How do Covid-19 improve the air quality in China?

Abstract

Covid-19 has severely affected the social and economic activities among all human beings, and because of that, different scholars have been endeavoring in various studies to study the virus and its impact on different areas. As one of the fundamental factors for human living, air quality draws attention from scholars. However, the relationship between air quality and Covi-19 is still under research due to the virus' continuity and time limits. Thus, this study aims to investigate the impact of Covid-19 on air quality in China by incorporating a rich data set from Github. We studied cross-provinces data set for 27 provinces before and after Covid-19, which provides further evidence for the impact of Covid-19 on air quality. It is found that the air quality index (AQI) and the concentrations of PM2.5, PM10 and SO2 declined 21%, 23%, 31% and 14% respectively when the lockdown period began (after 26th January of 2020). The improvement of air quality was strongly related to the government emergency response during this pandemic. Results indirectly demonstrated the relative importance of social activities on air quality, providing some insights with policymakers so that they can take this insight into account in dealing with air quality issues in the future.

Introduction

Since the start of 2020, the contagion of Covid-19 has been substantially widespread among a lot of countries worldwide. In order to prevent the further harm of the pandemic on the lives of citizens, many countries had enacted different stringent protocols in order to contain the spread of such a virus right after the emergence of cases, no matter if it is in the area of mobility across inland and outland, stay-home protocols or personal behaviour (mandatory mask-wearing) (鄔偉傑,2015).

However, other than the livelihoods and economic activities that had been negatively impacted drastically, we would like to carry out our interest on how Covid-19 had affected the air quality during the time of lockdown as this is also another main matter that affects millions of people worldwide. For countries like China, as one of the fastest-growing countries in the world, the air pollution condition has been increasingly concerning at the same speed with its economic development(Guo et al., 2004). By comparing the differences among provinces under covid-19, we can know how different levels of the halt on economic activity or social activity affects the air quality in daily life. Thus, the main purpose of this study is to identify the causal effect between air quality and Covid-19 by involving R and Python to analyze the relevant data set, and most importantly, draw insight.

Research Background and literature review

Since the outbreak of covid-19, scholars have been studying the related issues. Specifically, the linkage between air quality and covid-19 draws great attention in academics. Existing literature delved into the impact of covid-19 on air pollutants across countries or cities from a global or national-specific perspective. Focusing on air quality changes within the nation, Berman and Ebisu (2020) pointed out that air quality improved in the United States by comparing the county level differences. Similarly, Brodeur et al.(2020) concluded that covid-19 decreased the level of air pollution owing to the safe home policy in the United States. Both results are consistent with what He et al. (2020) found in their paper, in which they investigated the air quality changes by comparing warm and cold regions in China across times and found there is a causal relationship between covid-19 and air pollution. All of these studies employed the Difference in difference(DID) method regarding city changes within a nation. Furthermore, Dang and Trinh (2021) explored the impact of covid-19 on air pollution for 164 countries on a global scale while Lenzen et al. (2020) only look for 38 countries and Venter et al. (2020) studied for only 34 countries. The difference among their study is that Dang and Trinh (2021) used the regression discontinuity design approach (RDD) while others took the DID method, and the measurement of air quality also differs a bit across their models due to different considerations. In the literature of air quality, the measurement of air quality generally includes PM10, PM2.5, and NO2, CO, SO2 and O3 (Zeger et al., 2000; Cross et al., 2000). However, for the study in the context of covid-19, difference combinations are selected. For example, Dang and Trinh (2021) only focus on NO2 and PM2.5 while Briz-Redón and his colleagues (2021) studied CO, SO2, PM10, O3 and NO2. Considering the importance of AQI in the context of China (Xue et al., 2019), we also add this item in measuring air quality while keeping PM2.5, PM10 and SO2. It is believed that including more related items for the measurement of air quality can provide more information for our analysis and make a small difference compared to the existing literature regarding the situation in China (Almond et al., 2020). To sum up, covid-19 improved the air quality is the common consensus from these studies although very few researchers have counter opinions(e.g. Almond et al., 2020; Briz-Redón et al., 2021).

However, to the best of our knowledge, no research compared differences among all provinces in China. Given that China is known as the " World Factory " having a serious issue in air pollution and the up to date evidence has shown that it is the center of the outbreak, we believed that exploring the difference among provinces within China can fill the research gap by providing more information for the accumulation of knowledge in the covid-19 and air quality issues and also enriching the understanding on the relationship between them. As within-nation analysis on this issue tends to employ the DID approach, and we found RDD should be more comprehensive and suitable for our research based on the discussion of Dang and Trinh (2021) in their paper. Thus, regarding previous research and the proven relationship between air quality and covid-19, this research will apply the RDD method using all provinces' data to compare the before covid and after covid air quality in China.

Methodology

Based on Dang and Trinh (2021)'s paper, we apply the Regression Discontinuity Design(RDD) in the Time model in order to avoid the omitted variable bias caused by the difference between cities' policies. Benefitting from taking COVID-induced lockdowns as an exogenous variable, we can compare the air quality metrics before and after the policy shock.

Before we implement the experiment to test our hypothesis, the defined variables and the model for this research were identified. The model is shown as follows:

$$A_{it} = \sigma L_{it} + f(d_{it}) + \mu_i + \pi_t + \varepsilon_{it}$$

where **A_it** is the outcome that measures air quality including **PM10, PM2.5, SO2 and AQI**, **i** represents a specific element and **t** stands for the time period. **L_it** is the treatment act as a dummy variable, equals 1 after the policy shock and 0 otherwise. **d_it** denotes the days from the lockdown dates. For **f(d_it)**, it represents 4 functions we use to test the linearity of the regression, including (1) the linear model (**dit**), (2) the interaction term (**L_it*d_it**), (3) the quadratic model (**d_it**^2), (4), the quadratic model of the interaction term (**L_it*d_it**^2). μ_i and **π_t** represent the fixed effects as the province fixed effect and time fixed effect. ε_it is the error term. Although the RDD estimates the Local Average Treatment Effect and the bandwidth interval was not crucial so long as it covers the before and after period around the threshold, our optimal bandwidths were obtained regarding the Imbens and Kalyanaraman (2012) 's data-driven selection procedures.

To get the research results, R and Python are mainly used in this study. The data was obtained from Github incorporating 27 provinces in China. We first cleaned the data before running the RDD. Some missing data appeared for some variables in the original data set, which accounted for less than 5%. Considering the weight of missing data, we used the average mean to replace the missing value instead of deleting them.

Data Collection

We have collected the city-level daily concentrations of three pollutants (PM2.5, PM10 and SO2) and AQI for 27 provinces of China from China National Environmental Monitoring Centre (CNEMC)'s daily air quality readings of local monitoring stations from January 1, 2020, to December 31, 2020.
Also, for the province name (including Chinese and English names of the provinces included), we have collected these from China's Custom website.

Results and discussion

By using a panel dataset, the impact of city lockdown on air quality levels in China was investigated. The result suggests that there is a strong relationship between the stringency of lockdown level and air pollutant emissions.

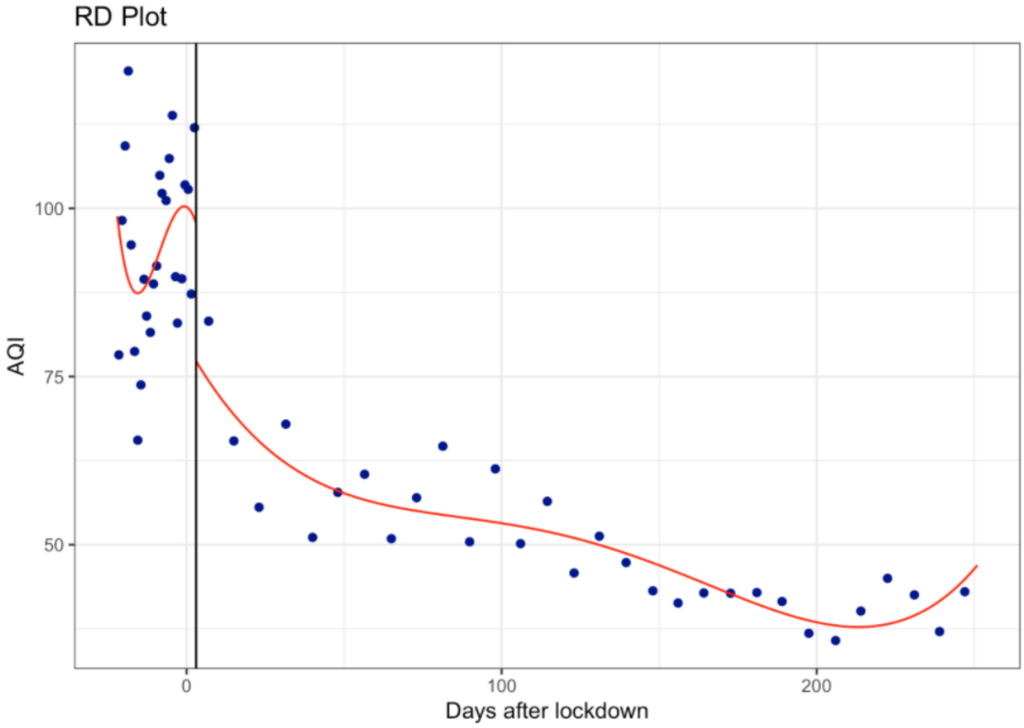
	Dependent variable:							
	AQI		PM2.5_24h		PM10_24h		SO2_24h	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
treatment	17.972	-14.833***	-2.933	-12.261***	26.558**	-9.087***	6.507***	-3.578***
	(11.449)	(1.984)	(8.819)	(1.527)	(12.396)	(2.148)	(1.849)	(0.321)
	t = 1.570	t = -7.477	t = -0.333	t = -8.027	t = 2.142	t = -4.231	t = 3.520	t = -11.154
	p = 0.117	p = 0.000	p = 0.740	p = 0.000	p = 0.033	p = 0.00003	p = 0.0005	p = 0.000
threshold	-2.037***	-0.162***	-0.680	-0.147***	-2.202***	-0.164***	-0.594***	-0.017***
	(0.645)	(0.005)	(0.496)	(0.003)	(0.698)	(0.005)	(0.104)	(0.001)
	t = -3.161	t = -35.743	t = -1.371	t = -42.150	t = -3.155	t = -33.369	t = -5.704	t = -23.315
	p = 0.002	p = 0.000	p = 0.171	p = 0.000	p = 0.002	p = 0.000	p = 0.000	p = 0.000
treatment:threshold	1.875***		0.533		2.038***		0.577***	
	(0.645)		(0.497)		(0.698)		(0.104)	
	t = 2.909		t = 1.074		t = 2.920		t = 5.539	
	p = 0.004		p = 0.283		p = 0.004		p = 0.00000	
Constant	54.501***	87.317***	50.065***	59.396***	44.695***	80.352***	4.621**	14.710***
	(11.431)	(1.854)	(8.805)	(1.427)	(12.376)	(2.007)	(1.846)	(0.300)
	t = 4.768	t = 47.096	t = 5.686	t = 41.612	t = 3.611	t = 40.029	t = 2.504	t = 49.068
	p = 0.00001	p = 0.000	p = 0.000	p = 0.000	p = 0.0004	p = 0.000	p = 0.013	p = 0.000

Graph 1.

As defined by the scholars, a high level of AQI is associated with bad air quality, in other words, the higher the AQI, the worse the air quality. As shown in Graph 1, Column(1), Column(3), Column(5) and Column(7) are the regression with interaction of treatment and threshold while Column(2), Column(4), Column(6) and Column(8) don't consider interaction. Generally, the p-value of Column(1), Column(3), Column(5) and Column(7) are larger than that of Column(2), Column(4), Column(6) and Column(8) which shows the regression without interaction term is more statistically significant, showing a better relationship.

Secondly, Column(2) of Graph 1 illustrates, in the presence of the lockdown period, AQI decreased by around 14.83 units ($p<0.05$), showing the improvement of air quality during that period. Moreover, PM2.5, PM10 and SO2 levels are improved by 12.26 units($p < 0.05$), 9.09 units($p < 0.05$) and 3.58 units($p < 0.05$) respectively, which means the lockdown policy bring on positive impact on air pollution in general.

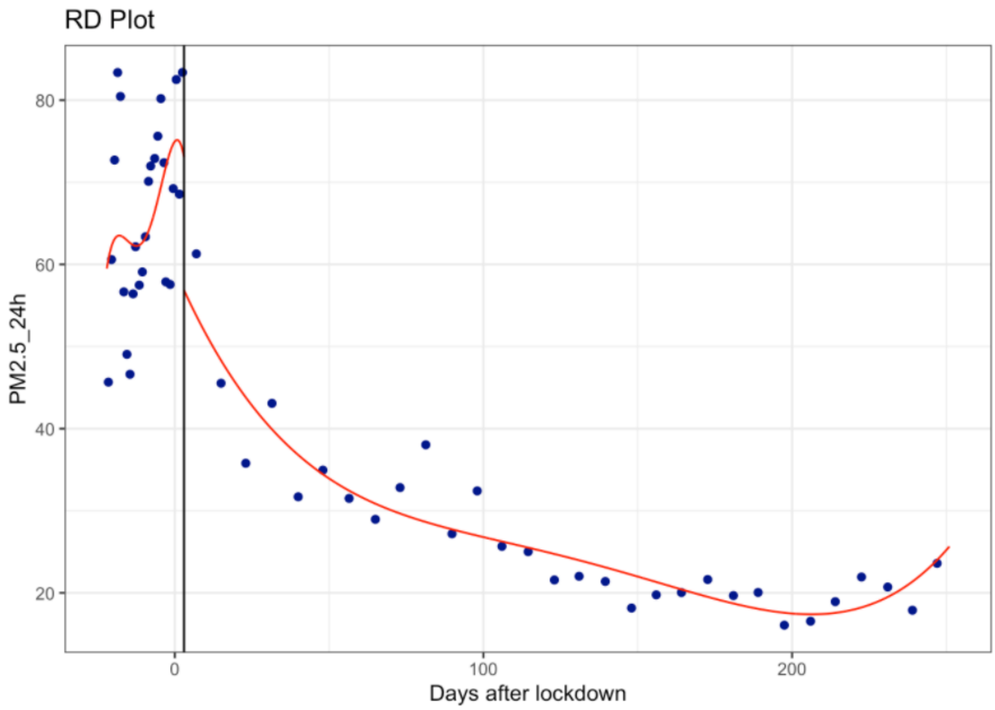
[1] “Mass points detected in the running variable.”



Graph 2

Furthermore, from the above Graph 2, it can be seen that AQI($p < 0.05$) decreased by around 21%, showing that the air quality increased significantly.

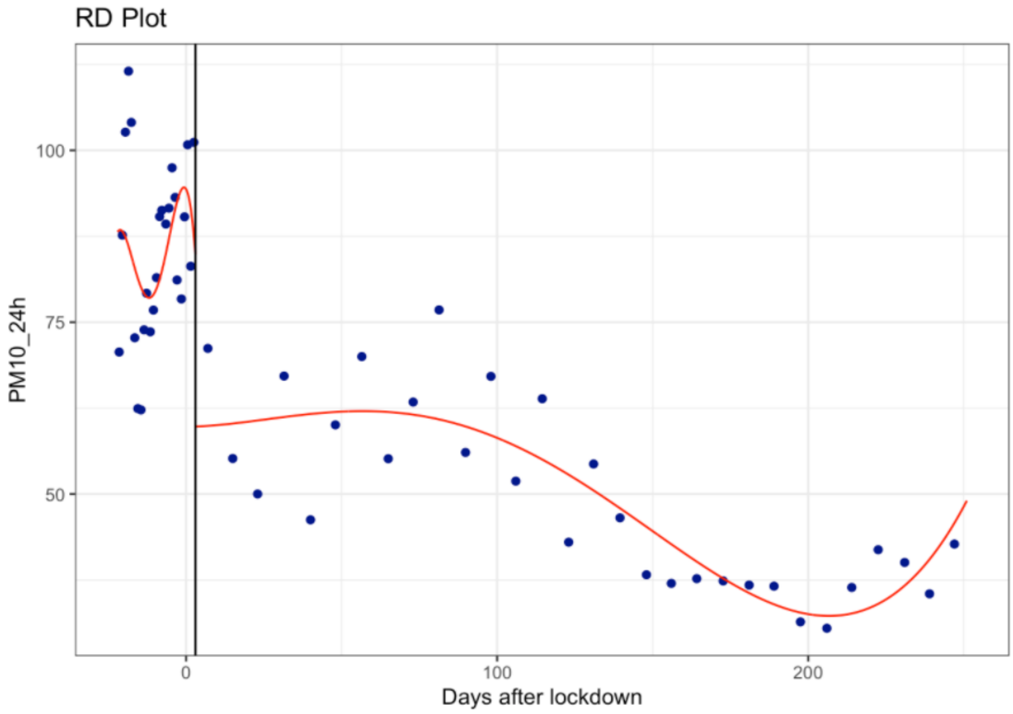
[1] “Mass points detected in the running variable.”



Graph 3

As shown in Graph 3, PM2.5($p < 0.05$) improved by around 23%, indicating that the presence of Covid-19 improved significantly via the decrease in PM2.5.

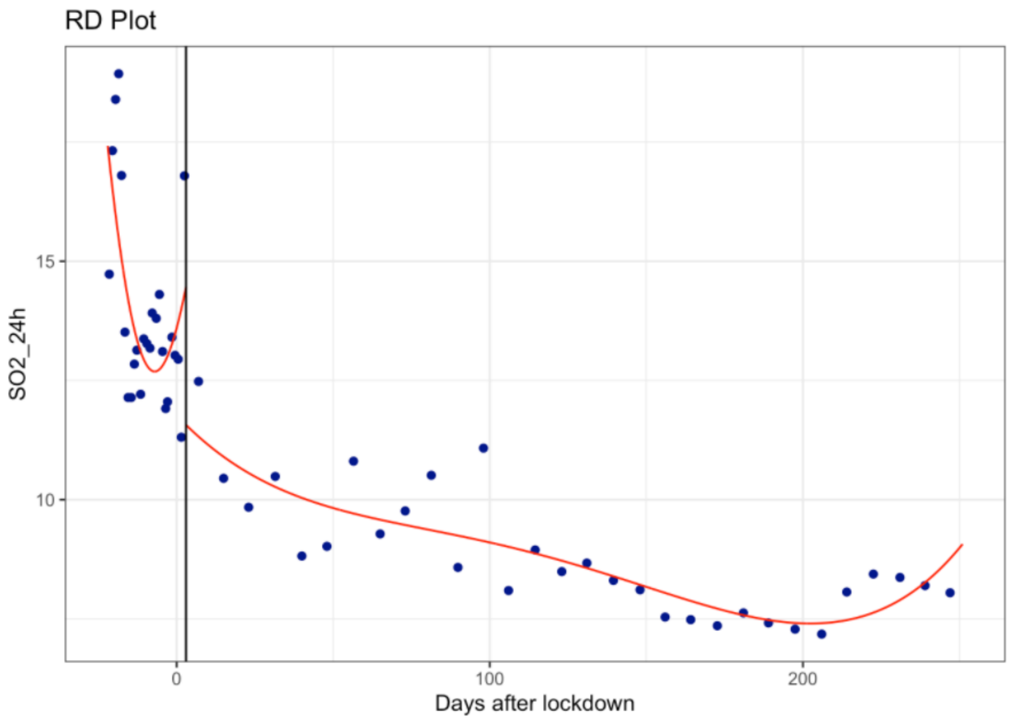
[1] "Mass points detected in the running variable."



Graph 4

From Graph 4, PM10($p < 0.05$) has the largest improvement among all air quality-related measurement items, by around 31%, portraying a significant improvement in air quality.

[1] "Mass points detected in the running variable."



Graph 5

From Graph 5, SO2($p < 0.05$) shows the least improvement, by around 14%. Such a dramatic boost in the air quality interprets there may be a positive effect on the health level of human-being in the short run. However, the air quality level dropped significantly after April/May illustrating that the operation of factories worsen the environment again.

Generally, the main reason for the results may be attributed to northern cities relying more on coal for electricity and heating. City lockdown significantly reduces people's travel needs and associated consumption of coal for power or heating, which consequently resulted in the reduction of air pollution. Based on the results, several reasons are concluded in explaining why lockdown positively correlated to air quality:

1. From the production and consumption aspect, cities rely more on coal for electricity and heating which may count as one of the main reasons for our results. City lockdown significantly dropped people's production needs and associated consumption of coal for power or heating. The decreased total

consumption of coal, which consequently resulted in the decline of air pollution levels.

2. From a human activity perspective, the stringency plan under the Covid-19 period that limited human daily activities significantly may also improve air quality. For example, traffic restrictions effectively reduced secondary particle emissions leading to the improvement of air quality during the lockdown period. Cruising taxis and online car-hailing operations across provinces and cities were also suspended.
3. From a travelling perspective, China, as a well-known tourist attraction, suspended its tourism industry during the pandemic resulting in a fundamental reduction in the flow rate of travellers. Since all citizens all over around the world have been staying in their own countries, in which substantially decreased the traffic and the consumption such as plastic bottles also indirectly decreased. Therefore, the pollutants caused by tourism overall may drop sharply.

All in all, the online data set of AQI, daily PM2.5, daily PM10 and two air pollutants on the filter observations from 1 January to 31 December 2020, were used to figure out the changes in air quality in response to the policy of COVID-19 lockdown (before lockdown, during the lockdown, and after lockdown) in China. In this study, it is found that prohibiting the production of factories, daily human activities as well as the tourism industry are seemingly the key factors for reducing the emissions of several gaseous pollutants and dropping the level of PM2.5 and PM10. Although some affected industries during the pandemic are suspended in the short run leading to the temporary improvement in air quality, the air pollutants may rebound once the industries operate normally in the long run. Therefore, readjusting the industrial and energy structure would be critical for the fundamental improvement of air quality.

Practical implications

Air pollution problems may cause large social costs such as lower productivity, sick leave, and other pressures on the health system. It also creates a huge burden to the public health system in the long run if it keeps a poor level. A better response to policy, confirmed by this paper, should involve incentives that shift economies towards a cleaner production as well as consumption of goods and services. The results provide some insight with us from the policymaking perspective. There are several suggestions that can be taken into account in making policies:

1. By setting up a pollution cost through taxes or quota prices, it can incentivize innovation and investment in green technologies. Referring to carbon taxes and cap-and-trade systems that reduce greenhouse gas emissions, pollution costs in terms of such taxes can be used to formulate environmental friendly policies for society.
2. Even in the highest level of restriction, the improvement of air quality is just around 20%. Moreover, the air quality going back to the original level after the lockdown period illustrates the government cannot rely on the short-term positive effect of COVID-19. Instead, the government should keep progress on the long-run air quality improvement plans. For example, the government can plan ahead for five years and conduct KPI for every single year, such as focusing on reducing PM2.5 in the first year and PM10 in the second year. Such measures can help to clearly reduce the related air quality pollutants one by one, it’s believed that doing so will make the policy become more specific and effective.
3. In terms of PM2.5, PM10, NO2, CO pollutants, traffic flue gas, industry exhaust

gas as well as human-being activity exhaust gas will be reduced by increasing promotion of renewable sources cars, upgrading green production technologies and optimizing the production plan. Government can cooperate with electronic car manufacturers to encourage more citizens to use electric vehicles instead of petrol trucks, which can help to reduce the emission of carbon dioxide.

4. Considering the SO2 pollutants, it is suggested that coal-fired power plants should improve the combustion condition in the boiler to fulfil a better combustion result.
5. As for O3 pollutants, it is recommended that the discharge of NO2 and CO should be controlled in order to lower the level of production of O3. Besides, facilitating the transformation of O3 into other chemical elements may also be helpful.

Limitations

There are some limitations regarding our research. Our literature does not explicitly consider the effect that the region-to-region and date-to-date variables, driven by meteorology, have on observed atmospheric concentration changes. It will be more accurate if meteorology study is taken into consideration such as chemical transport modeling which can decrease associated uncertainties. Besides, there is only one Stringency Index dataset issued by Oxford available for reference. As the stringency index is calculated with several assumptions and critical judgements, it may contain bias in the absence of other official's stringency index data reference. For example, the index of the workplace closure level is still extremely high given that many workplaces have already opened for a period of time due to the improvement of Covid-19 in reality. In other words, some of the indexes are not up to date which may cause bias in the result.

Conclusion

In conclusion, this research confirmed the significant positive impact of the stringency index in terms of the positive influence of Covid-19 on air pollution given that some bias may be existing due to the methodology limits, but it still provides practical implications for policymakers. Managers are suggested to take the social activity, production activity, travelling pattern into consideration in formulating air quality issues.

Remarks: Our cleaned data file is too big so it is uploaded on google drive, please refer to the below link so that you can get it, thank you very much!
https://drive.google.com/file/d/1fZXzJEV64jklUoYxPCrLh9LK43OlURzO/view?usp=sharing

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