Evaluating the effects of energy and economic growth on Carbon dioxide emission (using spatial panel data)

Hedayat Hosseinzadeh[1]

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Abstract

Energy is one of the most important inputs in production. Energy usage and energy diffusion of fossil fuels in process of production cause greenhouse gases (CO_2) emission and destruction of environment. According to the importance of issues like energy usage and economic growth, this paper, concerning the effects of proximity, evaluates the effects of energy usage and economic growth on emission of Carbon dioxide (CO_2) in MENA Zone countries during the period of 1994-2013. In every country, greenhouse gases (CO_2) emission is the function of not only domestic factors but also economic activities of neighboring countries.

The results of the model estimation indicate that proximity effect is verified in the model studying on. Also, the results show that log variable of energy usage has positive and significant effect on CO_2 emission. Log variable of income per capita affects CO_2 emission positively and significantly, and square log variable of per capita income has negative and significant effect on dependent variable. So, environmental Kuznets hypothesis is not rejected in MENA Zone.

JEL Classification: C33 ،Q43 ،O44

Key words: Energy Usage, Economic Growth, Carbon dioxide emission, spatial panel data

1- Assistant Professor, department of economics, Payame Noor University, Iran

1. Introduction

Energy is one of the most important and substantial issues of the world, and plays a vital role in political, international and economic relations. Energy is propulsion of development, and industrial wheels do not work without it. Using different kinds of fossil fuels produce dangerous pollutants which their accumulation in the atmosphere, during decades, causes serious dilemma. Carbon dioxide is one of the most important greenhouse gases which warms the earth gradually and causes a lot of side effects which, nowadays, is called climate changes.

The consequences of climate changes affect the whole of the earth. So that, there are a lot of discussions about expected harms of global warming, and consensus that emission of greenhouse gases provide substantial dangers in climate changes. So, most of the experts verify the basic reduction in the amount of carbon and doing investment to reduce the dangers of environmental changes (Stern, 2008).

In recent years, relationship between energy usage, economic growth and environment destruction creates great discussions among proponents of environment and economic growth. That is, economic growth requires high energy usage and causes more pollution (due to energy usage) and environmental destruction. Therefore, proponents of environment believe that economic growth should be sheathed to improve this condition. On the other hand, the proponents of economic growth believe that economic growth can happen with reduction in pollution and increase in environmental quality, simultaneously. This issue, recently, is considered in endogenous growth theories. This effect is discussed in environmental Kuznets curves (EKC) as well.

Economic growth and energy usage are the most important factors of environmental effects. That is, increase in economic growth causes more utilization of natural resources, and on the other hand, production of products with low quality creates more environmental pollution. In this field, there are many studies, which environmental Kuznets curves is one of them. In most of these studies, different environmental quality indexes and estimation approaches are used to test the hypotheses; and different results are achieved about the acceptance or rejection of the environmental Kuznets hypotheses. With considering the EKC hypothesis, which shows the path of economic development in different stages during the time and a long term relationship, this development path can be observed by cross sectional data of different regions during the time which indicate the amount of emission in various countries with different income levels. Therefore, EKC is a domestic issue of a

country, while most of the empirical studies considered this hypotheses with cross sectional data (in these studies, the effects of proximity among countries are not considered). However, it seems that changes in income per capita of one country cause a change in environmental quality of other countries. In other words, the proximity effects among countries have impacts on their pollution which is not considered in empirical studies. So, in order to fill this gap in literature, this paper, using the spatial panel data approach, will evaluate the effects of economic growth and energy usage on emission of carbon dioxide in MENA Zone countries during the period of 1984-2013. The rest of this paper organizes as follows:

Second section reviews some of the theoretical background about the issue. In section 3 empirical studies are discussed. Section 4 introduces the spatial panel data approach in brief. The model and statistical database will be introduced in section 5. Section 6 presents the estimation results and analysis of research findings. Ultimately, section 7 is assigned to conclusion.

2. Theoretical background

In recent years, the evaluation of the relationship between real income per capita and environmental quality indexes or testing the environmental Kuznets hypotheses is considered deeply by environmental economists. From theoretical aspects, this relationship which is presented in the Environmental Kuznets Curves can be discussed in three frameworks: Scale Effect, Composition Effect and Technique Effect. Scale effects represent changes in economic activity size, composition effect shows changes in product portfolio, and technique effect indicates changes in production methods and changes toward clean technology. In other words, increase in economic growth through scale effect will increase environment pollution; while according to the composition and technique effects, pollution will diminish. So, environmental Kuznets hypotheses represents that increase in economic growth in early stages will increase environment pollution because, in early stages, the scale effect dominate the composition and technique effects; but then, in later stages, environment pollution will be decreased.

The main international attempt to reduce the unfavorable effects of global climate change is to produce less carbon dioxide in the world. The success in achieving the goal depends on the countries producing oil to engage commitment of global goals of CO2 level. One of the

global attempts to control pollution is to make Kyoto treaty. It is determent, in this treaty, that emission of carbon dioxide will be reduced, in average, to 5.2 during the period of 2008-2012, and its emission reach below than its level in 1990.

According to several studies about testing the environmental Kuznets hypotheses in developed and developing countries, which the most important once are Maddison (2006), Liu and et al (2014), Mercan and Karakaya (2015) and Xiao and et al (2015), most of these studies apply different environmental quality indexes and different estimation approaches to test the hypotheses; and they have reached to different results about rejection or acceptance of the environmental Kuznets hypotheses. Many of these studies assume space stability and estimate a common functional form, using panel data approach, for all regions or countries. Just a few studies calculate the spatial relationship and space instability in the EKC framework. Nevertheless, analyzing the EKC relation is done by common econometrics methods such as minimum list squares and co-integration methods, and the local spatial differences are not considered. Removing the spatial lag variables may cause in bias and inconsistent results[1]. We can find this spatial dependence in Liu et al. (2014) findings. Their results show that in all of the countries studied in the sample, carbon dioxide emission is associated with an increase in income per capita. But when they limit their analysis to high income countries, an inverse U relationship is found.

In most of the studies about testing the environmental Kuznets hypothesis, dependent variable is air or water pollution, and variables such as national income per capita, population density and other economic- population variables are considered as the explanatory variables. Since income per capita, by its own, cannot determine the optimum pollution in EKC model framework, so some of the researchers, in addition to income per capita, add other variables to the model in order to economically analyze the environment (Flores and et al, 2009).

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3. Previous studies

On the impact of energy consumption, economic growth and CO_2 emission, there are several studies which the most important once are mentioned in this section.

Roca et al (2001), investigate the relationship between economic growth and air pollution in Spain. The results indicate that environmental Kuznets curve hypothesis is not verified in Spain. So, we cannot consider that economic growth can, lonely, solve the environmental problems. In other empirical study, Halkos (2003), evaluate the relationship between economic growth and SO_2 in 73 countries during the period of 1960-1990, using Generalized Method of Moments and random coefficients. The results derived from first method verify the environmental Kuznets curve hypothesis which show the return point between $2850-6230, however, the random coefficients method dose not confirm the hypothesis. Muller &Wagner (2004) using data of 107 countries during the period of 1986-1998, and focusing on econometric issues such as intersectional correlation and co-integration technics, show that the return point of income, under technological progress, will be $3000; otherwise there will be a continuous increase in pollution. Sadeghi and Saadat (2004), investigate the causal relationship among population growth, environmental pollution and economic growth, using Hisiao causality test and time series data over 1967-2001 in Iran. The results demonstrate that there is a bilateral relationship between environmental effects and economic growth, but there is only a unilateral relationship from population growth toward environmental effects.

Hong & Wagner (2008) evaluate the relationship among CO_2, SO_2 and gross domestic production, using nonlinear co-integration approach for 19 industrial countries during the years 1870-2000. According to the results, in half of the countries, environmental curve hypothesis was verified. Mazzanti et al (2008) investigate the environmental Kuznets curve for emission of greenhouse gases in Italy during the years 1990-2001. The results indicate that whenever the focus, in Italian provinces, would be on the production activities, the hypothesis will be verified.

Musolesi et al (2010) examine the environmental Kuznets curve hypothesis for CO_2 emission in 109 countries during the period of 2001-1959. The results verify the hypothesis in industrial countries, however in low developed countries there is a positive relationship between income and CO_2 emission. Bagliani et al (2010) investigate the relationship between economic growth and environmental pollution in

151 chosen countries during the period of 2003-1961. The hypothesis is not confirmed in countries studied on. Behbudi et al. (2010) survey the relationship among energy consumption, economic growth and carbon dioxide per capita emission over the years 1967- 2004 in Iran. In the paper, co-integration approach and vector error correction model are used to estimate the model. The results show a positive relationship between independent variables such as energy consumption, economic growth, trade openness, urbanization and carbon dioxide per capita emission, the dependent variable.

Sunila Sharma (2011) surveys the factors effecting carbon dioxide emission, using panel data for 69 countries during the years 1985-2005, and dynamic panel data method. Also, they considered three subsections of low, medium and high income to do homogenous analysis. The results indicate that trade openness, GDP per capita and energy consumption, which is measured by electricity consumption per capita and energy consumption per capita, have positive effect on CO_2 emission. However urbanization, in all the income groups, has negative impact on dependent variable. Overall estimates show that GDP per capita and energy consumption per capita, significantly affect the CO_2.While, urbanization, trade openness, and electricity consumption per capita negatively affect the carbon dioxide emission. Saleh et al (2011) using the vector error correction pattern, evaluate the relationship among water pollution, GDP per capita and energy consumption intensity. The results indicate that GDP per capita has a positive and significant relationship with water pollution. Moreover, there is no significant relation between water pollution and energy consumption. Mir Shojaean and Rahbar (2011) estimate the environmental space curve of carbon dioxide and particles, for Asian countries over 1999-2007. Their findings demonstrate that space spillovers of CO_2 and particle pollutants can explain, in order, 10 and 11 percent of pollutant changes in Asian countries. Also, there is an inverse U relationship between income per capita and carbon dioxide per capita production.

Mohamadzade et al. (2012) using the composite spatial auto regressive model, examine the environmental Kuznets hypothesis in MENA Zone countries over the period of 1990-2009. The results indicate that the log variable of income per capita has positive effect, while square log variable of income per capita negatively and significantly affect the carbon dioxide emission. In addition, lag variable (space dependence) has a positive and significant effect on

carbon dioxide emission which verifies the environmental Kuznets hypothesis and the existence of spatial effects.

Hermann Pythagore et al. (2013), using spatial econometrics method, examine the environmental Kuznets hypothesis in European countries during the years 1961-2009. The results show CO_2 emission stability in these countries. Moreover, CO_2 per capita emission in one country causes an increase in CO_2 per capita emission in neighboring country.

Xueting Zhao et al (2014) spatially analyze the CO_2 emission in china provinces during 1991-2010. They have examined the factors effecting CO_2 emission by using the spatial panel data models. They discovered that gross domestic production in province level and population density negatively, and energy consumption structure in transportation section positively effect on CO_2 emission.

Mercan and Karakaya (2015) investigate the relationship among energy consumption, economic growth and CO_2 emission in 11 OECD countries, using dynamic panel data approaches. The results of model estimation indicate that energy consumption has positive effect on pollution diffusion. While economic growth has negative effect on. Xiao and et al (2015) survey the effect of spatial distribution of energy consumption on CO_2 emission in china. The results demonstrate that energy consumption positively affects CO_2 emission. Also, there is a positive correlation among energy consumption, pollution diffusion and economic growth.

Emami Meibodi et al. (2016) investigate the long term relationship between economic growth and environment destruction in Iran during 1980-2005, using co-integration approach. The results demonstrate that economic growth and agricultural and industrial activities directly affect the water pollution in long time, while, trade openness has an inverse effect on it.

In sum, in most of the empirical studies about the environmental Kuznets hypothesis, common approaches of time series and panel data econometrics are used, while, in these studies, proximity effects of countries on greenhouse gases emission is not considered. So, this paper uses spatial panel data, which differentiate this paper from others, for CO_2 per capita emission index in Middle East countries to test the environmental Kuznets hypothesis.

4. Methodology

The paper uses spatial econometrics and data are in the form of spatial panel data. Panel data is made from time series and cross section data combination. Panel data is used in two forms: micro panel or macro panel. Empirical analysis, in panel data rather than other data, has special importance. Anselin (1988) introduced, for the first time, the econometrics which includes facts of special economics. He argues that common econometrics methods which are based on Gas-Markove assumptions are not suitable for regional studies, because he faced with two problems of spatial inter-dependence of observations and spatial inconsistency (Asghari & Akbari, 2002).

Spatial dependence means an observation with location i is dependent to other observations with location j. spatial inconsistency, which is due to model parameters, changes while moving on coordinate plane. In order to solve these problems, Anselin (1988) used maximum likelihood to estimate the parameters.

In this paper, proximity, which reflects relative location of one region in geographical space compared to other spatial units, is used to determine the location and make weighting spatial matrix. That is, number one is used for the country which has a neighborhood with considered country, while when there is no proximity, zero will be used. The obtained matrix, which is proximity matrix, is symmetric and diagonal elements always are zero.

In spatial econometrics models, in order to show the effects of neighboring observations as an explanatory variable, spatial weight matrix or proximity matrix is used. There are different approaches to form proximity matrix, which include linear proximity, bilateral linear, and queen-like.

When estimating the model, we should use standardized matrix which is called weighting spatial matrix. In this matrix, standardization is done on the basis of sum of proximity matrix rows, and each of the elements is divided to the sum of the rows. This matrix is called standardized first order contiguity matrix. Normalizing the proximity matrix and multiplying it in dependent variable vector results in a new variable which shows the means of observations of neighboring regions which is called spatial lag variable. The spatial panel data model is a spatial econometrics model which include the spatial lag of both dependent and independent variables. The spatial panel data model (SPDM) is defined as follows:

$$Y_{it} = \delta \sum_{j=1}^{N} w_{ij} Y_{it} + \alpha + \sum_{i=1}^{m} \beta_i X_{it} + \lambda_t + \varepsilon_{it} \quad (1)$$

$$Y_{it} = \delta W Y_{it} + X_{it}\beta + \mu_i + \lambda_t + \varepsilon_{it}$$

$$Y_{it} = (I - \delta W)^{-1}(X_{it}\beta) + (I - \delta W)^{-1}\mu_i + (I - \delta W)^{-1}\lambda_t + (I - \delta W)^{-1}$$

In this equation, Y_{it} is dependent variable in region i in time t, X_{it} is the independent variable vector in time t, α shows the intercept, parameter of δ as like β parameter are vectors of $K \times 1$ coeficients, μ_i and λ_t , in order, are individual fixed effects and time fixed effects.

5. Estimated model and database

According to the literature and previous studies such as liu et al. (2014) and Mercan and Karakaya (2015), our model will be as follows:

$$CO_{2it} = \alpha_i + \rho W CO_{2it} + X_{it}\beta + \varepsilon_{it} \quad (2)$$

In the above equation, CO_{2it} is carbon dioxide per capita emission in country i in time t, X_{it} is the vector of independent variables such as income per capita, square income per capita, energy consumption and trade openness. α_i is the individual effects of each country. W is standardized proximity matrix *(*n×n*)*, ρ indicates the existence of spatial dependencies between observations, β and ρ are parameters that should be estimated. Equation (2) will be estimated with spatial approach.

The data and information used in this paper are gathered from compact disk of development indexes of World Bank (2014) for the period of 1994-2014.

6. Model estimation and analysis

In spatial econometrics models, it`s better first to do tests related to spatial dependencies, and recognize that whether the model has proximity effects or not, then estimate the model[1]. In this section, before estimating the model, testing the spatial dependencies is required. To do this, we use LM test. The results of the LM test are reported in table (6-1):

1- Microsoft which is used to estimate the model is STATA 14.

Table (6-1): the results of LM test statistic for significance of spatial dependencies.

χ^2 Statistic	Degree of freedom	p-value
3.74	1	0.05

Source: Research Computing

The results indicate that null hypothesis of no significant spatial dependency between observations, in confidence level of 5%, will be rejected. So, the spatial dependencies between observations are verified. Therefor we can say that there is a spatial relationship in dependent variable.

Now, we use a spatial panel data model with respect to spatial dependencies between observations. In this model, first we form the proximity matrix for 20 countries[1] over the years 1994-2013. That is, we consider number 1 for neighboring countries and zero otherwise. So, the symmetric matrix of 20×20 is made whose elements on the main diagonal are zero and off-diagonal elements are zero or one. In the second step, in order to define the weighting spatial matrix, we use standardized first order contiguity matrix. After formation of weighting spatial matrix, the model will be estimated. The results of model estimation are reported in table (6-2):

Table (6-2): the results of spatial panel data model (with fixed effects) estimation

variable	Coefficient	Z statistic	p-value
Spatial lag of CO_2	0.21	12.58	0.000
Log of gross domestic product	0.48	3.16	0.002
Log square of gross domestic product	-0.004	-1.46	0.17
Trade openness	-0.086	-4.08	0.000
Energy consumption	0.13	4.76	0.000
Intercept	0.65	0.83	0.4
Wald test	2399.16		0.000
Correlation coefficient	0.02	158.21	0.000
R^2	0.97		

Source: Research Computing

1- When forming the proximity matrix, according to Madison (2006) and Ciriaci & Palma (2010), countries with distance less than 2000 Km are considered as neighboring countries.

The results of model estimation, by auto-regressive spatial panel data with fixed effects method, demonstrate that log variable of spatial lag carbon dioxide is significantly positive and equals 0.2. log variable of income per capita has a positive and significant effect on carbon dioxide emission. That is, when, in this country group, income per capita increases one percent, carbon dioxide emission will increase in 0.48 percent. Moreover the square log variable of income per capita has significantly negative effect on carbon dioxide per capita emission which implicates to the verification of inverse U hypothesis between income per capita and carbon dioxide per capita emission. In other words, the signs of variables income per capita and square income per capita are as expected, and the U shaped hypothesis of Kuznets curve is confirmed. The results of this paper are consistent with Maddison (2006), Song et al (2008) and Ciriaci & Palma (2010).

In addition, as expected, the coefficient of energy consumption, in our country group, is positive which show that an increase in growth is accompanied by an increase in energy consumption and reasonably, an increase in energy consumption leads to an increase in pollution emission. So, we can propose decrease in energy consumption as a method to decrease pollution. Of course, the policies of reducing energy consumption is not the only way insuring desirable level of environment quality accompanied with desirable level of economic growth and social welfare. Concerning the technology effect, two strategies are considered: first, promoting the technology of fossil fuels usage to increase energy efficiency and decrease pollution (such as solidification of carbon combustion), the other is to use more of renewable energy and clean fuels which in the case of a rise in fossil fuels prices, this strategy will be so interested.

In order to reduce pollution by polluted reduction policies, we should consider the initial costs and investment efficiency. Also, we can analyze the relationship between production and pollution in detail, by determining exact measure of pollutant produced in different sectors, considering the effects of technology change, changes in production methods, and changes in relative share of production factors.

The variable of spatial dependency has a positive and significant effect on carbon dioxide emission. So that, the coefficient estimated for this variable equals 0.02. The result indicates that only 2 percent of changes in carbon dioxide per capita production in countries of MENA Zone are due to spatial spillover of the pollution from neighboring

countries. Since the coefficient is significant, so the spatial spillover effects in air pollution by neighboring countries is verified.

The variable of trade openness has negative and significant on CO_2 emission. That is, trade openness leads to manufacturing technology entry to the country which can decrease greenhouse gases production. This result is consistent with the Jalil and Mahmud (2009) research.
In addition, R^2 equals 0.97, which shows 97 percent of changes in log variable of carbon dioxide per capita in country group are explained by changes of independent variables and spatial lag.
After verifying the spatial effects in panel data model, it`s better to determine whether the model of fixed effects or the model of random effects is accepted. To do so, we use spatial Hasman test. The results are reported in table (6-3):

Table (6-3): the results of spatial Hasman test

χ^2 statistic	p-value
6.635	0.000

Source: Research Computing

According to the results, null hypothesis of existence of spatial error (random effects) is rejected and model estimation by fixed effects (spatial lag) is verified.

Overall, we can say that environmental Kuznets curve for countries of Middle East region and North Africa during the years 1994-2013, is confirmed. Part of carbon dioxide emission, in these countries, is dependent on proximity effects. In other words, in addition to income per capita, which is the factor of increasing greenhouse gases specially carbon dioxide emission, proximity and neighboring countries is the other factor of carbon dioxide per capita emission. The important point in testing the environmental Kuznets hypothesis is that, spatial lag variable have to be significant which, in this paper, shows the average proximity effect in carbon dioxide per capita emission equals 0.02. So, an increase in proximity of countries study on, causes an increment in carbon dioxide emission in these countries.

7. Conclusion

This paper which aims to investigate the effects of energy consumption and economic growth on carbon dioxide emission in countries of Middle East and North Africa over 1994-2013, has used spatial panel

data approach to estimate the model. The results of model estimation demonstrate that the variable of income per capita has positive effect, while the square variable of income per capita has negative effect on pollution which shows environmental Kuznets hypothesis is confirmed in these countries. These results are consistent with Modison (2006), Song et al (2008) and Ciriaci & Palma (2010). Also, as it was expected, the coefficient of energy consumption is positive which shows that an increase in economic growth is associated with an increase in energy consumption. Therefore, reasonably, an increase in energy consumption leads to the increase in pollution emission. So, in order to reduce pollution, it`s better to reduce energy consumption. Of course, the policies of reducing energy consumption is not the only way insuring desirable level of environment quality accompanied with desirable level of economic growth and social welfare. Concerning the technology effect, two strategies are considered: first, promoting the technology of fossil fuels usage to increase energy efficiency and decrease pollution (such as solidification of carbon combustion), the other is to use more of renewable energy and clean fuels which in the case of a rise in fossil fuels prices, this strategy will be so interested.

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