Pakistan Journal of Commerce and Social Sciences
2020, Vol. 14 (2), 569-602
Pak J Commer Soc Sci

Spatial Econometric Model of the Spillover Effects of Financial Development on Carbon Emissions: A Global Analysis

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Article History

Received: 17 Feb 2020 Revised: 4 June 2020 Accepted: 16 June 2020 Published: 30 June 2020

Abstract

This study investigates the impact of financial development (FD) on CO_2 emissions in the presence of economic growth, industrial growth, and renewable energy consumption. The sample size consists of panel of 89 countries for the period 1992-2014. The empirical analysis has been done by applying spatial econometrics techniques for exploring the spillover effects from the neighboring countries. The results demonstrate that spatial dependency exists among the sample economies. The spatial segregation analysis reveals that both local (direct) and spillover (indirect) financial development effects significantly lower local carbon emissions. Furthermore, the results demonstrate that in developed countries FD lowers the CO_2 emissions whereas in developing countries FD increases the carbon emissions. The findings are useful for economic policy makers for devising economic and environment related policies by considering the intensity of FD spatial effects in the local economy's pollution level. The findings of this study are also useful for highlighting the fact that whether local economy's environment improved (or deteriorated) because of its own initiatives (pressure) for (on) environment or due to other country's initiatives (pressure) regarding FD.

Keywords: financial development, economic growth, industrial growth, renewable energy consumption, spillover effect, CO_2 emissions, spatial analysis.

1. Introduction

With the rapid increase in industrialization, the world has benefited from higher knowledge of production, economic growth, income and living standard. These gains are, however, coupled with higher environmental problems (Majeed & Ayub, 2018; Cherniwchan, 2012). Therefore, the world is now facing serious challenge of higher greenhouse gas (GHGs) emissions. Among all, CO_2 emissions are observed as harmful threat to environment due to their strong impact on global warming with 75% contribution in the total greenhouse emissions (Sirag *et al.*, 2018; Majeed & Mumtaz, 2017). As a result, economic, political, social, and various other environmental issues are observed across the world particularly in low income and middle-income countries. For example, rise in biodiversity loss, rise in sea levels, increase in food insecurity, poverty and income inequality are the major effects of environmental degradation caused by increased carbon emissions (IPCC, 2014; Dryzek, 2016).

From the last few decades global carbon emissions have increased greatly. World Bank (2020) statistics show that global carbon emissions have risen from 19324 million (kt) in 1980 to 36138 million (kt) in 2014. This rising trend has engrossed the attention of numerous scholars and policy makers internationally. In last decade there has been extensive research on the subject matter. There are number of studies that have explored numerous determinants of CO_2 emissions such as population growth (Dietz & Rosa, 1997), financial development (FD) (Yuxiang & Chen (2010); Majeed & Mazhar, 2019b; Majeed *et al.,* 2020), urbanization (Siddique et al., 2016), renewable energy consumption (Majeed & Luni, 2019) and trade (Siddique & Majeed, 2015; Majeed & Mazhar, 2020).

The global trend of financial development also signifies major improvements after recovery from economic crisis of Great Depression. According to Global Financial Development database (2020) FD proxied by domestic credit to private secretor increased from 70.637 % of GDP in 1980 to 126.945 % of GDP in 2018. This increase indicates that world economies are regulating their financial sector considerably since the past few decades. Considering this rising trend, substantial investigation has also been done on analyzing the possible effect of FD on CO_2 emissions. However, the clarity on the effect of FD on carbon emissions is not achieved as the studies have produced mixed evidence. According to Yuxiang & Chen (2010) and Bello & Abimbola (2010) FD lower the CO_2 emissions. In addition, Majeed & Mazhar (2019b) argued that FD improves the environmental quality by introducing modern and environment friendly technologies, providing research and development projects and facilitating financial and technical assistance to firms. However, this favorable environmental impact only depends on the financial sector priority towards maintaining a healthy and protective environment.

On the contrary, numerous studies explores that FD upswings the environmental related issues. The studies such as Zhang (2011), Tang & Tan (2014) and Tsaurai (2019) argued that industrial value added and stock traded enhance the energy consumption which in turn causes high CO_2 emissions, exhaustion of ecosystem and health problems. In addition, Sadorsky (2010) found that financial support to financial market results in more purchase of machinery, automobile and electrical devices. These facilities provide help to investors to enlarge their business, build up new production plants and machinery which, in turn, enhance the CO_2 emissions.

Thus, many studies have investigated the FD and CO_2 emissions nexus. But these all studies are limited in their scope because they do not capture the spatial dependency of carbon emissions and financial development. These studies do not consider how geographical space and spatial process play vital role in pollution spillovers. Anselin (1988) and LeSage *et al.* (2009) argued that regions are affected by the adjacent regions.

Likewise, first law of geography states that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1979). It violates the assumption of classical econometric model that observations are independent of other observations. So, ignoring the spatial effects leads to misspecification of the model and estimation bias.

Furthermore, it is vital to consider spatial dependency while analyzing CO_2 emissions (Long et al., 2016). According to Wang et al. (2017) hypothesis "All the subjects that are related to environmental issues are inherently spatial". So, carbon emissions of one region do not stand alone, they also cause spillover effects on neighboring countries. For example, China's environmental degradation causing serious environmental problems for South Korea and Japan because of cross border pollution. Additionally, it is important to control for spatial dependency because today world economies are closely integrated with each other through trade, financial flows and other forms of global interactions. Financial reforms of one country have impact on other countries (Simmons & Elkins, 2004). For example, financial reforms in one country attracts more foreign direct investment or trade, neighboring countries may feel competitive pressure to match these policies. According to Maddison (2006), competition among regions to attract trade or capital causes changes in environmental policies. Moreover, according to Burnett et al. (2013) and Zhao et al. (2014) there exists significant spatial dependency for different determinants of carbon emissions. So, it is important to capture the spatial dependency while analyzing carbon emissions. Hence, in this paper we investigate the spatial dependency for FD and CO_2 emissions nexus and try to fill the research gap.

The main contribution of this study is that it applied spatial econometric techniques for investigating the spillover effects of FD on CO_2 emissions. The previous studies for example Zhang, (2011), Tang & Tan (2014), Siddique et al. (2016), and Tsaurai (2019) investigated the FD and CO_2 emissions nexus through standard econometric techniques. To the best of our knowledge this is the first study which examines the impact of financial development on CO_2 emissions through spatial econometrics. Before this study Mahmood et al. (2019) spatially examined the CO_2 emissions, FD and foreign investment nexus for six East Asia countries by employing Spatial Durbin Model. Whereas, this study has done global analysis for investigating FD and CO_2 emissions nexus. Additionally, in this study we have done analysis by estimating four types of spatial econometrics models namely "Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), Spatial Autocorrelation Model (SAC) and Spatial Durbin Model (SDM)". Moreover, in this paper we explore the spatial effects of economic growth, industrial growth, and renewable energy consumption on CO_2 emissions. Furthermore, we have also done the sensitivity analysis by adding additional control variables. Lastly, comparative analysis is conducted for developed and developing countries.

In particular, our study answers the three important questions. First, whether there exists spatial autocorrelation for carbon emissions across nations or not. Second, how does financial development affect environmental quality while controlling the spatial effects? Third, how FD directly impacts CO_2 emissions. Fourth, whether FD also has an indirect impact on CO_2 emissions through spatial linkages.

In contrast to previous studies that mostly focus on policy formulation stances for environmental conservation, our study analyzes how spatial interaction between FD and carbon emissions may help researchers and environmentalist to reconsider the effect on environmental quality through spatial econometric lens. The findings of our study reveal that neighboring countries FD have negative spillover effects on given country's carbon emissions. Further, the direct impacts of local FD also have environmental pleasant effects on local carbon emissions. As increases in FD provides incentive-based loan to the firms that use less energy intensive methods and technologies, thereby producing low carbon products (eco-friendly innovation), and help reduce carbon emissions. These findings are useful for policymakers and environmentalist because in an attempt to conserve environment, they may focus on not only development of their local financial sector but also on developing financial linkages cross borders so that environmental favorable effects (direct and spillover) of FD can be achieved. Doing so help reduce carbon emissions by many folds because of environmental conserving spillover effects from neighboring countries.

The remaining study is arranged as follow: Section 2 consists of literature review. Section 3 presents the data. Section 4 explains the methodology. Section 5 presents the results. Lastly, section 6 concludes this study.

2. Literature Review

In the economic and environmental literature numerous studies are conducted for investigating the determinants of CO_2 emissions. Keeping in mind the nature of present study the related theoretical and empirical literature is provided under the following sub-headings:

2.1 Financial Development and CO_2 Emissions

In the recent studies FD is considered as an important determinant of environmental quality. Theoretically, it has both positive and negative impacts on environment. It decreases the level of carbon emissions by providing financial support to domestic firms for installing clean and modern technology in production process (Aye & Edoja, 2017). Moreover, when firms grow and institutionalize their environmental responsibilities, carbon emissions contained. It was observed for the case of China that with the higher financial and technical support for corporations, carbon emissions declined over the period 1999-2006 (Yuxiang & Chen, 2010).

Along with providing certain benefits, FD also has the ability to harm the environmental health through various mechanisms. First, financial assistance to manufacturing activities helps to expand the scale of business, which results in higher emissions when production activities are largely based on conventional environmental polluting technologies. Second, FD attracts FDI, which can also increase pollution in the presence of weak environmental regulations. Third, consumers get more credit facilities to afford automobiles, which also pollute the environment.

Other than these direct mechanisms the association between FD and environmental quality also work through the two famous hypothesis in the literature namely "environmental Kuznets curve (EKC)" and "pollution haven hypothesis (PHH)".

Regarding the EKC hypothesis it can be said that during the EKC stages, development have both negative and positive impacts on financial sector which in turn effect the environment either in a positive or in a negative manner. For instance, in the initial stages of development when economy expands, unlike other sectors financial sector also grows. Due to which investment, manufacturing activities and use of home appliances increase, which in turn increase GHGs emissions. However, with the increase in FD investment in green and clean technology also increases which in turn help to manage carbon emissions.

On the other hand, PHH specifies some spatial impacts of FD. In general, PHH postulates that firms and countries move their pollution-intensive production to the countries having less-sticker environmental regulations. Thus, increase in FD attracts FDI and if the purpose is just profit-making then national economy allows the FDI even it is pollution intensive. In this way, pollution from one country to another country transfers through the development in financial sector. In contrast, pollution halo hypothesis assumes that worldwide companies transfer greener technology to host country through FDI. It is also directly linked with FD as in the presence of FD local and international firms are attracted for more investment. So, technological transmission in terms of advanced energy efficient technologies, pollution abatement technologies and renewable energy using technologies helps to manage the other country's pollution.

Based on these theoretical arguments FD-environmental quality relationship is empirically tested by the numerous studies covering both panel and time-series data sets. By utilizing the data of 129 economies, Al-Mulali et al. (2015) argued that FD helps to curb the carbon emissions and has a pleasing effect on the environment. Siddique et al. (2016) with the same objective conducted their study by using the South Asian economies' data from 1983 to 2013. By employing panel cointegration they explored that FD decrease the carbon emissions. Likewise, Xiong & Qi (2018) employ the data of 30 Chinese provinces, Hamdan et al. (2018) utilize the data of five ASEAN nations and Majeed & Mazhar (2019b) conducted global analysis of 131 countries and concluded the favourable impact of FD on environmental quality.

Whereas, Sadorsky (2010) examined FD and energy use nexus for a panel of 22 developing countries. He argued that overall FD increases the energy use which in turn enhances the carbon emissions. Tsaurai (2019) proxied FD with domestic credit to financial sector and identified the harmful effects of FD on CO_2 emissions for West African nations. Baloch et al. (2019) and Zakaria & Bibi (2019) use Driscoll-Kraay panel regression model for 59 BRI countries and employ South Asian economies data and obtain similar results. According to them FD provokes the use of luxuries products like automobile, refrigerator, washing machines, and air conditioner that consume more energy and pollute the environment. Furthermore, incorporating the time series data Zhang (2011) for China, Islam et al. (2013) and Boutabba (2014) for India and Tang & Tan (2014) for Malaysia found FD leads to degradation of environment. The overall effect of FD on environmental quality is inconclusive as studies are conducted using diverse methodologies, sample size, and environmental indicators. Moreover, the studies also suffer from omitted variable bias and ignore the protentional heterogeneity among different cross-sections and spatial effects which create biasedness in the findings.

2.2 Economic Growth and CO_2 Emissions

In the theoretical terms, economic growth and environmental quality are highly linked. According to Grossman & Kruger (1995) growth and emissions are non-linearly related and have an inverted U-shaped relationship. According to them, in the earlier phases of development environmental quality deteriorates with the rise in economic activities and we observe positive association between the two variables. However, after some time with the advancement of new technology and increase in public awareness about the environment, the negative relationship can be seen.

Based on theoretical notions economic growth is regarded as significant determinant of environment. Therefore, the empirical literature is abundant with GDP-environment nexus where studies are conducted using different economies data set and time periods. The findings of these studies are different because of different indicators for environmental quality and different econometric techniques. Some studies (Copeland & Taylor, 2004; Majeed, 2018; Majeed & Luni, 2019) accept the validity of EKC hypothesis. According to them in the earlier stages of development economic growth result in an increase in carbon and other greenhouse gas emissions which later reduced with the improvement in research, education, public awareness and technology.

The studies by Roca et al. (2001) and Fodha & Zaghdoud (2010) also obtain similar results. Furthermore, the recent studies by Dogan & Inglesi-Lotz (2020) for seven European countries and Ridzuan *et al.* (2020) for Malaysian economy find the positive association between GDP and environmental indicators while negative association between GDP square and environmental indicator. In short, they also accept the validity of EKC hypothesis.

In a recent study, Majeed & Mazhar (2020) argue that climate change has become a greatest threat to sustainable development goals. Using the data from 1961 to 2018 this study performs the empirical analysis for the group of countries (upper, middle and lower) and regions (OECD, South Asian, SAARC and BRICS economies). By exploiting the first and second-generation econometric methods and fixed effects quantile regression the result for long run and for different quantiles are presented. The findings accept the validity of EKC hypothesis for upper income and OECD countries while reject for the group of middle and lower income, South Asian, SAARC and BRICS economies. Further, their findings reveal that the scale and technique effects of EKC, and the impact of other explanatory variables (biocapacity, human capital and trade) on ecological footprint depends on the existing ecological footprint level, development levels and regional locations.

2.3 Industrialization and CO_2 Emissions

Presently, industrialization process is reached at its maximum. Due to which global community, on one side, benefited from its various attractive features like increase in income, education and health facilities and in turn an improved living standard. However, on the other hand, the world also suffers from its negative externalities like deterioration in the environmental quality in the form of dust, fumes and other dangerous gas emissions. In the theoretical sense, with the increase in industrialization the pace of economic activities, involving scale of production and energy use increase. In addition, initially the production structure also changes from less-energy intensive techniques to high-energy intensive techniques (i.e. more use of energy and pollution-intensive technology) which cause a rise in GHGs emissions (Zhu et al., 2017). Indeed, industrialization increases energy consumption and it contributes almost 51 % of global energy use (Sieminski, 2013).

Based on the theoretical arguments various researchers have tested the industrialization and environmental quality nexus. Zhao *et al*. (2010) utilize the data from 1996 to 2007 and explore various causes of carbon emissions for the municipality of China (Shanghai). By employing "Log-Mean Divisia Index method" they explore that industrial production is among one of the prime factors which causes high CO_2 emissions. Additionally, Ahuti (2015) argued that industrial growth upsurges the concentration of pollutant emissions (CO_2, Methane, Sulphur) in the atmosphere and leads to high global temperature, soil moisture, humidity and precipitation. Li & Lin (2015) by adopting panel data of 73 countries for the period 1971 to 2010 also found the positive impact of industrialization on carbon emissions. Likewise, Liu & Bae (2018) by employing ARDL and the panel data set of 1970-2015 and Dong *et al.* (2019) for 14 developed countries over the period 1960-2013 found the similar conclusion. According to them growth in industrial sector increases carbon emissions.

Whereas, the study by Cole et al. (2008) underlined that higher industrial research & development (R&D) expenditures help to improve the environmental quality. Because with the help of higher R&D efficient ways of production are explored that consume less energy. Other than R&D expenditures, industrial structure also assists the economies to improve their environment quality. As knowledge intensive and technological based industries consume low energy and release low carbon emissions (Zhou et al., 2013).

Additionally, Kwakwa et al. (2014), Xu & Lin (2015) and Aboagye (2017) explored an inverted U-shaped relationship between industrial development and CO_2 emissions. These studies argued that, at initial stage of industrialization, industries consume more energy and cause high CO_2 emission. In long run industries become efficient and use modern technologies in production process which leads to lower carbon emission. Additionally, Zheng et al. (2019) employ panel quantile regression for 102 Chinese's cities and conclude that industrialization have a favourable impact on CO_2 emissions. However, with further expansion emissions intensity reduces with the improvement in technology. Whereas, the recent study by Opoku & Boachie (2020) highlighted the insignificant impact of industrial growth on environmental quality. Based on studies' sample size and methodological differences the literature presents inconclusive results.

2.4 Renewable Energy Consumption (REC) and CO_2 Emissions

As discuss earlier a plenty of research conducted on EKC hypothesis and explored non-linear association between income per capita and carbon emissions. That directed towards the requirement of technological advancement and efficient energy use. Therefore, the researcher also started to see the impact of renewable energy resources on environmental quality. Recently, renewable energy consumption is considered as the crucial determinant of CO_2 emissions. It is less-pollution intensive and help to manage increased energy demand (Le & Park, 2020).

Akella et al. (2009) argued that utilizing renewable energy in energy related production process decreases the thermal pollution which in turn condenses the carbon dioxide emissions. Furthermore, renewable energy reduces the carbon emission as it does not emit pollution, and it can replace the traditional technologies which depends on fossil fuel consumption (Bilgili et al., 2016; Majeed & Luni 2019). Adding further, Ferguson (2007) and Elliott (2007) claim that renewable energy consumption is carbon free energy source and provides solution to global warming and problems related to energy security.

The empirically studies on REC and environment found mixed results. On one side studies explore that REC increases the carbon emissions (Apergis et al., 2010; Boluk & Mert, 2014; Jebli & Youssef, 2017). On the other side (Bilgili et al., 2016; Ito, 2017; Kahia et al., 2019; Sharif et al., 2019; Erdogan et al., 2020; Jebli et al., 2020; Le & Park, 2020) found that REC reduces the CO_2 emissions.

2.5 Determinants of CO_2 Emissions in the Spatial Framework

Recently, numerous studies explored different determinants of carbon emissions through spatial econometric techniques. Liu et al. (2014) by applying spatial econometric techniques found that GDP, trade and energy intensity have negative indirect and positive direct impact on CO_2 emissions. Further, according to Hao et al. (2018) because of spillover effects coal consumption in one region of China increases emissions in other regions of China. Additionally, Zhao et al. (2017) explored that in China spatial effects exists for sulfur dioxide during 2001-2014. Furthermore, Mahmood et al. (2019) spatially analyzed the carbon emissions, FD and foreign investment nexus for six East Asian countries. By employing spatial Durbin model, they found that direct FD has an insignificant while indirect FD has a negative significant effect on CO_2 emissions. The study of Mahmood et al. (2019) is limited to East Asian countries and cannot be generalized globally.

In sum, numerous studies investigated the association among FD and CO_2 emissions. These studies, however, have relied on standard econometrics techniques for exploring the empirical relationship among the two variables. Thus, it is important to consider the spatial effects while investigating the FD-environment nexus. In this study we will investigate the FD-CO_2 emissions nexus through spatial econometrics techniques and fill the research gap.

3. Data Set

This study investigates the association between FD, economic growth, industrial growth, renewable energy consumption and CO_2 emissions for 89 countries over the period 1992-2014. The study sample and time period are based on data availability. Since, spatial analysis requires balance panel data set, most of the countries have been screened. Similarly, the time span is limited to availability of all observations for all selected countries. The data of all variables is extracted from World Bank (2020). CO_2 emission is the dependent variable. FD, economic growth, industrial growth and renewable energy consumption are taken as independent variables. All the variables are taken in logarithmic form except financial development. Table 1 illustrates the complete description, data source and description of the variables.

Table 1: Data Source and Construction

Variables	Description	Data Source
CO_2 emissions	Kilotons (kt)	World bank (2020)
Financial development (domestic credit to private sector)	% of GDP	World bank (2020)
Economic growth (GDP per capita)	2010 constant US$	World bank (2020)
Industrial Growth (Industry (including construction), value added)	constant 2010 US$	World bank (2020)
Renewable energy consumption	% of total final energy consumption	World bank (2020)

3.1 Construction of the Variables

3.1.1 Carbon Emissions

The dependent variable is carbon emissions. It is taken as log of carbon emissions measured in kilotons (kt). "Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid and gas fuels and gas flaring".

3.1.2 Financial development (FD)

In this study FD is proxied by "domestic credit to private sector" measured as % of GDP. "It refers to financial resources provided to the private sector by financial corporations such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable that establish a claim for repayment". Aye & Edoja (2017) argued that FD lowers the level of carbon emissions by facilitating domestic firms with financial assistance for clean and modern technology in production process. Whereas, according to Sadorsky (2010) financial aid to financial market results in more purchase of machinery and automobile which leads to high CO_2 emissions.

3.1.3 Economic growth (EG)

EG is considered as one of the most significant determinant of CO_2 emissions. It is constructed by taking the log of GDP per capita (constant 2010 US$). According to Grossman & Krueger (1995) the association between environmental quality and economic development is grounded on "scale effect, composition effect and technique effect". Scale effect postulates that EG has a negative effect on environment quality. As high EG upsurges the used of energy consumption from fossil fuels which leads to deterioration of environment (Edenhofer et al., 2011). According to composition effect the positive or negative impact of EG on environment depends on the structural change in the economy. Such as transfer of economy from agrarian based to energy intensive industrialization leads to deterioration of environment. Whereas, shift of economy from pollution intensive industries toward service-oriented industries decrease environmental degradation (Sarkodie & Strezov, 2018). Lastly, according to technique effect increase in income leads to introduction of new technologies which are eco-friendly and as a result environmental quality improves.

3.1.4 Industrial growth

Another important determinant of carbon dioxide emission is industrial growth. It is measured by taking the log of "industry (including construction) value added (constant 2010 US$)". It is defined as "Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources". According to Ahuti (2015) industrial growth increases the energy consumption specially by burning of fossil fuels which leads to high accretion of GHGs (CO_2, Methane, Sulphur) in the atmosphere. These gases lead to high global temperature, soil moisture, humidity, and precipitation.

3.1.5 Renewable Energy Consumption (REC)

Lastly, to account the role of REC we use the log of REC measured as % of total final energy consumption. In other words, "renewable energy consumption is the share of renewable energy in total final energy consumption". According to Majeed & Luni (2019) renewable energy reduces the carbon emission as it does not pollute atmosphere.

4. Methodology

In this study we examine the effect of FD on carbon emissions by applying spatial econometrics techniques. Spatial econometrics deals with spatial dependency and spatial heterogeneity. Generally, spatial econometrics analysis consists of two steps. In the first step we explore the spatial autocorrelation by employing "Moran's I test, Geary's test, Moran scatter plot and Moran spatial map". If the spatial autocorrelation exists, then we move to the second step and construct different spatial models for estimating spatial dependency. LeSage & Pace (2009), and Elhorst (2014) argued that there are four types of spatial econometrics models used in spatial analysis namely "Spatial Autoregressive model (SAR), Spatial Error Model (SEM), Spatial Autocorrelation Model (SAC) and Spatial Durbin Model (SDM)".

4.1 Spatial Autoregressive Model (SAR)

Spatial autoregressive model is also known as spatial lag model (SLM). The SAR or SLM is applied to the situation when carbon emission of Local County is affected by the carbon emission of adjacent countries because of the spillover effects. SAR model can be presented as:

$$Y = \rho WY + X\gamma + \mu$$

Where y denotes the n x 1 vector of endogenous variable (carbon emissions). X is n x n matrix of exogenous variables (financial development, GDP per capita, industrial growth and renewable energy consumption) and Wy (spatial lag of dependent variable).

4.2 Spatial Error Model (SEM)

Another way of exploring spatial relationship is to explain spatial dependency in the error term. So, for reflecting the dependence in the disturbance process we can take the spatial lags. SEM model can be presented as:

$$Y = X\beta + \mu$$

$$\mu = \lambda Wu + \varepsilon$$

$$y = X\beta + (I_n - \lambda W)^{-1}\,\varepsilon$$

Where "λ"" is coefficient of spatial autoregressive, "W" is the spatial weight matrix, "X" is matrix of independent variables, "β" is regression coefficient, "μ"is spatial autoregressive error term and "ε" is vector of independent disturbance term.

4.3 Spatial Durbin Model (SDM)

SDM not only includes the spatially lagged dependent variable but it also incorporates spatially lagged explanatory variables. SDM model is effective because of omitted variable bias and externalities-based motivation. SDM can be written as:

$$y = PWy + x\beta + Wx\gamma + c$$

$$y = (i_n - PW)^{-1}(x\beta + Wx\gamma) + (i_n - PW)^{-1}c$$

4.4 Spatial Autocorrelation Model (SAC)

SAC is the combination of SAR and SEM model. So, SAC model comprises spatial dependence of both dependent variable and disturbance term. It can be presented in following form:

$$Y = \delta Wy + X\beta + \mu$$

$$\mu = \lambda Mu + \varepsilon$$

$$y = (I_n - \delta W)^{-1}\,X\beta + (I_n - \delta W)^{-1}\,(I_n - \delta M)^{-1}\,\varepsilon$$

These spatial models cannot be estimated through OLS. Thus, we estimated spatial model with maximum likelihood technique.

4.5 Spatial Weight Matrix

In spatial econometrics the spatial weight matrix or W matrix is the device which is used for reflecting spatial dependency. Spatial weight matrix gives information about which region is a spatial neighbor of another country. Spatial weight matrix can be defined as W with elements w_{ij} showing that whether observation *i* & *j* are spatially related to each other. Generally spatial weight matrix is row standardized. Broadly, there are two methods for constructing the weight matrix namely weight matrix based on contiguity and weight matrix based on distance. In this study we have constructed weight matrix based on distance.

4.6 Econometric Model

The econometric model for this study is carried from the studies of Bekhet et al. (2017) and Khan et al. (2019) with some modifications. So, for empirically examining the effect of FD on carbon emissions following econometric model is being developed.

$$LCO2_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 LGDP_{it} + \beta_3 LIGC_{it} + \beta_4 LREC_{it} + v_i + \mu_t + \varepsilon_{it} \ldots\ldots \text{ (1)}$$

Where, log of carbon emissions (LCO_2), financial development (FD), log of GDP per capita (LGDP), log of industrial growth (LIGC) and log of renewable energy consumption (LREC). This model is estimated through pooled OLS, fixed and random effects. As in this paper we are investigating the spatial dependency, therefore, spatial econometric model is specified as follows:

$$LCO2_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 LGDP_{it} + \beta_3 LIGC_{it} + \beta_4 LREC_{it} + \delta W * LCO2_{it} + \gamma_1 W * FD_{it} + \gamma_2 W * LGDP_{it} + \gamma_3 W * LIGC_{it} + \gamma_4 W * LREC_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \text{ (2)}$$

Here, W represents the weights matrix that is 89 x 89 in dimension. According to the definition of weight matrix "δ" presents the spatial dependency of CO_2 emissions between the countries. Moreover, "γ's" represent the impact of adjacent countries explanatory variables on local carbon emissions whereas "β's" show the direct impact of FD, economic growth, industrial growth and REC on local carbon emissions.

5. Results and Discussion

This section illustrates the findings of empirical analysis. The section is further divided into subsections. Section 5.1 consists of spatial dependency test. Section 5.2 presents the results of POLS, Fixed and Random Effects. Section 5.3 consists of Spatial Fixed Effects with SAR, SEM, SAC and SDM. Section 5.4 reports the direct, indirect, total and feedback effects. Section 5.5 consists of sensitivity analysis. Lastly, section 5.6 reports the finding of comparative analysis.

5.1 Spatial Autocorrelation (Dependence) Test

Before estimating different spatial econometrics models, we employed different diagnostic tests for detecting the spatial autocorrelation. The four tests namely "Moran's I, Geary's, Moran scatter plot and Moran spatial map" have been applied for checking the presence/absence spatial dependency.

5.1.1 Global Spatial Autocorrelation

Moran's I and Geary's are considered as two measures of global spatial autocorrelation. Table 2 shows the findings of "Moran's I and Geary's C tests". The null hypotheses of these tests are that "there is no global spatial autocorrelation". The findings demonstrate that there exists global spatial autocorrelation as probability values of both tests reject the null hypothesis that "there is no global spatial autocorrelation" and accept the alternative.

Table 2: Moran's I and Geary's c

	Moran's I	**Geary's C**
Log of carbon emissions	0.373***	0.614***
	(0.000)	(0.000)
Financial development	0.519***	0.491***
	(0.000)	(0.000)
Log of GDP per capita	0.376***	0.608***
	(0.000)	(0.000)
Log of industrial growth	0.405***	0.579***
	(0.000)	(0.000)
Log of renewable energy	0.410***	0.469***
	(0.000)	(0.000)
Probability value in Parentheses (*** P<0.01)		

5.1.2 Moran Scatter Plot

To visually explore the spatial dependency, we employed Moran scatter plot. We select one point (2010) to display Moran scatter plot for CO_2 emissions of 89 countries. The horizontal axis presents the countries carbon emissions and vertical axis presents the corresponding spatial lag. Figure 1 presents the Moran scatter plot. The scatter plot is divided in four quadrants. The I quadrant consists of “High-High (HH)” clustering which shows that countries with high carbon emissions are enclosed by neighbouring countries with high carbon dioxide emissions. The II quadrants represent the “Low-High (LH)” clustering which infers that countries with low carbon dioxide emissions are enclosed by neighbouring countries with high carbon dioxide emission. The III quadrant is “Low-Low (LL)” clustering which illustrates countries with low CO_2 emissions are enclosed by neighbouring countries with low values. The IV quadrant is “High-Low (HL)” clustering which shows that countries with high values are enclosed by countries with low values. The I and III quadrants show the positive spatial autocorrelation. The II and IV quadrants present the negative spatial autocorrelation.

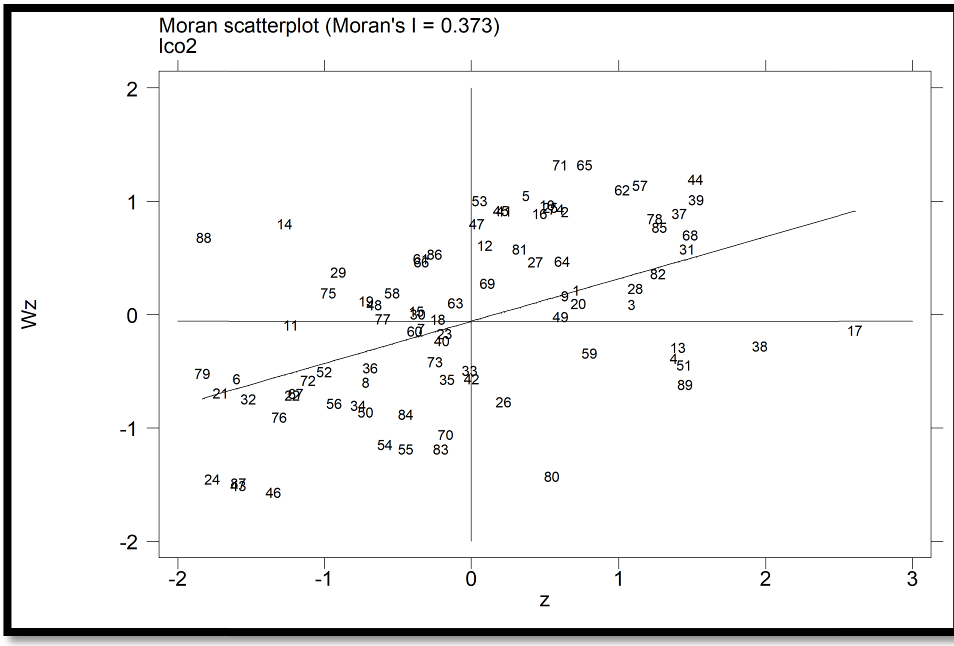

Figure 1: Moran Scatter Plot

5.1.3 Moran Spatial Map

Figure 2 presents the geographical spatial map of carbon emissions for the year 2010. In this map the values are given according to the order from deep color to light color. The dark color shows the countries where CO_2 emissions are high and light color represents the countries with low carbon emissions.

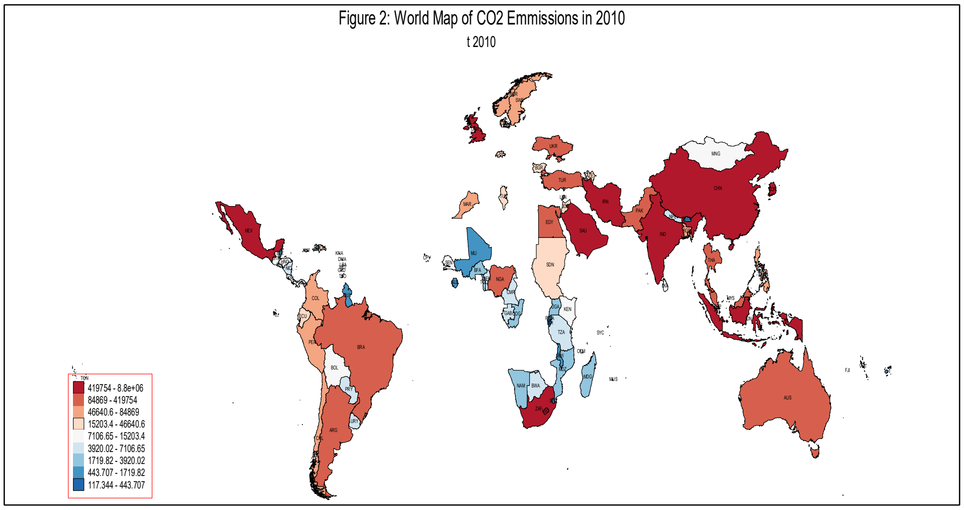

Figure 2: Moran Spatial Map for Carbon Emissions

5.2 Results of POLS, Fixed & Random Effects

Table 3 illustrates the findings of POLS, FE & RE with non-spatial model. The results reveal that FD has a negative effect on CO_2 emissions inferring that FD improves environmental quality. The estimated results demonstrate that 1 % rise in FD leads to 0.005 % decrease in CO_2 emissions. These findings are parallel with the results of Yuxiang & Chen (2010) and Al-Mulali et al. (2015). According, to these studies FD decreases CO_2 emissions by introducing modern and environment friendly technologies, promoting research and development projects and offering financial and technical assistance to firms.

The effect of economic growth (GDP) on CO_2 emission is positively significant, implying that 1 % upsurge in economic growth causes 0.613 % (column 1) to 0.723 % (column 3) increase in carbon dioxide emissions. This result is parallel with the findings of Baloch *et al*. (2019). According to this study high economic growth upsurges the energy consumption especially fossil fuels, which leads to environmental degradation.

The estimated results reveal that industrial growth is significantly and positively associated with CO_2 emissions. The coefficient value infers that 1 % rise in industrial growth led to 0.40 % (column 1) to 0.150 % (column 3) rise in CO_2 emissions. These findings are consistent with Abokyi et al. (2019). Moreover, according to "Environmental Protection Agency" industrial pollution is accountable for 50 % of worldwide pollution as industrial production emits GHGs such as CO_2, Methane and Sulphur.

The findings demonstrate that renewable energy consumption (REC) has a negative effect on CO_2 emissions. 1 % incline in renewable energy causes 0.197 % (column 1) to 0.136 % (column 3) decrease in CO_2 emissions. These results are consistent with the studies of Bilgili et al., (2016) and Majeed & Luni, (2019). Furthermore, according to

Akella et al. (2009) renewable production reduces the CO_2 emission by reducing thermal pollution. However, these results do not capture the complete picture, as the impact of neighborhood countries is not estimated by these conventional econometrics techniques. The next sections present results based on spatial econometrics techniques.

Table 3: Regression of POLS, FEM & REM

	1	**2**	**3**
	POLS	**FE**	**RE**
	-0.00249***	-0.000642**	-0.000942***
Financial development	(0.00)	(0.00)	(0.00)
	0.613***	0.701***	0.723***
Log of GDP	(0.04)	(0.04)	(0.04)
	0.400***	0.127***	0.150***
Log of Industrial growth	(0.04)	(0.03)	(0.03)
Log of renewable energy consumption	-0.197***	-0.137***	-0.136***
	(0.01)	(0.01)	(0.01)
	-13.83***	-10.05***	-11.08***
Constant	(0.21)	(0.40)	(0.37)
Observations	2047	2047	2047
Number of groups	89	89	89
R-squared	0.936	0.659	0.9361
Hausman test	-	-	51.43
			0.000
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)			

5.3 Results of Spatial Fixed Effects (SAR, SEM, SAC and SDM)

Table 4 reports the findings of spatial models. In this paper, we have estimated four spatial models with maximum likelihood. Column 1 illustrates the result of SAR, column 2 consists of SEM, and column 3 presents the findings of SAC. Lastly, column 4 shows the estimates of SDM. The findings of all these models indicate that there exists spatial dependency. Furthermore, the coefficients of weight matrix are statistically significant which confirm the existence of spillover effects.

Moreover, ρ (coefficient of spatial autoregressive and spatial autocorrelation) and λ (coefficient of spatial autocorrelation) are statistically significant. The significance of ρ reveals that spatial spillover effects of carbon emissions are obvious. Moreover, the significance of λ indicates that other than explanatory variable there are some factors in the error term which are contributing to autocorrelation. The significance of ρ and λ implies that because of spillover effects carbon emission of one country is affected by both local and neighbour countries' financial development.

Furthermore, the findings demonstrate that coefficient of FD is negatively significant inferring that 1% rise in FD causes 0.0007 % (column 1) to 0.001% (column 4) decrease in carbon emissions. These findings are parallel with Al-Mulali *et al*. (2015). According, to them FD provides technical and financial assistance to firms so that they can introduce modern and clean technology in production process. This eco-friendly production process thereby decreases the level of carbon emissions.

Table 4: Spatial Regression Analysis (Fixed Effects)

	1 SAR	2 SEM	3 SAC	4 SDM
Financial Development	-0.000716**	-0.000617**	-0.000964***	-0.00104***
	(0.00)	(0.00)	(0.00)	(0.00)
Log of GDP	0.627***	0.694***	0.575***	0.519***
	(0.04)	(0.04)	(0.05)	(0.05)
Log of Industrial Growth	0.150***	0.132***	0.142***	0.167***
	(0.03)	(0.03)	(0.03)	(0.03)
Log of Renewable Energy Consumption	-0.134***	-0.136***	-0.133***	-0.131***
	(0.01)	(0.01)	(0.01)	(0.01)
Wx				
W* Financial Development	-	-	-	-0.00201***
				(0.00)
W* Log of GDP	-	-	-	0.564***
				(0.08)
W* Log of Industrial Growth	-	-	-	-0.361***
				(0.06)
W* Log of Renewable Energy Consumption	-	-	-	-0.0103
				(0.02)
Ρ	0.0739***	-	0.168***	0.00722
	(0.02)		(0.04)	(0.03)
Λ	-	0.0246	-0.168***	-
		(0.03)	(0.06)	
σ^2	0.0338***	0.0340***	0.0348***	0.0330***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	2047	2047	2047	2047
Number of groups	89	89	89	89
R-squared	0.934	0.934	0.930	0.919
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

The findings demonstrate that economic growth (GDP) has a positive impact on CO_2 emissions. 1% rise in economic growth (GDP) causes 0.627 % (column1) to 0.519 (column 4) % increase in CO_2 emissions. Furthermore, the results identify that the coefficient of industrial growth is positively significant implying 1 % infer in industrial growth leads to 0.150 (column 1) to 0.167 (column 4) % increase in carbon dioxide emissions. This finding is aligned with Abokyi *et al*. (2019).

The results show that REC has a negative effect on CO_2 emissions indicating that 1 % incline in renewable energy leads to 0.197 % (column 1) to 0.136 % (column 4) decrease in CO_2 emissions. These finding are consistent with the study of Majeed & Luni (2019).

They argued that REC reduces the CO_2 emissions as it does not emit pollution, and it can replace the traditional technologies which depend on fossil fuel consumption. Furthermore, in order to make a choice between fixed and random effects Hausman test has been employed. The results of Hausman test support the selection of spatial fixed effects.

5.4 Direct, Indirect, Total and Feedback Effect

This section presents the direct, indirect, total and feedback impacts of FD on carbon emissions. The direct impact demonstrates that the change in region dependent variable (carbon emissions) is because of the explanatory variables (FD, economic growth, industrial growth and renewable energy consumption) of the same region. Whereas, the indirect (spillover) effects capture the change in endogenous variable that is caused by the independent variables of other regions (neighboring countries). The total impact is sum of direct & indirect effects.

Table 5 reports the estimated results of direct, indirect and total effects with spatial autoregressive model. The findings reveal that in total impacts 1 % upsurge in FD causes 0.00078 % decline in carbon emissions. The total effect of FD is composed mostly of the direct effect. In the indirect effects, the coefficient of FD is also negatively significant. This illustrates that FD in the neighboring countries has favorable environmental effects on the local carbon emissions. These indirect effects invalidate pollution halo hypothesis. Similarly, the direct effects also have pleasant environmental effect as the coefficient suggest that 1 % increases in local FD lower carbon emissions by 0.00072 % in a given country. These negative direct impacts of FD on carbon emissions are parallel with the existing studies of Yuxiang & Chen (2010), Al-Mulali *et al.* (2015) who found a negative effect of FD through investment in environment friendly technology. According to these studies FD decreases the level of carbon emissions by facilitating domestic firms with financial assistance so that they can introduce clean and modern technology in production process. Further, the coefficient of direct effects is larger than indirect effects indicating that the increases in local FD has a larger favorable environmental effect than that of neighboring FD. As both direct & indirect impacts of FD on CO_2 emissions are negative hence, these results may be wisely scrutinized by policy makers who intend to develop financial sector and protect environmental quality through control emissions.

Economic growth is found to have positive and significant impact on carbon emissions consistently in direct, indirect and total effects. These estimated positive impacts of GDP are in parallel with the findings of non-spatial study by Roca et al. (2001), Fodha & Zaghdoud (2010) and Ridzuan et al. (2020). In particular, the direct effects of economic growth suggest that carbon emissions increase by 0.628 percent as a result of 1 percent rise in GDP growth. This increase in carbon emissions by local GDP growth is much higher than the rise in the emissions by neighboring economic growth. As the indirect estimate indicate that the local carbon emissions upsurge by 0.0491 percent as a result of 1 percent increases in economic growth of neighboring countries.

Similar to economic growth, industrial growth is also found to have positive and significant effect on CO_2 emissions. The indirect effects demonstrate that local carbon emissions increase by 0.0491 percent as a result of 1 percent rise in neighbor economies' industrial growth. However, these impacts are stronger when local industrial growth occurs. In particular, the rise in local industrial growth increases carbon emissions by large magnitude of 0.150 in a given country. The combined (total) impacts of both direct and indirect effects is 0.162 indicating those local as well as neighboring countries' industrial growth increases local carbon emissions by 0.162 percent. As industrialization occurs it enhances economies of scale and energy usage thereby deteriorate environment quality through air pollution. Further, the use of energy intensive technologies and techniques become common. These energy intensive technologies and techniques spillover to the neighboring economies having similar economic traits thereby enhancing carbon emissions through spatial effects. This positive association between industrialization and carbon emission is in accordance with the findings of Ahuti (2015), Li & Lin (2015) and Dong et al. (2019).

The effects of renewable energy consumption are negative significant. As REC is less pollution intensive, therefore its consumption produces less harmful byproducts (one of which is low carbon emissions). Moreover, renewable energy consumption also decreases fossil fuel consumption which is one of the key sources of carbon emissions globally. The estimate of indirect effect suggests that local carbon emissions decreases by 0.0106 percent because of 1 percent rise in REC by the neighboring economies through spillover effects. Similarly, the local rise in REC also decreases carbon emission by 0.135 percent. These positive effects are in line with non-spatial claims by Ferguson (2007), Elliott (2008), Akella et al. (2009), Bilgili et al. (2016), and Majeed & Luni (2019).

Table 5: Spatial Partitioning of Direct, Indirect and Total Impacts (SAR)

	Direct	Indirect	Total	Feedback
Financial development	-0.000726**	-0.0000583*	-0.000784**	-0.00001
	(0.00)	(0.00)	(0.00)	
Log of GDP	0.628***	0.0491***	0.677***	0.001
	(0.04)	(0.01)	(0.04)	
Log of industrial growth	0.150***	0.0121**	0.162***	0
	(0.03)	(0.01)	(0.04)	
Log of renewable energy consumption	-0.135***	-0.0106***	-0.146***	-0.001
	(0.01)	(0.00)	(0.01)	
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

Table 6 reports the estimated results of direct, indirect and total effects with spatial autocorrelation model. The findings indicate that 1 % upsurge in FD leads to 0.0011 % decline in CO_2 emissions. Where 0.0009 is direct and 0.0019 is indirect effect. The sign of FD effects on carbon emission are same (negative) as obtained spatial autoregressive model. However, the size of estimated coefficients is larger than SAR estimates. Similarly, the effects (direct, indirect, and total) of FD on carbon emissions are also highly significant (1 percent level of significance). Here, in SAC model the negative association between FD and carbon emission again directed the presence of invested U-shape relationship. The findings are in parallel accordance with the findings of Yuxiang & Chen (2010), Al-Mulali et al. (2015), and Majeed (2018).

Likewise, the effects of GDP and industrial growth are also consistent with the effects of SAR in terms of sign and level of significance. However, the strength of estimated effects is slightly larger than SAR modeling indicating that when interactive effect between endogenous variable and error term is estimated the size of direct and indirect effects becomes large. Studies such as Fodha & Zaghdoud (2010), Ridzuan et al. (2020) incorporate the role of economic growth and Li & Lin (2015) and Dong et al. (2019) analysing the role of industrialization documented similar findings in their non-spatial analysis.

REC is also found to have consistent (compared to direct, indirect and total effects of SAR) findings. The sign and significance level is similar to documented in Table 6. Whereas, the magnitude of the size of the effects are minutely large. The effects are in accordance with the results of Akella et al. (2009) and Bilgili et al. (2016).

Table 6: Spatial Partitioning of Direct, Indirect and Total impacts (SAC)

	Direct	**Indirect**	**Total**	**Feedback**
Financial Development	-0.000981***	-0.000196**	-0.00118***	-0.001697
	(0.00)	(0.00)	(0.00)	
Log of GDP	0.579***	0.112***	0.691***	-0.048
	(0.05)	(0.02)	(0.05)	
Log of Industrial Growth	0.144***	0.0283***	0.172***	-0.006
	(0.03)	(0.01)	(0.04)	
Log of Renewable Energy Consumption	-0.134***	-0.0262***	-0.161***	0
	(0.01)	(0.01)	(0.01)	
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

In spatial analysis, direct, indirect and total effects of SDM are essentially important to estimate because of superiority of spatial Durbin model specification over SAR and SAC. Table 7 demonstrates the estimated findings of direct, indirect, and total effect with spatial Durbin model. The findings suggest that 1 % rise in FD cause 0.003 % decrease in CO_2 emissions in total effect. Where 0.001 is direct and 0.002 is indirect effect indicating that 1 % rise in local FD decreases the carbon emissions by 0.001 % and 1 % upsurge in neighboring countries' FD lower the carbon emissions by 0.002 %, respectively. The magnitude of these effects is larger compared to the size of FD effect in SAC model. This indicates that FD effect carbon emissions in larger magnitude as unbiased effects are obtained through SDM.

Surprising, the size of indirect effects of GDP growth become significantly large (0.568) than the size obtained through SAC (0.112) and SAR (0.049) when biasness through SDM is removed. This large size of GDP growth indicates that spillover effects of neighboring countries' economic growth are much higher on local carbon emissions. In other words, neighboring countries' GDP growth is one of the factors causing increased carbon emissions in local environment. This implies that spatial effects of neighboring economies' economic growth may not be ignored while protecting environmental quality.

Similarly, the indirect effects of industrial growth are also wroth noticing because of large magnitude and opposite sign compared to the indirect effects obtained through SAR and SAC. The coefficient suggests that 1 percent rise in neighboring countries industrial growth causes local carbon emissions to decrease by 0.360 percent. The decrease in carbon emissions is supported on theoretical ground that after consistent high rate of industrialization, countries begin investing in green industrial technology. The size of indirect effects of industrial growth is bigger than the magnitude of the direct effects. Therefore, this bigger magnitude justifies negative total effects. The underline reason behind strong indirect effect is that there may be the situation that local's economy industrial growth does not increase or the economy is in the initial stages of development in which increased in industrial growth increases carbon emissions. However, the neighbor' economy may experience structural shift and started to improve its relationship with environment through the introduction and use of green and clean technology. Therefore, on one hand, through knowledge spillover local economies' CO_2 emissions decrease and on the other hand local economies may import clean technologies that help them to reduce local GHGs emissions. The negative relationship between industrial growth and CO_2 emissions is in accordance with the results of Cole *et al*. (2008) and Zhou *et al*. (2013). The indirect effects of REC are insignificant in SDM specification indication that there are no spillover effects of REC on given country's carbon dioxide emissions.

Table 7: Spatial Partitioning of Direct, Indirect and Total impacts (SDM)

	Direct	**Indirect**	**Total**	**Feedback**
Financial Development	-0.00105***	-0.00200***	-0.00306***	-0.000433
	(0.00)	(0.00)	(0.00)	
Log of GDP	0.520***	0.568***	1.087***	-0.107
	(0.05)	(0.07)	(0.07)	
Log of Industrial Growth	0.167***	-0.360***	-0.193***	0.017
	(0.03)	(0.06)	(0.07)	
Log of Renewable	-0.131***	-0.0124	-0.143***	0.003
Energy Consumption	(0.01)	(0.02)	(0.02)	
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

5.5 Sensitivity Analysis

To check the robustness of our results sensitivity analysis is conducted. In sensitivity analysis two additional control variables urbanization and trade openness have been incorporated. Table 8 reports the results of sensitivity analysis. The results demonstrate that there exists spatial dependency among the sample economies. Furthermore, the coefficients of weight matrix are statistically significant. These findings confirm the presence of spillover effects. Additionally, the significance of rho and lambda also confirm the existence of spatial dependency. Therefore, our findings are robust to the inclusion of additional variables.

Table 8: Results of Sensitivity Analysis

	1	2	3	4
	SAR	**SEM**	**SAC**	**SDM**
Financial Development	-0.000730**	-0.000628**	-0.000981***	-0.00107***
	(0.00)	(0.00)	(0.00)	(0.00)
Log of GDP	0.635***	0.703***	0.583***	0.526***
	(0.04)	(0.04)	(0.05)	(0.05)
Log of Industrial Growth	0.151***	0.133***	0.144***	0.170***
	(0.03)	(0.03)	(0.03)	(0.04)
Log of Renewable Energy Consumption	-0.136***	-0.137***	-0.134***	-0.132***
	(0.01)	(0.01)	(0.01)	(0.01)
Urbanization	-5.18*	-4.98*	-4.99*	-4.94*
	(0.00)	(0.00)	(0.00)	(0.00)
Trade	0.000521*	0.000570*	0.000313	0.000607**
	(0.00)	(0.00)	(0.00)	(0.00)
Wx				
W* Financial Development	-	-	-	-0.00210***
				(0.00)
W* Log of GDP	-	-	-	0.564***
				(0.08)
W* Log of Industrial Growth	-	-	-	-0.356***
				(0.06)
W* Log of Renewable Energy Consumption	-	-	-	-0.0122
				(0.02)
W* Urbanization	-	-	-	-2.56
				(0.00)
W* Trade	-	-	-	-0.00144*
				(0.00)
Ρ	0.0750***	-	0.167***	0.00851
	(0.02)		(0.04)	(0.03)
Λ	-	0.0258	-0.165***	-
		(0.03)	(0.06)	
σ^2	0.0338***	0.0340***	0.0347***	0.0330***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	2047	2047	2047	2047
Number of groups	89	89	89	89
R-squared	0.931	0.931	0.927	0.916
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

5.6 Comparative Analysis of Developed and Developing Countries

Lastly, comparative analysis has been done for developed and developing countries. Table 9 report the findings of developed countries with fixed effects. The findings infer that FD has a significant negative effect on CO_2 emissions. The findings infer that 1% rise in FD causes 0.0009 % decline in CO_2 emissions. These findings are parallel with the results of (Xiong & Tu,2017; Paramati et al.,2017). Xiong & Tu (2017) argued that FD lowers the CO_2 emission in developed countries and rises the carbon emission in developing countries. According, to Paramati et al. (2017) FDI and stock market development reduce the CO_2 emissions in both developed and developing countries.

Table 9: Developed Countries Analysis (Fixed Effects)

	SAR	SEM	SAC	SDM
Financial Development	-0.000907***	-0.000546**	-0.000963***	-0.000936***
	(0.00)	(0.00)	(0.00)	(0.00)
Log of GDP	0.327***	0.463***	0.294***	0.0778
	(0.05)	(0.05)	(0.05)	(0.06)
Log of Industrial Growth	0.197***	0.148***	0.205***	0.308***
	(0.04)	(0.04)	(0.04)	(0.04)
Log of Renewable Energy Consumption	-0.107***	-0.113***	-0.102***	-0.0986***
	(0.01)	(0.01)	(0.01)	(0.01)
P	0.243***	-	0.305***	0.187***
	(0.03)		(0.04)	(0.04)
Λ	-	0.212***	-0.124*	-
		(0.04)	(0.07)	
Σ^2	0.0214***	0.0222***	0.0220***	0.0206***
	(0.00)	(0.00)	(0.00)	(0.00)
Direct Effect				
Financial Development	-0.000931***	-	-0.000999***	-0.000988***
	(0.00)		(0.00)	(0.00)
Log of GDP	0.332***	-	0.302***	0.0988
	(0.05)		(0.05)	(0.06)
Log of Industrial Growth	0.201***	-	0.211***	0.304***
	(0.04)		(0.04)	(0.04)
Log of Renewable Energy Consumption	-0.109***	-	-0.105***	-0.0971***
	(0.01)		(0.01)	(0.01)

Indirect Effect				
Financial Development	-0.000285***	-	-0.000410***	-0.00106*
	(0.00)		(0.00)	(0.00)
Log of GDP	0.0996***	-	0.120***	0.513***
	(0.02)		(0.02)	(0.10)
Log of Industrial Growth	0.0611***	-	0.0861***	-0.111
	(0.02)		(0.03)	(0.10)
Log of Renewable Energy Consumption	-0.0328***	-	-0.0424***	0.0421**
	(0.01)		(0.01)	(0.02)
Total Effect				
Financial Development	-0.00122***	-	-0.00141***	-0.00205***
	(0.00)		(0.00)	(0.00)
Log of GDP	0.432***	-	0.422***	0.612***
	(0.06)		(0.06)	(0.10)
Log of Industrial Growth	0.262***	-	0.297***	0.194*
	(0.06)		(0.06)	(0.11)
Log of Renewable Energy Consumption	-0.142***	-	-0.148***	-0.0549**
	(0.01)		(0.01)	(0.02)
Wx				
W* Financial Development	-	-	-	-0.000744
				(0.00)
W* Log of GDP	-	-	-	0.423***
				(0.09)
W* Log of Industrial Growth	-	-	-	-0.153*
				(0.09)
W* Log of Renewable Energy Consumption	-	-	-	0.0549***
				(0.02)
Observations	1104	1104	1104	1104
Number of Groups	48	48	48	48
R-Squared	0.934	0.941	0.926	0.789
Standard Errors in Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

Table 10 show the findings of developing countries with fixed effects. The results infer that in developing countries FD have a positive effect on CO_2 emissions implying that 1% upsurge in FD leads to 0.002 % increase in CO_2 emissions. These results are parallel with (Sadorsky 2010; Al mulali et al., 2015; Hafeez et al., 2018). According to these studies financial assistance to manufacturing activities helps to expand the scale of business, which results in higher emissions when production activities are largely based on conventional environmental polluting technologies. Moreover, consumers get more credit facilities to afford automobiles, which also pollute the environment.

The comparative analysis concludes that FD lowers the carbon dioxide emissions in developed countries whereas in developing countries FD increases the carbon emissions. These findings are parallel with Xiaong et al. (2020) who concluded that FD decreases the CO_2 emissions in well-developed regions of China, whereas increases the CO_2 emissions in less developed regions of China. This happens due to the fact that developed countries have already achieved high level of technological advancement, so these countries have the ability to expand their business horizon without damaging the environment. Whereas, developing countries' priority is development and they are struggling for achieving the development goals by neglecting the environmental concerns. Hence, financial services in these economies are also biased towards gaining high profits so here, the use of inefficient production techniques contributes to CO2 emissions.

Table 10: Developing Countries Analysis (Fixed Effects)

	SAR	**SEM**	**SAC**	**SDM**
Financial Development	0.00293***	0.00315***	0.00348***	0.00298***
	(0.00)	(0.00)	(0.00)	(0.00)
Log of GDP	0.766***	0.801***	0.646***	0.631***
	(0.07)	(0.06)	(0.08)	(0.08)
Log of Industrial Growth	0.0454	0.0412	0.0640	0.0988**
	(0.05)	(0.05)	(0.05)	(0.05)
Log of Renewable Energy Consumption	-0.632***	-0.632***	-0.637***	-0.621***
	(0.04)	(0.04)	(0.04)	(0.04)
Ρ	0.0357	-	0.137***	-0.0411
	(0.03)		(0.05)	(0.04)
Λ	-	-0.0601	-0.205***	-
		(0.05)	(0.07)	
$Σ^2$	0.0363***	0.0362***	0.0371***	0.0352***
	(0.00)	(0.00)	(0.00)	(0.00)
Direct Effect				
Financial Development	0.00291***	-	0.00347***	0.00292***
	(0.00)		(0.00)	(0.00)
Log of GDP	0.767***	-	0.650***	0.630***
	(0.07)		(0.08)	(0.08)

Log of Industrial Growth	0.0460	-	0.0650	0.101**
	(0.05)		(0.05)	(0.05)
Log of Renewable Energy Consumption	-0.634***	-	-0.641***	-0.621***
	(0.04)		(0.04)	(0.04)
Indirect Effect				
Financial Development	0.000109	-	0.000545**	0.00485***
	(0.00)		(0.00)	(0.00)
Log of GDP	0.0277	-	0.0983***	0.192
	(0.03)		(0.03)	(0.14)
Log of Industrial Growth	0.00199	-	0.0106	-0.157*
	(0.00)		(0.01)	(0.09)
Log of Renewable Energy Consumption	-0.0238	-	-0.0996***	-0.103
	(0.02)		(0.04)	(0.09)
Total Effect				
Financial Development	0.00302***	-	0.00402***	0.00777***
	(0.00)		(0.00)	(0.00)
Log of GDP	0.795***	-	0.748***	0.822***
	(0.06)		(0.07)	(0.12)
Log of Industrial Growth	0.0479	-	0.0755	-0.0562
	(0.05)		(0.06)	(0.10)
Log of Renewable Energy Consumption	-0.657***	-	-0.741***	-0.724***
	(0.05)		(0.06)	(0.10)
Wx				
W* Financial Development	-	-	-	0.00508***
				(0.00)
W* Log of GDP	-	-	-	0.229*
				(0.14)
W* Log of Industrial Growth	-	-	-	-0.161
				(0.10)
W* Log of Renewable Energy Consumption	-	-	-	-0.128
				(0.09)
Observations	943	943	943	943
Number Of Groups	41	41	41	41
R-Squared	0.936	0.940	0.915	0.922
Standard Errors In Parentheses (*** P<0.01, ** P<0.05, * P<0.1)				

6. Conclusion

Since world countries cannot unleash harmful effects of air pollution, therefore, environmentalists and researchers are working on how to control emissions and conserve environment as emissions produce by one country affect environmental quality of not only given country but also of neighboring countries. The available literature on subject matter up has till now largely ignored the presence of spatial effects of FD on CO_2 emissions. The growing debate on the relationship between FD, the growth of carbon emitting sector and the inclusion of spatial spillovers in this association makes our study interesting and useful.

This paper investigates the association between FD, economic growth, industrial growth, renewable energy consumption and carbon emissions. The sample size consists of 89 countries for the period 1992-2014. FD is proxied by "domestic credit to private sector". The empirical analysis is performed by applying spatial econometric techniques. Broadly, there are two steps in spatial analysis. In the first step (for exploring the spatial autocorrelation) we have employed different diagnostic tests. The findings of Moran's I test, Geary's test, Moran scatter plot and Moran spatial map indicates that there exists spatial autocorrelation among FD and CO_2 emissions.

In the next step we have estimated different spatial model namely "Spatial Autoregressive model, Spatial Error Model, Spatial Autocorrelation Model and Spatial Durbin Model". The findings of these models demonstrate that there exists spatial dependency among the sample economies. Furthermore, the coefficients of weight matrix are statistically significant except renewable energy consumption. These findings confirm the existence of spillover effects. Additionally, the significance of rho and lambda confirmed the existence of spatial dependency. Furthermore, we have also estimated the direct, indirect and total effects. The finding reveals that local financial development (direct) and neighboring countries FD (spillover effects) has significant negative effect on local carbon emissions.

Based on these findings this study suggests that carbon emissions are not only determined locally rather neighboring countries also determined them as the emissions in given country also get effected by surrounding countries. So, it is very important to take into account spatial dependency while analyzing carbon emissions. Furthermore, economies may take into account financial development of both local and neighboring countries while formalizing polices related to reduction in carbon emissions. As both local and neighboring countries' FD have a significant impact on CO_2 emissions. Further, our study encourages local and neighboring countries to develop their financial sector enough that it provides easy availability of special loans with lower interest rate to environment friendly firms. This channeling of enhanced financial development in environmentally friendly machinery and equipment in turns produces sustainable system and reduces carbon emissions in given as well as neighboring countries' atmosphere.

6.1 Contribution of the study

This study contributes to existing literature in a number of ways. First, it acknowledges the possibility of spatial spillover effects on environmental quality. For this, our study employed spatial econometric techniques for examining the spillover impacts of FD on CO_2 emissions. The earlier studies such as Zhang (2011), Tang & Tan (2014), Siddique *et al.* (2016) and Tsaurai (2019) examined the financial development and carbon emission nexus through standard econometric techniques. To the best of our knowledge, this is the first study that explores the effect of financial development on CO_2 emissions through the spatial econometrics. Before this study, Mahmood *et al.* (2019) spatially analyzed the carbon emissions, FD, and FDI nexus for six East Asia countries by employing spatial Durbin model only. Whereas, our study has done global analysis for investigation of FD and CO_2 emission nexus. Secondly, in this study we have done the analysis by estimating four types of spatial econometric models namely "Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), Spatial Autocorrelation Model (SAC) and Spatial Durbin Model (SDM)". Thirdly, our study also analyzed the spatial effects of REC and industrial growth on carbon emissions. Lastly, we have done the sensitivity analysis by adding additional control variables to assess the strength of baseline findings.

6.2 Usefulness of the study

This study is helpful for environmental and economic policymakers in formulating the environmental policies keeping in mind spillover effects of neighboring countries' financial development. Our study evident that financial development of given as well as neighboring countries' help reduce local carbon emissions. Therefore, policymakers may formulate such polices that promote financial globalization specifically for the purpose of eco-friendly innovations in neighborhood. Such policies will help reducing carbon emissions not only through localized effect but also through environmental favorable spillover effects from neighboring countries.

6.3 Theoretical Contribution

The empirical findings of this study demonstrate that FD has a favorable effect on CO_2 emissions. These findings are consistent with the "ecological modernization and environmental transition theories". According to these theories, technological advancement, innovations and modernization help in removing environmental related problems and improve the quality of environment. Development of financial sector provides technical and financial assistance to firms so that they can introduce modern and clean technology in production process. Resultantly, the eco-friendly production process decreases the level of carbon emissions. Further, we can say that our findings support the pollution halo hypothesis as neighbor's economy FD has a favorable impact on local economy's carbon emissions. The mechanism is that the development in financial sector in the neighbor country promotes the use of green and clean technologies in the national and multinational firms. So, with the help of neighbor economy's multinational companies' green technology is promoted in the local economy that in turn helps to reduce GHGs emissions.

6.4 Future Research Direction

This study recommends that future analysis can be extended by assuming the possibility of asymmetry in spatial interactions of FD with carbon emissions. Furthermore, future studies can also consider other potential significant determinants of carbon emissions such as financial inclusion, institutional structure, financial instability, and globalization.

Grant Support Details / Funding

This research work received no research grant.

REFERENCES

Aboagye, S. (2017). Economic expansion and environmental sustainability nexus in Ghana. *African Development Review*, *29*(2), 155-168.

Abokyi, E., Appiah-Konadu, P., Abokyi, F., & Oteng-Abayie, E. F. (2019). Industrial growth and emissions of CO2 in Ghana: The role of financial development and fossil fuel consumption. *Energy Reports*, *5*, 1339-1353.

Ahuti, S. (2015). Industrial growth and environmental degradation. *International Education and Research Journal*, *1*(5), 5-7.

Akella, A. K., Saini, R. P., Sharma, M. P. (2009). Social, economical and environmental impacts of renewable energy systems. *Renewable Energy*, *34*, 390-396.

Al-Mulali, U., Tang, C. F., & Ozturk, I. (2015). Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. *Environmental Science and Pollution Research*, *22*(19), 14891-14900.

Anselin, L. (1988). Spatial econometrics: Methods and models. Boston, MA: Kluwer Academic.

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics*, *69*(11), 2255-2260.

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO_2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics & Finance*, *5*(1), 1379239.

Baloch, M. A., Zhang, J., Iqbal, K., & Iqbal, Z. (2019). The effect of financial development on ecological footprint in BRI countries: Evidence from panel data estimation. *Environmental Science and Pollution Research*, *26*(6), 6199-6208.

Bekhet, H. A., Matar, A., & Yasmin, T. (2017). CO2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. *Renewable and Sustainable Energy Reviews*, *70*, 117-132.

Bello, A. K., & Abimbola, O. M. (2010). Does the level of economic growth influence environmental quality in Nigeria: A test of environmental Kuznets curve (EKC) hypothesis? *Pakistan Journal of Social Sciences*, *7*(4), 325-329.

Bilgili, F., Koçak, E., & Bulut, U. (2016). The dynamic impact of renewable energy consumption on CO2 emissions: A revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews*, *54*, 838-845.

Boluk, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy*, *74*, 439-446.

Boutabba, M. A. (2014). The impact of financial development, income, energy and trade on carbon emissions: Evidence from the Indian economy. *Economic Modelling*, *40*, 33-41.

Burnett, J. W., Bergstrom, J. C., & Dorfman, J. H. (2013). A spatial panel data approach to estimating US state-level energy emissions. *Energy Economics*, *40*, 396-404.

Cherniwchan, J. (2012). Economic growth, industrialization, and the environment. *Resource and Energy Economics*, *34*(4), 442-467.

Cole, M.A.,Elliott, R. J., & Shanshan, W. U. (2008). Industrial activity and the environment in China: an industry-level analysis. *China Economic Review*, *19*(3), 393-408.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature*, *42*(1), 7-71.

Dietz, T., & Rosa, E. A. (1997). Effects of population and affluence on CO2 emissions. *Proceedings of the National Academy of Sciences*, *94*(1), 175-179.

Dogan, E., & Inglesi-Lotz, R. (2020). The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: Evidence from European countries. *Environmental Science and Pollution Research*, *27*, 12717-12724.

Dong, F., Wang, Y., Su, B., Hua, Y., & Zhang, Y. (2019). The process of peak CO2 emissions in developed economies: A perspective of industrialization and urbanization. *Resources, Conservation and Recycling*, *141*, 61-75.

Dryzek, J. S. (2016). Institutions for the anthropocene: Governance in a changing earth system. *British Journal of Political Science*, *46*(4), 937-956.

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Kadner, S., Zwickel, T., & Matschoss, P. (Eds.). (2011). *Renewable energy sources and climate change mitigation: Special report of the intergovernmental panel on climate change*. Cambridge University Press.

Elhorst, J. P. (2014). *Spatial econometrics: From cross-sectional data to spatial panels.* Berlin: Springer.

Elliott, D. (2007). *Nuclear or not? Does nuclear power have a place in a sustainable energy future?* (eds.). Palgrave Macmillan UK.

Erdogan, S., Okumus, I., & Guzel, A. E. (2020). Revisiting the Environmental Kuznets Curve hypothesis in OECD countries: The role of renewable, non-renewable energy, and oil prices. *Environmental Science and Pollution Research*, 1-9.

Ferguson, C. D. (2007). *Nuclear energy: Balancing Benefits and Risks* (Council Special Report No. 28). Council on Foreign Relations Press, New York, US.

Fodha, M., & Zaghdoud, O. (2010). Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve. *Energy Policy*, *38*(2), 1150-1156.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377.

GFDD (2020). Global Financial Development Database. Washington, DC: The World

Bank. [ONLINE] Available at: https://datacatalog.worldbank.org/dataset/global-financial-development (Accessed on November 27th, 2019).

Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does finance affect environmental degradation: Evidence from One Belt and One Road Initiative region?. Environmental Science and Pollution Research, 25(10), 9579-9592.

Hamdan, R., Ab-Rahim, R., & Fah, S. S. (2018). Financial development and environmental degradation in ASEAN-5. *International Journal of Academic Research in Business and Social Sciences*, *8*(12), 14-32.

Hao, Y., Wu, Y., Wang, L., & Huang, J. (2018). Re-examine environmental Kuznets curve in China: Spatial estimations using environmental quality index. *Sustainable Cities and Society*, *42*, 498-511.

IPCC. (2014). Summary for Policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.

Islam, F., Shahbaz, M., Ahmed, A. U., & Alam, M. M. (2013). Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. *Economic Modelling*, *30*, 435-441.

Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics*, *151*, 1-6.

Jebli, M. B., & Youssef, S. B. (2017). The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North Africa countries. *Ecological Indicators*, *74*, 295-301.

Jebli, M. B., Farhani, S., & Guesmi, K. (2020). Renewable energy, CO2 emissions and value added: Empirical evidence from countries with different income levels. *Structural Change and Economic Dynamics, 1-9*.

Kahia, M., Jebli, M. B., & Belloumi, M. (2019). Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries. *Clean Technologies and Environmental Policy*, *21*(4), 871-885.

Khan, S., & Majeed, M. T. (2019). Decomposition and decoupling analysis of carbon emissions from economic growth: A case study of Pakistan. *Pakistan Journal of Commerce and Social Sciences, 13*(4), 868-891.

Khan, S., Peng, Z., & Li, Y. (2019). Energy consumption, environmental degradation, economic growth, and financial development in globe: Dynamic simultaneous equations panel analysis. *Energy Reports*, *5*, 1089-1102.

Kwakwa, P. A., Arku, F. S., & Aboagye, S. (2014). Environmental degradation effect of agricultural and industrial growth in Ghana. *Journal of Rural and Industrial Development*, *2*(2), 22-29.

Le, T. H., Chang, Y., & Park, D. (2020). Renewable and Nonrenewable Energy Consumption, Economic Growth, and Emissions: International Evidence. *The Energy Journal*, *41*(2), 73-92.

LeSage, J., & Pace, R. K. (2009). *Introduction to spatial econometrics*. Chapman and Hall/CRC.

Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: Does the level of development matter?. *Renewable and Sustainable Energy Reviews*, *52*, 1107-1122.

Liu, X., & Bae, J. (2018). Urbanization and industrialization impact of CO2 emissions in China. *Journal of Cleaner Production*, *172*, 178-186.

Liu, Y., Xiao, H., Zikhali, P., & Lv, Y. (2014). Carbon emissions in China: A spatial econometric analysis at the regional level. *Sustainability*, *6*(9), 6005-6023.

Long, R., Shao, T., & Chen, H. (2016). Spatial econometric analysis of China's province-level industrial carbon productivity and its influencing factors. *Applied Energy*, *166*, 210-219.

Maddison, D. (2006). Environmental Kuznets curves: A spatial econometric approach. *Journal of Environmental Economics and Management*, *51*(2), 218-230.

Mahmood, H., Furqan, M., & Bagais, O. (2019). Environmental accounting of financial development and foreign investment: Spatial analyses of East Asia. *Sustainability*, *11*(1), 13.

Majeed, M. T. (2018). Information and communication technology (ICT) and environmental sustainability in developed and developing countries. *Pakistan Journal of Commerce and Social Sciences*, *12*(3), 758-783.

Majeed, M. T., & Ayub, T. (2018). Information and communication technology (ICT) and economic growth nexus: A comparative global analysis. *Pakistan Journal of Commerce and Social Sciences, 12*(2), 443-476.

Majeed, M. T., & Luni, T. (2019). Renewable energy, water, and environmental degradation: A global panel data approach. *Pakistan Journal of Commerce and Social Sciences*, *13*(3), 749-778.

Majeed, M. T., & Mazhar, M. (2019a). Environmental degradation and output volatility: A global perspective. *Pakistan Journal of Commerce and Social Sciences, 13*(1), 180-208.

Majeed, M. T., & Mazhar, M. (2019b). Financial development and ecological footprint: A global panel data analysis. *Pakistan Journal of Commerce and Social Sciences*, *13*(2), 487-514.

Majeed, M. T., & Mazhar, M. (2020). Reexamination of environmental Kuznets curve for ecological footprint: The role of biocapacity, human capital, and trade. *Pakistan Journal of Commerce and Social Sciences*, 14(1), 202-254.

Majeed, M. T., & Mumtaz, S. (2017). Happiness and environmental degradation: A global analysis. *Pakistan Journal of Commerce and Social Sciences*, *11*(3), 753-772.

Majeed, M. T., Samreen, I., Tauqir, A., & Mazhar, M. (2020). The asymmetric relationship between financial development and CO 2 emissions: the case of Pakistan. *SN Applied Sciences*, 2, 1-11.

Opoku, E. E. O., & Boachie, M. K. (2020). The environmental impact of industrialization and foreign direct investment. *Energy Policy*, *137*, 111178.

Paramati, S. R., Mo, D., & Gupta, R. (2017). The effects of stock market growth and renewable energy use on CO2 emissions: Evidence from G20 countries. *Energy Economics*, *66*, 360-371.

Ridzuan, N. H. A. M., Marwan, N. F., Khalid, N., Ali, M. H., & Tseng, M. L. (2020). Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: Evidence of the environmental Kuznets curve. *Resources, Conservation and Recycling*, *160*, 104879.

Roca, J., Padilla, E., Farré, M., & Galletto, V. (2001). Economic growth and atmospheric pollution in Spain: Discussing the environmental Kuznets curve hypothesis. *Ecological Economics*, *39*(1), 85-99.

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy*, *38*(5), 2528-2535.

Sarkodie, S. A., & Strezov, V. (2018). Assessment of contribution of Australia's energy production to CO2 emissions and environmental degradation using statistical dynamic approach. *Science of the Total Environment*, *639*, 888-899.

Sharif, A., Raza, S. A., Ozturk, I., & Afshan, S. (2019). The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. *Renewable Energy*, *133*, 685-691.

Siddique, H. M. A., & Majeed, M. T. (2015). Energy consumption, economic growth, trade and financial development nexus in South Asia. *Pakistan Journal of Commerce and Social Sciences (PJCSS), 9*(2), 658-682.

Siddique, H. M. A., Majeed, M. T., & Ahmad, H. K. (2016). The impact of urbanization and energy consumption on CO_2 emissions in South Asia. *South Asian Studies, 31*(2), 745-757.

Sieminski, A. (2013). *International energy outlook 2013* (EIA Report No.0484). US Energy Information Administration.

Simmons, B. A., & Elkins, Z. (2004). The globalization of liberalization: Policy diffusion in the international political economy. *American Political Science Review*, *98*(1), 171-189.

Sirag, A., Matemilola, B. T., Law, S. H., & Bany-Ariffin, A. N. (2018). Does environmental kuznets curve hypothesis exist? Evidence from dynamic panel threshold. *Journal of Environmental Economics and Policy*, *7*(2), 145-165.

Tang, C. F., & Tan, B. W. (2014). The linkages among energy consumption, economic growth, relative price, foreign direct investment, and financial development in Malaysia. *Quality & Quantity*, *48*(2), 781-797.

Tobler, W. R. (1979). Cellular geography. In *Philosophy in geography* (pp. 379-386). Springer, Dordrecht.

Tsaurai, K. (2019). The impact of financial development on carbon emissions in Africa. *International Journal of Energy Economics and Policy*, *9*(3), 144-153.

Wang, Z., & Ye, X. (2017). Re-examining environmental Kuznets curve for China's city-level carbon dioxide (CO2) emissions. *Spatial Statistics*, *21*, 377-389.

World Bank (2020). World Development Indicators. Washington, DC: World Bank. [ONLINE] Available at: https://databank.worldbank.org/source/world-development-indicators (Accessed on November 27th, 2019).

Xiong, L., & Qi, S. (2018). Financial development and carbon emissions in Chinese provinces: A spatial panel data analysis. *The Singapore Economic Review*, *63*(02), 447-464.

Xiong, L., Tu, Z., & Ju, L. (2017). Reconciling regional differences in financial development and carbon emissions: A dynamic panel data approach. *Energy Procedia*, *105*, 2989-2995.

Xu, B., & Lin, B. (2015). How industrialization and urbanization process impacts on CO2 emissions in China: Evidence from nonparametric additive regression models. *Energy Economics*, *48*, 188-202.

Yuxiang, K., Chen, Z. (2010). Financial development and environmental performance: Evidence from China. *Environment and Development Economics*, *16*(1), 1-19.

Zakaria, M., & Bibi, S. (2019). Financial development and environment in South Asia: The role of institutional quality. *Environmental Science and Pollution Research*, *26*, 7926-7937.

Zhang, Y. J. (2011). The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy*, *39*(4), 2197-2203.

Zhao, M., Tan, L., Zhang, W., Ji, M., Liu, Y., & Yu, L. (2010). Decomposing the influencing factors of industrial carbon emissions in Shanghai using the LMDI method. *Energy*, *35*(6), 2505-2510.

Zhao, X., Burnett, J. W., & Fletcher, J. J. (2014). Spatial analysis of China province-level CO_2 emission intensity. *Renewable and Sustainable Energy Reviews*, *33*, 1-10.

Zhao, X., Deng, C., Huang, X., & Kwan, M. P. (2017). Driving forces and the spatial patterns of industrial sulfur dioxide discharge in China. *Science of the Total Environment*, *577*, 279-288.

Zheng, H., Hu, J., Wang, S., & Wang, H. (2019). Examining the influencing factors of CO2 emissions at city level via panel quantile regression: Evidence from 102 Chinese cities. *Applied Economics*, *51*(35), 3906-3919.

Zhou, X., Zhang, J., & Li, J. (2013). Industrial structural transformation and carbon dioxide emissions in China. *Energy Policy*, *57*, 43-51.

Zhu, Z., Liu, Y., Tian, X., Wang, Y., & Zhang, Y. (2017). CO2 emissions from the industrialization and urbanization processes in the manufacturing center Tianjin in China. *Journal of Cleaner Production*, *168*, 867-875.