The Influences of Seasons and Vaccination in the Rise of Covid-19

Abstract

This study aims to find a relationship between COVID-19 number of cases with the seasons and find the positive impact of vaccinations towards the COVID-19. Data from various sources was collected and compiled and assembled from 4 different countries (Japan, America, Luxembourg and Israel), then we apply the differential equation model for non linear data to determine the impact of seasons and vaccinations towards the number of covid. Initially we hypothesized that during low temperature season, the number of covid rises. It turned out that in winter and spring, the covid case growth rate is much higher than the other seasons. We also hypothesized that vaccination could reduce the number of covid cases. However, we reject this hypothesis. At last, we did extra analysis and found that vaccination does reduce the number of positive rates in most of the country.

I. Background and significance

Countries in temperate zones of the southern and northern hemispheres have four seasons divided every 3 months based on meteorology. With each season having different temperatures, everytime the temperature drops it could cause a hazard on the human immunity system. These could cause the body to get sick such as cold, cough, and even COVID. The seasonal signals of the covid-19 time series are extracted using the EEMD method, and a modified Susceptible, Exposed, Infectious, Recovered (SEIR) model incorporated with seasonal factors is introduced to quantify its impact on the current covid-19 pandemic. Huang et al. (2020b) found that 60.0% of the confirmed cases of covid-19 occurred in places where the air temperature ranged from 5 °C to 15 °C.

Nevertheless, the number of new cases for covid has been a rollercoaster. According to biological, epidemiological, and clinical studies, there is evidence that a previous covid-19 infection reduces the risk of getting reinfected with covid. Vaccination uses the body's natural defenses to build resistance to specific infections and makes the immune system stronger. Thus, it should help to stabilize the number of patients. However, the covid has never come to an end. Therefore, further analysis on vaccine effect could help us determine the effectiveness of covid.

Based on primarily literature review, we hypothesize that one of the causes of new covid case rise is the fact that season changes especially in winter where the temperatures are low. On top of that we also hypothesize that with the help of vaccines, it should decrease the number of new cases drastically since it helps with our immune system. We want to find out whether the vaccination actually affects the cases of covid-19 and whether different seasons have some effects on the number of cases.

II. Materials and Methods

The data are collected from 4 countries (United States, Japan, Luxembourg, and Israel). The countries are developed countries that have 4 seasons, population density bigger than 35 and life expectancy bigger than 75. The data are daily data from February 2020 to October 2022. (See **Table 1).**

We normalize the data and plot it to see if there is anything unusual or different about the effect of vaccination in each country during a season. Then, for each season, before and after vaccination, we model the s shaped-curve data, using the logistic model and compare the values of r estimates (the increasing rate of the sigmoidal curve). Denote the number of infected people (confirmed) at time t as the differential equation model is as follows:

$$N(t) = \frac{N_0 k}{N_0 + (k - N_0)e^{-rt}} + d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where N_0 is the total covid cases starts from zero, k is the carrying capacity; the potential number of contaminated and r is the rate of total covid cases growth. To know how the seasons affect covid, we divided the data into 4 countries (Japan, America, Israel, and Luxembourg) and applied the differential equation model to get the estimated values of r the growth rate of total covid cases

Table 1. Variable Description

Variable	Description
Total Cases	The cumulative number of people getting infected by covid-19
New Cases	A snapshot data of number of people getting infected by covid-19
New Vaccinations	A snapshot data of number of people getting vaccinated
Total Deaths	The cumulative number of deaths
New Deaths	A snapshot data of the number of deaths
Positives Rate	The percentage of all covid-19 tests performed daily that are positive
Location	Existing country in the data – intermediate / beginner, source
Date	The date of the day - the font?
Months	Extract month from the date
Seasons	The seasons of each available date

III. Results

According to the data we obtained, the number of reported new cases of all 4 countries during the winter ranges from 0 to 1,355,216. Other seasons have a much lower number of reported new cases, ranging from 0 to 26,999. The mean of new cases of all 4 countries in winter is 64,645.43, while it is only 22,933.5 in other seasons. It is clearly seen that during winter the number of new cases spikes.

To analyze the impact of winter towards covid, the first non-linear regression model is created. Thus, we obtain the r estimates, in the United States and Israel has the highest covid growth rate during winter, which is 0.106 and 0.143. While in Japan and Luxembourg, the highest covid growth rate is in spring, which is 0.128 and 0.162 (see **Appendix Table 2**). From here we utilize tideman voting method ("ranked pairs method") to decide which seasons have the most impact regarding the covid growth rate, the result is winter and spring (see **Figure 1**).

United States

1. Winter
2. Summer
3. Fall
4. Spring

Japan

1. Spring
2. Summer
3. Fall
4. Winter

Israel

1. Winter
2. Spring
3. Fall
4. Summer

Luxembourg

1. Spring
2. Summer
3. Winter
4. Fall

Figure 1. The seasons order on each country based on the covid cases growth rate

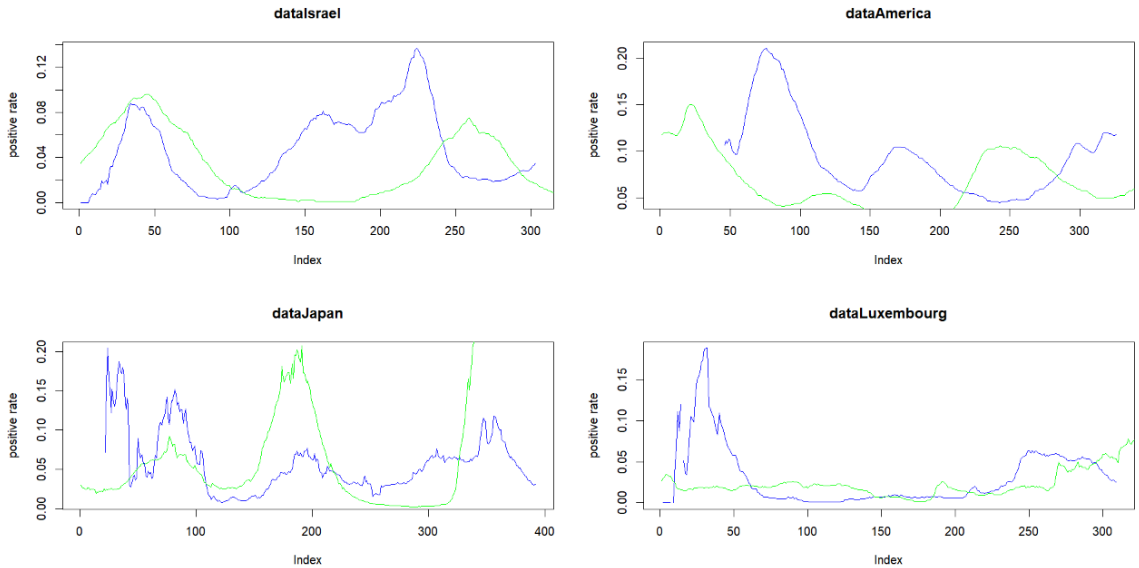

Figure 2. The positive rate on each country before omicron (green = after vaccines, blue = before vaccines)

To gain a better understanding towards the correlation of covid and vaccinations, we divide the data from each country into 2 categories, i.e before vaccines and after vaccines and apply the differential equation model towards the data. Then the model produces a much higher covid case growth rate after vaccines then before vaccines (for each 4 countries). We also applied the differential equation model towards the total deaths in each country depending on before and after vaccines ($N_0$is the total deaths from zero, r is the total death growth rates), but the total death growth rate for each country after vaccines is still much higher than before vaccines.

We further suspect that this number is the result of a growing population and much more contagious variant of covid-19; such as omicron. Therefore, we calculate the positive rate of covid before omicron exists (November 24, 2021) on each 4 sample countries, to accurately calculate the effect of vaccines towards covid before and after vaccines. Interestingly the positive rates are much lower after vaccination than before vaccination, except for Japan (see **Appendix Table 3**).

IV. Discussion and Conclusion

The covid outbreak is a problem faced by many countries or even the whole world and is still being felt today. This analysis helps to show which factors are best suited to model the cause of covid. The first attempt at modeling resulted in acceptance for the first hypothesis that covid could increase due to the low temperature seasons. In spite of that, We reject the second hypothesis where vaccination could reduce the number of new cases of covid. Further analysis confirmed that vaccination aided in the reduction of covid positive rates. For this analysis, we hypothesize that the rise in new cases of covid and deaths is due to a more contagious covid variant (such as omicron) or an increase in population size, which is why we chose to use positive rates of covid before omicron existed.

For future studies, we should analyze how each type of vaccine affects each covid variant and does the growth of population really affect the number of new cases of covid and deaths. However, considering that there are still deficiencies in this analysis, such as a lack of adequate data and ongoing cases of covid in the world, there are several countries that do not produce covid data so we only take them from a few major countries. Hopefully, by improving the level of covid alertness and from the data we have, it can help people to be better prepared for the next wave of covid.

V. References

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APPENDIX

Table 2. Model estimates and accuracy results

country	k	n	r	RMSE	R^2	category
United States	1.09E+00	1.05E-02	1.06E-01	5.50E-05	1.00E+00	winter
	3.95E-01	1.83E-03	6.04E-02	4.00E-06	9.99E-01	summer
	4.99E-01	1.10E-02	3.55E-02	1.10E-05	9.96E-01	spring
	8.04E-01	1.23E-02	3.85E-02	1.60E-05	9.97E-01	fall
	2.42E+00	1.11E-02	1.30E-02	6.82E-04	9.93E-01	before vaccines
	1.46E+00	6.11E-03	4.70E-02	4.84E-03	9.85E-01	after vaccines
	7.32E+00	1.19E-01	7.14E-03	3.67E-03	9.70E-01	before vaccines (total deaths)
	9.72E-01	7.72E-02	2.13E-02	5.57E-04	9.93E-01	after vaccines (total deaths)
Japan	8.23E-04	3.38E-03	3.81E-03	8.76E-07	5.93E-01	winter
	2.04E-03	4.12E-06	9.11E-02	1.43E-10	1.00E+00	summer
	5.82E-04	1.73E-06	1.28E-01	3.06E-11	9.99E-01	spring
	1.33E+04	1.92E-04	2.96E-02	4.63E-09	9.92E-01	fall
	1.18E-01	9.04E-05	1.35E-02	2.10E-07	9.89E-01	before vaccines
	6.02E-02	9.38E-04	2.35E-02	8.80E-06	9.68E-01	after vaccines
	7.64E+05	2.72E-04	1.12E-02	8.67E-07	9.61E-01	before vaccines (total deaths)
	2.63E-02	1.85E-03	2.56E-02	1.92E-06	9.74E-01	after vaccines (total deaths)
Israel	8.10E-02	2.56E-05	1.43E-01	1.27E-06	9.99E-01	winter
	3.71E-03	4.72E-05	7.20E-02	5.30E-09	9.96E-01	summer
	5.91E-04	3.35E-06	1.41E-01	2.00E-10	9.96E-01	spring
	7.33E-03	3.58E-04	1.15E-01	3.35E-08	9.95E-01	fall
	1.32E-02	7.93E-06	3.58E-02	1.68E-07	9.92E-01	before vaccines
	1.77E-02	1.62E-04	7.63E-02	2.31E-08	1.00E+00	after vaccines
	9.94E-03	6.96E-05	2.42E-02	7.75E-08	9.89E-01	before vaccines (total deaths)
	4.54E-03	4.56E-05	6.62E-02	7.33E-09	9.98E-01	after vaccines (new deaths)
Luxembourg	3.46E-03	3.71E-05	8.62E-02	1.94E-09	9.99E-01	winter
	1.33E-04	4.38E-07	1.09E-01	2.00E-11	9.91E-01	summer
	1.38E-04	1.02E-06	1.62E-01	2.00E-11	9.93E-01	spring
	1.20E-03	4.80E-06	7.79E-02	2.80E-10	9.97E-01	fall
	2.18E-03	1.52E-06	2.69E-02	9.88E-09	9.82E-01	before vaccines
	6.17E-03	1.01E-04	3.31E-02	3.83E-08	9.93E-01	after vaccines
	3.93E-03	5.38E-05	1.14E-02	1.50E-08	9.54E-01	before vaccines (new deaths)
	6.66E-04	3.29E-05	2.50E-02	2.70E-10	9.94E-01	after vaccines (new deaths)

Table 3. Positive rate before and after vaccines (before omicron exists)

country	min	max	range	mean	category
Israel	0	0.14	0.14	0.05	before vaccines
	0	0.1	0.1	0.04	after vaccines
America	0.04	0.21	0.17	0.09	before vaccines
	0.02	0.15	0.13	0.07	after vaccines
Japan	0.01	0.2	0.19	0.06	before vaccines
	0	0.21	0.21	0.05	after vaccines
Luxembourg	0	0.19	0.19	0.03	before vaccines
	0	0.06	0.06	0.02	after vaccines