization in the environment: Accounting ecological footprint indicators for selected one-belt-one-road initiative countries. *J. Clean. Prod.* **2020**, *250*, 119518. [CrossRef]
19. Shahzad, U.; Fareed, Z.; Shahzad, F.; Shahzad, K. Investigating the nexus between economic complexity, energy consumption and ecological footprint for the United States: New insights from quantile methods. *J. Clean. Prod.* **2021**, *279*, 123806. [CrossRef]
20. Al-Mulali, U.; Ozturk, I. The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. *Energy* **2015**, *84*, 382–389. [CrossRef]
21. Nathaniel, S.; Anyanwu, O.; Shah, M. Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. *Environ. Sci. Pollut. Res.* **2020**, *27*, 14601–14613. [CrossRef] [PubMed]
22. Mrabet, Z.; Alsamara, M.; Mimouni, K.; Mnasri, A. Can human development and political stability improve environmental quality? New evidence from the MENA region. *Econ. Model.* **2021**, *94*, 28–44. [CrossRef]
23. Khan, A.; Muhammad, F.; Chenggang, Y.; Hussain, J.; Bano, S.; Khan, M.A. The impression of technological innovations and natural resources in energy-growth-environment nexus: A new look into BRICS economies. *Sci. Total Environ.* **2020**, *727*, 138265. [CrossRef] [PubMed]
24. Alola, A.A.; Bekun, F.V.; Sarkodie, S.A. Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. *Sci. Total Environ.* **2019**, *685*, 702–709. [CrossRef] [PubMed]
25. Yang, B.; Usman, M.; Jahanger, A. Do industrialization, economic growth and globalization processes influence the ecological footprint and healthcare expenditures? Fresh insights based on the STIRPAT model for countries with the highest healthcare expenditures. *Sustain. Prod. Consum.* **2021**, *28*, 893–910. [CrossRef]
26. Zambrano-Monserrate, M.A.; Ruano, M.A.; Ormeño-Candelario, V.; Sanchez-Loor, D.A. Global ecological footprint and spatial dependence between countries. *J. Environ. Manag.* **2020**, *272*, 111069. [CrossRef]
27. Ahmed, Z.; Zhang, B.; Cary, M. Linking economic globalization, economic growth, financial development, and ecological footprint: Evidence from symmetric and asymmetric ARDL. *Ecol. Indic.* **2021**, *121*, 107060. [CrossRef]

28. Koilo, V. Evidence of the Environmental Kuznets Curve: Unleashing the Opportunity of Industry 4.0 in Emerging Economies. *J. Risk Financ. Manag.* **2019**, *12*, 122. [CrossRef]
29. Moutinho, V.; Madaleno, M.; Elheddad, M. Determinants of the Environmental Kuznets Curve considering economic activity sector diversification in the OPEC countries. *J. Clean. Prod.* **2020**, *271*, 122642. [CrossRef]
30. Rasoulinezhad, E.; Saboori, B. Panel estimation for renewable and non-renewable energy consumption, economic growth, CO_2 emissions, the composite trade intensity, and financial openness of the commonwealth of independent states. *Environ. Sci. Pollut. Res.* **2018**, *25*, 17354–17370. [CrossRef]
31. Anser, M.K.; Alharthi, M.; Aziz, B.; Wasim, S. Impact of urbanization, economic growth, and population size on residential carbon emissions in the SAARC countries. *Clean Technol. Environ. Policy* **2020**, *22*, 923–936. [CrossRef]
32. Wu, D. Spatially and temporally varying relationships between ecological footprint and influencing factors in China's provinces Using Geographically Weighted Regression (GWR). *J. Clean. Prod.* **2020**, *261*, 121089. [CrossRef]
33. Haldar, A.; Sethi, N. Effect of institutional quality and renewable energy consumption on CO_2 emissions—An empirical investigation for developing countries. *Environ. Sci. Pollut. Res.* **2020**, *28*, 15485–15503. [CrossRef] [PubMed]
34. Sarkodie, S.A.; Adams, S. Renewable energy, nuclear energy, and environmental pollution: Accounting for political institutional quality in South Africa. *Sci. Total Environ.* **2018**, *643*, 1590–1601. [CrossRef] [PubMed]
35. Shahbaz, M.; Mallick, H.; Mahalik, M.K.; Loganathan, N. Does globalization impede environmental quality in India? *Ecol. Indic.* **2015**, *52*, 379–393. [CrossRef]
36. Sabir, S.; Qayyum, U.; Majeed, T. FDI and environmental degradation: The role of political institutions in South Asian countries. *Environ. Sci. Pollut. Res.* **2020**, *27*, 32544–32553. [CrossRef] [PubMed]
37. Welsch, H. Corruption, growth, and the environment: A cross-country analysis. *Environ. Dev. Econ.* **2004**, *9*, 663–693. [CrossRef]
38. Lægreid, O.M.; Povitkina, M. Do Political Institutions Moderate the GDP-CO_2 Relationship? *Ecol. Econ.* **2018**, *145*, 441–450. [CrossRef]
39. Wang, Y.; Kang, L.; Wu, X.; Xiao, Y. Estimating the environmental Kuznets curve for ecological footprint at the global level: A spatial econometric approach. *Ecol. Indic.* **2013**, *34*, 15–21. [CrossRef]
40. Maddison, D. Environmental Kuznets curves: A spatial econometric approach. *J. Environ. Econ. Manag.* **2006**, *51*, 218–230. [CrossRef]
41. Jiang, L.; Zhou, H.; Bai, L.; Zhou, P. Does foreign direct investment drive environmental degradation in China? An empirical study based on air quality index from a spatial perspective. *J. Clean. Prod.* **2018**, *176*, 864–872. [CrossRef]
42. Kang, Y.-Q.; Zhao, T.; Yang, Y.-Y. Environmental Kuznets curve for CO_2 emissions in China: A spatial panel data approach. *Ecol. Indic.* **2016**, *63*, 231–239. [CrossRef]
43. Abdo, A.-B.; Li, B.; Zhang, X.; Lu, J.; Rasheed, A. Influence of FDI on environmental pollution in selected Arab countries: A spatial econometric analysis perspective. *Environ. Sci. Pollut. Res.* **2020**, *27*, 28222–28246. [CrossRef]
44. Bu, Y.; Wang, E.; Jiang, Z. Evaluating spatial characteristics and influential factors of industrial wastewater discharge in China: A spatial econometric approach. *Ecol. Indic.* **2021**, *121*, 107219. [CrossRef]
45. Li, J.; Li, S. Energy investment, economic growth and carbon emissions in China—Empirical analysis based on spatial Durbin model. *Energy Policy* **2020**, *140*, 111425. [CrossRef]
46. Liu, H.; Song, Y. Financial development and carbon emissions in China since the recent world financial crisis: Evidence from a spatial-temporal analysis and a spatial Durbin model. *Sci. Total Environ.* **2020**, *715*, 136771. [CrossRef]
47. Mahmood, H. CO_2 Emissions, Financial Development, Trade, and Income in North America: A Spatial Panel Data Approach. *SAGE Open* **2020**, *10*, 2158244020968085. [CrossRef]
48. Majeed, M.T.; Mazhar, M. An empirical analysis of output volatility and environmental degradation: A spatial panel data approach. *Environ. Sustain. Indic.* **2021**, *10*, 100104. [CrossRef]
49. Selden, T.M.; Song, D. Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? *J. Environ. Econ. Manag.* **1994**, *27*, 147–162. [CrossRef]
50. Cropper, M.; Griffiths, C. The Interaction of Population Growth and Environmental Quality. *Am. Econ. Rev.* **1994**, *84*, 250–254.
51. Galeotti, M.; Lanza, A. Richer and cleaner? A study on carbon dioxide emissions in developing countries1This study does not necessarily reflect the views of the International Energy Agency or any of its member countries. *Energy Policy* **1999**, *27*, 565–573. [CrossRef]
52. Bagliani, M.; Bravo, G.; Dalmazzone, S. A consumption-based approach to environmental Kuznets curves using the ecological footprint indicator. *Ecol. Econ.* **2008**, *65*, 650–661. [CrossRef]
53. Effiong, E. On the urbanization-pollution nexus in Africa: A semiparametric analysis. *Qual. Quant.* **2017**, *52*, 445–456. [CrossRef]
54. Xu, S.-C.; Miao, Y.-M.; Gao, C.; Long, R.-Y.; Chen, H.; Zhao, B.; Wang, S.-X. Regional differences in impacts of economic growth and urbanization on air pollutants in China based on provincial panel estimation. *J. Clean. Prod.* **2019**, *208*, 340–352. [CrossRef]
55. Malik, M.Y.; Latif, K.; Khan, Z.; Butt, H.D.; Hussain, M.; Nadeem, M.A. Symmetric and asymmetric impact of oil price, FDI and economic growth on carbon emission in Pakistan: Evidence from ARDL and non-linear ARDL approach. *Sci. Total Environ.* **2020**, *726*, 138421. [CrossRef] [PubMed]
56. Zafar, A.; Ullah, S.; Majeed, M.; Yasmeen, R. Environmental pollution in Asian economies: Does the industrialisation matter? *OPEC Energy Rev.* **2020**, *44*, 227–248. [CrossRef]

57. Uddin, M.M.M. What are the dynamic links between agriculture and manufacturing growth and environmental degradation? Evidence from different panel income countries. *Environ. Sustain. Indic.* **2020**, *7*, 100041. [CrossRef]
58. Tiba, S.; Belaid, F. The pollution concern in the era of globalization: Do the contribution of foreign direct investment and trade openness matter? *Energy Econ.* **2020**, *92*, 104966. [CrossRef]
59. Hachaichi, M.; Baouni, T. Downscaling the planetary boundaries (Pbs) framework to city scale-level: De-risking MENA region's environment future. *Environ. Sustain. Indic.* **2020**, *5*, 100023. [CrossRef]
60. Weir, D.; McQuillan, D.; Francis, R.A. Civilian science: The potential of participatory environmental monitoring in areas affected by armed conflicts. *Environ. Monit. Assess.* **2019**, *191*, 618. [CrossRef]
61. Abumoghli, I.; Goncalves, A. Environmental Challenges in the MENA Region. Available online: https://wedocs.unep.org/handle/20.500.11822/31645 (accessed on 17 September 2021).
62. World Development Indicators. Available online: https://databank.worldbank.org/source/world-development-indicators# (accessed on 18 January 2021).
63. Freedom House Website. Available online: https://freedomhouse.org (accessed on 18 January 2021).
64. Freedom House Freedom in the World 2020 Methodology. Available online: https://freedomhouse.org/sites/default/files/2021-02/Freedom_in_the_World_2020_Methodology.pdf (accessed on 18 January 2021).
65. Freedom House Freedom in the World 2014 Methodology. Available online: http://www.freedomhouse.org/report/freedom-world/freedom-world-2014 (accessed on 18 January 2021).
66. Bartholomew, D.J. *Principal Components Analysis*, 3rd ed.; Peterson, P., Baker, E., McGaw, B.B.T.-I.E., Eds.; Elsevier: Oxford, UK, 2010; ISBN 978-0-08-044894-7.
67. Artemiou, A.; Li, B. Predictive power of principal components for single-index model and sufficient dimension reduction. *J. Multivar. Anal.* **2013**, *119*, 176–184. [CrossRef]
68. LeSage, J.; Pace, R.K. *Introduction to Spatial Econometrics*; CRC: Boca Raton, FL, USA, 2009; ISBN 9781420064254.
69. Belotti, F.; Hughes, G.; Mortari, A.P. Spatial Panel-data Models Using Stata. *Stata J.* **2017**, *17*, 139–180. [CrossRef]
70. Morin, A.J.S.; Myers, N.D.; Lee, S. Modern Factor Analytic Techniques. In *Handbook of Sport Psychology*; Tenenbaum, G., Eklund, R.C., Eds.; John Wiley & Sons: Hoboken, NJ, USA, 2020; pp. 1044–1073. ISBN 9781119568124.
71. Kahia, M.; Ben Jebli, M.; Belloumi, M. Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries. *Clean Technol. Environ. Policy* **2019**, *21*, 871–885. [CrossRef]
72. Liu, Y.; Xiao, H.; Zikhali, P.; Lv, Y. Carbon Emissions in China: A Spatial Econometric Analysis at the Regional Level. *Sustainability* **2014**, *6*, 6005–6023. [CrossRef]
73. You, W.; Li, Y.; Guo, P.; Guo, Y. Income inequality and CO2 emissions in belt and road initiative countries: The role of democracy. *Environ. Sci. Pollut. Res.* **2020**, *27*, 6278–6299. [CrossRef] [PubMed]
74. Samreen, I.; Majeed, M.T. Spatial econometric model of the spillover effects of financial development on carbon emissions: A global analysis. *Pakistan J. Commer. Soc. Sci.* **2020**, *14*, 569–602.
75. Madani, K. How International Economic Sanctions Harm the Environment. *Earth's Future* **2020**, *8*, e2020EF001829. [CrossRef]