Spatial Environmental Kuznets Curve for Asian Countries: Study of CO\textsubscript{2} and PM10

Mirshojaeian Hosseini, H.*\textsuperscript{1}, Rahbar, F.\textsuperscript{2}
1-Ph.D. Student, Faculty of Economics, University of Tehran Researcher, Hiroshima University, Japan
2-Assoc. prof., Faculty of Economics, University of Tehran-Iran
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Introduction
The Grossman and Kruger’s study (1991) about the relationship between economic growth and environmental quality drew the attention of many researchers and international institutions. Environmental Kuznets Curve (EKC) has been extracted from the study of Kuznets (1955), who believed that there is an inverted U-Shape relationship between economic growth and income inequality. Environmental Kuznets Curve was introduced based on a similar relationship, i.e. in the first steps of economic growth and with increase in per capita income, pollution gradually increases. When per capita income reaches to its turning point, pollution reaches to its peak. If increasing the per capita income continues, pollution mitigates and environmental quality increases.
Numerous theoretical and practical studies have been done with regard to the EKC relationship during the last twenty years. One of the new improvements in the study of EKC relationship is paying attention to spatial nature of environmental phenomena. Considering the spatial dimension in the EKC studies, known as spatial environmental Kuznets curve (SEKC) began from the study of Rupasingha et al. (2004). The concept of the SEKC is entirely similar to that of EKC, except that it considers spatial autocorrelation of environmental pollutants as one of the explanatory variables. The present investigation attempts to examine the SEKC for two pollutants, i.e. carbon dioxide (CO\textsubscript{2}) and particulate matters (PM10), in geographical scope of Asian countries over the period of 1990–2007. While findings show the significant effects of spatial surpass of CO\textsubscript{2} and PM10 in Asian countries, there is an inverse U-Shape relationship between per capita income and per capita CO\textsubscript{2} emission, and a direct relationship between per capita income and the emission of PM10 per square meter.

Materials and method
The concept of SEKC is found based on the theory of spatial autocorrelation of environmental phenomena, simply defined as the relationship between the characteristics of neighboring spatial units. Hubert and Golledge (1981) define it as follows: If set S contains n geographical units, then spatial autocorrelation will be the relationship between the characteristics of each n units and a criterion of geographical contiguity for all n(n-1) members of set S.
Maddison (2006, 2007) states five mechanisms for spatial autocorrelation of environmental phenomena. The first mechanism is explained within the framework of pollution displacement hypothesis. In this hypothesis, high-income countries import the products, whose productions pollute the environment. In fact, the high-income countries send out their pollution to the countries with low income. Composition of the above-mentioned hypotheses with this finding that trade volume between countries has inverse relationship with their distance, directs us toward this point that environmental quality of a country is a function of environmental features of its neighbors.
The second mechanism is technology diffusion through foreign direct investment and international trade. Again, we can refer to a large body of studies that show geographical distance as a constraint of technology diffusion. Therefore, it is expected that developed countries transfer most of their green technologies toward their neighbors. The third mechanism is strategic reaction of countries to the trans-boundary flows of pollutants. In this mechanism, environmental spatial relationship is defined not based on distance, but based on known meteorological patterns. The forth mechanism is simultaneous attempt of countries for environmental standards improvement to attract more foreign investment or for commercial aims. Simultaneous attempt of countries in a region means that change in environmental policies of a country will be influenced by change in environmental policies of neighboring countries. The fifth mechanism is imitation from environmental policies of neighboring countries. Governments would like to utilize the experiences of other countries with a little modification instead of bearing consequences of a new experience. When imitation reduces the decision-making costs, using the experiences of neighboring countries minimizes the cost.

The usual method for the estimation of SEKC utilizes spatial econometric models. Spatial econometrics was proposed by Anselin (1988) and drew huge attention especially in the regional sciences. With the approach, he could address two problems that arise when sample data has a spatial configuration which is largely ignored in traditional econometrics. The first problem is spatial dependence. Spatial dependence in a collection of sample data observations refers to the fact that one observation associated with location i depends on other observations at location j. The second problem is spatial heterogeneity that refers to the variation in relationship over space. For instance, economic inequality in a country has the problem of spatial heterogeneity, because the mean and variance of this variable alter in different samples (locations) of the country. These problems seriously violate Gauss-Markov assumptions and make the ordinary least square (OLS) estimation biased and inconsistent. A family of spatial econometric models, which concerns spatial autocorrelation of observations, is spatial autoregressive models. Spatial autoregressive can be extended to its variants, i.e. SAR and SEM. SAR model is analogous to an autoregressive (AR) time-series model, but with lags over geographic distance rather than time. Therefore, for the country i, one spatial lag refers to all of i’s contiguous geographic neighbors. SEM model is analogous to the moving average (MA) time-series model for contiguous geographic neighbors, which includes a spatially correlated error structure.

In order to find the relationship between economic growth and environmental quality with a spatial framework, the SEKC of Asian countries for two global (CO2) and local (PM10) pollutants are estimated. To consider the dynamic pattern of this relationship, two panel SAR and SEM models are specified. The main questions of this study are as follows: How much can the spatial spillover of CO2 and PM10 emissions in a country explain the emission level of these pollutants in neighboring countries? Which one of global or local pollutants has more significant spatial spillover effect? Finally, what is the relationship between per capita income of Asian countries and their level of CO2 and PM10 emission?

According to data availability and necessity of complete information for all observations to execute a spatial econometric model, the data has been extracted for the variables of 35 Asian countries over the period of 1990–2007 from the World Bank databases. The variables in our study are as follows: per capita CO2 emission (ton), PM10 emission in space unit (μg/m$^3$), real per capita gross national product (buying power equality, based on international fixed price of USD, 2005), industry Share (VAT share of industry in gross national product), population density (population per Km$^2$), and trade openness (ratio of export + import to gross national product).

**Conclusion**

Findings show that the spatial autocorrelation can be seen in both of the pollutants. It means that the value and significance of spatial autocorrelation for PM10 is higher than that of CO2. It confirms the previous studies results showing that the spatial spillover of pollutants from a country to its neighbors is more...
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significant for local pollutants than for the global ones. The findings show while spatial spillover of CO2 from neighboring countries to destination country can explain about 10% of changes in its CO2 emission, this phenomenon indicates about 17% of the change with regard to PM10. The EKC relationship for CO2 pollutant follows the known inverse U-shape pattern, while this relationship is monotonically increasing for PM10.

Therefore it can be claimed that regarding the fundamental changes in the world economic structure and the appearance of new economic superpowers in Asia, i.e. India and China, we will observe an increase in CO2 and PM10 pollutants in near future. It will cause this continent to become one of the most polluted regions all over the world. Due to the nature of CO2, damages arising from this pollutant will affect the global ecosystem, and all countries will be involved in its effects. However, by increasing income in Asian countries, CO2 emission will decrease, while the increasing trend of PM10 will continue.

Key words
Spatial autocorrelation, Spatial environmental Kuznets curve, Spatial panel data model, Asian countries
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