Socio-Economic Cost of BS VI and its Impact on health: A Panel Data Analysis

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Abstract

This paper tries to evaluate the effect of vehicular emissions on human health, particularly focusing on Acute Respiratory Illness (ARI), and the impact of policy intervention by introducing Bharat Stage VI (BS VI) emission standards. By utilizing a panel dataset representing Indian states and union territories, the primary objective of this study is to analyse the effectiveness of implementing the emission standards on health and the environment using quantitative measures, employing both a mixed effects model and a Differences-in-Differences model. Findings from this study suggests that the increase in the number of registered motor vehicles and public transport over the period of study between the years 2013 and 2022 has resulted in an increase in the levels of $PM_{2.5}$ *pollution and has indirectly affected the health of the population which is seen in the number of registered cases for Acute Respiratory Infection. It is also clear that the constant investment of the government on public health has helped in reducing the effect of infection.*

Keywords: Air pollution, BS VI, Acute Respiratory Infection, vehicular emissions

JEL codes: Q53, I18, H23, C23, Q58

1. Introduction

Right from when the first animal life form took birth, it has been on constant movement in order to survive. The evolution has not paralysed the ability to move but has improved it further to sustain life for over a million years now. Various ever-growing needs and desires have put humans on a constant move. Rapid evolution in science and technology has helped researchers to put their heart and souls to create newer technologies that help in easing out lives. These inventions act as a seed for economic growth. One such innovation was the creation of the motorised vehicle. Karl Benz applied for the patent of the world's first car and the first car as a motorised vehicle ever to be produced dating back to 1888, the invention by him has then transformed into a promising sector with over millions of vehicles rolling out each year and continuing further. Ever rising population, lifestyles and income levels of households has fuelled the automobile market to soaring new heights every year. With growth not only pertaining to the economy, the rise has led to a serious of health issues. To bring a control over the situation emission standards were introduced as one of the measures to bar the toxicity released from the tailpipes of motorised vehicles. India's recent emission standards titled the 'Bharat Stage VI' or shortly BS VI which was rolled out in 2020 acts as a regulation to which manufacturers have to stick on with to get permits of sale.

2. Literature Review

Considering the vastness of the topic, the literature review will be divided into sub groups focusing on different aspects as follows:

- Air Pollution
- Health Effects of Air Pollution
- Vehicular Air Pollution
- Emission Standards
- Review on emission standards

2.1. Air Pollution

Exponentially increasing population and production activities has put a lot of burden on our planet. The Health Effects Institute state that air pollution has become the fifth leading risk factor for mortality worldwide and is responsible for more deaths than many other risk factors.

The National Capital Region in India is well known to be the most polluted capital city in the world. With majority of the pollution covering the city of Delhi with a thick blanket towards the end of the year is majorly caused by spillover effects of crop burning from adjacent states and ever-increasing transport figures. Chowdhury et al., 2023, has covered extensively in his research about the economic impacts of air pollution by assessing two cities, viz., Delhi and Narnaul in Haryana. The study measures the economic cost using three approaches, which are, cost of illness, productivity based and by undertaking a contingent valuation exercise. The determined economic costs in terms of health expenditure are quoted at a whopping Rs.4.8 billion.

To improve air quality and enhance economic and social development, India has issued a National Ambient Air Quality Standard (NAAQS) for annual PM2.5 concentrations of 40µg/m3 (CPCB, 2009). But the records show that these numbers would be longing dream. As per the State of Global Air Report, India is far beyond the NAAQS or the WHO guidelines for PM2.5 by registering at levels of 91μg/m^3. IEA, 2016 states that about 1% of the Indian population are exposed to the safer limits of PM2.5 levels as stated by the guideline from WHO. An estimate from the OECD suggests that ambient air pollution alone may cost India more than 0.5trillion dollars per year (OECD, 2014).

2.2. Health impacts of Air pollution

Indian cities rank high in global air pollution for PM2.5 which is associated with severe health impacts. While for India their exact quantification remains uncertain, the scientific literature estimates large numbers, ranging between 483,000 and 1,267,000 cases of pre mature deaths annually from outdoor pollution, and 748,000 – 1,254,000 cases from indoor pollution. In 2017, over 4.9 million deaths were associated with air pollution and about 147 million healthy lives lost. Compared with other major urban areas in India, New Delhi had the highest number of deaths attributable to transportation emissions in 2015 and the highest mortality rate—9 deaths per 100,000 population. New Delhi accounted for 2.5% of transportation-attributable deaths from PM2.5 and ozone pollution in India in 2015. An estimated 74,000 premature deaths were attributable to transportation emissions in India 2015. This represents a 28% increase in annual transportation-attributable deaths in India compared with 2010.

Chronic exposure to ambient air pollution poses serious health issues related to heart and lungs. Some of the hazards include chronic obstructive pulmonary disease. Ischemic heart disease, stroke and lung cancer for adults and acute respiratory infection for children (Jain et al., 2017; Burnett et al.,2014)

2.3.Vehicular Pollution

The average vehicle age is about 6 years for motorized two & three wheelers, between 6 & 7 years for cars, 7.5 – 8 for buses and heavy-duty trucks and lorries (S. Baidya & J. Borken-Kleefeld,2009). Road transport includes variety of vehicles ranging from light-duty to heavy-duty vehicles, which are mostly powered by internal combustion (IC) engines. As IC engines fuelled by fossil fuels emit harmful gaseous pollutants as well as particulate, road transport sector is largely blamed for environmental and health hazards. High population growth, economic development and rapid urbanization have led to exponential growth in automotive population, hence associated health risks have also increased proportionately. Projection shows that the total number of road vehicles would reach between 2 and 3 billion by 2050. A vehicle's tailpipe plume also includes numerous semi-volatile and volatile organic compounds (VOCs) (e.g., polycyclic aromatic hydrocarbons (PAHs), benzene, ethene, ethylene and toluene), which are highly toxic. Therefore, vehicular emissions form a major fraction of air pollutants, particularly in urban areas, which has now become a serious concern due to their toxicological effects on human health and ecosystem. Experimental investigations have demonstrated that gaseous organic compounds emitted in the vehicular exhaust (both gasoline and diesel) lead to formation of secondary organic aerosols (SOAs), photo chemical smog, and ground level ozone (O3). Together, photo chemical smog and SOAs lead to haze formation, which is evolving as a serious issue in developing countries like China and India.

PM from the vehicular exhaust is usually composed of solid carbonaceous particles and organic compounds and can remain as suspended particles in the atmosphere or may deposit on the earth's surfaces. Because of the tiny sizes (μm-nm), PM is inhalable and gets easily transported through the human respiratory system. Transport sector is said to be responsible for approximately 18% of the total GHG emissions globally in 2016.

2.4.Emission Standards

The need for emission standards was brought up by A.J. Haagen Smit in 1952 when he found and a group of scientists recognized that the peculiar combination of warm climate, bounded landscape and rising population in Los Angeles, the State of California was the prevailing reason that the formation of large photochemical smog was composed of hydrocarbons and nitrogen oxides emanating from automobile exhaust emissions. Many nations came forward to put forth the needs of Emission standards and regulate vehicular emissions. S.Singh et al., 2022, discusses in detail about how the emission standards were rolled out in countries like the United States, Australia, Japan, Europe and India. Focusing particularly on India, the Clean Air Act in 1970, intended to reduce 90% of carbon monoxide, hydrocarbons and nitrogen oxide emissions from automobiles. This was later reformed into the Energy and Environmental Coordination Act in 1974 and the Clean Air Act Amendment in 1977.

Emission norms in India for petrol and diesel distillates date back to 1991, 1992 emphasizing the needs for catalytic convertors and unleaded petrol. On April 2000, Euro II norms were made important in the National Capital Region. The Mashelkar committee's report in 2002 was accepted by the Government to introduce the Indianized version of emission standards. This was the birth of the 'Bharat Stage Emission Standards' (BSES). This restricted the intensity of air pollutants emitted from vehicles and targeted mainly at bringing changes in the fuel efficiency and engine design. BS II was released in 2001 followed by BS III in 2005. BS IV came into existence in April 2010 by implementing in major cities and later enforced throughout India by April 2017. The delay in this process was equalled by leapfrogging to BS VI from BS IV directly.

Because of high health risks associated with vehicular emissions, most countries have imposed increasingly stringent emission legislations namely: Euro-VI in European Union (EU); Tier-3 and California standard in USA; China-6 in China; and BS-VI in India. Table 1 and Table 2 shows the comparison between BSVI and emission standards of other nations. This makes it clear that the introduced BS VI emission standards are of international quality and is at a competence level.

Table 1. Comparison of fuel specifications for select gasoline parameters

Fuel parameter	BS VI	Euro 6	EPA RFG average (2005)	EPA convetional gasoline average (2005)	Japan	South Korea	Worldwide Fuel Charter (Category 4)
Sulfur, ppm, max.	10	10	30 ppm (Tier 2) 10 ppm (Tier 3)	30 ppm (Tier 2) 10 ppm (Tier 3)	10	10	10
Research Octane (RON), min.	91/95	95[a]	NS	NS	89/96	91/94	91/95/98
Motor Octane (MON), min.	81/85	85[a]	NS	NS	NS	NS	82.5/85/88
Anti-Knock Index (AKI), min.	NS	NS	87/87/91	87/87/91	NS	NS	NS
Olefins, vol%, max.	21/18	18	11.2-11.9	11.6-12.0	NS	16-19[b]	10

NS = Not specified; / used to separate specifications for different gasoline grades; AKI = (RON+MON)/2
[a]Member states are permitted to allow regular grade gasoline with MON of 81 and RON of 91.
[b]Either aromatics 24 vol.% max and olefins 16 vol.% max or aromatics 21 vol.% max and olefins 19 vol.% max.

Table 2. Comparison of fuel specifications for select diesel parameters

Fuel parameter	BS VI	Euro VI	EPA coventional diesel	CARB designated equivalent limit	Japan	South Korea	Worldwide Fuel Charter (Category 4)
Sulfur, ppm, max.	10	10	15	15	10	10	10
Cetane Number (CN), min	51	51	Cetane index ≥ 40 or aromatics ≤ 35%	53	45	52[a]	55
Density @ 15°C, kg/m^3	820-860	845 (max)	NS	NS	NS	815-835	820-840
95% Distillation Boiling Point (T_{95}), °C, max.	370	360	NS	NS	360[b]	360[b]	340
Polycyclic aromatic hydrocarbons (PAH), mass %, max.	11	8	NS	3.5	NS	5	2
Flash Point, Abel, °C, min.	35	55	NS	NS	45	40	55

NS = Not specified
[a]48 from November 15 to February 18
[b]Maximum 90% distillation boiling point (T_{90}) specified in Japanese and South Korean standards

Source: ICCT WORKING PAPER 2016-9 Technical Background on India BS VI Fuel Specifications

Note: We do not delve into the technical aspects of the engine, air filter, fuel specifications and changes brought in the engineering or future for each Bharat Stage Emission Standards introduced so as to reduce ambiguity caused from technical jargons and to enhance readability.

3. Data and Methodology

3.1. Data

The data collected is secondary in nature obtained from various trusted, government reports from ministries and official websites of the Govt. of India. The data spans over 10 years (2013 – 2022) to find the effect of pollution and vehicles on human health. Another panel data of 7 years (2013 – 2020) is used to analyse the effect of public transport. The data is processed to a panel dataset by including states and union territories of India. For easier calculations and to make the panel data balanced, few assumptions are made which include for the data that had not been reported due to bifurcations of Andhra Pradesh, Telangana are averaged. Jammu and

Kashmir are taken together as one single state, Daman & Diu and Dadra and Nagar Haveli are also taken together.

3.1.1. PM$_{2.5}$

Particulate Matter emissions are categorised based on their sizes in microns(µm). Fine particles with diameters < 2.5 µm are termed as PM$_{2.5}$, coarse particles are those of diameters between 2.5 Um & 10Um are given by PM$_{10-2.5}$. Particles in the United States are termed as coarse when the diameters are >10 µm given by PM$_{10}$. Many studies use PM$_{2.5}$ for their studies for its detrimental effects on health and well-being. PM$_{2.5}$ is being used from the data provided by the Washington University in St. Louis by the Atmospheric Composition Analysis Group. The data is estimated based on satellite, simulation and monitor based readings providing us with the 'Annual regional geographical mean of PM$_{2.5}$ of India'. Most researchers have used PM$_{2.5}$ to determine the effect pollution on health. The variable is denoted by 'PM25' in this study.

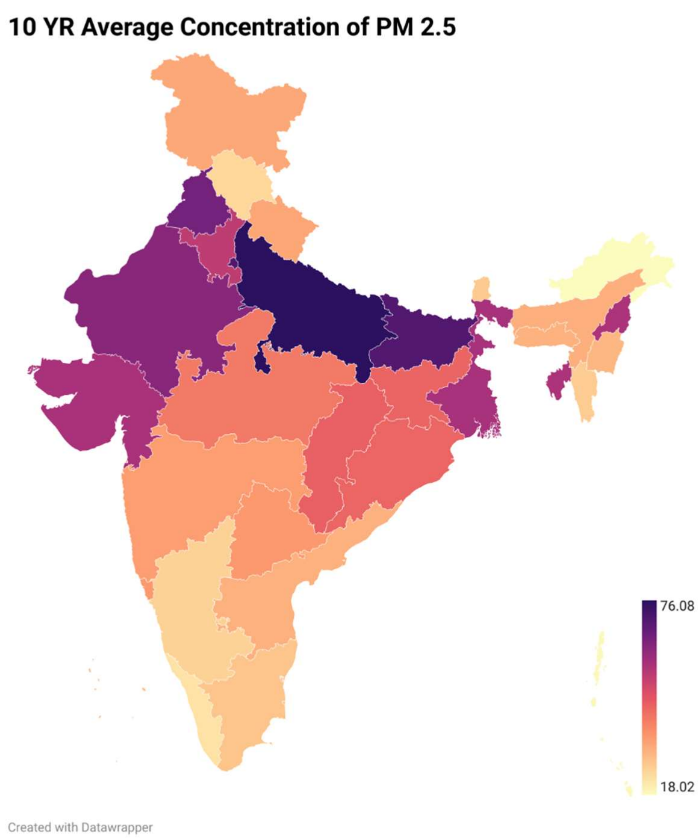

Figure 1: 10 Yr Average concentration of PM$_{2.5}$

(credits: datawrapper.de, created based on author inputs)

3.1.2. Acute Respiratory Illness

Higher short-term exposure to $PM_{2.5}$ and traffic-related pollutants are associated with increased risk of symptomatic acute respiratory infections among adults. The data is collected from the National Health Profile from the Central Bureau of Health Intelligence under the Directorate General of Health Services, Ministry of Health & Family Welfare, Govt. of India. The number of cases registered per year for Acute Respiratory Infection is denoted by 'ARI' in this study. This will be our dependent variable and will be examined to understand the health effect.

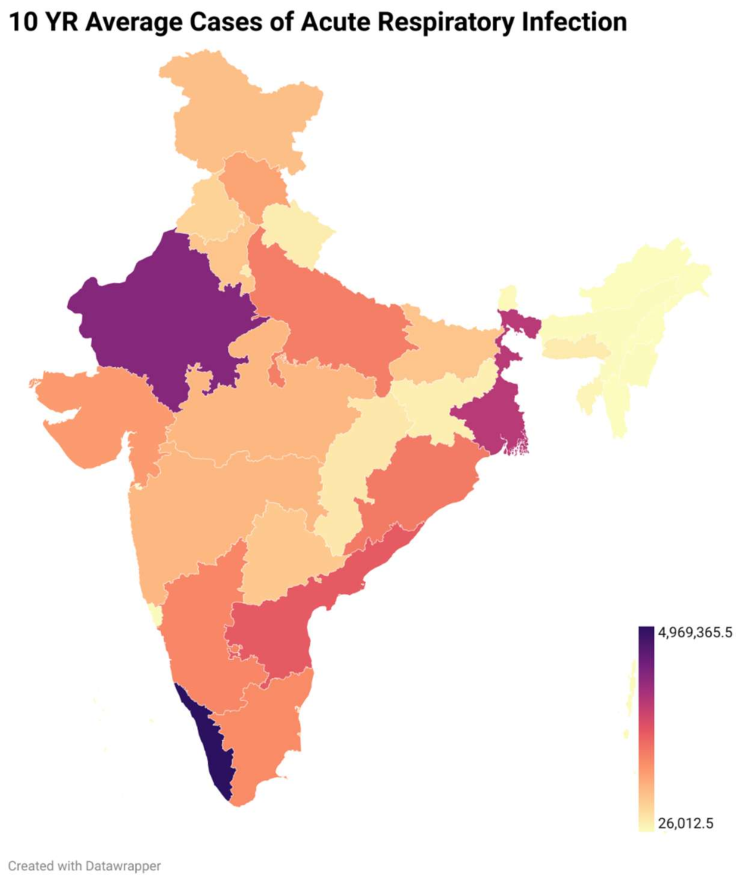

Figure 2: 10 Yr Average Cases recorded for Acute Respiratory Infection

(credits: datawrapper.de, created based on author inputs)

3.1.3. Government Health Expenditure

Government health expenditure refers to the financial resources allocated by a government for the maintenance and provision of healthcare services. This expenditure is crucial for improving health outcomes and can significantly influence economic growth and development. The data is obtained from the National Health Accounts, Ministry of Health & Family Welfare, Govt. of India. The variable is measured in Rs. Crores. And is termed as 'GHE'.

3.1.4. Transport

Rising population and economic growth has boosted the number of vehicles on the road. Transport is classified into 2 categories, transport and non-transport. Transport vehicles include Multi-axled/Articulated vehicles/Trucks & Lorries whereas non-transport vehicles include two wheelers, cars, jeeps, omni buses, tractors, trailers and others. Number of registered motor vehicles are divided as Transport vehicles and are taken as 'trans' and non-transport vehicles are taken as 'ntrans' in the study.

Public transport is the backbone for any nation. Transportation at lower costs enable people to save, reduce traffic and vehicular emissions. To analyse this effect, total number of buses from the state road transport corporations added with omni buses under the variable 'public' representing total public transport.

This data is retrieved from the Road Transport Year Book under the Ministry of Road Transport and Highways, Govt. of India.

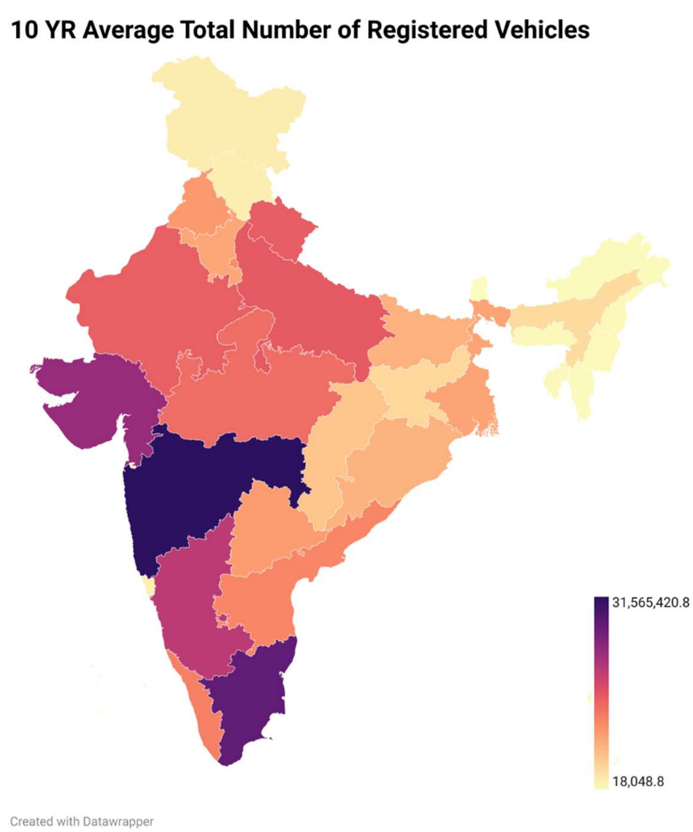

Figure 3: 10 Yr Average Total Number of Register Vehicles

(credits: datawrapper.de, created based on author inputs)

3.1.5. Weather

Weather plays a major role in the overall pollution in a state. Landlocked states have low variations in atmospheric pressure causing lower chances of wind patterns causing the pollution to stay for a long period. States with a coastal line have more influence on wind patterns (sea breeze and land breeze) causing the pollutions to disperse.

To observe the effect of weather, variables like 'rain' and 'coastal' are added. The variable 'rain' is the average annual rainfall derived from Rainfall Statistics of India released by the Meteorological Dept. of India. The 'coastal' variable is a dummy being 1 if the state has a coastal line and 0 if not and is manually given.

3.1.6. Population Density

India has become the number one country in terms of populations surpassing China recording a humongous population of 1.4 billion people. Rapidly increasing population demands more transport and economic activity rising production and consumption levels leading to an increase in pollution. To observe this effect, population density is included as 'popdens'. The population data is collected from Population Projection Estimates from the Census of India and dividing by the total land area obtained from indiastats.

3.2. Methodology

This paper aims to examine the effect of pollution levels caused by increasing number of vehicles on health. To achieve this goal, we deploy mixed effects model and a differences-in-differences model. All the variables are logged to cover the effects in a normal scale.

The dependent variable in our model is:

Acute Respiratory Infections (ARI) – representing respiratory health impacts

The independent variables include:

- pm2.5 – air pollution levels
- ghe – government health expenditure

- trans – number of registered transport vehicles
- ntrans – number of registered non-transport vehicles
- rain – annual rainfall, representing weather conditions
- popdens – population density
- coastal – a dummy variable indicating whether a state or union territory has a coastline (1 if coastal, 0 otherwise).

To examine the effects of pollution and vehicle growth on respiratory health, this study employs both **Mixed Effects Models** and **Differences-in-Differences (DiD) Analysis**.

3.2.1. Mixed Effects Model

Given the panel nature of the data, a mixed effects model is well-suited to control for unobserved heterogeneity between entities (states and union territories) and across time. The model incorporates random intercepts to capture state-level variations that are not accounted for by the independent variables, allowing us to estimate the effects of pollution and vehicular growth on health across diverse geographic areas.

Several models will be used to arrive at various results. All the variables are logged. A basic structure of the model is given below:

Mixed effects:

Model 1:

ARI ~ pm25 + ghe + trans + ntrans + rain + popdens + coastal

Model 2:

pm25 ~ trans + ntrans + rain + popdens + coastal

Model 3:

ARI ~ pm25 + ghe + public + rain + popdens + coastal

3.2.2. Differences-in-Differences (DiD) Model

To strengthen causal inference, a Differences-in-Differences approach is employed to measure the health impact of any significant policy changes during the study period, such as the implementation of the BS VI emission standards. By comparing states or time periods with different exposure levels to this policy, DiD allows us to isolate the effect of stricter emission controls on ARI rates. The DiD model can be expressed as:

$$log(ARIit) = \alpha + \delta Policy_{it} * policy\ group + \beta X_{it} + \lambda_t + \gamma_i + u_{it}$$

where:

- $Policy_{it}$ is a dummy variable that equals 1 for periods and regions affected by BS VI standards and 0 otherwise.
- Policy group analyses the impact of the policy on the upper quantile of states highly affected by $PM_{2.5}$
- δ captures the DiD estimate, representing the impact of the policy.
- λ_t denotes time fixed effects to control for year-specific factors.
- γ_i denotes entity fixed effects, capturing time-invariant characteristics of states/UTs.
- X_{it} represents other independent variables as defined earlier.
- u_{it} is the error term.

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4. Results and Discussion

The main goal of this study was to evaluate the effect of pollution and number of vehicles on human health. A Panel model was utilised, taking periods from 2013 – 2022 into consideration. The statistical programming language R was used to estimate the panel data quantitatively. The estimation results are presented below.

4.1. Mixed Effect Models

4.1.1. Model 1

Table 3: Estimates of FE model

	Estimates	
log(pm25)	0.228993	*
	(0.119357)	
log(ghe)	-0.54754	***
	(0.068719)	
log(trans)	-0.30975	**
	(0.096369)	
log(ntrans)	0.167773	*
	(0.091633)	
log(rain)	-0.28082	*
	(0.141703)	
log(popdens)	-0.12509	
	(0.33803)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Estimates of RE model

	Estimates	
(Intercept)	15.08999	***
	(1.605049)	
log(pm25)	0.289758	*
	(0.132002)	
log(ghe)	-0.52723	***
	(0.075065)	
log(trans)	-0.04465	
	(0.100516)	
log(ntrans)	0.38588	***
	(0.096089)	
log(rain)	-0.57408	***
	(0.145397)	
log(popdens)	-0.10462	
	(0.134408)	
coastal1	0.875832	*
	(0.394088)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

ARI ~ pm25 + ghe + trans + ntrans + rain + popdens + coastal

Almost all of the variables are significant. Population density has returned insignificant in both the models and transport vehicles is insignificant in the RE model. Looking at the FE model, we have, for a 1% increase in $PM_{2.5}$ there is a 0.22% increase in the cases of ARI. A 1% increase in gov. health expenditure returns a decrease of 0.54% in the number of ARI cases. In the RE model almost most of the estimates are similar to the FE model. For a 1% increase in registrations of non - transport vehicles there is a increase in the cases of ARI by 0.38%. Intercept as turned out to be highly significant in our model.

4.1.2. Model 2

Table 5: Estimates of FE model

	Estimates	
log(trans)	0.042057	
	(0.045366)	
log(ntrans)	-0.03466	
	(0.041728)	
log(rain)	0.115249	*
	(0.066952)	
log(popdens)	0.182958	
	(0.157274)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Estimates of RE model

	Estimates	
(Intercept)	2.047853	***
	(0.556117)	
log(trans)	0.064705	*
	(0.038132)	
log(ntrans)	-0.00681	
	(0.035181)	
log(rain)	0.008768	
	(0.054444)	
log(popdens)	0.153956	***
	(0.035205)	
coastal1	-0.31199	**
	(0.097857)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

pm25 ~ trans + ntrans + rain + popdens + coastal

only rain is significant in the FE model stating that when there is 1% increase in rainfall there is an increase in pollution by 0.18% which is against our idea as the reason for taking a weather effect is because humidity or rainfall decreases pollution. In the RE model coastal shows a significant effect where presence of coast line in a state brings down pollution by 0.31%. Population density is highly significant showing a 1% increase in density increases pollution by 0.15%. intercept is also highly significant in this RE model also.

4.1.3. Model 3

Table 7: Estimates of FE model

	Estimates	
log(pm25)	-0.01274	
	(0.101442)	
log(ghe)	-0.20727	***
	(0.060515)	
log(public)	-0.08129	
	(0.069175)	
log(rain)	-0.4146	***
	(0.123514)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Estimates of RE model

	Estimates	
(Intercept)	15.29267	***
	(1.146559)	
log(pm25)	0.024545	
	(0.107393)	
log(ghe)	-0.06896	
	(0.061772)	
log(public)	0.200713	***
	(0.059702)	
coastal1	0.862381	*
	(0.368492)	
log(rain)	-0.59536	***
	(0.122804)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

ARI ~ pm25 + ghe + public + rain + popdens + coastal

FE model shows rain and gov health expenditure to be significant but not the public transport. However, in the RE model, public transport coastal and rain turns out to be significant along with the intercept. The results of the RE model states that for a 1% increase in public transport the variable indicating health outcome which ARI shows a 0.20% increase in the number of cases. The variables included to account for weather changes i.e., coastal and rain are both significant. They affect the number of cases reported indirectly by influencing pollution levels.

4.2. Differences-in-Differences (DiD) model

Table 8: Estimates of DiD model

	Estimates	
policy	-0.526144655256	***
	(0.130061659667)	
policy_group	-0.308262293248	
	(0.407841006485)	
rain	-0.000022637370	
	(0.000158946635)	
ttrans	-0.000000090845	*
	(0.000000038862)	
policy:policy_group	0.064435812428	
	(0.219267648341)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The DiD model has turned to be in favour of our study. The policy intervention here is the introduction of the Bharat Stage VI emission standards. And the policy variable has turned out to be highly significant. It states that after the introduction of the policy there has been a decrease in the health outcome variable i.e., number of cases registered due to ARI. The additional variable included in the model total transport registrations has also turned out to be significant.

5. Conclusion

Based on the panel data, we aimed to establish a relationship between the number of registered motor vehicles and public transport to increasing pollution levels and respiratory infections. Transportation has been one of the few causes for increasing pollution levels in India. By reviewing existing literature and by implementing a panel data study containing all the states and union territories of India over a period of 10 years, with the help of quantitative econometric analysis, we were able to tie the knots. We found that increasing number of vehicles does have an impact over the existing pollution levels and government expenditure on health has actually helped in bringing a positive change in the level of health effects. We have also made it significant that the weather conditions for states with coastal lines help in regulating the pollution levels than the land locked states in the interior parts of India. There are many gaps in this study which may be the time period of 10 years that might be too small or might have produced approximated judgements on the results that we have arrived or the pooling of data from various sources and different metric units may have resulted in biased results. A.K. Agarwal & N.N. Mustafi., 2020 has stated about Real-World Driving Emissions, which is true as we don’t have present time values or immediate data to determine the effects rather, we chose to use historical data to arrive at our conclusions about the pollution levels and the relationship on the health effects. Many measures and newer technologies are brought into light for the betterment of the people and the ecosystem present around. To move towards a sustainable future and to live in a country with lesser pollution levels, from our study it is possible to arrive at a conclusion that the Bharat Stage emission standards iteration VI truly paves way by bringing a decrease in the level of pollution and indirectly helping in reducing the number of cases registered due to Acute Respiratory Infection.

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