Reexamining the Environmental Kuznets Curve: Empirical Evidence from India

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Abstract

The Environmental Kuznets Curve hypothesis is a theory which states that the connection between environmental pollution and economic expansion can be characterized by an inverse-U curve, where pollution increases in the early stages of industrialization and after a specific point of income per capita, environmental standards seem to benefit from economic growth (Stern, 2003). In addition, Porter's hypothesis states that stricter environmental regulations can positively influence technological progress, and through an increasing innovation capacity, improve economic growth and pollution levels. In this paper, I examine the validity of both theorems for three air pollutants of Indian states (SO_2, NO_2, SPM) and for a time span of 24 years (1990-2013). By using the Hausman specification test and several robustness tests as an attempt to provide more robust and concrete results, I conclude that the requirements of the EKC are only satisfied for the case of sulfur dioxide, with a turning point of around 43,750 Indian rupees. The differences we observe within the same indicators but also between SO_2, NO_2 and SPM pollutants of air, highlight the fact that different environmental policies are necessary to attack each pollutant separately and more efficiently.

Key words: Environmental Kuznets Curve, air pollutants, SO2, NO2, SPM, Porter hypothesis, India, NSDP, vehicular emissions, industrial production

Introduction

The 28th of March 2017, the President of the United States of America Donald Trump signed an executive order at the Environmental Protection Agency that stripped-down air regulations and undid Obama's clean power plans. Moment before signing the measure, the President stated that "he is making historic steps to lift the restriction on American energy, reverse government intrusion, cancel job killing regulations and increase economic opportunities". The association of economic growth and environmental degradation has always been in the center of several political agendas throughout the history and especially in the 21st century where the consequences of global climate change have begun to appear. The primary question that rises is whether or not economic growth alone can sufficiently reduce environmental pollution. Air quality levels and industrial pollution have been proven to be correlated, but the causality and the means by which they are connected are not clear, especially in the developing world.

The Environmental Kuznets Curve theorem was introduced by Grossman and Krueger and it supports an inverse-U curve in the environment - economic growth relationship. Several researches have been conducted since then to test the validity of this hypothesis with dubious results, especially in the local pollutants. While most of the existing papers tried to shed light in the EKC through a cross-country analysis, in this paper I focus my research on India, a country with many environmental and air quality issues. India is a newly industrialized country, member of the BRIC countries and one of the largest economies in the world in terms of GDP. In the last decades, India has introduced a massive number of environmental regulations, including air quality and pollution restrictions. Nevertheless, through examining the air pollution levels of three indicators (SO2, NO2, SPM) in 24 different states and from 1990 to 2013, I conclude that only sulfur dioxide emissions follow an EKC path in the case of Indian states.

The paper is organized as follows: In section 2, I present a review of the existing literature that deals with the environmental effects of economic expansion and the existence of the EKC. In section 3, I describe the data and provide more details on my main variables, its sources and the way that I decided to transform them in order to contribute on the research question. Section 4 provides the methodology, whereas section 5 shows my main results and the robustness checks of the paper that examine the sensitivity of my results. Finally, in section 6 I have my conclusions and possible discussion points based on the findings of the paper.

Literature review

2.1 Previous empirical researches

The association of economic growth with environmental degradation has become the center of attention of several researches since the 1990s and the empirical researches of Grossman and Krueger. However, findings and conclusions are mixed and vary according to different datasets and methodologies. The environmental Kuznets curve (EKC) states that in the first stages of industrialization and economic expansion, the measures of environmental degradation first rise (pre-industrial and industrial economies) but beyond some level of GDP per capita the direction reverses and high-income levels lead to improvements in the environmental conditions (Stern, 2003).

In Grossman and Krueger (1991), we find one of the first empirical researches of the link between economic growth, trade liberalization and the environmental degradation. The authors examined the relationship between per capita GDP at different income levels and various environmental indicators concerning the air pollution and their findings support the inverse-U curve relationship between economic growth and environmental pollution for two pollutants (SO_2 and smoke). More specifically, they found evidence that once a critical level of per capita income has been reached (about 4000 to 5000 US dollars) economic growth tends to have a positive impact in environmental pollution problems.

An early study of Shafik and Bandyopadhyay (1992) follows the same procedure by analyzing the environmental transformation at different economic levels of 149 countries for the period 1960-1990. Some of the main explanatory variables used are per capita GDP, investments rates, income growth, electricity tariff and trade as a percentage of GDP. Interestingly, in both papers we notice different results in the income–environment connection when indicators with a worldwide and global environmental impact are used (e.g. CO_2) and when pollutants with effects in a local and country specific level are used (e.g. SO_2, SPM). Going forward, since these two papers there has been a remarkable interest in the relationship between economic growth and environmental degradation.

A range of previous papers has tried to shed light to the EKC through a cross-country investigation (see Agras &Chapman, 1999; Stern, 2004). All these studies have sought to explain environmental pollution levels by way of a linear, squared and cubic expression of per capita income. Selden and Song (1994) focus entirely on air quality by using SO_2, SPM, NO_2 and CO_2 emission data. They emphasized on the relationship among real per capita GDP, environmental emissions and by using the population density as their only control variable, they found evidence that supports the EKC, with a turning point ranged at 8000 and 10000 USD[1]. Neumayer (2002) examines the relevant role that natural factors play in explaining the internationally distribution of CO_2 emissions among countries. For natural emissions, he uses the minimum and maximum temperatures as proxies for heating requirements, total land area impacted by human activities, the percentage of renewable energy of total energy and the oil and gas reserves. Even if he did find evidence that natural factors could explain part of the different environmental levels per countries, the income growth remains the main explanatory variable of difference across countries in CO_2 emissions.

Antweiler et al. (2001) developed a model of two factors of production (labor and capital) and two goods in order to separate the environmental impact of trade and economic growth into three basic segments: the composition, technique and scale effects. While the study of Grossman and Krueger was specified on the consequences of NAFTA, in this paper we see the joint examination of all three components of environmental degradation on a database of 40 countries with different characteristics. Their results indicate that all these effects are not just statistical constructs with no empirical impact, rather they play an important role in determining the environmental impact of trade liberalization, capital accumulation and technological progress and the aftermaths of environmental regulations. Barrett et al. (2000) present a different dimension of the environmental consequences of globalization, by examining its connection with the civil and political freedoms per country. Here we see again that for some pollution variables, an increase in civil and political freedoms improves the countries' environmental standards but for some other (oxygen regime of rivers) they have no effect. They concluded that even if civil and policy freedoms may play a significant role in the explanation of the inverse U curve, there are probably more factors to be considered in future research on the environmental impact of trade liberalization and globalization.

Overall most of the models that examine the Environmental Kuznets curve, conclude that income has the strongest effect on environmental quality of all the independent variables. Nevertheless, in Agras et al. (1999) they found no evidence for the existence of an EKC. This paper takes into account the price of energy and includes it in an econometric framework to test the energy/income and carbon dioxide/income relationship. Surprisingly, the inclusion of this variable changes the results

[1] The authors also point out that: "global income distribution is skewed with big difference between median and mean world income per capita; that means that the total emissions can still be increasing even if the per capita emissions are estimated to decrease at an acceptable low per capita level"

significantly and more importantly the trade variable, which becomes insignificant. The main takeaways from this paper are the relevance of energy prices as an indicator of energy demand and therefore carbon emissions, and the insignificant results regarding the environmental Kuznets curve. Harbaugh et al. (2002) reexamined the findings of Grossman and Krueger (1995) about the inverse U-shaped pollution-income relationship, by using up to date panel data of air pollution betwixt countries worldwide. They conducted several robustness tests to investigate the sensitivity of the Environmental Kuznets curve, and they concluded that the outcomes are highly sensitive to changes in countries, cities and years sampled. Therefore, they found little support for an inverse U-shaped relationship between the environment and income.

Cole et al. (1997) examined a wide range of environmental indicators to assess if the EKC holds for all of them. They employed a Hausman specification test to check the null hypothesis of exogeneity of income in the EKC. They also correct for autocorrelation and heteroscedasticity, but more importantly they calculated the standard errors at the turning point levels of income to indicate the significance and reasonability of their results. Once again, we see that EKC holds only for the local air pollutant, while environmental indicators with a global effect are either increasing with per capita income or have an unreliably high turning point with large standard errors[2].

2.2 Country specific studies

The environmental Kuznets curve theory describes a unique country's environmental transformation; nevertheless, most analyses have used cross-country data under the assumption that the pollution-growth relationship follows the same path for all the countries in the sample[3]. However, "the inverse U curve may not hold for specific countries, which could explain the great sensitivity of the EKC shapes revealed in many studies with respect to different time and country samples" (Wang et al., 2012). Historic approaches of the EKC through investigation of individual countries' characteristics have been taken relatively rare.

Friedl and Getzner (2002) explored the relationship between economic development and carbon dioxide for Austria. Through a time series approach, they studied the connection among income, trade and social structural changes to take into account the composition effect and the influence of

[2] In Arrow et al. (1995) we see that: "while SO2 and NOx are local emission, CO2 emissions cause problems in a global scale, which grow across time. Therefore, as we see in, free ride behavior might lead to a close relationship between carbon emissions and income at all levels of per capita income"
[3] This criticism can be spotted also in (Wang & He, 2012; Uchiyama, 2016) and in many other studies

an increase in the service sector (value added in the service sector relative to GDP). Concerning the last one, they found a low significance level of influence, which the authors explained by the fact that "carbon emissions are increasingly caused by public and private transport, and passenger transport is classified as serviced in the national accounts". The emission development was split into two periods because the oil crisis in the mid-1970s changed the energy supply significantly as it did the environmental policies. For the whole period, the time series of carbon dioxide emissions were non-stationary, while also further tests resulted into the rejection of no cointegration hypothesis between CO_2 and GDP. In general, an N-shaped relationship between GDP and CO_2 was found to fit the data most appropriately, which means that a second turning point where pollution levels start to rise again has been detected for the case of carbon dioxide in Austria.

Wang and He (2012) used a panel database of 74 Chinese cities for the period of 1990 – 2001 to explore the EKC theorem. The innovation of this paper is the inclusion of height and slope adjustments in the basic specification for the examination of the economic structure, development strategy and environmental regulation, which are considered as the determinants of both adjustments. Location wise variables are also included in the model and the results indicated that northern Chinese cities have more air pollution problems. The economic structure of China (K/L) was examined and found to have a negative and statistically significant impact on NO_2 emissions. The relationship between CO_2 and GDP per capita formed the main research topic of Lindmark (2002) where he focused on Sweden for the years 1870 – 1997, and of He and Richard (2009) for the case of Canada over a period of 57 years. In the first one, the author divided the sample into three sub-periods. In the first phase (1870 – WWI) the increase in emissions was created mainly by economic growth. The second phase (WWI – 1960s) is characterized by an even contribution to CO_2 emissions increase and in the third phase, technological and structural changes resulted the gradual improvements in air quality. On the other hand, in the case of Canada, the authors found no evidence that supports the Environmental Kuznets curve.

Roca et al. (2001) used data of six air pollutants in Spain (including SO_2 NO_x CO_2 emissions for the time span of 1973 – 1996) and economic growth was found to play a significant role, only in the emissions decrease of SO_2. For every indicator though, stricter environmental regulations were the most important aspect of emission reduction, regardless of the income levels, something which is not surprising as the study was focused in a highly developed European country. In the paper of Grote and Jena (2008) we find one of the only attempts to explore the growth – trade – environment nexus in India. Through a state wise panel examination for the time period 1991-2003 the authors try to investigate the impact of economic growth and trade on environmental pollution. Their model focused on the scale and technique effects of trade liberalization on environment. However, their results fail to shed light on the direct connection between economic growth, trade and the environment and each component (scale, technique, composition effects) does not show a strong link with environmental emissions. Nevertheless, their results indicate the importance of constructing an appropriate mechanism to explore each environmental pollutant individually, as the impact of growth and trade differs across the pollutants. Managi and Jena (2008) investigated the same Indian air pollutants for the period of 1991-2003 and for 16 Indian states. The difference in their approach is that they include productivity measures techniques to show that overall environmental productivity measures decrease over time in India. Their evidence is in favor of an EKC relationship between environmental productivity and income.

Several studies assess the connection between economic growth and a more global environmental indicator like CO_2 for India (Kanjilal et al., 2013; Pal et al., 2017; Tiwari et al., 2012). Nevertheless, they are all on a country level and they examine the EKC with a time series data approach, spreading for approximately 50 years. The drawback of this approach is that since they obtain their data on a country level and not in city or state level, they consequently have a limited number of observations. Finally, Sinha et al. (2016) conducted an interesting study about the EKC estimation for NO_2 emissions, for 139 Indian cities and for the time period of 2001-2013. By dividing every city in different groups (industrial, rural, etc), they concluded that the air quality levels are different within each area and therefore separate policies are necessary for NO_2 emission reduction.

2.3 Lessons from the past

The basic point of criticism of the EKC hypothesis is that the resulted curve is mainly a statistical result and not an economic path that can be applied for numerous countries with different characteristics. Since most existing studies derive the curve from a cross-section data, it is difficult to capture the socioeconomic, political and historical differences between the developed, developing and emerging countries worldwide and derive one environmental curve for all of them. Moreover, Arrow et al. (1995) point out that "even if most empirical results indicate that economic growth has an inverse-U shaped connection with the environmental conditions, there is no proof until now that alone can sufficiently provoke environmental improvements, nor that the indirect consequences of economic expansion should be overlooked". Besides the absence of separation between causality and correlation, several papers suggested the replacement of GDP with a more accurate measure of well-being, like the Net State Domestic Product (NDP). The Lucas' critique is also relevant in these kind of studies, in the sense that it is incorrect to foresee the consequences of different economic policies entirely based on past events and observations of historic data (especially highly aggregated data).

Furthermore, in most empirical studies, income is not considered an endogenous variable and the interconnection of the economic conditions and the environment has not been taken into account. However, an opposite path may also be considered in the growth – environment relationship. An example for this can be an environmental disaster, which can restrain economic expansion (Uchiyama, 2016). Therefore, it is crucial to consider the issue of endogeneity in the link between economic growth and environmental emissions, especially in cross-country studies. As for modeling, the issue of omitted variable bias can also be raised (Panayotou, 1997). Few studies within the EKC literature included control variables to capture the changes in the industrial production, socioeconomic structure, agriculture intensity, and analyze their impact on the environment. The issue of heteroscedasticity has also been highlighted especially in regressions of group data (Stern, 1996). Finally, the problem of data stationarity is pointed out by several criticisms of the EKC. Only few recent studies performed unit root and cointegration tests (e.g. Getzner et al., 2002, Wang et al., 2012).

2.4 Contribution to the existing body of knowledge

This paper contributes to the existing literature in several ways. First, it adds to the empirical literature on the EKC for SO_2, NO_2, and SPM emissions in India. Especially since it focuses on the EKC for a specific developing country, it will contribute to the existing limited related literature. In addition, several studies failed to identify the EKC relationship between indicators of environmental degradation and income, while some others reported unreliably high turning point of income levels or even an N or an S-shaped curve. Therefore, further investigation is required to test the questionable hypothesis of the Environmental Kuznets curve.

Secondly, it provides an analysis of the link between economic expansion and local pollution levels in India. Most empirical researches are based on a multi-country level analysis in which the Indian macroeconomic situation is captured and often included in the models. In order to better understand the environmental transformation of India throughout its recent economic expansion, a country specific study will be conducted. To my knowledge, at the time of writing this paper, the only papers emphasizing on Indian's states local emissions are the ones of Grote & Jena (2008) and Managi &

Jena (2008). Therefore, this work will widen the existing literature by using up-to-date data (1990 – 2013) but also extend the insofar research in India by including different dimensions of environmental pollution (vehicular emissions, industrial pollution, agricultural emissions, etc.) and investigate their effect in each Indian state and air indicator.

Finally and perhaps more importantly, the issue of endogeneity in the link between GDP per capita and environmental emissions, an issue where few environmental papers have examined in the past, will be investigated and possibly resolved by using the state-wise deposits by scheduled commercial bank as an instrumental variable. The idea behind this instrument is that an increase in the welfare of Indian state and an economic expansion will boost the bank deposits in each Indian bank without effecting the air pollution levels of each state. In the first part of my results, I will examine the existence of the EKC curve by using the fixed effects or random effects model, according to the outcomes of the Hausman specification test. In the later stages though, several robustness checks will be constructed to test the sensitivity of my results.

Data description

3.1 Summary

A panel database of 24 Indian states for the period of 1990-2013 is compiled in order to assess the impact of economic structure and uneven development on the relationship between pollution and economic growth in India and empirically analyze the existence of the EKC theory. The collection of reliable and up-to-date data for the time span of the study was a challenging quest as data availability varies across states and not all of them dispose of the same amount of information going back as far as 1990. The analysis is based on the annual air pollution concertation levels of 24 Indian states. Up to 2004, local environmental stations have been set up to almost all the cities in India. For the information about the air quality in several cities, I collected data for three environmental indicators, namely: SO_2, NO_2 and SPM. These indicators were gathered from 274 cities within industrial, residential, rural and other areas, and 436 different agencies and monitor stations in India.

The statistics of the variables used in our estimations are reported in Table 1. From this table, we can observe large variations between the states, not only in their income status, economic structure and industrial organization, but also in their air pollution levels. This could represent the tremendous economic growth that India faced during the period of study in every level of the economy, but it can also be interpreted as a sign of the high inequality between Indian states and even within the same cities. The 24 states I included in my study are the following: Andhra Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Orissa, Puducherry, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal.

Table 1. Descriptive statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Year	576	2002	6.928	1990	2013
State	576	12.50	6.928	1	24
SO2	493	13.57	10.69	0.250	81
NO2	496	24.41	13.69	1.5	112.5
SPM	418	197.6	93.23	18	471.5
Income	564	33,801	34,874	2,660	224,138
$Income^2$	564	2.357e+09	5.470e+09	7.076e+06	5.024e+10
$Income^3$	564	2.546e+14	9.817e+14	1.882e+10	1.126e+16
Capital/Labor	551	8.444	4.377	1.417	35.77
Service Intensity	561	48.86	12.37	26.69	105.9
Number of factories	552	6,214	6,840	25	37,378
Registered Vehicles	530	2,845	3,247	27	19,432
Credit to the Industry	548	244.5	613.8	0	6,460
Social Expenditure	506	97.64	122.6	1.600	782
Population Density	576	1,116	2,275	76	11,612
Production Foodgrains	522	9,502	9,983	25.40	50,745
Location	576	0.585	0.493	0	1

3.2 Dependent variables

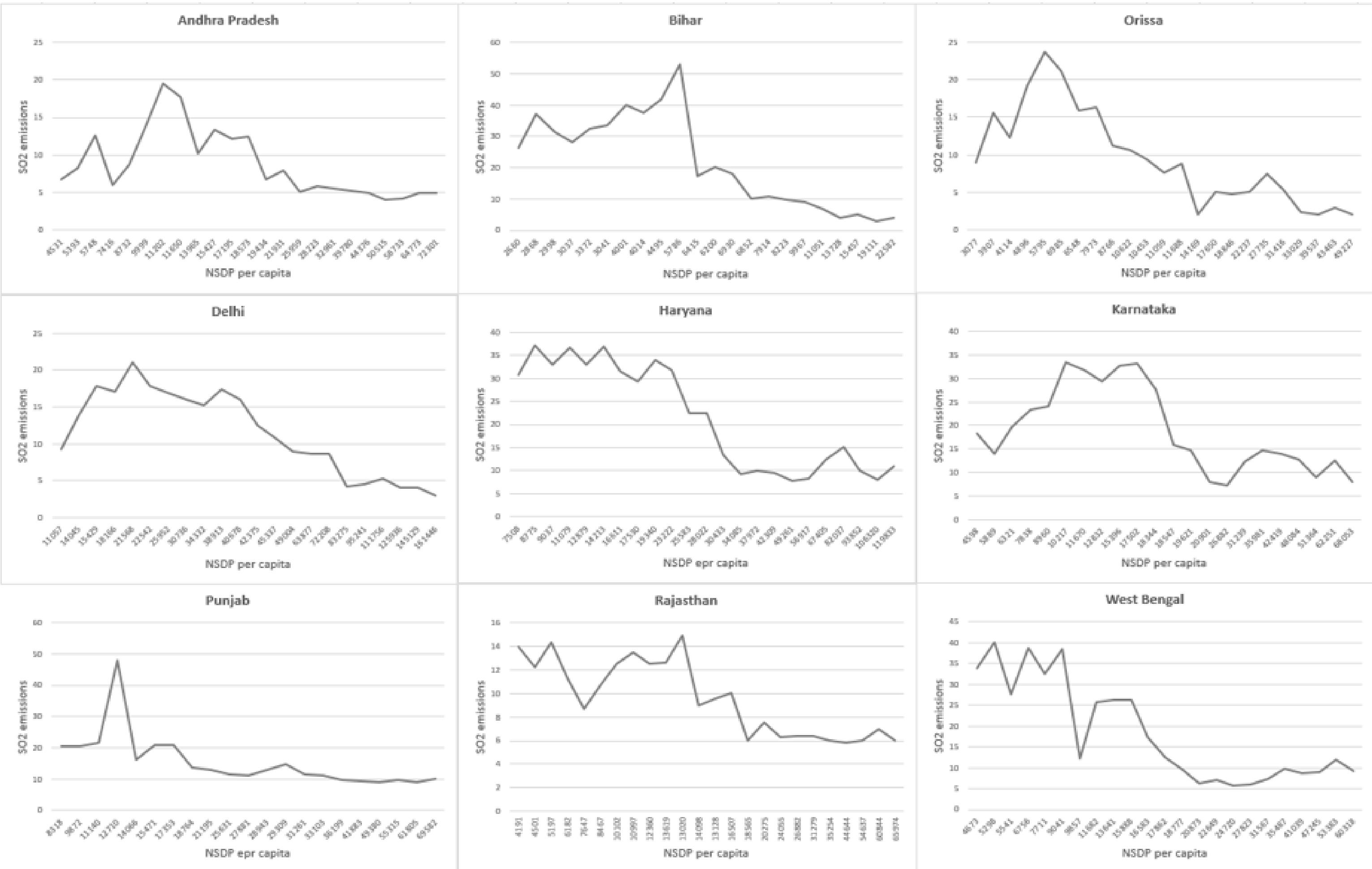
In the present study, three different environmental indicators are used: SO_2, NO_2 and SPM. All three of them are local emissions that represent the regional air quality levels from different monitoring stations across India. They are published from the Ministry of Environment and Forests Central Pollution Control Board and the open government data platform of India (OGD) on a daily and monthly basis. Some stations have been shifted or closed during the period of study, as they were not meeting the national standards for monitoring sites after changes in the areas. Data are in micrograms (one millionth of a gram) per cubic meter. From these data, the annual state levels of each of the indicators were calculated, by determining the median emission levels of several Indian cities per state. The reason for aggregating the database is to make the observations of economic and environmental status comparable for all the sample states within the time period of 1990-2013. The choice of the states I use in this study is based entirely on the data availability[4]

Sulfur dioxide (SO_2) is a gas with a characteristic irritating odor. It is one of the large-scale air pollutants and has an important impact in human health. When it is combined with water, it forms

[4] Some small states with a limited number of observations are excluded from the model (e.g. Daman and Diu)

sulfuric acid, the major component of acid rain[5]. One of the major source of SO_2 in the atmosphere is the fossil fuel burning by industrial facilities and power stations[6]. This colorless gas is significantly connected with energy production and distribution, and as this sector of Indian economy is mainly capital intensive, a possible measurement for this indicator can be the capital to labor intensity. Other non-natural sources of SO_2 are industrial activities such as extracting metal from ore, vehicles' emissions, and energy use in the households[7]. It has been estimated that almost 99% of the Sulfur dioxide presence in the atmosphere is a result of human activities[8]. India is the world's second largest emitter of sulfur dioxide after China, where most of the emissions come from the coal-fired power sector and several industrial activities. India's central pollution control board reported in 2012 that national concertation levels have gradually declined from 2001- 2010[9].

Figure 1. Sulfur dioxide emissions: Selected states



*Data regarding the SO2 emissions and NSDP per capita are available at the OGD of India and the Reserve bank of India

[5] https://www.qld.gov.au/environment/pollution/monitoring/air-pollution/sulfur-dioxide/
[6] https://www.epa.gov/so2-pollution/sulfur-dioxide-basics
[7] All information for SO_2 were gathered from the United states environmental protection agency, the European environmental agency and the Queensland Government website
[8] https://www.environment.gov.au/protection/publications/factsheet-sulfur-dioxide-so2
[9] NASA climate change: Indian's growing sulfur dioxide emissions.

In Figure 1, I present the sulfur dioxide emissions trend for nine selected Indian states. Interestingly for almost all the states, we can notice a period where the total emissions reach their highest value and then gradually start to reduce. This could be a sign of the EKC hypothesis for SO_2 emissions, something that previous studies for this specific local emission have also reported, both in case studies and in cross-country studies. Further investigation regarding the causality of this relationship is presented in the next chapters.

Nitrogen dioxide (NO_2) is a yellow-brown gas and it belongs to a wide group of highly reactive gasses known as oxides of nitrogen or nitrogen oxides (NO_x). The major human activities that contribute to an increase in nitrogen dioxide emissions are the burning of fuels mainly from industrial activities, burning gasoline and diesel fuels of cars, trucks and busses (almost 30% of the total emissions), power station activities and at a lower level agricultural activities (basically the burning of biomass)[10]. Agriculture emissions are mainly associated with agriculture-related activities like manure management, farmer's field production waste and burning of agro-industrial waste[11]. In addition, burning of agricultural biomass, as the farmer's burning of rice straw contribute significantly in the environmental degradation and in health problems[12].

Punjab and Haryana are the main producers of paddy straw (19-20 million tones) and of this paddy straw almost 90% is burned at the fields from the farmers[13]. A recent study conducted by the Pune Indian Institute of Tropical meteorology and the National Centre of Atmospheric Research in the US highlights the issue[14]. They report that "during the major harvesting period (March to May) burning agriculture production waste contribute up to 60% in the toxic air emissions (such as NO_2 and CO_2) in the eastern Indian region, 50% in central region, 25% in Indo-Gangetic region and 40% over the Bengal region"[15]. Air with high concentration levels of nitrous dioxide can be harmful for human's health by impairing diseases like asthma and cause symptoms like coughing, wheezing and difficulty in breathing. The environmental effects are mainly the form of acid rain, which harms the ecosystem (lakes, forests, etc), and the creation of smog with difficulties to see through[16].

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[10] GHG management institute and Icopal-noxite website: http://www.icopal-noxite.co.uk/nox-problem/nox-pollution.aspx

[11] http://www.wri.org/blog/2014/05/everything-you-need-know-about-agricultural-emissions

[12] http://news.stanford.edu/news/2014/july/biomass-burning-climate-073114.html

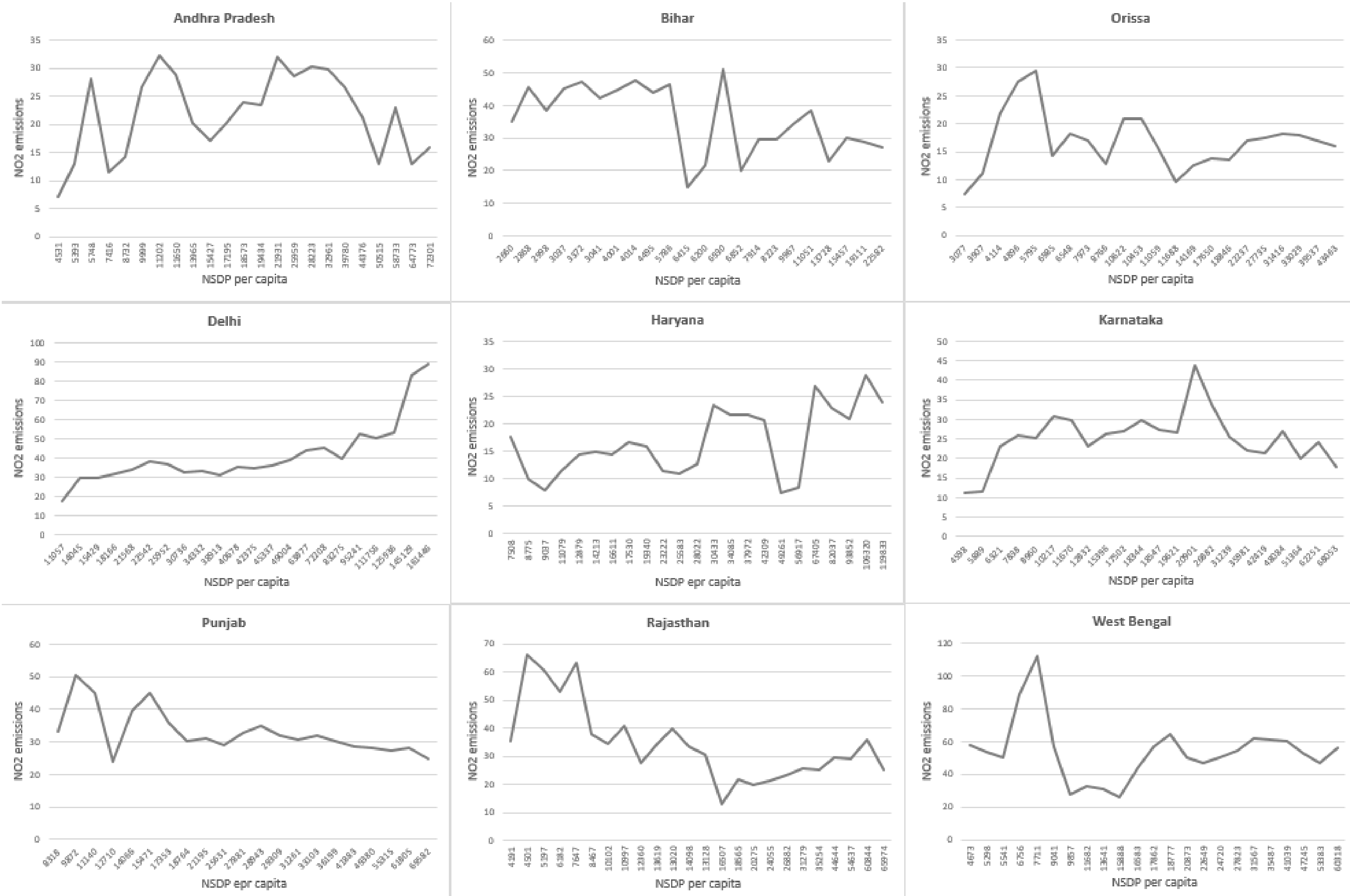
[13] http://www.downtoearth.org.in/news/crop-burning-punjab-haryana-s-killer-fields-55960

[14] Influence of springtime biomass burning in South Asia on regional ozone (O_3): A model based case study

[15] http://timesofindia.indiatimes.com/home/environment/pollution/Biomass-burning-a-major-source-of-pollution-in-India/articleshow/45093405.cms

[16] Information gathered from the United states environmental protection agency: https://www.epa.gov/no2-pollution

Figure 2. Nitrous dioxide emissions: Selected states



*Data regarding the NO2 emissions and NSDP per capita are available at the OGD of India and the Reserve Bank of India

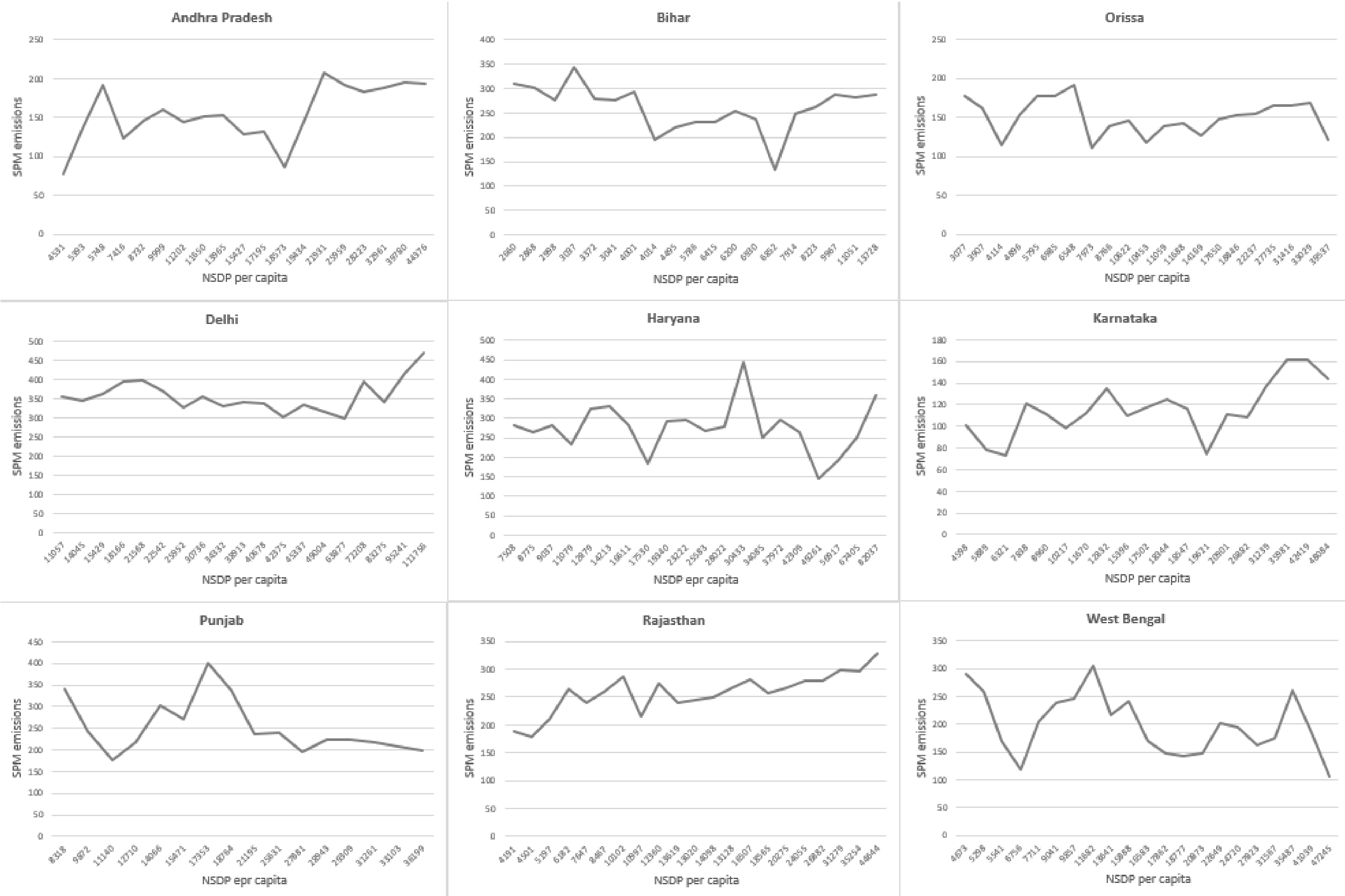
In Figure 2, we find the nitrous dioxide emissions trend for the same nine selected Indian states as in Figure 1 and the sulfur dioxide pollutant. Even if in the case of SO2 emissions we notice a period where the total emissions reach their highest value and then gradually start to reduce, which is something that may indicate the existence of an inverse-U relationship between economic expansion and environmental degradation, we cannot have a clear picture for the NO2 emissions. In Delhi, we notice an upward trend in this pollutant, while in many other cases like Andhra Pradesh and Bihar, the fluctuations over the years are not stable with many random changes in different NSDP levels.

The last environmental pollutant in this analysis is the suspended particulate matters (SPM) which are "divided solid and liquid matters that may be added to the air as a result of several combustion processes and industrial activities at the earth's surface"[17]. SPM emissions are the most common kind

[17] https://stats.oecd.org/glossary/detail.asp?ID=2623

of air pollutant nowadays and they have significantly negative effects for human health (especially small particulates like pm2.5). In principle, they are produced by industrial (dust and smoke) and agricultural activities, and complex reactions of chemicals (mainly from power stations and automobiles)[18].

Figure 3. SPM emissions: Selected states



*Data regarding the SPM emissions and NSDP per capita are available at the OGD of India and the Reserve Bank of India

Finally, in Figure 3 I present the SPM emissions graph in different levels of NSDP per capita. Once again, it is difficult to detect sings of the Environmental Kuznets curve as we did in the case of sulfur dioxide. For this pollutant, we notice that in most of the selected states remains stable over the years, except from the cases of Rajasthan and Karnataka where we see a slight increase in the high NSDP

[18]https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

levels. Nevertheless, the figures for all three environmental pollutants reveal different results, which makes the analysis of my main results in section 5 even more interesting.

3.3 Explanatory variables

The main independent variable for this study is the real net state domestic product per capita (Y) in current prices concerning the years 1990- 2013. In table 1, we can see that the quadratic and cubic forms of NSDP per capita (Y2 and Y3) are included to test the Environmental Kuznets curve hypothesis. These data are published by the Reserve Bank of India on an annual basis and the main source is the Central Statistic Office of the Ministry of Statistics and Program Implementation of India. The standard deviation of this variable is noticeably high (it varies from 2,660 to 224,138 rupees) something that highlights the economic progress of India, but also the high inequality within the states.

Furthermore, a set of control variables are included in the model in order to measure and offset their effect. The variable KL represents the capital to labor ratio and it captures the composition effects of the economy and more specifically the transformation of Indian states to different capital-intensive industries. Data about the state-wise fixed assets and state-wise total earnings are collected from the different versions of the Annual Surveys of Indian Industries (ASI) and the Reserve bank of India. Two more variables are included in the analysis to capture the Industrial organization of each state: the total number of factories per states and the state-wise credit to the industry by scheduled commercial banks. The first one is a proxy of the industrialization of each state and the second one a proxy about the financial position of the factories within each state. The numbers are in billions of rupees. The data for the first one were collected from the Annual Survey of Indian states and for the second one from the Basic Statistical Returns of Scheduled Banks of India and the Reserve bank of India.

The socioeconomic structure of each state is an important component of the environmental emissions level, and that is why three socioeconomic variables are included. In order to measure the sectoral NSDP coming from services as a percentage of total NSDP, data about the Service Intensity (ServInt) were gathered from the Ministry of Statistics and Program Implementation website and the Reserve bank of India. Information about the social expenditure per Indian states (SocialExpend[19]) are published in the Indian Handbook of Statistics on State Government Finance. The expectation about

[19] Numbers are in billions of Indian rupees

this variable is, that an increase in the financial support of the households and individuals will lead to higher environmental awareness and this will consequently decrease the environmental emissions per capita. Lastly, the number of registered vehicles per state is included to capture the part of the environmental degradation caused by transport fuel emissions. The database for this variable is available in the open government data platform of India and the Ministry of road transport and highways.

Population density is a variable that was constructed from the available data of Census 1991, 2001, 2011 and the World Bank Indicator database. As information regarding the annual state levels of population density (people per square km) are not available, an approximation was created by combining information from the annual population levels of India and the population density data from the Census publications. More specifically, by using the three available Census years of population density as my base years, I attempted to forecast the population density trend in each Indian state of the model for the years between 1991, 2001 and 2013. The Office of the Registrar General & Census Commissioner in India publish population information every 10 years; consequently, the approximation of population density that is used in this paper can only be based on these available data.

Going forward, the agriculture emissions may play an important role in exploring the causality of the Indian state's environmental transformation. For that reason, the variable "ProductionFoodgrains" is included in the model to measure the state-wise total production of foodgrains (rice, wheat, coarse cereals, pulses) per thousands of tones. Finally, the dummy "location" which takes the number 1 for north and 0 for south states is included as location specific variable. It is important to mention here that due to the limitations on the state-wise data availability, the trade intensity and the power requirements variables per Indian states are not included in the model, even if their impact on environmental emissions in the examined period of 1990-2013 might be significant.

Methodology

4.1 The model

In this paper, I attempt to examine the Environmental Kuznets curve for three environmental indicators in 23 Indian states. The main components upon which I will try to shed light on the developments in the environmental conditions for the last 23 years are the economic growth of India, its industrial organization and its socioeconomic conditions, three of the main sources of local environmental pollution. As mentioned already in Section 2, three specifications for the EKCs and local emissions have been investigated in the related literature: a linear, a quadratic (inverse U shape) and a cubic specification (N or inverse S shaped). Therefore, our empirical regression model can be described as follows:

$$E_{st} = \beta_0 + \beta_1 Y_{st} + \beta_2 Y_{st}^2 + \beta_3 Y_{st}^3 + \gamma_{st} + u_{st}$$

Where E denotes the environmental pollution indicators (SO_2, NO_2 and SPM), Y expresses the per-capita net state domestic product in current prices and γ represents the other control variables in the model. Moreover, s denotes the different states and t is time. The choice of the per capita net state domestic product as the main explanatory variable is based on previous investigations and criticisms of the EKC regarding the use of GDP and the necessity of its replacement with a more accurate measure of well-being like the NSDP. As already mentioned in the previous section of data description, our control variables explore the socioeconomic structure, the industrial organization and economic growth of each of the 23 Indian states in the model.

$$\gamma_{st} = \beta_4 KL_{st} + \beta_5 \text{ServInt}_{st} + \beta_6 \text{Nfactories}_{st} + \beta_7 \text{RegVehicles}_{st} + \beta_8 \text{CredIndustry}_{st} + \beta_9 \text{SocialExpend}_{st} + \beta_{10} \text{PopulationDensity}_{st} + \beta_{11} \text{ProductionFoodgrains}_{st} + \beta_{13} \text{Location}_s$$

KL_{st} describes the capital to labor ratio and capture the composition effects of the economy, ServInt_{st} is the service intensity per state and per year and Nfactories_{st} the total number of factories measured by units. The variable RegVehicles_{st} is the registered number of vehicles per state and over the years, CredIndustry_{st} expresses the amount of money that every state has received from the Indian scheduled banks to the industrial sector over the years, SocialExpend_{st} the total social expenditure per Indian states and $\text{PopulationDensity}_{st}$ is an approximation of the population density per Indian states. Finally, $\text{ProductionFoodgrains}_{st}$ is a proxy for the agriculture emissions and measures the total agricultural production of foodgrains and Location_s express the location (north – south) of each state.

If our results are statistically significant, indicate that $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$ and with the crucial turning point within an acceptable level of economic growth, then emissions exhibit an inverse-U relationship with per capita NSDP. If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, an N-shaped graph will be revealed and in the case where β_1 *and* β_2 result different signs ($\beta_1 < 0$, $\beta_2 > 0$ while $\beta_3 < 0$) an inverse-S shape relationship between emissions and economic growth will fit my data the best [20].

4.2 Econometrical approach

In the first stage of my results, I will apply a Hausman specification test to decide whether a fixed effects or a random effects model better fit my dataset and is more appropriate to use in order to test the EKC hypothesis for India. The null hypothesis here indicates that the random effects model is the best model to use and in the alternative hypothesis the fixed effects model gets preference. According to the results for each indicator, the appropriate method will be used and the assumption underlines each of these models will be examined. In Wooldridge (2015), we see that if the main explanatory variable is constant over time, we cannot use the fixed effects method to estimate its effect on the emissions. On the other hand, if the main interest is in a time-varying independent variable, then the fixed effect models is the most appropriate[21] (which is closer to our case for the per capita Y of India). Nevertheless, since there are still situations that a random effects model can fit the data (e.g. Cov($Y_{i,t}, a_i$) = 0 is the exception rather than the rule) the Hausman test will allow us to choose the appropriate estimation method (Wooldridge 6th edition, 2015). Furthermore, robust standard errors will be used to establish the significance of our coefficients and to control for the presence of heteroscedasticity in the model. The hypotheses that we are going to test for each environmental pollution indicator are the following:

H_0*:* Per capita Net State Domestic Product positively influence pollution levels in an Indian state over time but after a certain stage of economic growth, per capita Net State Domestic Product negatively influence pollution levels in a state over time (EKC exists in the economic growth-environment relationship)

H_1*:* Per capita Net State Domestic Product doesn't positively influence pollution levels in the early stages of Indian economic expansion and after a certain stage of economic growth, per capita Net

[20] In Friedl & Gelzner (2003) we see the description of all these cases and additionally the authors notice that *"in order an inverse U shape to result, the second coefficient has to be bigger that the first on in absolute terms (*$|\beta_1| > |\beta_2|$*) and the N-shape graph results only if* $|\beta_1| > |\beta_2| > |\beta_3|$*"*

[21] In addition, in Wooldridge (2015) we see that: "fixed effects allow for correlation between a_i and $Y_{i,t}$ which in general makes it a more convincing tool for estimating ceteris paribus effects"

State Domestic Product does not negatively influence pollution levels in Indian states over time (EKC does not exists in the economic growth-environment relationship)

The second stage will consist of several robustness checks in order to test the sensitivity of my results. More specifically, Net State Domestic Product (NSDP) will be replaced by the Indian Gross State Domestic Product (GSDP) as an alternative measurement of welfare. Despite the fact that the data availability for this specific measurement is limited, it will be useful to examine its interconnection with the environmental degradation especially since most existing studies of the EKC curve include this measurement as their main explanatory variable. Furthermore, the total air concertation levels will be transformed to capture the per capita air pollution levels. In this way, we will focus on the per capita environmental outcomes and the means that drive their fluctuations, which as we can notice from the existing literature can display significantly different results compared to the total emission levels. More specifically, in Selden and Song (1994) we see that "global income distribution is skewed with big difference between median and mean world income per capita; that means that the total emissions can still be increasing even if the per capita emissions are estimated to decrease at an acceptable low per capita level". Therefore, it is crucial to investigate also the GDP per capita-environmental degradation relationship and see whether it results different outcomes compared to the total emission levels.

In the last part of my results, I will examine the issue of a possible endogeneity between NSDP per capita and environmental emissions. In the presence of endogeneity, both models can produce spurious, biased and inconsistent estimates and in addition, our resulted hypotheses can be misleading. As already mentioned in Section 2, one can claim that a path from the environment to the economy can also be considered. Environmental disasters can restrain economic growth, but also in a less extreme scenario, improved environmental conditions can contribute to economic expansion through better living conditions. Therefore, as a first attempt, through the 2SLS method I will examine if the variable "state-wise deposits by scheduled commercial banks" is an appropriate instrument for the relationship between economic growth and environmental emissions, and as an postestimation test investigate whether or not NSDP per capita in indeed an endogenous variable. Information about the state-wise deposits by scheduled commercial banks were collected from the Reserve Bank of India and measures the total number of deposits per Indian state.

Results

5.1 Baseline results

In this section, I will analyze the main findings from the investigation of the Environmental Kuznets Curve in India, and I will examine whether the basic variables follow my initial predictions and expectations. All the tables with my baseline results, the alternative measurements and the robustness checks, can be found in the Appendix of this paper. The way I decided to organize my tables and present the outcomes, is based on previous empirical researches but also on the importance of each control variable in the model.

More specifically, in the first columns I present the results of the exclusive connection between income and the air pollution levels. Many early studies of the EKC have examined this relationship without including any control variables in their estimation; therefore, it is essential to explore how this connection reacts with and without control variables for the case of India[22]. In the next columns, I gradually add four control variables in the estimations, which in my belief play a significant role and have a direct connection with the environmental standards of the Indian states: the capital to labor ratio, the number of registered vehicles, the population density and the social expenditure per Indian state.

Porter hypothesis states that stricter environmental regulations can positively influence technological progress, and through an increasing innovation capacity, improve economic growth and pollution levels. The hypothesis was formulated by Michael Porter in 1995 and has been investigated in many papers since then with dubious outcomes. Nevertheless, I will examine the validity of this hypothesis specifically for the case of India. More specifically, I will test whether higher economic growth and increasing innovation capacity in India increased the capital to labor intensity and if this change drive states to exploit a reduction in the environmental pollution indicators[23]. Therefore, the first variable constitutes a crucial part of this paper, as it will sign the validity of the Porter hypothesis and the theory that supports that an increase in the capital to labor intensity will drive states to exploit a reduction in the environmental pollution indicators.

[22] A range of previous empirical researches of the inverse-U curve has been criticized for the significance of their results due to the omitted variable bias issue (see Stern (2003): The rise and fall of the Environmental Kuznets Curve)

[23] In Locatelli et al. (2014) we find the examination of this theory but from the perspective of trade liberalization and economic growth

The prediction for the second one is that as most of the environmental indicators in this study are directly connected with transportation fumes and emissions, an increase in the number of vehicles will also increase the air pollution levels per state. Although this variable is a good proxy for the vehicular emission levels, it does not take into account the category and quality of each registered vehicle, which are two characteristics that may be significant in determining the environmental pollution of transportation. Furthermore, population density approximates the living conditions and standards of each Indian state, and thus it is expected to have a positive and significant relationship with air indicators. Finally, the expectation for the social expenditure variable is that it will show a negative connection with the environmental pollution, as it measures the investment in human capital for each state, which is correlated with the economic situation, education level and environmental awareness of Indian citizens.

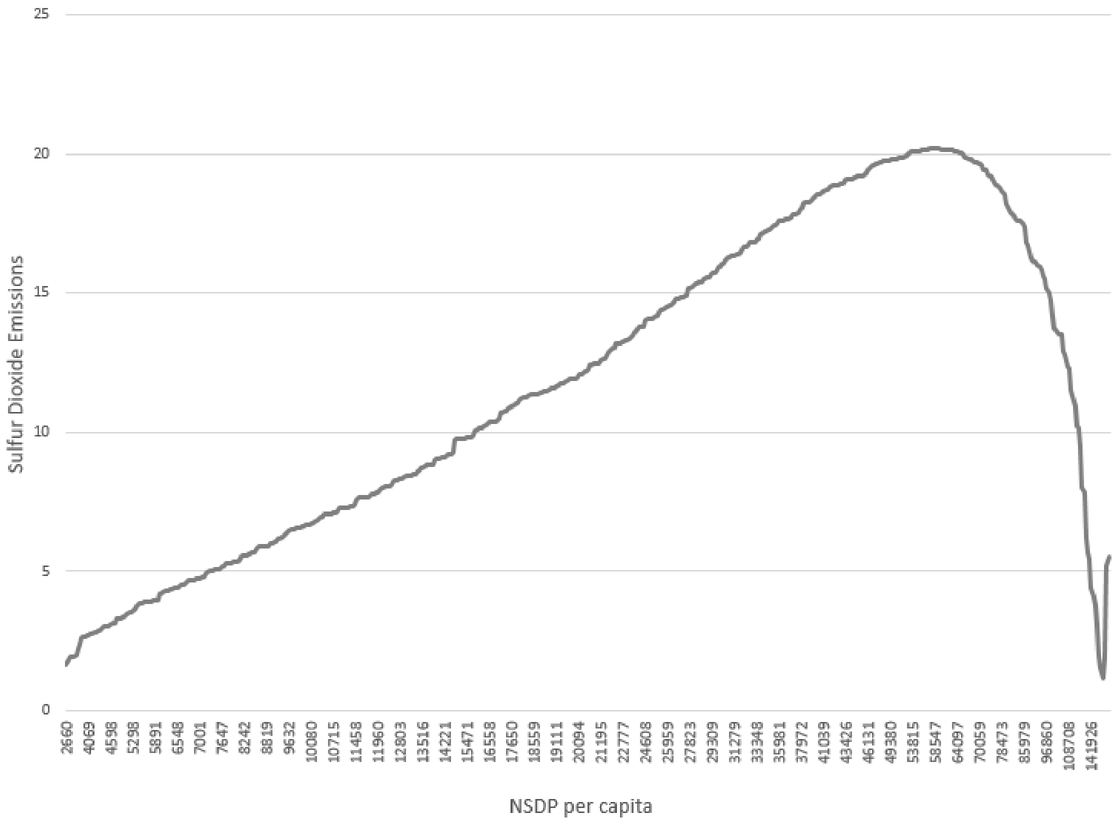
In the last stage of the tables, I present the final results with the inclusion of all the variables of my model. Besides the main explanatory variables, which I have already analyzed, I decided to include a set of other parameters with a direct but also indirect connection with the Environmental Kuznets Curve. The number of factories represents the level of industrialization of each state and a positive relationship with the pollution levels is expected. In the same group of variables, we find the credit to the industry. This measurement represents the amount of money that the industrial sector of each state has received over the years. The main prediction for this parameter is that it represents the financial power of the industrial sector and thus a negative relationship should be considered the most appropriate. However, it is questionable whether a better financial position in the area of industrialization can be associated with less environmental emissions from the industrial sector, as one may think that more credit to the industry could result into an increase in the industrial production and consequently into an increase in the air pollution. Therefore, it is interesting to explore the reaction of this variable and its association with the environmental indicators. Finally, a variable that also needs to be analyzed, is the production of foodgrains. This parameter captures the agricultural intensity of Indian states and as we analyzed in section 3, it is associated with agricultural emission and thus I expect it to have a positive impact in the air pollution levels. Nonetheless, a point of criticism can also be raised here because if it is not associated with farm pollution like the burning of biomass, it may have a positive contribution to air quality, as it can reveal the agricultural land over the total land area of each state and city.

Before I continue with the analysis of the results, I should mention that for all three cases and environmental indicators, the null hypothesis of the Hausman specification test, which states that the random effects model is the most appropriate method to use, is rejected and therefore the fixed effects model have been used. In Table 2, I present the main results of the SO_2 concentration levels. The first area that seems to be problematic not only for this table but also for all the estimations of this paper is the magnitude of the results. Even if we notice that several variables seem to have a significant and appropriate effect in the environmental pollution levels, the magnitude especially in the income coefficients seems to be very low. However, we should keep in mind that the variables are not transformed to US dollars as we see in many empirical researches, and they measure each relationship in Indian rupee. The exchange rate of Indian rupee to USD is 0.01547, and when the data are transformed to USD and I run my regression again, I find a coefficient of 0.0533 for NSDP per capita and for the case of sulfur dioxide, which is comparable with the results of Grote and Jena (2008) who examined the same indicators for India. Nevertheless, even if a part of the low magnitude may be explained by the use of Indian rupee, it still makes the validity of the results questionable and should be taken into consideration when evaluating the baseline results of this study.

Moving forward, after examining the first table we can conclude that an inverse-U curve can indeed characterize the relationship between SO_2 and Indian NSDP. All the conditions that we analyzed in section 4 are met and more precisely, $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, with a statistical significance at the 5% level and an acceptable turning point[24]. Therefore, we accept the null hypothesis and the existence of the EKC for the case of sulfur dioxide. The registered vehicles variable has a positive connection with income, which is according to my predictions as more vehicles indicate higher vehicular pollution levels. In addition, an increase in social expenditure seems to have a negative effect to the SO_2 levels, an outcome which again follows our initial expectations. The credit to the industry variable is significant and with a positive impact for this pollutant, which means that an increasing funding of the industrial sector will result an increase also in the pollutant levels for this specific emission, which is an interesting outcome in terms of environmental policy and should be taken into account in future economic policies in India. Finally, it is important to notice that in the first stages of my table, the requirements of the EKC are not met, due to the insignificant results for NSDP. Nevertheless, in the last columns when more control variables are included in the model, the variables obtain the required significance, which highlights the importance of controlling for other areas of pollution when examining the Environmental Kuznets Curve.

[24] The turning point of the EKC ($-\beta_1/(2\beta_2)$) is around 43,750 rupees and thus within an acceptable range of NSDP per capita for India

Figure 4. Environmental Kuznets Curve – Sulfur Dioxide



In figure 4, I present the graph of the EKC for the case of sulfur dioxide. In order to create this graph, I used the coefficients of my main variables of economic growth from Table 2 and the annual levels of NSDP per capita from all the states of India. Interestingly, we can clearly detect the existence of an inverse-U curve connection. In the early stages of economic growth, the trend of the line reveals a gradual increase of sulfur dioxide emissions, and it reaches its top at around 45,000-58,000 rupees[25]. After its highest point, the trend rapidly decreases, which is according to the predictions of the EKC and the aftermaths of the post-industrial period, with higher environmental awareness, more environmental regulations and bigger efforts to reduce the emissions and improve the air quality of India. Finally, the last point that needs to be emphasized is the slight increase that we can notice at the end of the graph, which highlights the possibility of an increase in SO_2 emissions in the future, where India is expected to keep on expand and grow its economy.

Regarding the other two indicators (SPM, NO_2) and their environmental concentration layer, from Tables 2 and 3 we can notice that we cannot find evidence that could support the Environmental

[25] The turning point is slightly different in the graph, as the coefficients of the exclusive connection of sulfur dioxide and economic growth is used, without the inclusion of any control variable.

Kuznets Curve relationship. The mystery in my results is that the only air pollutants, that economic growth was found to play a significant role is the emissions decrease of SO_2, something we can also see in the findings of Roca et al. (2001) and the examination of EKC for the case of Spain. This outcome may be explained by the fact that since the beginning of the 21th century, many new environmental regulations have been introduced worldwide to prevent further expansion of this air pollutant, due to its important impact in the environment (acid rain) and human health. Going forward, the capital to labor intensity reveals a positive relationship with air emissions only for the case of nitrous dioxide emissions. The coefficient is significant at the 10% level, meaning that we have some weak evidence that contradict the predictions of the Porter theorem, as an increase in the capital to labor ratio positively effects pollution over time.

From the nitrous dioxide results, we also see that the number of automobiles per state has a positive relationship with the emissions, while the population density reveals also a positive and statistical significant connection with NO_2 pollution, as I expected and analyzed in the beginning of this section[26]. The coefficient of population density for the case of SPM is also positive and highly significant, which indicates the importance of this variable for examining the environmental differences between the Indian states and their progress over time.

In table four and the SPM concentration results we notice that the variable of social expenditure is positively connected with the pollution levels, something that we did not see for the case of sulfur dioxide and it is not according to my predictions. Furthermore, population density seems to play again a significant role with a negative impact in the attempts of India for environmental improvements. Finally, for this pollutant the location seems to be also important, as all north Indian states seem to have higher pollution levels of SPM emissions. A Greenpeace report estimated that more than 1 million Indian die every year due to air pollution and announced that none of the North Indian states managed to meet the air quality standards in the beginning of the 21st century[27].

[26] For the variable of registered vehicles, the coefficient is significant at the 5% level, while the population density at the 1% level

[27] https://www.theguardian.com/world/2017/jan/13/all-north-indian-cities-fail-meet-air-quality-standards-report-finds

5.2 Alternative measures – Robustness checks

The baselines results of this paper revealed that the Environmental Kuznets Curve is thought to exist only for the case of SO_2 emissions in India. Although the magnitude of the relationship is relatively low, all necessary requirements to support an inverse-U curve relationship are met. For the other two air pollutants, the null hypothesis of the EKC was rejected, as there is not enough evidence to support such a connection with income growth. In this section, I will substitute some of the variables of the model in order to assess the robustness of my main outcomes about the effects of economic growth in environmental pollution.

Most of the existing papers that examined the Environmental Kuznets Curve have used the Gross Domestic Product growth as their main explanatory variable to capture the environmental consequences of economic expansion. In Section 3, I analyzed the necessity of establishing an alternative measurement of welfare and the reasons for using the NSDPpc for the case of India. Nevertheless, my first model modification will be its replacement with the Indian per capita GSDP for the time period of 1990 - 2013 and the examination of the sensitivity of my results. The data regarding the GSDPpc are available on the website of the Reserve Bank of India. The estimation results of the fixed effects model for the case of SO_2 are shown in Table 5. For the presentation of the table, I choose again to progressively include first the main independent variables of this paper, then the basic control variables and in the last column the final version of the regression. If we entirely focus on the connection between the sulfur dioxide and the linear, quadratic and cubic version of GSDPpc, we see that the estimated parameters are statistically significant and with the right sign for almost each group of the table. This implies that the expected sign conditions are again satisfied and the estimated curve is indeed U-shaped.

Moving to the main control variables, there are no major changes compared to our baseline results. The number of vehicles remains statistically significant and with a positive sign which support our initial statement that the vehicular fuel emissions is a significant component of the total sulfur dioxide sate levels. The social expenditure variable is negative and statistically significant at the 1% level, which indicates the importance of investing in human capital, and the service intensity is significant at the 10% level and with a negative sign, which follows my initial predictions that an increase in the service sector will results better environmental conditions for India. The R-squared has slightly decreased and is around 0.442, which means that only 50% of the environmental degradation can be explained by the movements of my benchmark model.

In table 6, I present the results of the same alternative measurements for the case of NO_2. Once again, we cannot notice sizable differences compared to our first stage regression. The expected sign conditions for the existence of the EKC are satisfied, but without the required significance. Therefore, we fail to detect the inverse-U curve relationship for this air pollutant. Turning to the other components of the model, despite the fact that in the first column of the table the capital to labor ratio is not significant, it becomes significant at the 5% level at the last columns when all variables are included and thus we can conclude that the findings in the baseline results for this variable are robust. Vehicular emissions continue to play a significant role also for this indicator with a coefficient of 0.00132, while population density remains positive and statistically significant at the 1% level.

Furthermore, if we focus on table 7 and the SPM emissions, we see that again the signs requirements are not satisfied with a negative and insignificant sign for the linear and a positive sign for the quadratic and cubic version of GSDPpc. Population density remains strongly positively and significantly associated with SPM emissions and the only coefficient which loses its significance is the social expenditure. Overall, for all the environmental indicators we can conclude that the main outcomes remain the same and the results we obtain are robust. The only case where the EKC can be identified is the concentration levels of sulfur dioxide.

The last part of the robustness tests, consists of a transformation in the dependent variables of the model in order to capture the per capita emission levels and not the total amounts. In section 2, we saw that in the paper of Selden and Song (2004), the authors point out that even if per capita emissions are decreasing, the total emission levels may still increase due to the shape of the global income distribution. This point of criticism can also hold for a country specific case, mainly because of the high income inequality that characterizes especially the Indian states. In addition, most empirical researches have performed their analysis based on the per capita GDP and emission levels. For these reasons, I decided to slightly transform my data and examine how sensitive my results are from this modification[28]. Interestingly, we cannot notice any differences regarding the shape of the curves. SO_2 concentration is the only pollutant that reveals an inverse-U Kuznets curve.

On the other hand, the results of several control variables seem to be less robust with this modification. For the sulfur dioxide case, even if social expenditure holds its sign and significance

[28] All indicators were transformed to nanograms per cubic meter in order to make easier the interpretation of the coefficients

and the contribution of the credit to the industry remains strong, the number of registered vehicles is not anymore significant and service intensity variable does not show the expected signs. In addition, population density is significant now at the 5% level and with the expected positive sign. In Table 10 and the SPM pollutant, we notice that almost all components lose entirely their significance, and in Table 9, despite the fact that population density, social expenditure and the registered vehicles reveal the expected relationship with air pollution, the capital to labor ratio loses entirely its significant, meaning that I don't have enough evidence to reject the Porter hypothesis in this version of my model.

To sum up, my overall findings suggest that we have enough evidence to support the Environmental Kuznets curve for India, but only for the case of sulfur dioxide emissions. However, the differences we observe within the same indicators but also between SO_2, NO_2 and SPM pollutants of air, highlight the fact that different environmental policies are necessary to attack each pollutant separately and more efficiently.

5.3 The issue of endogeneity

In the last part of my results, I investigate the issue of endogeneity between NSDP per capita and environmental emissions. The instrument I decided to use to resolve this possible issue is the state-wise deposits by scheduled commercial bank. The dataset for this variable is available in the Reserve Bank of India website, from 1990 until 2014. The idea behind this instrument is that an increase in the welfare of Indian state and an economic expansion will boost also the bank deposits in each Indian bank without having a direct effect in the environmental quality of each state. For what it concerns the two stages least squares (2SLS) results of this instrumental variable, I decided not to include them in this paper. After having ran the regression and reporting the first stage statistics, I conclude that my instrument is not strong enough to support the reported results, as its correlation with the endogenous variable is relatively weak[29]. In addition, from the postestimations and the tests of endogeneity, both the Durbin score and the Wu-Hausman statistics indicate that I cannot reject the null hypothesis which states that the variables are exogenous[30]. Therefore, I conclude that the IV – results of this regression do not meet the minimum requirements to include them in this paper as an investigation of the Environmental Kuznets Curve for India.

[29] The F-statistic is 0.00275, which is much smaller than any of the critical values of my model, and thus I cannot reject the null hypothesis of a weak instrument.
[30] P-values are 0.1430 and 0.1671 respectively

The evidence from the existing body of knowledge and the criticism of the EKC, provide strong arguments and proofs that support the endogeneity of income. Hence, I do not argue that income is indeed exogenous in my model, but since my instrumental variable is not strong enough to support the 2SLS results, I do not have enough evidence to investigate and resolve its exogeneity. The limitations of this study reveal the necessity for further future researches in the field of the EKC in order to resolve its numerous drawbacks and questionable results both in country specific cases and cross-countries investigation.

Conclusion

Air pollution is one of the major threats of humanity in the 21st century. Many fast-growing countries like India and China face numerous environmental problems in their way for further economic growth and expansion. The EKC theory however supports that after a point of per capita income, the direction reverses and high-income levels lead to improvements in the environmental conditions. The paper has analyzed whether this theory has indeed been present for India during its economic growth period. The focus of the analysis has not only been on industrialized states, but also on other advanced and emerging areas, covering 24 states in total over the period of 1990-2013, in order to obtain a complete view of the air pollution in India.

A key finding of the analysis is that there has indeed been a turning point of 43,750 Indian rupees in the air pollution-economic expansion connection, only for the case of sulfur dioxide emissions. The results for the existence of this turning point are robust and they appear in both cases of NSDP and GSDP per capita. By contrast, nitrous dioxide and SPM emissions do not meet the EKC criteria and though I cannot obtain an acceptable turning point for these pollutants, this does not mean that I have failed to obtain any evidence for the behavior of these two air emissions. In fact, I have failed to accept the Porter hypothesis for the case of nitrous dioxide, with a positive and significant coefficient of capital to labor ratio. For the case of NO_2 we can also see the importance of vehicular emissions and population density in the efforts for reducing the environmental degradation in Indian states. On the other hand, for the suspended particulate matters social expenditure has been found to play a significant role, which indicates the necessity of investing in human capital to attack this specific pollutant.

In terms of overall economic significance, the analysis of the paper shows that economic growth alone cannot sufficiently reduce environmental pollution in a fast-growing country like India. There has always been the notion among some policy makers that environmental improvements and pollution reductions are the aftermaths and the effects of industrial development and economic upswing in the modern capitalistic world. Although this paper faces many technical and econometrical limitations, I have enough evidence to support the necessity of obtaining different environmental policies to attack each pollutant separately and more efficiently. Government intervention in environmental policies are not job killing regulations that reduce economic opportunities. On the contrary, they are regulations that promote green and sustainable growth and better economic opportunities, secure the living conditions for millions of people especially in the developing world and alert every citizen worldwide for the consequences of the uncontrolled industrial expansion. While I am very cautious in making environmental policy suggestions based on my findings, by using different benchmarks in my model I highlight the existence of the EKC only for the case of SO_2 emissions and the need for further environmental awareness and air quality improvement in each Indian state.

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Appendix

Table 2: SO_2 Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y	-6.37e-05	0.000125	0.000472	0.000463	0.000467	0.000524	0.000650*	0.000791**
	(6.03e-05)	(0.000147)	(0.000305)	(0.000307)	(0.000337)	(0.000338)	(0.000360)	(0.000366)
Y2		-8.07e-10	-4.39e-09	-4.19e-09	-4.48e-09	-5.47e-09	-7.43e-09**	-9.04e-09**
		(4.81e-10)	(2.80e-09)	(2.81e-09)	(3.52e-09)	(13.45e-09)	(3.46e-09)	(3.55e-09)
Y3			1.10e-14	1.03e-14	1.20e-14	1.53e-14	2.18e-14**	2.61e-14**
			(7.71e-15)	(7.76e-15)	(1.06e-14)	(1.03e-14)	(9.82e-15)	(1.03e-14)
KL				0.154	0.282*	0.268	0.162	0.00123
				(0.159)	(0.164)	(0.159)	(0.156)	(0.120)
RegVehicles					0.000786*	0.000836*	0.00212**	0.00202**
					(0.000412)	(0.000416)	(0.000600)	(0.000731)
PopulationDensity						0.00239	0.00125	0.000370
						(0.00172)	(0.000851)	(0.00630)
SocialExpend							-0.0428***	-0.0503***
							(0.0123)	(0.0155)
CredIndustry								0.00345*
								(0.00171)
ServInt								-0.104
								(0.132)
Nfactories								-0.000328
								(0.000309)
ProductionFoodgr.								-0.000435
								(0.000259)
Location								4.040
								(3.739)
Constant	14.66**	5.901	-4.367	-6.299	-13.11	-16.26	-12.02	-0.373
	(5.734)	(8.931)	(11.21)	(10.85)	(11.72)	(12.32)	(11.67)	(18.19)
R-squared	0.344	0.358	0.371	0.378	0.391	0.399	0.423	0.448

Notes: Table 2 contains the results of a pooled ordinary least square regression of the yearly sulfur dioxide emissions for India and for the period between 1990 and 2013. The following independent variables are used: Y, Y2, Y3 which capture the annual NSDP levels per Indian states, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south; year dummies are include for each year of the sample. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** $p<0.01$, ** $p<0.05$, * $p<0.1$)

Table 3: NO_2 Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y	8.53e-05	-2.38e-05	0.000133	9.02e-05	724e-06	0.000108	0.000269	0.000326
	(0.000107)	(0.000168)	(0.000252)	(0.000260)	(0.000250)	(0.000240)	(0.000261)	(0.000287)
Y2		4.67e-10	-1.15e-09	-5.49e10	295e-10	-1.47e-09	-2.20e-09	-2.52e-09
		(8.43e-10)	(1.70e-09)	(1.74e-10)	(2.00e-09)	(1.77e-09)	(2.15e-09)	(2.39e-09)
Y3			4.95e-15	3.16e-15	1.00e-15	6.95e-15	7.35e-15	7.91e-15
			(5.14e-15)	(5.12e-15)	(5.06e-15)	(4.77e-15)	(5.35e-15)	(6.12e-15)
KL				0.421	0.617**	0.590**	0.416*	0.414*
				(0.270)	(0.275)	(0.265)	(0.224)	(0.215)
RegVehicles					0.00145***	0.00154***	0.00102**	0.00132**
					(0.000423)	(0.000408)	(0.000468)	(0.000530)
PopulationDensity						0.00424**	0.00559***	0.00518***
						(0.00179)	(0.00107)	(0.00127)
SocialExpend							0.00330	0.00439
							(0.0147)	(0.0230)
CredIndustry								0.0000952
								(0.0030)
ServInt								0.00947
								(0.0966)
Nfactories								-0.000510
								(0.000328)
ProductionFoodgr.								-0.000954
								(0.000366)
Location								2.425
								(2.425)
Constant	16.89**	21.94**	17.27	13.36	4.699	-0.982	-3.673	-3.969
	(8.905)	(9.393)	(12.40)	(13.22)	(7.966)	(8.377)	(9.507)	(11.14)
R-squared	0.076	0.082	0.084	0.110	0.159	0.186	0.192	0.204

Notes: Table 3 contains the results of a pooled ordinary least square regression of the yearly nitrous dioxide emissions for India and for the period between 1990 and 2013. The following independent variables are used: Y, Y2, Y3 which capture the annual NSDP levels per Indian states, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south; year dummies are include for each year of the sample. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** p<0.01, ** p<0.05, * p<0.1)

Table 4: SPM Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y	-0.000544*	-0.000279	-0.000635	-0.000691	0.000103	0.000314	0.00168	0.00108
	(0.000311)	(0.00111)	(0.000234)	(0.00240)	(0.00160)	(0.00174)	(0.00202)	(0.00230)
Y2		-1.15e-09	264e-09	3.94e-09	-8.78e-09	-1.62e-08	-2.27e-08	-2.32e-08
		(5.35e-09)	(2.46e-08)	(2.53e-08)	(1.81e-09)	(2.02e-08)	(2.39e-08)	(2.60e-08)
Y3			-1.16e-14	-1.56e-14	3.36e-14	6.53e-14	7.76e-14	7.92e-14
			(8.10e-14)	(8.26e-14)	(5.92e-14)	(6.73e-14)	(7.88e-14)	(8.44e-14)
KL				0.900	2.352*	2.467*	1.520	1.604
				(1.538)	(1.365)	(1.363)	(1.085)	(1.326)
RegVehicles					0.00213	0.00252	0.00502	-0.00529
					(0.00336)	(0.000314)	(0.00591)	(0.00622)
PopulationDensity						0.0198***	0.00946**	0.0109**
						(0.00942)	(0.00340)	(0.00400)
SocialExpend							0.260	0.0339**
							(0.164)	(0.161)
CredIndustry								-0.0112
								(0.0119)
ServInt								-0.232
								(0.547)
Nfactories								0.00152
								(0.00272)
ProductionFoodgr.								-0.00200
								(0.00250)
Location								38.80**
								(16.20)
Constant	280.8***	269.2***	279.4***	267.1***	119.1***	96.76**	24.87	1.009
	(45.58)	(67.05)	(87.85)	(83.92)	(39.96)	(45.27)	(63.63)	(67.34)
R-squared	0.115	0.116	0.116	0.117	0.156	0.171	0.183	0.194

Notes: Table 4 contains the results of a pooled ordinary least square regression of the yearly SPM emissions for India and for the period between 1990 and 2013. The following independent variables are used: Y, Y2, Y3 which capture the annual NSDP levels per Indian states, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south, and year dummies are include for each year of the sample. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** p<0.01, ** p<0.05, * p<0.1)

Table 5. Alternative measures: GSDPpc - SO_2 Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GSDPpc	-4.51e-05	0.0000602	0.000275	0.000271	0.000298	0.000323	0.000400*	0.000479**
	(4.21e-05)	(0.000105)	(0.000204)	(0.000203)	(0.000219)	(0.000219)	(0.000231)	(0.000217)
GSDPpc2		-3.30e-10	-1.99e-09	-1.89e-09	-2.15e-09	-2.57e-09	-3.72e-09**	-4.52e-09***
		(2.46e-10)	(1.37e-09)	(1.37e-09)	(1.75e-09)	(1.70e-09)	(1.62e-10)	(1.45e-09)
GSDPpc3			3.65e-15	3.41e-15	4.25e-15	5.39e-15	8.11e-15**	9.84e-15***
			(2.65e-15)	(2.66e-15)	(3.80e-15)	(3.66e-15)	(3.36e-15)	(2.99e-15)
KL				0.190	0.325*	0.319*	0.168	0.0150
				(0.171)	(0.175)	(0.172)	(0.159)	(0.148)
RegVehicles					0.000826*	0.000855*	0.00198***	0.00195**
					(0.000413)	(0.000424)	(0.000607)	(0.000721)
PopulationDensity						0.00193	0.000860	-0.000049
						(0.00173)	(0.00702)	(0.000581)
SocialExpend							-0.0406***	-0.0478***
							(0.0131)	(0.0142)
CredIndustry								0.00307**
								(0.00161)
ServInt								-0.122*
								(0.133)
Nfactories								-0.000373
								(0.000319)
ProductionFoodgr.								-0.000367
								(0.000278)
Location								3.572
								(3.626)
Constant	13.64**	7.582	-0.578	-2.864	-11.42	-13.71	-7.021	6.339
	(4.725)	(7.765)	(9.660)	(9.291)	(10.14)	(10.71)	(10.10)	(16.52)
R-squared	0.344	0.353	0.364	0.372	0.386	0.391	0.420	0.442

Notes: Table 5 contains the results of a pooled ordinary least square regression of the yearly sulfur dioxide emissions for India and for the period between 1990 and 2013. The following independent variables are used: GSDPpc, GSDPpc2, GSDPpc3 which capture the annual Indian GSDP levels, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south; year dummies are included in the model. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** $p<0.01$, ** $p<0.05$, * $p<0.1$)

Table 6. Alternative measures: GSDPpc - NO_2 Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GSDPpc	4.01e-05	7.35e-05	-8.79e-05	-0.000104	-5.78e-05	-4.57e-06	9.21e-05	0.000135
	(6.06e-05)	(0.000120)	(0.000225)	(0.000228)	(0.000195)	(0.000186)	(0.000219)	(0.000227)
GSDPpc2		-1.05e-10	1.15e-09	1.37e-09	1.10e-09	2.23e-10	-4.36e-11	-2.50e-10
		(2.86e-10)	(1.75e-09)	(1.76e-09)	(1.61e-09)	(1.24e-09)	(1.80e-09)	(1.78e-09)
GSDPpc3			-2.75e-15	-3.23e-15	2.66e-15	-3.02e-16	-3.00e-16	2.89e-18
			(1.64e-15)	(1.63e.15)	(2.05e-15)	(2.14e-15)	(2.26e-15)	(3.96e-15)
KL				0.422	0.615**	0.600**	0.443*	0.443**
				(0.264)	(0.269)	(0.268)	(0.215)	(0.201)
RegVehicles					0.00146***	0.00152***	0.000968*	0.00132**
					(0.000410)	(0.000401)	(0.000489)	(0.000541)
PopulationDensity						0.00397*	0.00553***	0.00520***
						(0.00194)	(0.00111)	(0.00131)
SocialExpend							0.00521	0.00692
							(0.0159)	(0.0246)
CredIndustry								-0.000132
								(0.00311)
ServInt								-0.00167
								(0.0901)
Nfactories								-0.000526
								(0.000324)
ProductionFoodgr.								-6.02e-05
								(0.000349)
Location								2.260
								(2.049)
Constant	20.61***	18.68**	24.83**	20.49*	6.392	1.598	-0.158	-0.140
	(5.577)	(8.399)	(10.55)	(11.07)	(6.542)	(7.095)	(9.323)	(11.33)
R-squared	0.065	0.066	0.072	0.097	0.152	0.175	0.187	0.198

Notes: Table 6 contains the results of a pooled ordinary least square regression of the yearly nitrous dioxide emissions for India and for the period between 1990 and 2013. The following independent variables are used: GSDPpc, GSDPpc2, GSDPpc3 which capture the annual Indian GSDP levels, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south, and year dummies are include for each year of the sample. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** p<0.01, ** p<0.05, * p<0.1)

Table 7. Alternative measures: GSDPpc – SPM Concentration Results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GSDPpc	-0.000354	-0.000819	0.000445	0.000421	-0.000811	-0.000878	0.000496	-0.000478
	(0.000216)	(0.000551)	(0.00166)	(0.00173)	(0.00103)	(0.00107)	(0.00119)	(0.00135)
GSDPpc2		1.50e-09	-8.54e-09	-8.03e-09	1.70e-09	-3.11e-10	-7.80e-09	7.51e-09
		(1.81e-09)	(1.18e-08)	(1.23e-08)	(7.60e-09)	(8.11e-09)	(9.98e-09)	(1.10e-08)
GSDPpc3			2.19e-14	2.08e-14	-5.15e-16	6.97e-15	2.09e-14	2.05e-14
			(2.37e-14)	(2.46e-14)	(1.72e-14)	(1.90e-14)	(2.39e-14)	(2.60e-14)
KL				0.808	2.590**	2.776**	1.606	1.674
				(1.583)	(1.328)	(1.334)	(1.022)	(1.240)
RegVehicles					0.00210	0.00244	0.00434	-0.00472
					(0.00324)	(0.00308)	(0.00599)	(0.00615)
PopulationDensity						0.0186**	0.00890**	0.0107***
						(0.00857)	(0.00341)	(0.00357)
SocialExpend							0.230	0.279
							(0.166)	(0.164)
CredIndustry								-0.00880
								(0.0126)
ServInt								-0.281
								(0.578)
Nfactories								0.00183
								(0.00279)
ProductionFoodgr.								-0.00175
								(0.00244)
Location								36.53**
								(15.90)
Constant	268.0***	294.3***	248.4***	237.7***	147.1***	130.3***	63.23	45.47
	(41.58)	(53.64)	(86.69)	(84.04)	(42.60)	(44.40)	(60.91)	(66.61)
R-squared	0.112	0.116	0.124	0.124	0.159	0.173	0.182	0.200

Notes: Table 7 contains the results of a pooled ordinary least square regression of the yearly SPM emissions for India and for the period between 1990 and 2015. The following independent variables are used: GSDPpc, GSDPpc2, GSDPpc3 which capture the annual Indian GSDP levels, KL which is the capital to labor ratio, Regvehicles which represents that annual number of registered vehicles per Indian state, PopulationDensity which measures the population density and it's created from the Indian Census data, SocialExpend which captures the total amount of money invested in human capital. CreditIndustry is a measurement of the financial funding of the industrial sector; ServInt is the intensity of service sector in different states, Nfactories the total number of Indian plants, ProductionFoodgr that captures the agricultural intensity and consist a proxy of the agricultural emissions. Finally, Location is a dummy variable, which takes the number 1 for north cities and 0 for south; year dummies are include for each year of the sample. The table includes country and time fixed effects. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** $p<0.01$, ** $p<0.05$, * $p<0.1$)

Table 8. Robustness check – SO2pc emissions

VARIABLES	(1)
Y	0.323***
	(0.0991)
Y2	-4.66e-06***
	(9.92e-07)
Y3	1.38e-11***
	(3.13e-12)
KL	6.061
	(85.89)
RegVehicles	0.396
	(0.273)
Population Density	1.409**
	(0.654)
Social Expenditure	-17.31**
	(7.963)
CredIndistry	2.618***
	(0.885)
ServInt	115.9***
	(42.06)
Nfactories	-0.0776
	(0.156)
ProductionFoodgr	-0.00476
	(0.120)
Location	3.792
	(4.343)
Constant	-10.851**
R-squared	0.275

Table 9. Robustness check – NO2pc emissions

VARIABLES	(1)
Y	0.0812
	(0.0795)
Y2	-1.32e-06
	(9.95e-07)
Y3	4.21e-12
	(3.15e-12)
KL	47.20
	(34.69)
RegVehicles	0.171*
	(0.0834)
Population Density	0.556*
	(0.248)
Social Expenditure	-6.167*
	(3.470)
CredIndistry	0.843
	(0.522)
ServInt	22.25
	(21.58)
Nfactories	-0.0198
	(0.0462)
ProductionFoodgr	0.0111
	(0.0291)
Location	1346
	(991.2)
Constant	-1,657
R-squared	0.174

Table 10. Robustness check – SPMpc emissions

VARIABLES	(1)
Y	-0.0787
	(0.320)
Y2	-1.09e-06
	(3.86e-06)
Y3	-3.09e-12
	(1.24e-11)
KL	239.6
	(210.4)
RegVehicles	0.691
	(0.549)
Population Density	-0.724
	(0.850)
Social Expenditure	-24.43
	(19.03)
CredIndistry	4.320
	(2.538)
ServInt	114.7
	(149.3)
Nfactories	-0.0272
	(0.211)
ProductionFoodgr	0.133
	(0.125)
Location	2588
	(3397)
Constant	8.969
R-squared	0.359

Notes: Table 8, 9 and 10 represent our last robustness checks. Table 8 contains the results of a pooled ordinary least square regression of the yearly sulfur dioxide emissions for India and for the period between 1990 to 2013. We report the results of our model when we substitute the main dependent variable, namely SO2, with SO2pc, in order to assess the effect of economic growth in per capita emission levels. Tables 9 and 10 examine the same relationship for nitrous dioxide and SPM, respectively. Robust standard errors are in parentheses. The * represents the statistical significance of the results (*** p<0.01, ** p<0.05, * p<0.1)