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The Descriptive Analysis of Air Pollutant Impact in Select Indian Cities

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ABSTRACT

Air pollution has significant impacts on Human Health. PM2.5 stands for Particulate Matter measuring 2.5 microns or less in diameter suspended in the air. PM2.5 can cause significant negative health impacts such as Ischemic Heart Disease (IHD), and Lung cancer. In India, 1.4 million people die each effect due to a health problem caused by air pollution. Heart disease 18,819 (2015), lung cancer 732,921 (2016) and 13% chronic obstructive pulmonary disease (COPD) are some of the major problems is observed in India. The objective of this study will be achieved using a Model estimated by ARIMA methodology. ARIMA methodology provides predicts prediction and forecasting abilities so that pollutant levels will be forecasting over time. We consider an Auto-Regressive Integrated Moving Average (ARIMA) model to explain the variability of particulate matter (PM2.5) levels across six different cities in India, using the daily observation data provided by the Central Pollution Control Board of India. Results from our model indicate that statistically significant differences exist in pollutant levels between Bangalore, Delhi, Chennai, Hyderabad, Vijayawada, and Vishakhapatnam. Seasonality in pollutant levels is also significant. Mean levels of pollutants are generally higher during winter months and lower around the monsoon season for all the south Indian cities. Results from our model could be useful for understanding and predicting the air pollutant trends and patterns of south Indian cities. The results can be of vital importance for environmental policy designs.

Keywords: Air pollution in India, ARIMA model, trends and patterns of PM2.5 levels.

INTRODUCTION

Air pollution has become a serious problem in India. Seven out of the top ten most polluted cities in the World in 2018 are Indian Cities (World Air Quality Ranking report). PM2.5 stands for Particulate Matter measuring 2.5 microns or less in diameter suspended in the air. The major sources of particulate matter pollution are combustion (vehicular emissions industry emissions, residential and commercial biomass burning) and through reactions of other airborne pollutants. PM2.5 can cause significant negative health impacts, as it can penetrate easily into the human respiratory system, affecting various organ systems. Respiratory problems such as asthma, lung cancer, and cardiovascular problems such as Ischemic Heart Disease (IHD) are some of the notable effects of PM2.5. WHO estimates that long-term risk of cardiopulmonary mortality increases by 6–13% per 10 µg/m3 of PM2.5 exposures. The Lancet Commission on Pollution and Health Reports Air pollution accounts for 1.81 out of 2.51 million deaths in India. Centre for Science and Environment (CES) estimates that more than 2.7 million people in India have died from heart disease aggravated by exposure to air pollution. The objective of this study is to estimate trends and patterns of Particulate Matter 2.5 Concentration levels in Indian cities. We estimate an Auto-Regressive Integrated Moving Average

(ARIMA) model to explain the variability of particulate matter (PM2.5) levels across various cities in India.

Air pollution has a significant effect on human health in India. Air pollutants are a long-term exposure to PM2.5 increases the Ischemic Heart Disease (IHD) mortality George D. et al (2015) Particulate matter 2.5 exposure in the first trimester of pregnancy affects gestational age at birth and increases the risk of preterm birth Hackmann (2015). Exposure to PM2.5 explains the occurrence of cardiovascular and respiratory diseases Peng et al (2008). Air pollutant levels change in accordance to the weather of any given place. It has been found that concentration levels of pollutants vary significantly in summer and between weekdays and weekends in the case of New York City DeGaetano and Doherty (2004). PM2.5 concentrations exhibit seasonality, with maximum levels in post-monsoon season and minimum levels in pre-monsoon season [Mohan and Kandya (2006), Kulshrestha and Satsangi et al (2009), SrimuruganandamBathmanabhan et al (2010), Tiwari S et al (2012). PM2.5 concentration trends rapidly increased in Delhi and other cities Pal et al (2018). Air pollutant concentration pm2.5 is the most dominant pollutant during 95% of the winter and 68% of monsoon days in New Delhi Shovan Kumar Sahu (2017). Crop stubble burning contributes to the severe pollution in Delhi H Cusworth et al (2018). PM2.5 are residential biomass fuel use for cooking and heating is the largest single sector influencing outdoor air pollution across most of India Venkataraman, C. et al (2018). Following the literature, we estimate the pm2.5 concentration levels in specific cities. PM2.5 has a significant association between PM2.5 exposure and increased risk of all-cause, cardiovascular and lung cancer mortality Zanobetti et al (2009) Lepeule et al (2012). Peters et al. (2001) In this author found that significant and independent associations between heart attack occurrence and both two-hour and twenty-four-hour PM2.5 concentrations before onset Laden et al. (2006) Pope et al. (2002) Cardiovascular and lung cancer mortality were each positively associated with ambient PM2.5 concentrations. Reduced the PM2.5 concentrations were associated with reduced mortality risk. Measurements of pm2.5, we quantify the magnitude of the influence of agricultural fire emission on surface air pollution in Delhi. Air pollution is not only a threat to public health, which affects social stability but also a bottleneck to the economic development of many places. The haze-fog pollution has negative effects on the environment, climate, human health, economic and other aspects, such as chronic diseases, respiratory and cardiac diseases, visibility reduction, damage of natural and agricultural systems and traffic accidents in the land, waterways, and air. Che, H (2013) Tao, J (2014). Diesel vehicles are the most significant impact on human health like a breathing problem, high pressure, eye irritation and even lung diseases (Dr. Indrajit Roy Chowdhury 2015). The seasonal ARIMA model provides reliable and satisfactory predictions for the air quality parameters and expected to be an alternative tool for practical assessment and justification Inderjeet Kaushik et al (2007). Monika Singh et al (2007) using the selected ARIMA models and Neural Network and then compared them to find which generally reveals its application and signifying its use as a modelling technique for determining the future values of concentration of pollutants and its use in different areas.

MATERIALS & METHODS

This study develops an econometric model using data obtained from the Central Pollution Control Board. The data spans over two-years with observations recorded on a daily basis from 2016 to 2017. A total of 169997 observations were recorded in the dataset on six cities in India. This data set organized into the database in SAS. This data has been analyzed using SAS SQL and SAS IML routines.

Descriptive statistics of the concentration of PM2.5 are presented it can be observed that the mean levels are generally higher during winter months and lower around the monsoon season for all the south Indian cities. The minimum value of 0.95 units was observed in Vijayawada during 2017 and a maximum value of 19556.16 units was observed in Bangalore during 2016 across the entire study area. The variability in pollutant levels is high in the months of July and August across all the cities. Months of January, February, and April have minimal variability in pollutant levels. Bangalore experienced good air quality for nine months from March to December. However, the month of May the air quality was moderate. Pollutant levels in Delhi are consistently higher than the rest of the cities. Delhi experienced Satisfactory (with AQI between 51 to 100) air quality in June to September and Moderate air quality (with AQI between 101 to 200) for January to May. Months of November and December experienced Poor (with AQI between 201 to 300) to Very poor (with AQI between 301 to 400) air quality. Most occurrences of Severe air quality (with AQI between 401 to 500) were observed in November. Chennai experienced Satisfactory air quality for most of the months and good air quality for July August and September months. Hyderabad experienced good air quality from May to November. Visakhapatnam and Vijayawada cities experienced good or satisfactory air quality for the most part of the year.

Vehicular exhaust is among the principal sources of PM2.5. It could be observed that the number of registered motor vehicles in India has increased steadily from year to year. The number of registered vehicles increased from 0.3 million in 1951. to 210 million in 2015. Two-wheeler vehicles account for 73.5%, while four-wheeled vehicles accounted for 13.6%. Buses account for 1% and goods vehicles to 4.4% of total registered vehicles. The total number of registered vehicles up to 2015 in respect of these cities was 66,244 thousand. Of these, Delhi (13.36%) recorded the highest number of registered motor vehicles, followed by Bangalore (8.40%), Chennai (7.45%) and Ahmadabad (5.16%), Mumbai (3.88%).

Statistical Analysis

Equation 1 shows a general regression model that can be used to estimate the concentrations of PM2.5.

$$\boldsymbol{y_t = m_t + e_t} \quad \text{………Equation 1}$$

Dependent Variable $y_t$is the PM2.5 concentration at time t and m_t is the conditional mean function or the mean value of concentrations at time t. $e_t$is the error term at time at time t which is distributed normally with mean 0 and variance of σ^2_t. Regular model simply assume that the error (σ^2_t) is stationary over time. Estimation was done in *SAS* using Base *SAS* and *SAS SQL*. An ARIMA model consists of three parameters of *p, d andq* describing the order of autoregressive (AR) Integrated (I) and moving average (MA) in the model. Since the original time series of the PM2.5 concentrations is nonstationary, its trend is captured in the model using an integer variable which starts at one for the first month and increases incrementally by one unit(microns) afterwards. Furthermore, to capture any possible seasonal pattern, eleven dummy variables representing each month are added into the model. Thus, the equation of the ARIMA model for the time series of concentration is as follow:

$$\boldsymbol{ARIMA(p,d,q) = c + \sum_{i=1}^{p} \varphi_i AR(i) + \sum_{j=1}^{q} \theta_j MA(j) + \sum_{k=1}^{11} \beta_k M_k} \quad \text{……..Equation 2}$$

Autoregressive Integrated Moving Average is calculated using the Equation 2. p is the order of AR operator. d is the number of times the data have been differenced. q is the order of the MA operator. c is the intercept. φi is the coefficient of the ith AR operator. Ɵj is the coefficient of the jth MA operator. Mk is a dummy variable which is 1 if the observation belongs to month k and zero otherwise. Bk is the coefficient of the binary variable of month k. Different models with various combinations of the p, d, and q are studied and the best model was determined based on the Akaike Information Criterion (AIC) and Schwarz's Bayesian criterion (SBC). The coefficients of the model are determined using Conditional Least Square.

RESULT

The results indicate that the ARIMA (1, 1, 1) was a better fitting model based on AIC or SBC criteria. The estimated parameter values are presented in Table 1. Models of PM2.5 for Bangalore, Chennai, and Delhi follow the same multiplicative seasonality patterns with a significant MA term (8th lag). AR1 parameters are all positive and statistically significant and are less than unity in magnitude. Parameter estimate representing the mean of PM2.5 is not statistically significant, given the differenced nature of the model. MA parameter estimates of Hyderabad and Vijayawada have 4th seasonal lag as significant and positive. MA parameter estimates of Visakhapatnam include a 12th seasonal lag. Root Mean Square errors from predictions are small in magnitude for all the estimated models.

Table 1: Conditional Least Square Estimation of ARIMA Model

Bangalore			Chennai		
Variable	Parameter Estimate	P value	Variable	Parameter Estimate	P value
MU	-0.00014	0.1334	MU	-	-
MA1,1(1)	0.77208	<.0001	MA1,1(1)	0.91179	<.0001
MA2,1(8)	0.97682	<.0001	MA2,1(8)	0.99414	<.0001
AR1,1(1)	0.343	<.0001	AR1,1(1)	0.4335	<.0001
AIC	1674.451		AIC	1841.819	
RMSE	0.389638		RMSE	0.393554	
Delhi			Hyderabad		
Variable	Parameter Estimate	P value	Variable	Parameter Estimate	P value
MU	0.10932	0.6435	MU	-5.50E-05	0.931
MA1,1(1)	0.94647	<.0001	MA1,1(1)	0.90652	<.0001
MA2,1(8)	0.46446	<.0001	MA2,1(4)	0.9142	<.0001
AR1,1(1)	0.61442	<.0001	AR1,1(1)	0.6837	<.0001
AIC	15473.4		AIC	212.361	
RMSE	79.24904		RMSE	0.351814	
Vijayawada			Vishakhapatnam		
Variable	Parameter Estimate	P value	Variable	Parameter Estimate	P value
MU	0.004065	0.1234	MU	0.000755	0.1843
MA1,1(1)	0.69566	<.0001	MA1,1(2)	0.75908	<.0001
MA2,1(4)	0.86913	<.0001	MA2,1(12)	0.8779	<.0001
AR1,1(1)	-0.87744	<.0001	AR1,1(1)	-0.33171	<.0001
AIC	359.0872		AIC	569.5488	
RMSE	0.818824		RMSE	0.381641	

CONCLUSION

This study developed a model to estimate and predict PM2.5 pollutant levels in six major cities in India, using the air pollutant monitoring data provided by the Central Pollution Control Board. ARIMA Model with seasonality using Conditional Least Squares was estimated. Pollutant levels of the current period were found to be dependent on previous period levels. Seasonality in pollutant levels is also significant. Mean levels of pollutants are generally higher during winter months and lower around the monsoon season for all the south Indian cities. Results from our model indicate that statistically significant differences exist in pollutant levels between Bangalore, Delhi, Chennai, Hyderabad, Vijayawada, and Vishakhapatnam.

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