frontiers | Frontiers in Environmental Science

ORIGINAL RESEARCH
published: 14 April 2022
doi: 10.3389/fenvs.2022.850273

RETRACTED: Effect of Islamic Financial Development on Carbon Emissions: A Spatial Econometric Analysis

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Specialty section:
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

Received: *07 January 2022*
Accepted: *02 March 2022*
Published: *14 April 2022*

Citation:
Al-Silefanee RR, Mamkhezri J, Khezri M, Karimi MS and Khan YA (2022) Effect of Islamic Financial Development on Carbon Emissions: A Spatial Econometric Analysis. Front. Environ. Sci. 10:850273. doi: 10.3389/fenvs.2022.850273

In this research, data from 36 countries from 2013 to 2018 were used to examine the factors influencing CO_2 emissions in Islamic countries, focusing on the impact of Islamic financial growth. The spatial econometric technique estimation findings indicate that there is no geographical association between CO_2 emissions in the analyzed countries. The test findings establish the existence of the Kuznets hypothesis for the environment. Additionally, trade openness and increased energy usage have resulted in an increase in CO_2 emissions. The impacts of traditional financial development factors, such as financial market and financial institution variables, were examined in this research. The findings indicate that the two variables have no direct and substantial influence on CO_2 emissions and that their significant effect on CO_2 emissions appears only when their nonlinear and spillover effects on energy consumption and economic growth are included. Additionally, the growth of financial institutions is inversely proportional to the intensity of carbon emissions. The results indicate that while the development of financial markets and institutions results in a significant increase in CO_2 emissions, the negative coefficient of the interaction between financial development and energy consumption indicates that financial development ensures energy efficiency, which reduces the intensity of carbon emissions. The findings indicate that the expansion and depth of Islamic finance, as measured by total assets, asset quality, earnings, and efficiency of Islamic banks, can result in a nonlinear increase in CO_2 emissions with a U-shaped relationship. The study of spillover effects demonstrates that in addition to their direct and positive effects on CO_2 emissions, the increase in Islamic social responsibility and consumer education, and awareness about Islamic banking reduce the enhancing effects of energy consumption on greenhouse gas emissions.

Keywords: Islamic financial development, environmental Kuznets hypothesis CO_2 emission, Islamic countries, energy efficiency, spatial econometrics

INTRODUCTION

As a result of climate and environmental changes, the health of the global community has become one of the most pressing concerns and challenges of our day. Global warming and environmental degradation are the principal impediments to long-term sustainable development, and CO_2 emissions are generally acknowledged as a key contribution to these issues as a result of the buildup of greenhouse gases (GHGs) on the planet's surface (United Nations, 2016). There has been an increase in world temperatures of 1.5°, according to the World Development Indicators (WDI 2020). As a consequence, the world's largest polluters must take rapid measures to limit their CO_2 emissions.

The United Nations Framework Convention on Climate Change (UNFCCC) was founded in 1992 in response to a substantial increase in the global temperature and its detrimental effects on the environment. It was only in 1997 that the Kyoto Protocol was drafted to help prevent global warming by setting emission limits on greenhouse gasses.

Financial development is an important explanatory variable that has been utilized extensively in prior research to indicate that variations in carbon emissions may be influenced by financial development. There is strong evidence to support the theory that financial development has direct and indirect impacts on carbon emissions (Tamazian et al., 2009; Giannetti et al., 2010; Gunasekaran et al., 2014; Shahbaz et al., 2016; Gokmenoglu and Sadeghieh, 2019; Wang et al., 2019; Shahbaz et al., 2020). The environmental Kuznets curve (EKC) is inverted and U-shaped, showing a link between economic growth and environmental degradation, according to these researchers' findings.

Industrial operations contribute to CO_2 emissions because the financial sector, which provides capital essential for expansion as well as R&D and is the main vehicle for knowledge transfer, assists manufacturing activities. While financial growth encourages sectors and governments to adopt environmentally friendly technologies capable of decreasing CO_2 emissions, it also encourages enterprises to seek environmentally sustainable projects capable of reducing CO_2 emissions (Tamazian and Rao, 2010; Acheampong et al., 2020). However, a few researchers report a negative impact due to their findings of a positive correlation between financial development and CO_2 emissions, which suggests that as financial development alleviates credit constraints and increases access to capital, economic growth, and output expands, CO_2 emissions go up (Sadorsky, 2011; Acheampong, 2019).

These two contributions to the literature on financial development and environmental quality are of major significance. A comparative method was used to examine how the Islamic financial market's major parameters influenced carbon emission intensity, taking into account the varying phases of Islamic financial development in various Islamic countries. According to Islamic economics, a banking or financial system that complies with Islamic financial rules is known as Islamic banking. Islamic banks in Muslim nations claim to follow Sharia rules and guidelines, and four Islamic banking principles are as follows: interest or usury is prohibited; ethical standards, moral, and social values are upheld; and liability and business risks are accepted. Given the positive and negative effects of financial development on greenhouse gas emissions, we require innovative approaches to financial development that can help reduce pollution. In this regard, a review of new methods for accrediting and developing the financial sector and their impact on pollution reduction can provide policy-makers with a policy framework for replacing outdated approaches with more efficient ones. On the other hand, the purpose of this study was not to assess the positive dimensions and efficiency of Islamic financial development in comparison to the global financial system, but to assess the positive and negative effects of Islamic financial development on air pollution and to provide a policy framework for Islamic developing countries.

Second, the majority of past research has relied on time series or panel data approaches. Given this, the present study employed a newly developed econometric technique called the spatial econometric analysis to determine whether financial development can effectively reduce emissions in Islamic countries. According to Anselin (1988), a spatial correlation exists between the units of a study due to the gravitational effect. Traditional analytic methods often neglect geographical factors, resulting in their failure, and the findings from this technique would fill a need in relevant research and contribute to the cross-border cooperation on CO_2 emission reduction among Islamic countries.

It follows that the major goal of this study was to analyze the relationship among Islamic financial development, renewable energy consumption, and CO_2 emissions in Muslim countries using an appropriate spatial econometric approach.

The following are the remaining portions of the study: financial development and CO_2 emissions are linked in *Literature Review*; *Methodology and Data* explains how the data sample and empirical models were selected; *Results and Discussion* explains the outcomes of the study; *Conclusions and Policy Implication* concludes the research.

LITERATURE REVIEW

An extensive body of research has been conducted on the relationship between financial development and CO_2 emissions, and this part covers some of the most relevant empirical investigations. Section one of the empirical literature review discusses how financial growth has a positive impact on CO_2 emissions both directly and indirectly. Economic sectors may receive low-interest funding and spend it on high-tech ventures, equipment acquisitions, and other projects that ultimately raise carbon emissions after a country's stock market is formed. FDI is a crucial way for host nations to reduce their energy intensity and CO_2 emissions, while financial growth and financial openness on the other hand attract FDI.

Jalil and Feridun (2011) revealed that Pakistan's carbon emissions were reduced as a result of financial growth, as assessed by the ratio of liquid liabilities to GDP and private sector loans.

Indonesia's financial growth and carbon emissions were examined by Shahbaz et al. (2013a) using the ARDL and Granger causality tests. Investing in ecologically friendly technology decreases CO_2 emissions, which improves environmental quality, according to their research. On the other hand, Shahbaz et al. (2013b) investigated how CO_2 emissions are linked to financial development, energy consumption, and economic growth in Malaysia, and found substantial long-term links among these variables. Progress in the finance sector also reduces CO_2 emissions. Because of rising energy use and economic growth, CO_2 emissions increase. Similarly, Al-Mulali et al. (2015) used FMOLS and cointegration to assess the impact of financial development on carbon emissions in 129 countries. They discovered that financial growth, defined as domestic lending to the private sector, was associated with an increase in greenhouse gas emissions.

Energy consumption and carbon emissions in 13 European and 12 East Asian and Oceania nations between 1989 and 2011 were analyzed by Ziaei (2015), who found that shocks to stock return rates have a long-term impact on energy consumption, notably in East Asia and Oceania.

It has been found that financial efficiency (the ratio of loans to deposits) reduces carbon emissions in 29 Chinese provinces, and the system-GMM was used to examine the impact of financial development on carbon emissions. In addition, Abbasi and Riaz (2016) found that the ARDL and VAR techniques used in Pakistan resulted in lower CO_2 emissions. Stock market capitalisation and traded stocks were used to symbolize financial progress.

An examination of Turkey's economic growth, CO_2 emissions, and financial development by Gokmenoglu and Sadeghieh (2019) revealed a connection among these three variables. To explore the long-term relationships between all of the research's variables, they adopted the ECM model. Fuel consumption has a long-term positive impact on carbon emissions, whereas economic expansion has a long-term negative effect, and financial development has a one-way influence on CO_2 emissions.

Renewable energy consumption and financial development were studied in depth in 24 MENA nations by Charfeddine and Kahia (2019), who looked at the relationship between renewable energy use and CO_2 emissions, as well as economic growth. A panel vector autoregressive analysis was used in this study. Using renewable energy and economic development has a strong correlation with CO_2 emissions, according to the study's results.

Financial progress and environmental performance have recently been the subject of a number of studies. According to Kayani et al. (2020), the world's top ten emitters of carbon dioxide (CO_2) have causal linkages to globalization, urbanization, financial development, and renewable energy consumption. Fully modified least squares (FMOLS) and a model for correcting panel vector errors (VECM) are used. Based on the results, it can be seen that there is a long-term correlation among rising CO2 levels, rising financial development, and the growth of urban populations. The study of financial development and CO_2 emissions at the province level in China by Zhao and Yang (2020) employed both static and dynamic analyses. According to the dynamic findings, regional financial development was greatly behind in its ability to reduce CO_2 emissions.

In 83 countries, from 1980 to 2015, Acheampong et al. (2020) used the instrumental variable generalized technique of the moment approach to assess the impact of financial market expansion on carbon emission intensity (GMM). Financial market expansion and its sub-measures, such as financial market depth and efficiency, were shown to contribute to the reduction of carbon emissions in both established and emerging financial nations, according to their results. According to Lv and Li (2021), a panel data spatial econometric approach was used to investigate the influence of financial development on CO_2 emissions for 97 countries from 2000 to 2014, and there is a geographical connection between CO_2 emissions across countries during this era. They also found that the economic advancement of a country's neighbors may affect the country's CO_2 emissions.

In addition, there is a recurring theme in earlier investigations. FDI, stock market indicators, and the indicators for the banking sector are often used as proxies to gauge financial progress. Conventional panel data and other economic methodologies that overlooked spatial heterogeneity within data and countries were used in several research studies, which combined these factors. Numerous studies have used the conventional panel data and other economic approaches that ignored geographical variability within data and nations.

A novel proxy for Islamic financial development was introduced and used for the first time in this work, which makes a significant contribution to the existing body of knowledge. Because of the interdependence of areas, spatial economic models must be studied to prevent biased empirical conclusions. However, we think that no nation is isolated. Problems caused by spatial dependence between characteristics cannot be fully resolved by standard techniques such as ordinary least squares and generalized method of moments (GMM) (Anselin et al., 2008). A spatial econometric approach is used here to examine the impact of financial development on CO_2 emissions.

A recent study by Agboola et al. (2021) examined the long-term and causal links among Saudi Arabia's energy consumption, total natural resource rent, economic growth, oil rent, and CO_2 emissions from 1971 to 2016. For the Toda-Yamamoto technique, they modified the Wald test used. The long-run equilibrium was found in the variables' empirical results, which showed a link between energy consumption and economic growth, as well as a one-way causal link between energy consumption and CO_2 emissions; an analogous unidirectional causal link between oil rent and CO_2 emissions was also found. Another study used a wide range of sophisticated econometric techniques to evaluate the link among natural resources, human capital, renewable energy, and the ecological footprint (EF) in the BRICS. Results showed that economic growth and resource exploitation increase the EF, but renewable energy lowers it, and that human capital was not yet at a level favorable to reducing environmental deterioration. To better understand how economic globalization has affected environmental deterioration in the E7 economies, researchers from Onifade et al. (2021) reviewed data from 1990 to 2016. FMOLS and dynamic ordinal least square (DOLS) were used to assess the long-term correlation between the variables. According to their findings, globalization has a detrimental impact on the E7 economies' CO_2 emissions and ecological footprint. They also found a link between globalization and a decline in natural resilience. The validity of an N-shaped hypothesis for nations in sub-Saharan Africa was tested by Bekun et al. (2021) using the pooled mean group autoregressive distributed lag (PMG-ARDL) and the Dumitrescu and Hurlin panel causality techniques. Using the N-shaped hypothesis, the researchers found that both conventional and renewable energy features had a short- and long-term impact on environmental quality, respectively, and proved its validity.

METHODOLOGY AND DATA

Empirical Model

The impacts of CO_2 emission drivers on financial development indicators were investigated in this study using spatial econometric models. As a result, the influence of financial development on CO_2 emissions was better understood, as was the impact of financial development in adjacent countries on domestic CO_2 emissions (i.e., likely spillover effects). Numerous models have been proposed in the literature to determine the spatial dependency of data. According to Anselin et al. (2008), a spatial panel model might incorporate a lagged dependent variable or include an error component that is spatially autoregressive. LeSage and Pace (2009) also developed the spatial Durbin model, which incorporates model-independent variables that are spatially lagged. The next section introduces the general formula for each of the three models. The following is the formulation of the spatial lag model:

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij} y_{jt} + \phi + x_{it}\beta + c_i\,(optional) + \alpha_t\,(optional) + v_{it} \tag{1}$$

where y_{it} is the dependent variable for cross-sectional unit $i = 1, \ldots, N$ at time $t = 1, \ldots, T$. x_{it} is a $1 \times K$ vector of exogenous variables, and β is a $K \times 1$ vector of parameters. Variable $\sum_{j=1}^{N} w_{ij} y_{jt}$ denotes the interaction effect of dependent variable y_{jt} in neighboring units on dependent variable y_{it}. w_{ij} is the $i,\ j-th$ element of a prespecified nonnegative $N \times N$ spatial weight matrix w (Baltagi, 2005).

To account for the idiosyncratic component, v_{it}, spatial weight matrix W and the error terms of adjacent unit j are used to calculate the error term of unit i, $u_{it} = \rho \sum_{j=1}^{N} w_{ij} u_{jt} + v_{it}$, or formally:

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij} y_{jt} + \phi + x_{it}\beta + c_i\,(optional) + \alpha_t\,(optional) + u_{it} \tag{2}$$

The spatial Durbin model should also be considered, according to LeSage and Pace (2009). Additional independent variables that may be spatially lagged have been added to the spatial lag model:

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij} y_{jt} + \phi + x_{it}\beta + \sum_{j=1}^{N} w_{ij} x_{ijt}\theta + c_i\,(optional) + \alpha_t\,(optional) + v_{it} \tag{3}$$

where θ is a $K \times 1$ vector of parameters.

The general form of the carbon emission intensity model that we intend to study experimentally in this study is from Shahbaz et al. (2016). In this study, the logarithm of the carbon emission ($\ln CO_2$) is regarded as a function of the logarithm of financial development ($\ln FD$), GDP per capita ($\ln GDPP$), the squared form of GDP per capita ($\ln GDPP^2$), energy consumption ($\ln ENE$), and trade openness ($\ln OPE$). The linear form of **Eq. 4** is used:

$$\ln CO_{2it} = \beta_1 + \beta_2 \ln GDPP_{it} + \beta_3 \ln GDPP_{it}^2 + \beta_4 \ln ENE_{it} + \beta_5 \ln OPE_{it} + \beta_6 \ln FD_{it} + c_i\,(optional) + \alpha_t\,(optional) + v_{it} \tag{4}$$

CO_2 emissions may be explained by factors such as energy consumption (Çelik and Deniz, 2009) and openness to international commerce (Çelik and Deniz, 2009) (Epule et al., 2012; Solarin et al., 2017; Acheampong 2019). Economics and environmental quality are connected, according to the environmental Kuznets curve hypothesis (EKC). First, the quality of the environment degrades as the economy expands (Grossman and Krueger, 1995; Lee et al., 2010). According to the EKC hypothesis, because the relationship between environmental quality and economic growth is inverted U-shaped, GDP per capita squared must be negative in the CO_2 emission equation.

According to Acheampong et al. (2020), Acheampong (2019), and Shahbaz et al. (2018), a nonlinear and inverted U-shaped relationship between carbon emissions and financial growth is feasible. To overcome this issue, the squared term of financial development is incorporated as a variable in the carbon emission intensity equation.

$$\ln CO_{2it} = \beta_1 + \beta_2 \ln GDPP_{it} + \beta_3 \ln GDPP_{it}^2 + \beta_4 \ln ENE_{it} + \beta_5 \ln OPE_{it} + \beta_6 \ln FD_{it} + \beta_7 \ln FD_{it}^2 + c_i\,(optional) + \alpha_t\,(optional) + v_{it} \tag{5}$$

Carbon emission intensity and financial development create an inverted U in the equation above. Growing financial markets initially increase carbon intensity, but at a certain degree of development, they begin to reduce it. Financial market growth initially decreases carbon emissions, but emissions increase when a certain level of financial development has been reached, according to a U-shaped link between financial market development and carbon intensity.

Growth in the financial sector is seen to be a catalyst for both economic expansion and technical improvement, which in turn leads to increased energy use. As a result, its immediate impact on emissions of greenhouse gases may be favorable. Consequently, new gear and equipment that use more energy may be purchased at a lower cost because of the strengthening of the financial sector

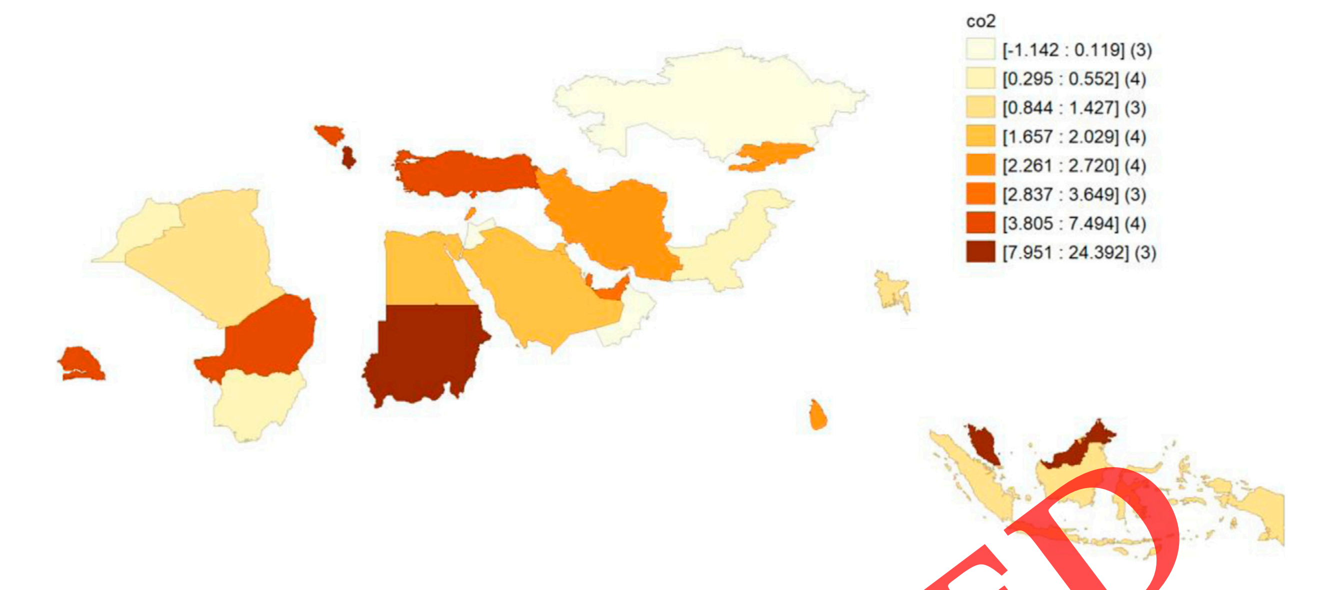

FIGURE 1 | CO_2 emission data in the sample countries.

(Sadorsky, 2010, 2011; Acheampong, 2019). Investment in R&D, technological development, and the adoption of environmentally friendly technologies may decrease greenhouse gas emissions *via* financial development (see Tamazian et al., 2009; Tamazian and Rao, 2010). The interplay of economic development with financial market and energy consumption on carbon emission intensity is examined using **Eqs 3**, **4**.

$$\begin{aligned}\ln CO_{2it} = {} & \beta_1 + \beta_2 \ln GDPP_{it} + \beta_3 \ln GDPP_{it}^2 + \beta_4 \ln ENE_{it} \\ & + \beta_5 \ln OPE_{it} + \beta_6 \ln FD_{it} \\ & + +\beta_7 (\ln FD_{it} \times \ln GDPP_{it}) + c_i\,(optional) \\ & + \alpha_t\,(optional) + \upsilon_{it} \qquad (6)\end{aligned}$$

$$\begin{aligned}\ln CO_{2it} = {} & \beta_1 + \beta_2 \ln GDPP_{it} + \beta_3 \ln GDPP_{it}^2 + \beta_4 \ln ENE_{it} \\ & + \beta_5 \ln OPE_{it} + \beta_6 \ln FD_{it} + \beta_7 (\ln FD_{it} \times \ln ENE_{it}) \\ & + c_i\,(optional) + \alpha_t\,(optional) + \upsilon_{it} \qquad (7)\end{aligned}$$

In these equations, the coefficient of the variable $(\ln FD_{it} \times \ln GDPP_{it})$ shows the financial development and economic growth interactions, while the coefficient for $(\ln FD_{it} \times \ln ENER_{it})$ demonstrates the interplay between financial development and energy use. How the GDP per capita and energy consumption affect carbon emissions in **Eqs 6**, **7** is as follows:

$$\frac{d(\ln CO_{2it})}{d(\ln GDPP_{it})} = \beta_2 + 2\beta_3 \ln GDPP_{it} + \beta_7 \ln FD_{it}$$

$$\frac{d(\ln CO_{2it})}{d(\ln ENE_{it})} = \beta_4 + \beta_7 \ln FD_{it}$$

Here, separating the direct effects of GDP per capita and energy consumption on carbon emissions using the coefficientβ_2, if coefficient β_7 is negative, with higher financial development, then financial development reduces the effects of carbon emissions with moving to newer technologies, although the direct effect of financial development is expected to be positive. Additionally, to examine the impact of financial development on CO_2 emissions based on countries' various degrees of economic growth and development, we have values from **Eq. 6**:

$$\frac{d(\ln CO_{2it})}{d(\ln FD_{it})} = \beta_6 + \beta_7 \ln GDPP_{it}$$

Data

Data from Islamic countries between 2013 and 2018 were used for this review. **Figure 1** depicts the CO_2 emission data for the example countries, which were selected from a list of over 36 countries because data for each Islamic country were not readily available. **Table 1** summarizes the criteria and information sources that were used in the inquiry.

Unlike previous studies that used only Islamic financial concentration (Gazdar et al., 2019) and Islamic financial depth (Gazdar et al., 2019; Moradbeigi and Law, 2016; Law and Singh, 2014), this study's Islamic Financial Development Indicator (IFDI) incorporated multiple dimensions to assess Islamic financial development. The Islamic Finance Development Indicator's components are shown in **Table 2**. The Indicator's several components are based on significant current topics such as the quantitative growth of international financial institutions and markets (Quantitative), the effectiveness of governance and risk management systems designed to safeguard stakeholders (Corporate Governance), the sharia governance quality required to guarantee that Islamic financial organizations and products adhere to sharia norms (Sharia Governance), social contribution of the enterprise under Islamic principles (Social

TABLE 1 | Variable definition.

Variable	Variable constructed	Source
$\ln CO_{2it}$	$\ln CO_{2it} = \log(CO_{2it})$ CO_{2it} = CO_2 emissions (metric tons per capita) in country i in period t	WDI
$\ln GDPP_{it}$	$\ln GDPP_{it} = \log(GDPP_{it})$ GDP_{it} = GDP per capita in 2010 prices$ in country i in period t	WDI
$\ln ENE_{it}$	$\ln ENE_{it} = \log(ENER_{it})$ ENE_{it} = Energy use (kg of oil equivalent per capita) in country i in period t	WDI
$\ln OPE_{it}$	$\ln OPE_{it} = \log(OPE_{it})$ OPE_{it} = Trade openness (total exports and imports divided by GDP)	WDI
$\ln FI_{it}$	$\ln FI_{it} = \log(1 + FI_{it})$ FI_{it} = the Development of Financial Institution	IMF
$\ln FM_{it}$	$\ln FM_{it} = \log(1 + FM_{it})$ FM_{it} = the Development of Financial Market	IMF

WDI: World Development Indicator; https://datacatalog.worldbank.org/dataset/world-development-indicators. IMF: International Monetary Fund; https://data.imf.org/

TABLE 2 | Islamic finance development indicator (IFDI).

Quantitative development (QDE)	Knowledge (KNO)	Corporate social responsibility (CSR)	Governance (GOV)	Awareness (AWARE)
Islamic Banking Takaful	Education	Funds disbursed to charity/Zakat/Qard Hasan	Regulation	Seminars
Islamic Financial Institutions Sukuk Funds	Research	Disclosed CSR activities	Sharia governance Corporate governance	Conferences News

SOURCE: the islamic corporation for the development of the private sector; https://www.zawya.com/islamic-finance-development-indicator/#

Responsibility), and the availability and quality of education to guarantee that industry personnel is knowledgeable about Islamic financial concepts (Education).

Data for the years 2013–2018 are summarized in **Table 3**. The standard deviations for the majority of variables were much lower than the mean, indicating that the model variables were very stable.

RESULTS AND DISCUSSION

It was required to go through the processes of model selection which entails conducting a series of hypothesis tests. Because of the large number of estimated models in this research, it was impossible to provide the statistics necessary to pick all models. Thus, **Tables 4**, **5** provide just the test data for four distinct models of the Islamic Financial Development Index (IFDI).

To begin, the spatial and time-period fixed-effects models were evaluated using the likelihood ratio (LR) to the time-period and spatial fixed-effects models individually to rule out the possibility of these effects being present in the model. When the null hypothesis was rejected, the geographical and time-period fixed effects became more significant. **Table 4** presents the LR test statistics for each model in the last row. The significance of the test results shows that the null hypothesis was rejected and that alternative models should address

TABLE 3 | Summary statistics over 2013–2018.

Variable	Mean	Median	Maximum	Minimum	Std. dev	Observations
$\ln CO_2$	1.17	1.22	3.44	−2.36	1.48	168
$\ln GDPP$	8.74	8.52	11.1	6.22	1.3	168
$\ln OPE$	4.25	4.25	5.91	2.95	0.61	168
$\ln ENE$	9.51	9.52	10.23	8.2	0.41	168
$\ln IFDI$	2.97	3.09	4.89	0.35	0.98	168
$\ln QDE$	2.25	2.5	4.6	0	1.23	168
$\ln KNO$	2.59	2.75	5.44	0	1.22	168
$\ln CSR$	2.41	3.27	4.7	0	1.73	168
$\ln GOV$	3.08	3.48	4.7	0	1.33	168
$\ln AWAR$	3.07	2.92	5.5	0.77	1.1	168
$\ln FI$	0.33	0.34	0.56	0.17	0.09	168
$\ln FM$	0.22	0.21	0.54	0	0.17	168

TABLE 4 | Spatial lag or the spatial error in the spatial and time-period fixed-effects model.

		Pooled OLS		Spatial fixed effects		Time-period fixed effects		Spatial and time-period fixed effects	
Model 1	LM spatial lag	15.089	(0.000*)	1.845	(0.174)	9.258	(0.002*)	1.249	(0.264)
	LM spatial error	7.898	(0.005*)	0.875	(0.35)	7.784	(0.005*)	2.137	(0.144)
	LR-test			836.187	(0.000*)	12.476	(0.052**)		
Model 9	LM spatial lag	15.16	(0.000*)	1.837	(0.175)	9.166	(0.002*)	1.323	(0.25)
	LM spatial error	7.579	(0.006*)	0.86	(0.354)	7.453	(0.006*)	1.952	(0.162)
	LR-test			837.082	(0.000*)	13.406	(0.037**)		
Model 17	LM spatial lag	17.025	(0.000*)	2.003	(0.157)	11.089	(0.001*)	1.595	(0.207)
	LM spatial error	10.528	(0.001*)	0.977	(0.323)	10.343	(0.001*)	2.738	(0.098)
	LR-test			836.283	(0.000*)	14.113	(0.028**)		
Model 25	LM spatial lag	14.474	(0.000*)	2.025	(0.155)	9.332	(0.002*)	1.659	(0.198)
	LM spatial error	8.041	(0.005*)	0.681	(0.409)	7.888	(0.005*)	2.509	(0.113)
	LR-test			835.498	(0.000*)	16.418	(0.012**)		

p-*Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

TABLE 5 | Spatial Durbin model and Hausman test.

	Fixed-effects estimator	Random-effects estimator	Fixed-effects estimator	Random-effects estimator	Fixed-effects estimator	Random-effects estimator	Fixed-effects estimator	Random-effects estimator
	Model 1		Model 9		Model 17		Model 25	
Wald test: spatial Durbin model against spatial lag model	7.943 (0.159)	17.02 (0.004*)	7.684 (0.262)	18.213 (0.006*)	10.106 (0.12)	19.521 (0.003*)	7.097 (0.312)	19.104 (0.004*)
Wald test: spatial Durbin model against spatial error model	6.66 (0.247)	12.665 (0.027**)	6.614 (0.358)	13.721 (0.033**)	8.555 (0.2)	14.832 (0.022**)	5.915 (0.433)	14.525 (0.024**)
LR test: spatial Durbin model against spatial lag model	9.548 (0.089***)	16.23 (0.006*)	9.085 (0.169)	18.129 (0.006*)	12.738 (0.047**)	19.871 (0.003*)	8.998 (0.174)	19.018 (0.004*)
LR test: spatial Durbin model against spatial error model	7.55 (0.183)	14.023 (0.015**)	7.463 (0.28)	15.145 (0.019**)	10.222 (0.116)	16.038 (0.014**)	7.029 (0.318)	14.879 (0.021**)
Hausman test-statistic								
Hausman test-statistic: the spatial lag model	26.165	(0.000*)	32.049	(0.000*)	44.978	(0.000*)	30.157	(0.000*)
Hausman test-statistic: the spatial Durbin model	34.08	(0.000*)	23.958	(0.032**)	34.889	(0.001*)	38.643	(0.000*)

p-*Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

geographical and time-period fixed effects concurrently. As a result, we will evaluate Lagrange multiplier (LM) statistics in the following for the spatially and time-period fixed-effects model in the final column on the left.

Second, assess whether or not the inclusion of spatial lags or geographic errors in the model improves the model considerably in the absence of spatial interactions. An autoregressive spatial error was used in conjunction with spatially lagged dependent variables to achieve this goal. With or without the spatial and time-period fixed effects defined in the LR test, this test was run on residuals of a non-spatial model. This resulted in discarding non-spatial models and replacing them with those based on a spatial delay or mistake.

Both geographical and time-period fixed-effects models support the lack of a non-spatial model, according to **Table 4**'s results. All four models provide statistically insignificant results when viewed at a 1% level of significance. The existence of spatial interaction effects during the model selection process was excluded because the test results revealed that they should not be included for evaluating alternative CO_2 emission models.

In the third phase, the results of the Hausman test were examined to see whether the probable fixed-effects model can be replaced with the model of random effects. To begin, we will look at Hypothesis 1, which asserts that the model contains random effects. The Hausman test findings in **Table 5** show that random effects were rejected for both Durbin and lag models, and that fixed effects were accepted at a 5% significance level.

Finally, we examined two theories. First, the geographic Durbin model may be reduced to a spatial lagged model; if the

TABLE 6 | Estimation results of different models for **Eq. 4**.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
ln *GDPP*	2.71 (0.000*)	2.599 (0.000*)	2.566 (0.000*)	2.536 (0.000*)	2.574 (0.000*)	2.628 (0.000*)	2.607 (0.000*)	2.531 (0.000*)
ln $GDPP^2$	−0.128 (0.000*)	−0.123 (0.000*)	−0.121 (0.000*)	−.117 (0.000*)	−0.122 (0.000*)	−0.125 (0.000*)	−0.124 (0.000*)	−0.119 (0.000*)
ln *OPE*	0.213 (0.000*)	0.215 (0.000*)	0.215 (0.000*)	0.203 (0.000*)	0.212 (0.000*)	0.212 (0.000*)	0.213 (0.000*)	0.212 (0.000*)
ln *ENE*	0.376 (0.000*)	0.396 (0.000*)	0.402 (0.000*)	0.378 (0.000*)	0.399 (0.000*)	0.384 (0.000*)	0.407 (0.000*)	0.4 (0.000*)
ln *IFDI*	0.029 (0.04**)							
ln *QDE*		0.012 (0.214)						
ln *KNO*			−0.007 (0.568)					
ln *CSR*				0.009 (0.047**)				
ln *GOV*					0.001 (0.916)			
ln *AWAR*						0.014 (0.068***)		
ln *FI*							−0.504 (0.183)	
ln *FM*								0.059 (0.722)
LogL	292.517	291.169	290.547	292.382	290.385	292.077	291.29	290.444
R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

*p-Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

second hypothesis is valid, the geographic Durbin model may be reduced to a spatial error model (Burridge, 1981). Our model's spatial lagged independent variable may be evaluated for significance using these two tests. To do this, we employ either the LR or the Wald statistical test. Positive and negative traits may be found in each of these exams. More models have been estimated for LR testing than for Wald tests, which are more sensitive to nonlinear constraints (Hayashi, 2000, p.122).

A Hausman test result showed that all models have a fixed-effect model; thus, the test statistics for the fixed-effect models are assessed based on these findings in **Table 5**. All models saved for Models (1) and (3) are statistically insignificant for the two tests, the LR and Wald, except for the LR test to compare the spatial Durbin model *versus* the spatial lag model. However, the test results of the two other models were not significant enough to warrant further examination. The Wald test, on the other hand, returns the opposite conclusion. Although this may be done with less confidence for Models (1) and (3), the spatial Durbin model in all of them can be transformed to a space-based error model and space-based delay model in light of the Wald test findings that validated the null hypothesis. As a consequence, the presence of a spatially delayed independent variable was ruled out, and the estimation results may now be analyzed using geographical and time-period fixed effects with non-spatial effects.

Tables 6–9 show the estimate results for various models for **Eqs 4–7**. The logarithms of GDP per capita, energy consumption, and trade openness all have a positive and substantial influence on the logarithm of CO_2 emissions, as shown in **Table 6**. Each percentage point rise in GDP per capita results in an approximately 2.5 percent increase in greenhouse gas emissions. In addition, each percent increase in per capita energy consumption corresponds to an increase of around 0.4 percent in greenhouse gas emissions. Additionally, each unit increase in the trade openness variable results in a 0.2% rise in CO_2 emissions. The findings corroborated those found in experimental research. **Tables 7–9** show comparable findings. Additionally, the squared component of GDP per capita has a negative influence on greenhouse gas emissions, resulting in an inverted U-shaped connection between GDP growth and CO_2 emissions, confirming the EKC hypothesis. The positive and significant variable coefficient for the Islamic Financial Development Index (IFDI) in **Table 6** indicates that IFDI results in higher CO_2 emissions. The coefficient was statistically significant at a 10% level. Additionally, only the coefficients of the CSR and AWAR indices were positive and statistically significant at the 10% level. Moreover, the coefficients of financial development indices were insignificant for the components of the financial institution and financial market development.

To gain a better understanding of how financial development indicators affect CO_2 emissions, the models included the squared forms of the financial development index and its constituent components in **Table 7**. The inclusion of the variable in the model had no discernible effect on the calculated coefficients. Only the

TABLE 7 | Estimation results of different models for **Eq. 5**.

	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
ln *GDPP*	2.68 (0.000*)	2.543 (0.000*)	2.543 (0.000*)	2.587 (0.000*)	2.681 (0.000*)	2.58 (0.000*)	2.21 (0.000*)	2.465 (0.000*)
ln $GDPP^2$	−0.126 (0.000*)	−0.118 (0.000*)	−0.12 (0.000*)	−0.119 (0.000*)	−0.125 (0.000*)	−0.122 (0.000*)	−0.101 (0.002*)	−0.116 (0.000*)
ln *OPE*	0.215 (0.000*)	0.204 (0.000*)	0.216 (0.000*)	0.215 (0.000*)	0.216 (0.000*)	0.214 (0.000*)	0.205 (0.000*)	0.216 (0.000*)
ln *ENE*	0.376 (0.000*)	0.396 (0.000*)	0.399 (0.000*)	0.375 (0.000*)	0.392 (0.000*)	0.381 (0.000*)	0.435 (0.000*)	0.402 (0.000*)
ln *IFDI*	0.06 (0.093***)							
ln $IFDI^2$	−0.007 (0.34)							
ln *QDE*		0.041 (0.031**)						
ln QDE^2		−0.009 (0.075***)						
ln *KNO*			0.007 (0.773)					
ln KNO^2			−0.003 (0.51)					
ln *CSR*				−0.012 (0.403)				
ln CSR^2				0.006 (0.105)				
ln *GOV*					−0.028 (0.127)			
ln GOV^2					0.009 (0.06***)			
ln *AWAR*						0.043 (0.097***)		
ln $AWAR^2$						−0.005 (0.24)		
ln *FI*							2.081 (0.092***)	
ln FI^2							−3.825 (0.028**)	
ln *FM*								0.391 (0.29)
ln FM^2								−0.544 (0.314)
LogL	292.988	292.795	290.771	293.733	292.203	292.791	293.749	290.968
R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

*p-Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

coefficients for quantitative development and financial institutions have an inverted U-shaped influence on greenhouse gas emissions; the remaining coefficients for model input variables were insignificant.

To examine the possible spillover effects of financial development, **Table 8** examines the interaction between financial development and economic growth. Except for Model 23 and Model 22, the computed coefficients did not provide meaningful findings. Although the impacts of financial development on greenhouse gas emissions were significant in all models, the interaction coefficient was negative. The coefficient of Islamic financial development was likewise positive and significant at the 10% level in Model 17, while the interaction terms were not significant in this model. When the impacts of GDP per capita on CO_2 emissions were examined in Models 22 and 23, the following effects were observed:

$$\frac{d(\ln CO^2)}{d(\ln GDPP)} = 2.581 - 0.242\ln GDPP - 0.013 \times (\ln AWAR) \tag{8}$$

$$\frac{d(\ln CO^2)}{d(\ln GDPP)} = 2.037 - 0.162\ln GDPP - 0.638 \times (\ln FI) \tag{9}$$

While the direct effects of financial development on CO_2 emissions were positive and significant, the effects of various economic development levels on such effects were negligible for the majority of the variables. However, economic development

TABLE 8 | Estimation results of different models for **Eq. 6**.

	Model 17	Model 18	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
ln *GDPP*	2.702	2.594	2.545	2.604	2.57	2.581	2.037	2.356
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.001*)	(0.000*)
ln $GDPP^2$	−0.126	−0.122	−0.12	−0.121	−0.121	−0.121	−0.081	−0.109
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.022)	(0.001*)
ln *OPE*	0.215	0.215	0.215	0.197	0.213	0.221	0.209	0.217
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)
ln *ENE*	0.381	0.397	0.402	0.388	0.399	0.375	0.421	0.397
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)
ln *IFDI*	0.182							
	(0.061***)							
ln *IFDI* × ln *GDPP*	−0.018							
	(0.11)							
ln *QDE*		0.024						
		(0.761)						
ln *QDE* × ln *GDPP*		−0.001						
		(0.874)						
ln *KNO*			0.003					
			(0.968)					
ln *KNO* × ln *GDPP*			−0.001					
			(0.885)					
ln *CSR*				0.045				
				(0.252)				
ln *CSR* × ln *GDPP*				−0.004				
				(0.363)				
ln *GOV*					0.006			
					(0.955)			
ln *GOV* × ln *GDPP*					−0.001			
					(0.962)			
ln *AWAR*						0.122		
						(0.023**)		
ln *AWAR* × ln *GDPP*						−0.013		
						(0.041**)		
ln *FI*							5.31	
							(0.026**)	
ln *FI* × ln *GDPP*							−0.638	
							(0.014**)	
ln *FM*								1.451
								(0.154)
ln *FM* × ln *GDPP*								−0.153
								(0.166)
LogL	293.829	291.182	290.558	292.81	290.386	294.211	294.379	291.432
R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

*p-Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

might mitigate the positive impacts of *AWAR* and *FI* on CO_2 emissions in the following ways:

$$\frac{d(\ln CO^2)}{d(\ln AWAR)} = 0.122 - 0.013 \times \ln GDPP \qquad (10)$$

$$\frac{d(\ln CO^2)}{d(\ln FI)} = 5.31 - 0.638 \times \ln GDPP \qquad (11)$$

Table 9 produces more significant findings when the interaction terms of financial development and energy use were included. In models 25, 28, 30, 31, and 32, the coefficient of the variable of financial development and its interaction with energy consumption was significant. The coefficients for financial development were positive, whereas the coefficients for interaction terms were negative. Energy consumption had the following influence on CO_2 emissions in these models, which correspond to the *IFDI*, *CSR*, *AWAR*, *FI*, and *FM* variables:

$$\frac{d(\ln CO^2)}{d(\ln ENE)} = 0.586 - 0.079 \times (\ln IFDI) \qquad (12)$$

$$\frac{d(\ln CO^2)}{d(\ln ENE)} = 0.402 - 0.026 \times (\ln CSR) \qquad (13)$$

$$\frac{d(\ln CO^2)}{d(\ln ENE)} = 0.458 - 0.028 \times (\ln AWAR) \qquad (14)$$

$$\frac{d(\ln CO^2)}{d(\ln ENE)} = 0.858 - 1.213 \times (\ln FI) \qquad (15)$$

$$\frac{d(\ln CO^2)}{d(\ln ENE)} = 0.551 - 0.555 \times (\ln FM) \qquad (16)$$

TABLE 9 | Estimation results of different models for **Eq. 7**.

	Model 25	Model 26	Model 27	Model 28	Model 29	Model 30	Model 31	Model 32
ln *GDPP*	2.996	2.611	2.597	2.689	2.671	2.768	2.072	2.194
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)
ln $GDPP^2$	−0.143	−0.123	−0.122	−0.125	−0.128	−0.132	−0.094	−0.101
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.005)	(0.002*)
ln *OPE*	0.224	0.214	0.218	0.212	0.217	0.217	0.193	0.214
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)
ln *ENE*	0.586	0.403	0.434	0.402	0.492	0.458	0.858	0.551
	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)	(0.000*)
ln *IFDI*	0.776							
	(0.009*)							
ln *IFDI* × ln *ENE*	−0.079							
	(0.012**)							
ln *QDE*		0.051						
		(0.741)						
ln *QDE* × ln *ENE*		−0.004						
		(0.798)						
ln *KNO*			0.116					
			(0.605)					
ln *KNO* × ln *ENE*			−0.013					
			(0.584)					
ln *CSR*				0.26				
				(0.057***)				
ln *CSR* × ln *ENE*				−0.026				
				(0.067***)				
ln *GOV*					0.279			
					(0.292)			
ln *GOV* × ln *ENE*					−0.029			
					(0.293)			
ln *AWAR*						0.28		
						(0.072***)		
ln *AWAR* × ln *ENE*						−0.028		
						(0.086***)		
ln *FI*							11.246	
							(0.03**)	
ln *FI* × ln *ENE*							−1.213	
							(0.023**)	
ln *FM*								5.37
								(0.034**)
ln *FM* × ln *ENE*								−0.555
								(0.036**)
LogL	295.711	291.203	290.702	294.11	290.955	293.59	293.935	292.693
R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

*p-Value, *, **, and *** show significance at 1, 5, and 10% levels, respectively. Source: Authors' estimations.*

CONCLUSIONS AND POLICY IMPLICATION

The factors impacting greenhouse gas emissions in Islamic nations have been explored in this study using spatial econometrics, with particular emphasis on the effect of the Islamic Financial Development Indicator (IFDI). Our sample spanned 2013–2018. The experimental findings indicated that there was no spatial association between the CO_2 emissions of the countries analyzed. The estimated findings indicated that the spatial and time-period fixed-effects models might provide a more accurate representation of CO_2 emissions. Different models' estimations indicated the presence of the environmental Kuznets curve (EKC) hypothesis in the countries studied. Additionally, countries' increased trade openness has resulted in increased greenhouse gas emissions. Moreover, the energy consumption variable has a direct influence on greenhouse gas emissions in a positive direction. Although the bulk of the countries analyzed are emerging and less developed, the empirical estimation obtained the predicted theoretical assumptions. The effectiveness of the study's primary variable, financial development, was assessed from a variety of perspectives and aspects. The impacts of traditional financial development factors such as the financial market and financial institutions were examined in this research. The findings indicated that these two variables have no direct and significant influence on greenhouse gas emissions, and that their significant effects on greenhouse gas emissions occur only when their nonlinear and spillover effects on energy consumption and economic development are included. The variable "development of financial institutions" showed an inverted U-shaped association with the intensity of carbon emissions. However, no such nonlinear effects were identified for the variable describing financial market development. These findings demonstrated that although the expansion of financial institutions increases carbon emission intensity, it decreases when a certain level of financial market indicators is reached.

There is a large increase in greenhouse gas emissions due to the growth of financial markets and financial institutions, whereas the favorable impacts of energy consumption on greenhouse gas emissions have decreased. Thus, access to capital markets removes limits on capital expansion, resulting in economic development. Financial development has a positive impact on greenhouse gas emissions; however, the negative interaction coefficient between financial development and energy consumption shows that financial development ensures energy efficiency, which in turn reduces the intensity of carbon emissions. According to this study, economic growth has a beneficial influence on CO_2 emissions because of the development of financial institutions; however, this effect was not substantial for the financial market development index.

Additionally, the different characteristics of the Islamic Financial Development Indicator (IFDI) on CO2 emissions were explored in this research. The outcomes were generally identical to those of more traditional methods of financial development. In terms of the Islamic development index, only the CSR and AWAR indices have a positive and substantial impact on the overall index. Nonlinear impacts on greenhouse gas emissions are also observed by the quantitative development index. According to the quantitative development index, the increase in Islamic finance's total assets, asset quality, profitability, and efficiency may contribute to a nonlinear increase in CO_2 emissions regardless of how much it expands or deepens the Islamic financial market. The index's U-shaped association with CO_2 emission suggested that beyond a certain level, emissions begin to decline.

Islamic financial development index components, in addition to their direct and positive impacts on greenhouse gas emissions, diminish the positive effects of energy consumption on greenhouse gas emissions through boosting energy efficiency. The AWAR index measures how well customers are educated and aware of Islamic banking's benefits. However, the CSR index is a measure of the financial components of social responsibility in Islam. There was also evidence that the AWAR index had a direct impact on production efficiency; consequently, a better environment can be obtained as a result of the growth of the Islamic financial market. A key regulatory weapon for environmental sustainability and drastically reducing climate change should be the financial markets. Policy-makers in these countries should promote investment in ecologically friendly areas of the economy, even if the financial industry directly raises carbon emissions as economic development rises.

DATA AVAILABILITY STATEMENT

The data used in the research are included in the section of the article entitled Data, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

Conceptualization: MK and MSK; Data collection: RA-S and YAK; Analysis: MK and JM; Writing original manuscript: MK, MSK, and RA-S; Editing: JM and YAK; Funding: JM.

FUNDING

This research was partially funded by U.S. National Science Foundation award #OIA-1757207 received by JM.

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