Impact of odd-even transportation policy on Pollution level in Delhi

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Introduction:

The Delhi government implemented its odd-even scheme during November 4-15, 2019, announced by Chief Minister Arvind Kejriwal. The Odd-Even Policy is a transport rationing mechanism to control pollution levels by restricting the number of on-road vehicles per day. The aim of this policy was to reduce the number of on-road vehicles in a day by about half and thereby reducing the alarming levels of pollution in the State of Delhi.

The scheme, which has been the Aam Aadmi Party (AAP)-led government's pet project to fight air pollution in the smoke-infested Delhi, was also implemented twice in 2016(1-15, Jan 2016 and 15-30, April 2016). For two weeks, each time. In this paper I have tried to determine the impact of odd even schemes on pollution level.

Objective:

- Plot the pollutant data over time
- To note down whether peak level of pollution comes down when odd even is implemented
- To fit a model ranging from rdd and finding Kurtosis
- To find other factors which affect pollution level in Delhi

Literature review:

1)Mathur et al. analyzed the impact of odd even transportation policy and other factors on pollution level in Delhi. They took data of 5 pollutants from 9th April 2015 through 29th July 2018 of 9 different locations. They considered various factors like wind speed, average temperatures, relative humidity and rainfall; fringe factors like ban on sale of crackers, dummy for Deepawali and parallel build-up of highway for movement of trucks at the outskirts of Delhi, burning of agricultural residue in surrounding states, price of fossil fuels, spatial dependence among nine different locations of Delhi, number of CNG/electric cars plying in Delhi, number of registered public and private vehicles, among others. They used spatial regression and RDD. In this way they got the impact of odd even policy on pollution level. Data was taken from CPCB. In the end they suggested policies for reduction of pollution level like, Acid rain, Elevated road corridor, connecting different locations of Delhi with metro rail, Improving Public Transportation running on CNG, Use of alternative fuel based on Jethropha, mustard and Sarso plants, Use of Bio Fuel, Electricity run vehicles, Investment in Renewable energy, reducing industrial emissions by shifting industries out of Delhi, Improving Green cover to absorb carbon emissions, etc

2)A Conceptual Review of the Odd-Even Policy on Delhi's Urban Environment Shahan Sud and Sindhujaa Iyengar: This paper identifies existing policies and evaluates how effective these policy and management options are in sustaining ecosystem services in Delhi and harmonizing them with human needs. The scope of this paper is restricted to the Odd-Even Policy implemented by the Government of Delhi in January-February 2016, and how structural reformations and policy adjustments can be made to the same in order to make it conducive to the indigenous ecosystem services and with that of people's needs. Consequently, this paper studies whether the proposition stands or the objectives are required to be achieved through alternatives therein. The methodology of research engages in a comparative analysis of the Odd-Even policies implemented in Beijing and Delhi. The research findings are normative, and prescribe reforms to the Delhi model. Data are obtained from secondary sources.

3)Singhania, K., Girish, G.P. and Vincent, E.N. (2016) Impact of Odd-Even Rationing of Vehicular Movement in Delhi on Air Pollution Levels. Low Carbon Economy, 7, 151-160: In this study, they investigated the impact of Odd-Even rationing of vehicles plying on the roads of the National Capital city of Delhi, India on air pollution levels by considering both residential and industrial areas of Punajbi Bagh, R.K. Puram, Anand Vihar, Mandir Marg, NSIT Dwarka and Shadipur of the city and have analyzed its impact by employing event study techniques and by utilizing daily data of NO_2, SO_2, O_3, PM-10 and PM-2.5. They considered ±15 day window for their analysis to assess the impact on air pollution levels pre-odd even rationing and post-odd even rationing and has statistically investigated whether this bold move by the State Government of Delhi has helped in the reduction of air pollution levels in the city or not. With the State Government considering implementing Odd-Even rationing permanently, the present study is intended to provide insights to policy makers to make an informed decision and also facilitate in implementing future policies for controlling air pollution levels in the city.

4)EFFECT OF ODD EVEN SCHEME TO COMBAT AIR POLLUTION IN NCT OF DELHI. Aparna Katiyar, S. K. Singh and A. K. Haritash: In their paper they stated that while some reduction in air pollution is likely to happen due to odd-even scheme, a single factor or action cannot substantially reduce air pollution levels in Delhi. Therefore, a comprehensive set of actions following an integrated approach is required to make substantial improvement in air quality.

5)The Good and Bad of 'Odd-Even Formula': Case Study of Delhi and Alternative Measures towards Sustainable Transport Aanchal Airy and Jyoti Chandiramani: This present paper attempts to showcase the different angles on the odd-even formula and its repercussion in the city of Delhi; challenges faced and would suggest innovative solutions from across the world
to reduce vehicular pollution and to provide a sustainable network of transport system to converge to the goals of sustainable development.

Data source:

Daily data from the website of office of **CPCB** of pollutants like $CO2$, CO, $SO2$, NO, pm-10 For data please see - **Appendix**

Software used:

Stata version 13

Commands used:

edit

summarize

var_name

summarize

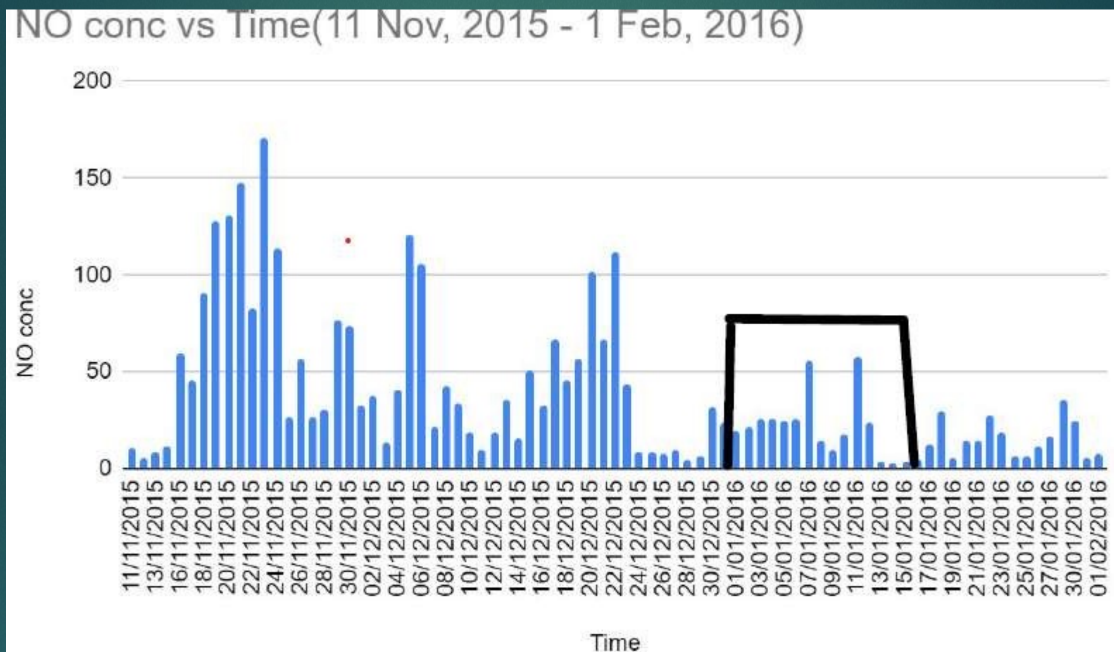
var_name, detail

regress dependent_var ind_var#1 ind_var#2 ind_var#3

Finding Kurtosis of pollutant level during odd-even scheme's implementation

First phase: January 1-15, 2016

NO (Nitric Oxide):



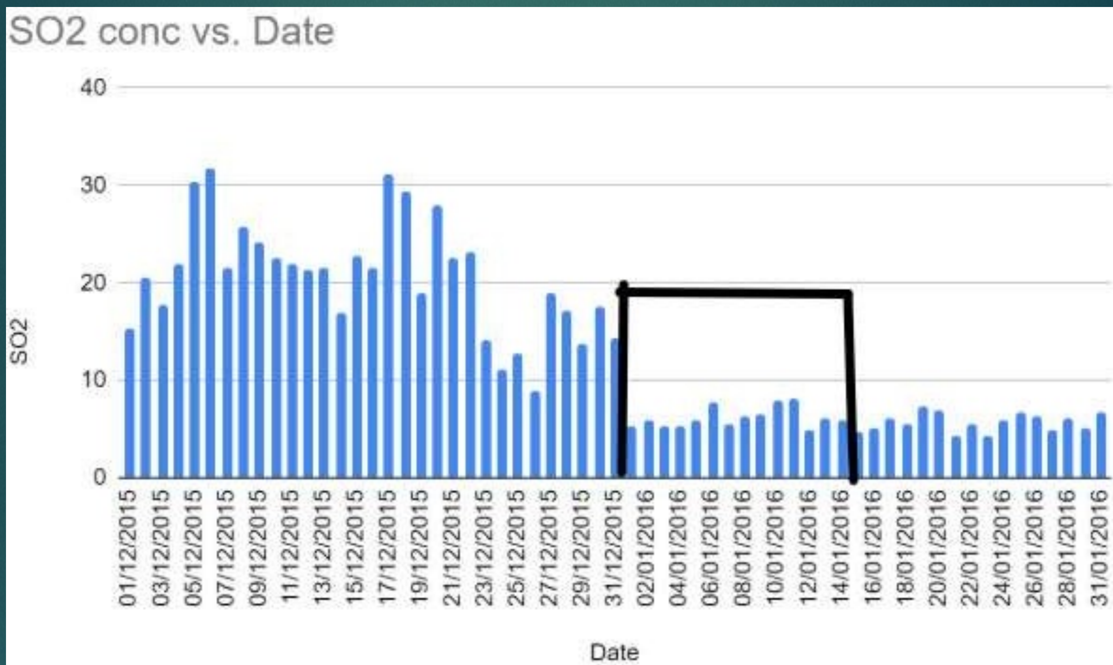
Marked region denotes the time of odd-even scheme implementation

Various parameters during scheme are below:

	Percentiles	Smallest		
1%	2.81	2.81		
5%	2.81	3.42		
10%	3.42	3.55	Obs	15
25%	9.48	9.48	Sum of Wgt.	15
50%	21.56		Mean	21.91733
		Largest	Std. Dev.	16.38059
75%	25.33	25.33		
90%	55.63	25.69	Variance	268.3237
95%	57.87	55.63	Skewness	1.05865
99%	57.87	57.87	Kurtosis	3.566232

So the **Kurtosis** of NO conc. during implementation of odd even, first time in 2016 is: **3.567**

SO_2:



Marked region denotes the time of odd-even scheme implementation

Various parameters during scheme are below:

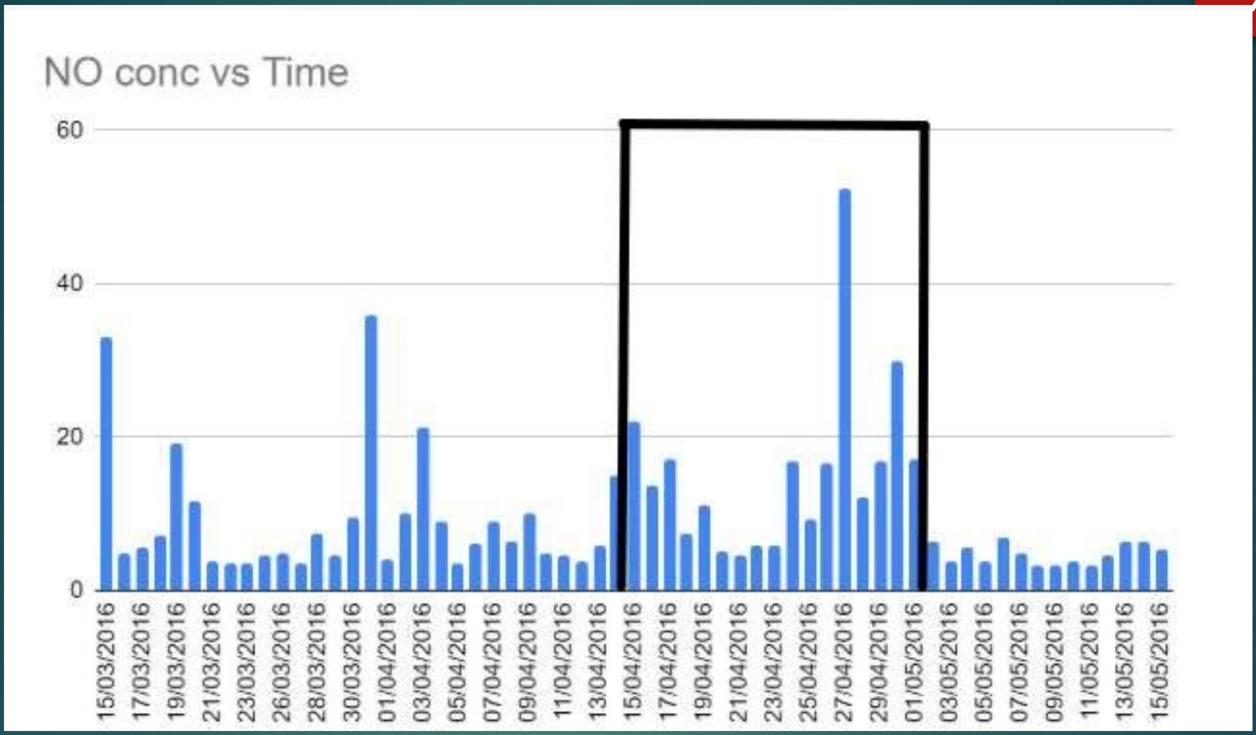
The **Kurtosis** of SO_2 conc. during implementation of odd even, 1st time in 2016 is: **2.385**

var1

	Percentiles	Smallest		
1%	4.6	4.6		
5%	4.6	4.82		
10%	4.82	5.24	Obs	15
25%	5.29	5.29	Sum of Wgt.	15
50%	5.9		Mean	6.07
		Largest	Std. Dev.	1.053206
75%	6.59	6.59		
90%	7.83	7.67	Variance	1.109243
95%	8	7.83	Skewness	.6479491
99%	8	8	Kurtosis	2.384856

Second phase: April 15-30, 2016

NO concentration:



Marked region denotes the time of odd-even scheme implementation

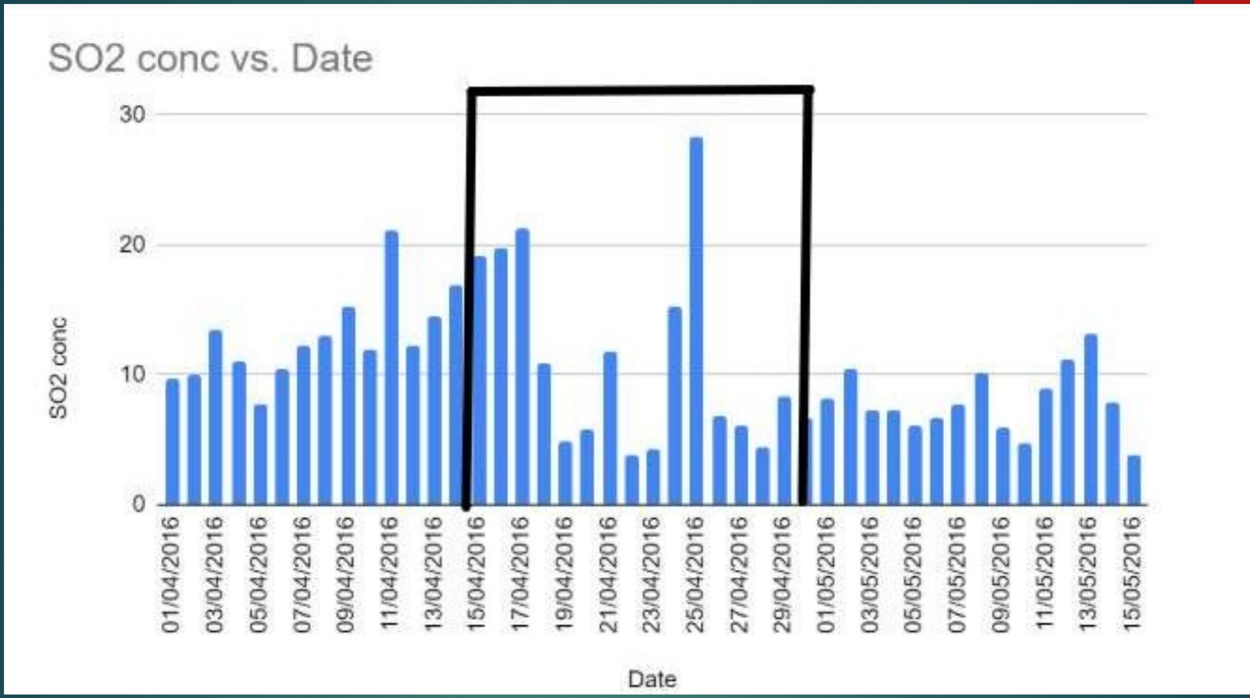
Various parameters during scheme are below:

The **Kurtosis** of NO conc. during implementation of odd even, 2nd time in 2016 is: **6.683**

var1

	Percentiles	Smallest		
1%	4.5	4.5		
5%	4.5	5.05		
10%	5.05	5.85	Obs	16
25%	6.725	5.98	Sum of Wgt.	16
50%	12.875		Mean	15.39937
		Largest	Std. Dev.	12.03806
75%	16.92	17.04		
90%	29.83	22.16	Variance	144.915
95%	52.43	29.83	Skewness	1.939047
99%	52.43	52.43	Kurtosis	6.682883

SO_2:



Marked region denotes the time of odd-even scheme implementation

Various parameters during scheme are below:

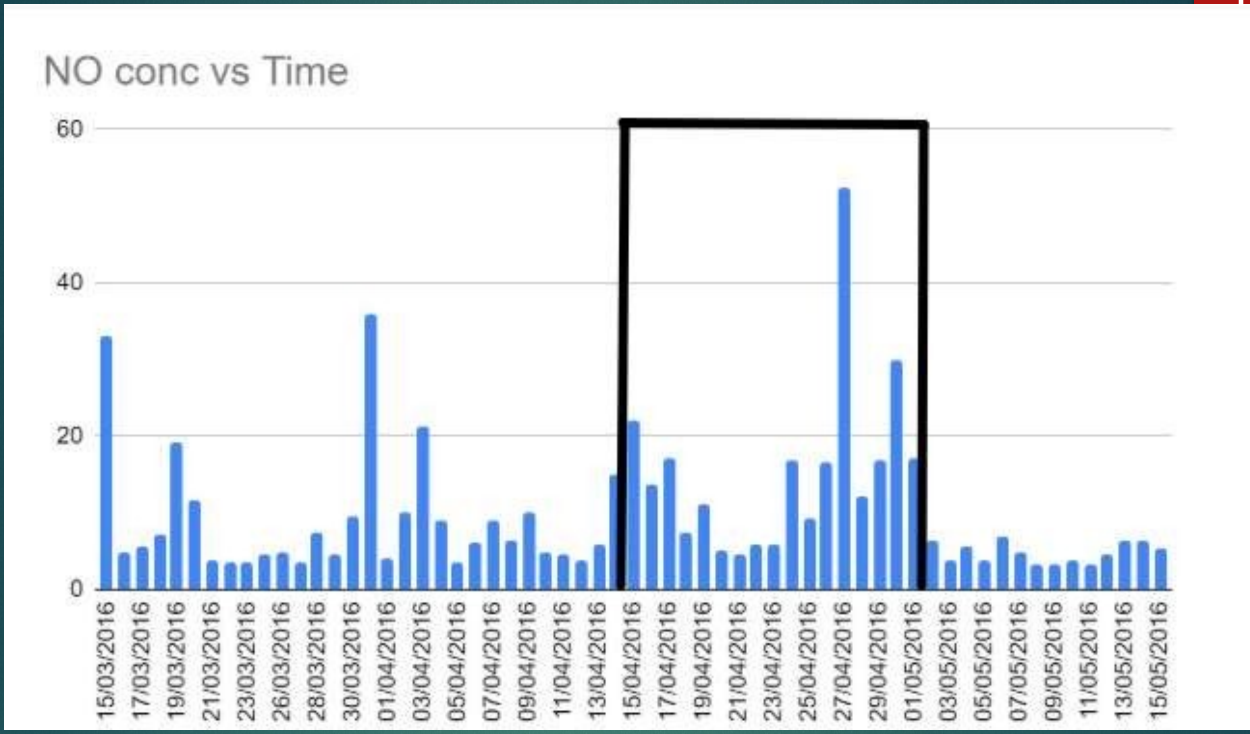
So the **Kurtosis** of SO_2 conc. during implementation of odd even, 1st time in 2016 is: **2.72**

var1

	Percentiles	Smallest		
1%	3.75	3.75		
5%	3.75	4.31		
10%	4.31	4.4	Obs	16
25%	5.32	4.94	Sum of Wgt.	16
50%	7.645		Mean	11.10187
		Largest	Std. Dev.	7.488057
75%	17.225	19.23		
90%	21.23	19.73	Variance	56.07099
95%	28.37	21.23	Skewness	.9388604
99%	28.37	28.37	Kurtosis	2.722986

3rd phase: November 4-15, 2019

NO conc.:



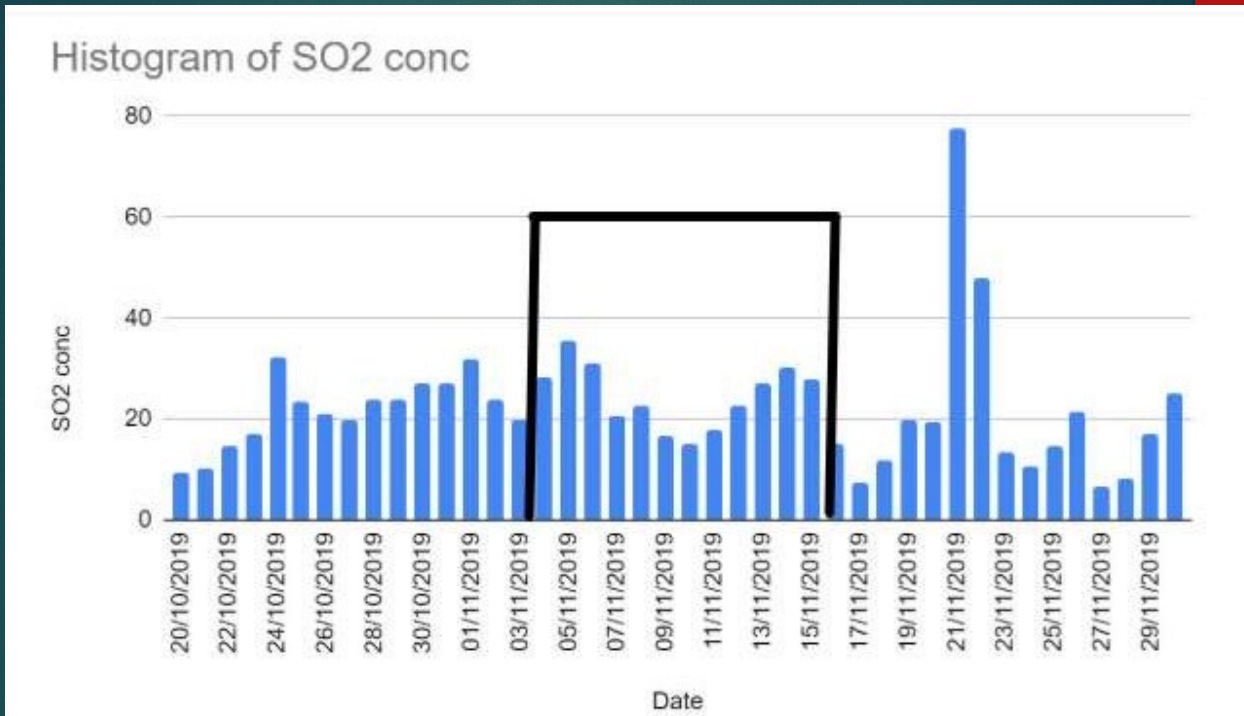
Marked region denotes the time of odd-even scheme implementation

Various parameters during scheme are below:

The **Kurtosis** of NO conc. during implementation of odd even, 3rd time is: **4.796**

		var1		
	Percentiles	Smallest		
1%	9.29	9.29		
5%	9.29	11.58		
10%	11.58	11.99	Obs	12
25%	12.765	13.54	Sum of Wgt.	12
50%	15.005		Mean	19.68583
		Largest	Std. Dev.	11.16126
75%	24.95	23.64		
90%	30.29	26.26	Variance	124.5738
95%	48.74	30.29	Skewness	1.591715
99%	48.74	48.74	Kurtosis	4.795191

SO_2:



Marked region denotes the time of odd-even scheme implementation

Various parameters during scheme are below:

The **Kurtosis** of SO_2 conc. during implementation of odd even, 3rd time is: **1.92**

var1

	Percentiles	Smallest		
1%	14.98	14.98		
5%	14.98	16.46		
10%	16.46	17.89	Obs	12
25%	19.22	20.55	Sum of Wgt.	12
50%	24.79		Mean	24.54667
		Largest	Std. Dev.	6.356677
75%	29.225	28.34		
90%	31.1	30.11	Variance	40.40734
95%	35.34	31.1	Skewness	.0113934
99%	35.34	35.34	Kurtosis	1.919477

Fitting Model through Regression:

The following equation is used to describe the relation of each pollutant with the policy parameter:

$Y_{it} = \Theta + \rho D_{t} + \varepsilon_{it}$

Final equation without any polynomial terms will be:

$$Y_{it} = \alpha + \rho_0 oddevenrule + \beta_1 rainfall + \beta_2 windspeed + \beta_3 avgtemp + \beta_4 rh + \beta_5 highway + \beta_6 crackerban + \beta_7 petrol + \beta_8 diessel + \beta_9 agriresidual + \beta_{10} electriccar + \beta_{11} privatevehicles + \beta_{12} Publicvehicles + \varepsilon_{it}$$

The various independent variables will be like:

- Relative Humidity (%)
- Temperature(C)
- Wind Speed(m/s)
- Dummy for odd-even scheme

On regressing the pollutant data with the independent variables, following result is obtained:

. regress conc Humidity temp windspeed

Source	SS	df	MS
Model	61229.4001	3	20409.8
Residual	586260.656	1225	478.580128
Total	647490.056	1228	527.272033

Number of obs =	1229
F(3, 1225) =	42.65
Prob > F =	0.0000
R-squared =	0.0946
Adj R-squared =	0.0923
Root MSE =	21.876

conc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Humidity	.0235894	.0334877	0.70	0.481	-.0421102	.0892891
temp	-.3807286	.0980578	-3.88	0.000	-.5731085	-.1883488
windspeed	-13.57858	1.591776	-8.53	0.000	-16.70148	-10.45567
_cons	41.32941	3.743764	11.04	0.000	33.98451	48.67431

Final Equation -

$\boldsymbol{Y_{it} = 41.32 - 13.58 * windspeed - 0.38 * avgtemp + 0.024 * rh + \varepsilon_{it}}$

Where,

Y_{it}: Pollution level rh: relative humidity

Regression with a dummy:

On regressing the pollutant data with the independent variables and odd-even dummy, following result is obtained:

```
. regress conc1 humidity temp wind_speed oe_dummy
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Source	SS	df	MS
Model	61728.3174	4	15432.0793
Residual	585761.739	1224	478.563512
Total	647490.056	1228	527.272033

Number of obs =	1229
F(4, 1224) =	32.25
Prob > F =	0.0000
R-squared =	0.0953
Adj R-squared =	0.0924
Root MSE =	21.876

conc1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
humidity	.0229684	.0334927	0.69	0.493	-.042741	.0886778
temp	-.387127	.0982561	-3.94	0.000	-.579896	-.1943579
wind_speed	-13.68861	1.595393	-8.58	0.000	-16.81862	-10.5586
oe_dummy	-6.520156	6.385773	-1.02	0.307	-19.04843	6.008118
_cons	41.71395	3.762595	11.09	0.000	34.3321	49.0958

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Final Equation with odd-even dummy is:

Y_{it} = 41.71 - 6.52*Odd_even - 13.68*$windspeed$ - 0.38*$avgtemp$ + 0.023*rh + ε_{it}

Where,

Y_{it}: Pollution level rh: relative humidity

Results and policy conclusion:

In its **introductory phase**, the odd-even scheme proved to be a successful measure in curbing air pollution in Delhi. During this time, Delhi experienced the lowest pollution peaks compared to previous high smog episodes in the winter.

This reduction in pollution was visible despite hostile weather conditions — no wind, temperature dip and western disturbance.

Particulate matter and nitrogen oxide load from cars reduced while the scheme was operational. The impacts were not just limited private vehicular emissions. There were ancillary benefits as well. During those 15 days, lower road congestion led to a more efficient functioning of public transport.

There is a direct correlation between congestion and pollution as congestion lowers fuel efficiency. Road rationing led to higher bus speeds.

The sale of petrol and diesel also dropped by 4.7 per cent and 7.8 percent respectively between December 2015 and January 2016. This is another indicator of reduced pollution levels.

There was reduction in the rate of improvement of air quality after the scheme ended.

The **second phase** saw some counter-intuitive trends. Air pollution levels tanked during the first nine days but then saw an unprecedented rise from April 22..

During the 2nd phase particulate matters of size pm 2.5 and pm10 increased. Later, automobile companies used this analysis in a Supreme Court hearing to argue against stringent actions imposed on the automobile industry, reasoning that vehicles are an insignificant contributor to pollution.

Using National Aeronautics and Space Administration satellite imagery, it was found a sudden spike in crop fires in Punjab and Haryana from April 21.

Even though the wind speed was conducive for low pollution levels, a sudden spurt in these fires along with **garbage burning** at Bhalswa garbage dump led to abnormally high levels of particulate matter.

The third phase we can see there are very uncertain changes in the concentration of SO_2 and NO, which shows the scheme didn't give results as expected.

Policy Suggestions:

- Addressing infrastructural and policy issues are instrumental in making the odd-even scheme a success.
- Public transport in Delhi assumes a major role when it’s operational. According to a directive issued by the Supreme Court, Delhi needs 11,000 buses and it has around 5,500.
- The operating time of the scheme needs to be 24 hours instead of the current 8-to-8 system, which incentivizes commuters to reschedule their travels defeating the purpose of the idea itself.
- Prices of public transport need to be made negligible, it should provide last-mile connectivity and availability also needs to improve.
- The scheme needs to be introduced in coordination with the Uttar Pradesh and Haryana governments to combat traffic confusion.
- Including two-wheelers in the scheme will also be a welcoming step, but it will increase the pressure on the already overburdened public transport.
- The odd-even scheme should be treated as an emergency measure and should be implemented for not more than three to four days.

References:

1)Mathur et al. (2019), "The impact of odd even transportation policy and other factors on pollution in Delhi: A spatial and RDD analysis," ARTNeT Working Paper Series, No. 182, March 2019, Bangkok, ESCAP.

2)Central Pollution Control Board, 2003, Parivesh Newsletter, Transport Fuel Adulteration. 3)Central Pollution Control Board (CPCB),(1999), Parivesh Newsletter 6 (1), Delhi.

4)Singhania, K., Girish, G.P. and Vincent, E.N. (2016) Impact of Odd-Even Rationing of Vehicular Movement in Delhi on Air Pollution Levels. Low Carbon Economy, 7, 151-160.

5)Effect of ODD EVEN SCHEME to combat air pollution in NCT OF DELHI. Aparna Katiyar , S. K. Singh and A. K. Haritash

6)The Good and Bad of 'Odd-Even Formula': Case Study of Delhi and Alternative Measures towards Sustainable Transport Aanchal Airy and Jyoti Chandiramani

7)A Conceptual Review of the Odd-Even Policy on Delhi's Urban Environment Shahan Sud and Sindhujaa Iyenga

Appendix:

CO data:

Jan, 1-15, 2016:

var1

	Percentiles	Smallest		
1%	.45	.45		
5%	.45	.46		
10%	.46	.48	Obs	15
25%	.51	.51	Sum of Wgt.	15
50%	.74		Mean	.7313333
		Largest	Std. Dev.	.2270263
75%	.9	.9		
90%	1.01	.91	Variance	.051541
95%	1.19	1.01	Skewness	.3247265
99%	1.19	1.19	Kurtosis	2.113016

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April, 15-30, 2016:

. summarize var2,detail

var2

	Percentiles	Smallest		
1%	.6	.6		
5%	.6	.68		
10%	.68	.7	Obs	16
25%	.725	.72	Sum of Wgt.	16
50%	.985		Mean	1.08625
		Largest	Std. Dev.	.4827404
75%	1.235	1.29		
90%	1.7	1.3	Variance	.2330383
95%	2.53	1.7	Skewness	1.775928
99%	2.53	2.53	Kurtosis	6.069852

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Nov, 4-15, 2019:

```
. summarize var3,detail

                            var3
-------------------------------------------------------------
      Percentiles      Smallest
 1%           .9             .9
 5%           .9           1.07
10%         1.07           1.13       Obs                  12
25%         1.16           1.19       Sum of Wgt.          12

50%        1.345                      Mean              1.365
                        Largest       Std. Dev.       .294973
75%        1.545           1.54
90%          1.6           1.55       Variance       .0870091
95%         1.98            1.6       Skewness       .4137633
99%         1.98           1.98       Kurtosis       2.726727
```

NO_2 data:

Jan, 1-15, 2016:

```
                            var1
-------------------------------------------------------------
      Percentiles      Smallest
 1%         9.43           9.43
 5%         9.43           9.45
10%         9.45          12.47       Obs                  15
25%        13.25          13.25       Sum of Wgt.          15

50%        16.59                      Mean           18.08533
                        Largest       Std. Dev.      6.569687
75%        25.22          25.22
90%        27.68          25.57       Variance       43.16078
95%        30.79          27.68       Skewness       .5267811
99%        30.79          30.79       Kurtosis       2.194752

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April, 15-30, 2016:

var2

	Percentiles	Smallest		
1%	13.48	13.48		
5%	13.48	14.82		
10%	14.82	15.48	Obs	16
25%	18.085	17.92	Sum of Wgt.	16
50%	23.025		Mean	23.30062
		Largest	Std. Dev.	6.744654
75%	28.06	29.8		
90%	30.97	30.39	Variance	45.49035
95%	38.32	30.97	Skewness	.4844743
99%	38.32	38.32	Kurtosis	2.697322

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Nov, 4-15, 2019:

var3

	Percentiles	Smallest		
1%	35.62	35.62		
5%	35.62	36.03		
10%	36.03	36.83	Obs	12
25%	39.615	42.4	Sum of Wgt.	12
50%	49.43		Mean	49.01333
		Largest	Std. Dev.	11.56392
75%	53.705	53.21		
90%	61.52	54.2	Variance	133.7243
95%	75.3	61.52	Skewness	.8259724
99%	75.3	75.3	Kurtosis	3.264909

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Table for **Kurtosis** of pollutant data during odd- even implementation:

Odd-Even Time	Kurtosis value(NO)	Kurtosis value(SO_2)	Kurtosis value(CO)	Kurtosis value(NO_2)
Jan, 1-15, 2016	3.567	2.38	2.11	2.195
April, 15-30, 2016	6.68	2.72	6.07	2.697
Nov, 4-15, 2019	4.796	1.92	2.73	3.26

Data links:

Filtered Data:

https://docs.google.com/spreadsheets/d/1MYeH7dAWh9Rgrq_cS4mRRYG-zOOYEo_X4RMFbxXntEU/edit?usp=sharing

It contains following variables:

Pollutant

Conc.[ug/m-cube]

Humidity(%)

Temp(C)

Wind Speed(m/s)

SO_2 conc. With date:

https://docs.google.com/spreadsheets/d/11L1I84UqQhHuWBOVI6JWCDUFpCkVkTr-_TSfgJqwN_Tw/edit?usp=sharing

NO conc. Data with time:

https://docs.google.com/spreadsheets/d/1_r1LECZE4ACvjYbt8VKLz-_si9gZtyxG8_dJiOPtBDs/edit?usp=sharing

Source of Data:

http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria.aspx - CPCB