Ecological Indicators 67 (2016) 1–11

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Environmental Kuznets curve estimation for NO_2 emission: A case of Indian cities

Avik Sinha*, Joysankar Bhattacharya

Department of Economics, Indian Institute of Management Indore, India

ARTICLE INFO

Article history:
Received 17 May 2015
Received in revised form 5 February 2016
Accepted 7 February 2016
Available online 25 April 2016

Keywords:
Environmental Kuznets curve
Environmental degradation
Growth
NO_2
India

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 NO_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

As economy moves along the growth trajectory, environment tends to deteriorate at an increasing rate. With higher level of income, when economy starts developing, the pace of deterioration slows down, and at a particular level of income, environmental degradation starts to come down. In the literature of environmental economics, this phenomenon is referred to as environmental Kuznets curve (EKC) hypothesis. This phenomenon is termed after Simon Kuznets (1955), who described the inverted U-curve association between income inequality and economic development. While establishing a relationship between pollution and economic development, Grossman and Krueger (1991) found its resemblance with Kuznets' inverted U-curve relationship, and named it after Simon Kuznets.

By far, the existing studies on EKC hypothesis have focused on either cross-country analysis or intra-provincial analysis of a particular country. In this study, we have analyzed the NO_2 emission data for 139 Indian cities during 2001–2013. The analysis is done by segregating the entire dataset into industrial and residential category, and then segregating each of the two segments in terms of income level, i.e. low, medium, and high income. This bifurcation was taken to visualize the income-pollution association at various levels of income, and therefore, analyzing policy implications may 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 remained largely unaddressed in the literature, and that is 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 in some of the studies as trade, financial development, and technological advancement, as according to Hill and Magnani (2002), per capita income may not be the only indicator for economic growth. Apart from income, this study has taken electricity consumption and petroleum consumption as two other explanatory variables. These two variables are the proxy measures for energy consumption.

In methodological terms, this study employs panel regression on parameters validated by auxiliary regressions on orthogonally 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 has been pointed out by several researchers. This study has used orthogonal transformation of parameters, followed by auxiliary regression on transformed parameters for removing multicolinearity from the data. Contribution of this study is not only in terms of finding EKC for Indian cities, but also in terms of employing a more refined set

* Corresponding author at: Indian Institute of Management Indore, FPM 105, Prabandh Shikhar, Rau-Pithampur Road, Indore, Madhya Pradesh 453556, India. Tel.: +91 9713340444.
E-mail address: f11aviks@iimidr.ac.in (A. Sinha).

http://dx.doi.org/10.1016/j.ecolind.2016.02.025
1470-160X/

of parameters, which have hardly been considered in the literature so far.

2. Review of literature

The literature on EKC hypothesis is extensive in the field of ecological economics. For NO_2 emission, studies have been carried out on cross-sectional data (Panayotou, 1993; Hill and Magnani, 2002) and panel data (Grossman and Krueger, 1995; Egli, 2001; Archibald et al., 2004; Welsch, 2004; Fonkych and Lempert, 2005; Song et al., 2013) and all of these studies are based on a group of countries. Apart from the works of Carson et al. (1997), Roumasset et al. (2006), Park and Lee (2011) 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 the aforementioned studies have considered provincial differences in emission, no study has 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.

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. Since India is a net oil importing nation, and Indian industries and households depend on commercial and combustible electricity consumption for their subsistence (Sinha and Mehta, 2014), we have taken energy consumption in the form of electricity consumption and petroleum consumption as explanatory variables in our study.

3. NO_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, CO_2 emission has gone up by 72%, SO_2 emission has gone up by 54%, and NO_2 emission has gone up by 42% (Lu et al., 2011; Haq et al., 2015). If we look at the emission affecting tropospheric region, then the NO_2 should be considered as the primary pollutant in this case, as 79% of the tropospheric atmosphere consists of nitrogen (N_2). It is majorly responsible for creation of ground-level ozone, a primary component of smog. It is also responsible for creation of various nitrate compounds, which add to the level of respiratory particulate matters in the lower atmosphere. Owing to these reasons, rise in the level of NO_2 emission can cause serious damage to ambient atmosphere.

In India, reasons behind rise in the level of NO_2 emission are different for industrial and residential areas. In industrial areas, rise in the NO_2 emission can be attributed to rise in the level of direct fossil fuel consumption, in the form of coal and oil. Consumption of coal majorly takes place at the thermal power plants, and due to the high temperature (more than 1700 °C) in the furnaces, molecular N_2 and oxygen (O_2) react with each other and form NO_2 (Zeldovich, 1946). This is the primary source of NO_2 emission in industrial areas. Apart from this, contribution of oil combustion stands second in the rise in NO_2 emission. This direct consumption of petroleum fuel is majorly visible in vehicular transportation, which is evident in the industrial cities in India. The first incident is referred to as the *Thermal* NO_2 and the second one is referred to as the *Fuel* NO_2.

For the residential areas, rise in the NO_2 emission can be attributed to rise in the vehicular congestion, level of humidity, heights of buildings, and improper usage of burners. Continuous rise in population in the residential areas has been creating pressure on the existing road transport infrastructure, and this can be experienced in the vehicular congestions in almost every city in India. Traffic fumes generated out of these congestions is the primary cause of NO_2 emission in residential areas in India (Bhaduri, 2013). Apart from that, emergence of high flame cooking can also be attributed to one of the reasons behind rise in NO_2 emission in the residential areas (Relwani et al., 1986). In this case, the fuel input rate and the color of flame have found to have significant impact on NO_2 emission. Yellow-tipping flames generate more amount of NO_2 in the indoor atmosphere compared to blue-tipping flames (Himmel and DeWerth, 1974). Heights of building and level of humidity do not directly add to the level of NO_2 emission, but they catalyze the growth and spreading. 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 therefore, usage of air-conditioning systems rise in the neighborhood areas. 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.

Central Pollution Control Board of India has already set a number of emission standards, according to which level of NO_2 emission should not be more than 40 $\mu g/m^3$ in any industrial or residential cities of India. Bharat Stage emission standards are also in place for controlling the vehicular emissions. Presently, Bharat Stage IV has been implemented only across 14 cities[1] in 2010, and Bharat Stage V is yet to be implemented in 2017. Based on the reports of Central Pollution Control Board, Supreme Court of India has passed a directive in 2001 for controlling ambient air pollution in 16 cities across India. However, in spite of these policies in place, NO_2 emission across several Indian cities is rising.

4. Econometric methodology and data

For the analysis, the entire dataset of 139 cities for 2001–2013 has been segregated into industrial and residential areas,[2] as the emission pattern in these two areas differ significantly, and therefore, they should be analyzed in isolation. For analyzing the impact of pollution on level of income, dataset for each of the two areas has been segregated into three parts, namely low, medium, and high income. This will allow us to observe the income-emission association in a comparative manner.

For achieving the research objective, we have formulated the following regression model:

$$E_{ijk} = a_0 + a_1 C_{jkl} + a_2 POP_{jk} + a_3 Y_{jk} \cdot POP_{jk} + a_4 Y_{jk} + a_5 Y_{jk}^2 + a_6 Y_{jk}^3 + \varepsilon_t \quad (1)$$

where, E is the emission, C is the city specific effect, POP is the population, Y is the city level income, i is the pollutant (NO_2 in this case), j is the income level, k is the area classification, l is city specific effects, and ε is error term.

[1] National Capital Region, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Sholapur, Jamshedpur and Agra.

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