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Estimation of environmental Kuznets curve for SO_2 emission: A case of Indian cities

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ABSTRACT

Interaction between environmental degradation and economic growth is a growing matter of interest among policymakers. Here we have estimated Environmental Kuznets Curve (EKC) for 139 Indian cities considering SO_2 emissions. Study has been done for 2001–2013, and the data have been segregated by residential and industrial areas, and as well as low, medium, and high income areas. By virtue of different forms of EKC being found, policy level decisions have been designed. Moreover, non-rejection of EKC hypothesis reemphasized the impact of growth catalyzing economic policy decisions on environment.

1. Introduction

When an economy starts moving along the growth trajectory, then at the earliest stage of economic growth, environment deteriorates rapidly due to ambient air pollution, deforestation, soil and water contamination, and several other factors. With rise in the level of income, when economy starts to develop, the pace of deterioration slows down, and at a particular level of income, environmental degradation starts to come down and environmental quality improves. This hypothesized association between environmental degradation and income takes an inverted U-shaped form. This phenomenon is referred to as Environmental Kuznets Curve (EKC) hypothesis in the literature of environmental economics, named after Simon Kuznets (1955), who described the inverted U-curve association between income inequality and economic development. Grossman and Krueger (1991) later found its resemblance with Kuznets' inverted U-curve relationship while establishing a relationship between pollution and economic development.

The existing studies on EKC hypothesis have so far focused on either cross-country analysis or intra-provincial analysis of a particular country. In this study, we have analyzed the SO_2 emission data for 139 Indian cities during 2001–2013. The analysis is done by segregating the entire dataset into industrial and residential categories, and then segregating each of the two segments in terms of income level, i.e. low, medium, and high income. This schema of segmentation was designed to visualize the income-pollution association at various levels of income, and therefore, analyzing policy implications can be more effective. The literature of EKC hypothesis has majorly looked into the income-pollution association without considering different income levels for any particular context. This is one area, which is largely unaddressed in the literature has remained the focus of this study.

In EKC hypothesis, economic growth has been taken as the explanatory variable for environmental degradation, and economic growth has been parameterized in several ways in the literature. It has been primarily indicated as growth in per capita income and apart from income, this study has also taken electricity consumption and petroleum consumption as two other explanatory variables. These two variables have been considered as the proxy measures for energy consumption.

In methodological terms, this study employs panel regression on parameters validated by auxiliary regressions on orthogonally

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transformed dataset. Due to usage of power terms, EKC models suffer from multicolinearity. In most of the existing studies, this issue has been ignored and this study has tried orthogonal transformation of parameters, followed by auxiliary regression on transformed parameters to remove multicolinearity from the data.

2. Review of literature

The literature on EKC hypothesis is extensive in the field of ecological economics. The studies have been carried out on various pollutants, like NO_2 (Panayotou, 1993; Grossman and Krueger, 1995; Egli, 2001; Hill and Magnani, 2002; Archibald et al., 2004; Welsch, 2004; Fonkych and Lempert, 2005; Song et al., 2013; Sinha, 2016; Sinha and Bhattacharya, 2016), CO_2 (Moomaw and Unruh, 1997; Roberts and Grimes, 1997; Roca and Alcántara, 2001; Martínez-Zarzoso and Bengochea-Morancho, 2004; Galeotti et al., 2006; Sinha, 2014, 2015; Sinha and Bhattacharya, 2014; Alam et al., 2016; Shahbaz et al., 2016), SPM (Selden and Song, 1994; Vincent, 1997; Matsuoka et al., 1998; Torras and Boyce, 1998; Dinda et al., 2000; Wheeler, 2001; Binti Borhan and Musa Ahmed, 2010; Miah et al., 2011), RSPM (McConnell, 1997; Wheeler, 2001; Dasgupta et al., 2002; Rupasingha et al., 2004; Alpay, 2005; Kumar and Foster, 2009; Orubu and Omotor, 2011; Feizpour and Shahmohammadi Mehrjardi, 2014), and many others. As our present study relates to EKC estimation for SO_2 emission, therefore we will focus our review of literature at the studies, which have considered SO_2 as the primary pollutant.

For SO_2 emission, studies have been carried out on cross-sectional data (Panayotou, 1993; Taskin and Zaim, 2000; Bimonte, 2002; Khanna and Plassmann, 2004) and panel data (Selden and Song, 1994; Shafik, 1994; Grossman and Krueger, 1995; Kaufmann et al., 1998; List and Gallet, 1999; Harbaugh et al., 2002; Millimet et al., 2003; Galeotti et al., 2006; Soytas et al., 2007; Apergis and Payne, 2009; Al Sayed and Sek, 2013) and all of these studies are based on a group of countries. Apart from the works of Lantz and Feng (2006), Akbostancı et al. (2009), Song et al. (2013), hardly any study has attempted to analyze the EKC of a particular country. Moreover, for a country with high population density, it is not always feasible to end up with a single EKC only. Though these studies have considered provincial differences in emission, no study has so far considered different income levels of a country and the differential impact of income levels on emission. In this study, we have segregated Indian cities in terms of three income levels, namely low, medium, and high income and observed the income-emission association under EKC framework.

Apart from that, while estimating EKC for any context, researchers have majorly taken indicators of economic growth, like trade (Suri and Chapman, 1998), financial development (Tamazian et al., 2009), and technological progress (Bhattarai and Hammig, 2001) as explanatory variables in EKC framework. These variables are different indicators of economic growth. For ambient air pollution, more specific explanatory variables are required, and a recent work of Onafowora and Owoye (2014) has considered this aspect. They have taken energy consumption as an explanatory variable, which is relevant for our study as well. As India is net oil importing nation, and Indian industries and households depend on commercial and combustible electricity consumption (Sinha and Mehta, 2014), we have considered energy consumption in the form of electricity consumption and petroleum consumption as explanatory variables in our study.

3. SO_2 emission in India

Due to rapid growth in industrialization, India has experienced a significant growth in the fossil fuel consumption. Adverse effects of this growth have been seen in the growth of ambient air pollution. During the last decade, SO_2 emission has gone up by 54% (Lu et al., 2011; Haq et al., 2015). Looking at the emission affecting stratospheric region, SO_2 is considered as the primary pollutant in this case, as the sulphur aerosols formed in this region are majorly caused by SO_2 emission (Friend et al., 1973; Whitby, 1978; Turco et al., 1979; Surratt et al., 2007). Apart from that, SO_2 is soluble in airborne water globules, and thereby, forming sulphurus and sulphuric acid in the form of acid rains (Penkett et al., 1979). Formation of aerosols after reacting with particulate matters can create severe respiratory problems (Brain and Valberg, 1979), and even premature births (Hastwell, 1975). Mainly for these reasons, rise in the level of SO_2 emission can cause serious damage to ambient atmosphere, and the human life.

In India, reasons behind rise in the level of SO_2 emission differ between industrial and residential areas. In industrial areas, rise in the SO_2 emission can be attributed to rise in the level of direct fossil fuel consumption, in the form of coal and crude oil. Majority of these two fossil fuels used in India are high in sulphur content. Consumption of coal is majorly seen in the thermal power plants and manufacturing sectors, whereas the crude oil with greater sulphur content, i.e. sour crude oil is used in the transportation sector. Combustion of these fossil fuels at high temperature (more than 1500° C) oxidizes the sulphur contents (Krawczyk et al., 2013). Burning of coal is the major source of SO_2 emission in industrial areas. Apart from that, direct consumption of sour crude oil, i.e. low quality high-speed diesel and petrol in vehicular transportation leads towards emission of SO_2 in the industrial areas. As there are only two stratovolcanos in India (Barren Island and Narcondam), and out them, only Barren Island is currently active, therefore, the SO_2 generation out of volcanic eruption may not be considered in this case.

For the residential areas, the level of SO_2 emission is comparatively lower than the emission level in industrial areas (Hindy et al., 1990; Mathew et al., 2015). Even if small, the growth in emission in residential areas can be attributed to burning of coal and sour crude oil for cooking purpose. Kerosene, the form of sour crude oil used in domestic purpose is the mostly used petroleum product in the households. This case is similar to that of the cases of Chinese and Japanese households, where coal-stoves (Chen et al., 2005) and kerosene heaters (Ritchie and Oatman, 1983) are primarily used for cooking purpose. Burning of these fuels generate SO_2 in the indoor atmosphere. This problem is catalyzed by means of the lack of ventilation in the residential area cities. Heights of building and level of humidity do not directly add to the level of SO_2 emission, but they catalyze the growth and spreading by restricting ventilation. This scenario has already been experienced in other Asian cities, like Hong Kong (Lau, 2011). Heights of the building resist sunlight and ventilation in the neighborhood and massive usage of air-conditioning systems in the neighborhood areas aggravates the situation. Moreover, rooftop solar panels cannot be installed in the neighborhood areas due to lack of sunlight. These in one hand reduce energy efficiency by elevating the level of fossil fuel based energy consumption, and on the other hand, increase the level of humidity and outdoor temperature. This catalyzes the formation of smog in residential areas.

4. Econometric methodology and data

We have collected data of 139 Indian cities for the duration of 2001–2013. For the analysis, the entire dataset has been segregated into industrial and residential areas,[1] as the emission pattern in

[1] Central Pollution Control Board collects and publishes separate data for industrial and residential areas.