Vaccines for the COVID-19 α Variant: An Econometric Analysis

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ABSTRACT

This study examines the success of COVID-19 vaccines in four European countries and Israel for the α variant. These countries respond to the vaccines with varying degrees of success. Countries with successful vaccination programs take about 160 days to get to the minimum number of new cases. Only Italy and Israel came close to eradicating the virus. Vaccines and previous infections have a similar prophylactic effect on new infections. Second doses for the most part add little protection to those who have only one dose. Vaccines become very effective after seven days although there are some added benefits that accrue to individuals in the second week after vaccination. The effect of vaccines on new cases is non-linear and exhibits a decreasing marginal effect. COVID-19 is spread by asymptomatic carriers, a feature of the disease which was discernable at the same time that public health agencies were discouraging the use of masks by the general public and downplaying the importance of social distancing. These were major policy errors and led to many unnecessary deaths.

Keywords: Alpha variety, COVID-19, distributed lag model, vaccines.

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I. INTRODUCTION

Since the end of 2020 new vaccines have become available which give hope that COVID-19 can be treated effectively and that populations can be spared from the most damaging consequences of the virus. These are the class of mRNA vaccines that trigger an immune response without using the live virus that causes COVID-19. Once triggered, the body then makes antibodies. Antibodies protect individuals from being infected from the real virus. These are produced by the Moderna and Pfizer-BioNTech. At the same time, four more COVID-19 vaccines have emerged. These are from the more conventional class of recombinant adenovirus vaccines from Gameleya (Sputnik Light), Oxford-AstraZeneca, CanSino, and Johnson&Johnson. This list comes from a New York Times report [1].

Many European countries have been able to develop comprehensive vaccination programs and have vaccinated large proportions of their populations using these new vaccines. A sample of large European countries in this position is France, Germany, Italy, and the United Kingdom as well as Israel, which is of interest as the country with the most aggressive vaccination programme. All of these countries eventually had very low rates of COVID-19. However, there is considerable variety in the success of these vaccination programmes and that raises some interesting issues concerning their effectiveness.

Some of these programs are sufficiently well developed to allow for a preliminary evaluation. The α variant has now largely completed its run and has been replaced by the δ variant. It is now possible to begin the examination of how effective vaccines were in combatting the effects of the virus. However, this is not an easy task since the δ variant arrived

before the α variant had run its course. The purpose of this paper is to look at a number of issues that are of interest to the research community as well as to countries that are still in preliminary stages of their vaccine rollout. The first issue to be considered concerns the actual features of these advanced programs. Was COVID 19 eradicated and if so, how long did it take to reach eradication? What was the relationship between the evolution of new cases and the share of the population vaccinated? At a more technical level, there are some questions about the difference in the immunological effects of vaccinations versus those which arise as a consequence of getting the virus. Are the protective effects of a vaccine the same as getting COVID-19? How important is the second dose? How long does it take for vaccines to become effective? What role do asymptomatic cases play in the evolution of the virus?

Using data from Our World in Data [2] simple graphical relations between reported new cases of COVID-19 and the country's vaccination rate are examined for five countries all of which are well into their vaccination program with at least 50% of the population with at least one dose. This data is then analyzed using a distributed lag econometric model to answer some of the more technical questions. The model's parameter estimates for selected countries are displayed in Table II.

II. DATA FROM FOUR LARGE EUROPEAN COUNTRIES AND ISRAEL

In Table I some of the pertinent features of how the virus evolved in the five countries under consideration are displayed. Vaccination rates are shown in Fig. 1 for the United Kingdom, characteristics that are typical of the other countries under consideration.

TABLE I: SELECTED STATISTICS ON NEW CASES AND VACCINATION RATES FOR FIVE COUNTRIES

Country	Number of Cases at Peak	Vaccination Rate at Peak	Duration to Peak	Duration to $\alpha=0$	Duration to $\delta>0$	Duration to Minimum
France	124	16.3	103	229	114	170
Germany	37	6.3	109	226	82	183
Italy	40	6.1	69	221	114	181
United Kingdom	100	3.9	32	199	119	146
Israel	119	28.2	33	192	114	160

Table Note: Cases are number of new cases per hundred thousand of population.

The response to vaccinations is similar in the other countries; but as is shown in Table I there is some variety in the timing of the responses¹. These are likely due to variation in the rate at which the vaccine was dispensed and differences in social distancing and the wearing of masks. The onset of the δ variant occurred at about the same date for all of the countries. Germany looks different because it started its vaccination programme later than the other countries. Israel and the United Kingdom responded fairly rapidly to the increase in the share of the population getting the first dose of a vaccine, taking just over a month for the number of new cases to start falling. However, it took much longer for France and Germany, over 100 days, to show any effect of the vaccine. There are also considerable differences in the timing and the extent of the vaccine roll-out. The most rapid roll-out occurred in Israel with 60% of the population having the first dose in 63 days but then the rate increased very slowly after that. France, Germany, and Italy were much slower to roll out vaccinations. The number of new cases reached their minimum after 160 days on average, but only Israel was able to nearly eradicate the α virus and this success was short-lived as the δ variant took over and generated a new and even bigger wave of infections. This feature of the pandemic is shared by the other four countries. It is clear from Fig. 1 that the response to vaccines exhibits decreasing marginal effectiveness. There is also a decline in the rate of increase in the vaccination rate as it became harder to recruit individuals who were willing to be vaccinated. These characteristics are found in the four other countries as well.

The raw data provides some information about the characteristics of the virus, but formal statistical models are needed to answer some of the more specific questions that were mentioned in the introduction.

Fig. 1. New cases per hundred thousand (Series 1) and vaccination rates (Series 2): United Kingdom.

¹ Because of the vaccine manufacturers and other clinical trial results on the effectiveness of the vaccines it is assumed that new cases of the virus do respond to these vaccines [13], [14].

² This may appear to be an odd definition as it does not consider those who have been diagnosed with COVID-19. But u_t is the proper variable

III. AN ECONOMETRIC MODEL FOR COVID 19 DATA

The model that will be used to analyze COVID-19 comes from the family of distributed lag models that have been developed by econometricians. These models are described in [3]. It is an alternative to the famous SIR (Susceptible, Infected, Recovered) model described by [4] and more recently by [5]. It was used here because, unfortunately, the data available is not suitable for use in the SIR model.

To see what this involves defining the variable n_t as the number of reported new cases on day t per hundred thousand (100K) of the population. Let u_t be the number of individuals who were infected but not diagnosed with the COVID-19 virus on day t per 100K and let c_t be the proportion of the population that had ever been infected by day t per 100K². c_t and n_t are observed whereas u_t is not. COVID-19 is a communicable disease which means that it is acquired through contact with others who are infected. The potential for being infected is determined by how dangerous the contact individual is. The distributed lag model assumes that the contribution to current observed new cases depends on the sum of possible contacts from previously infected individuals where the lag weights decline geometrically reflecting the assumption that infected individuals become less dangerous the longer, they have been infected. The lag distribution parameter is λ and is less than 1. The model is described by the following equation:

$$n_t = \alpha_0 + \alpha_1 c_t + f(v_{(t-k)}) + \beta \sum_{j=0}^{\infty} (1-\lambda) \lambda^j u_{(t-j)} + \varepsilon_t \quad (1)$$

Both u and ε are random effects and are assumed to be uncorrelated. In equation (1) the vaccination rate, v_t , has an effect on new cases with a delay of k days. Various values of k were considered in the estimation procedure. The function $f()$ determines the degree of non-linearity in the effect of vaccinations on new cases. It can be the identity function, the logarithm of the $\sin^2$ function; the choice of $f()$ is determined by what best fits the data. Routine calculations show that equation (1) becomes:

$$n_t = \alpha_0(1-\lambda) + \lambda n_{t-1} + \alpha_1 f(c_t) - \lambda \alpha_1 f(c_{(t-1)}) + \alpha_2 f(v_{(t-k)}) - \lambda \alpha_2 f(v_{(t-k-1)}) + \beta(1-\lambda) u_t + \varepsilon_t - \lambda \varepsilon_{t-1} \quad (2)$$

where the lagged value of n_t captures the cumulative effect of the unobservable previously infected members of the population of new cases. The total number per 100K of ever

to consider because those who have been diagnosed with the infection are either in self-isolation or in a hospital and pose no risk to the general public.

infected cases, c_t , is included as it operates in much the same way as the vaccination rate and its inclusion relates to the SIR model where $(1 - c_t)$, the share of the population at risk, and is a key element in that model. Whether vaccinations have the same immunological impact as having had the disease can be determined by testing the hypothesis that $\alpha_1 = \alpha_2$.

Equation (2) was estimated using non-linear least squares on the four European countries and Israel. Estimates of the parameters in equation (2) are displayed in Table II.

TABLE II: PARAMETER ESTIMATES FOR THE MODEL DESCRIBED BY EQUATION 2

Country	Parameter Estimates			Restrictions	
	λ	α_1	R^2	$\alpha_1 = \alpha_2$	$v=c$
France	0.953 (0.003)	-15.604 (2.804)	0.085	Yes	Yes
Germany	0.549 (0.061)	-1.177 (-1.177)	0.365	Yes	Yes
Italy	0.921 (0.022)	-8.587 (2.724)	0.899	Yes	Yes
United Kingdom	0.826 (0.026)	-19.855 (1.721)	0.974	Yes	Yes
Israel	0.723 (0.048)	-17.623 (5.914)	0.839	Yes	Yes

Table notes: Standard errors are in round brackets.

There is some variation in the estimates of α_1 . The effect of the vaccine was much larger for Israel and the United Kingdom than for Germany or Italy. It is also possible that the benefits of protecting individuals against the virus by mask wearing and social distancing were more significant in Italy than in the other two countries. Press reports did indicate that in both Israel and the United Kingdom that there was a lack of enthusiasm for both imposing and following the restrictions involved in COVID-19 safety protocols so more of the success was due to the vaccines.

All of the vaccination rate coefficients are significant as is λ , the coefficient of n_{t-1} . It is always significantly less than 1 so that (2) has a steady state in which n_t can be zero. This depends on the long run vaccination rate. Simulations of (2) yield values of the long run vaccination rate of around 73% for Israel, for example, so that when the vaccination rate reaches this level, absent the δ variant, there should be no new cases of COVID-19. The model does converge to $n_t = 0$ because $\lambda < 1$; there is also no evidence of non-stationarity in the model [3].

At this rate, the proportion of ever infected is around 10%. This is good news for countries like the United Kingdom and the United States because it means that populations with 83% immunity could eventually be free of the α variant of the disease; 100% immunity is not required nor does the vaccine have to be 100% effective.

Unfortunately, vaccines are much less effective against the δ variant. A recent Mayo Clinic study by [6] of six American states found that the Pfizer-BioNTech vaccine was less than 50% effective against the δ variant for individuals with two doses, so it is impossible to determine what the vaccination rate has to be for the eradication of the δ variant.

It should be noted that in Table II there are no estimates of α_2 or β . Wald tests show that α_1 and α_2 are the same for all five countries. The immunological benefits from the vaccine are the same as those from contracting the virus. The models for each country were estimated with this restriction so there are only estimates of α_1 . β cannot be estimated since it is not

identified.

For each country effect of the lagged vaccine rate on new cases is non-linear as is clear from Fig. 1. $\ln(v_{t-k})$ fits the data much better than v_{t-k} . This means, as noted earlier, that the marginal effect of vaccines declines in absolute value as the rate increases. Various values of k were tried. A value of 7 for k worked well suggesting that much of the effect of the vaccine had been acquired by the end of the first week after vaccination. However, 12 and 14 days were better indicating that the full two-week period that manufacturers had specified was required for the vaccines to be fully effective.

There has been considerable discussion at WHO and the CDC as well as in individual countries about the correct approach to the administration of the second dose of the vaccine. In Canada, for example, the initial policy was to allocate scarce resources equally to both first and second doses. As the pandemic became more unmanageable the policy changed and those given a first dose had a four-month deferment of the second dose. This turned out to be a wise decision because the efficacy of the first dose was large and quite long lived and the marginal benefits of the second dose were almost negligible. The result that the effect second dose was relatively unimportant was obtained by including the proportion of the population with two doses, $v_{2(t-k)}$, as a regressor. For all five countries the coefficients of $\ln(v_{2(t-k)})$ were not significantly different from $\ln(v_{1(t-k)})$. However, this result may not hold for the second variant as it is much less resistant all of the vaccines currently in use.

In the introduction, the issue of the role of asymptomatic cases was raised. In the model described by (2) the basic premise is that all cases are caused by contact with individuals without symptoms. The data supports this as a maintained hypothesis. First, the R^2 values are very high, especially for the United Kingdom. Secondly, the model's ability to track the actual data is very good for all of the countries under consideration. For all five countries whose models were estimated predicted values of new cases pick up the major turning points in the actual data as well as the trends. In the prediction model the actual value of n_{t-1} is replaced by its predicted value using a regression of n_t on $\ln(c_t)$ and $\ln(v_{t-k})$ and their lags. The prediction performance of the model for the United Kingdom, one of the chosen countries, is shown in Fig. 2.

Fig. 2. Predicted (Series 1) vs actual (series 2) new cases per hundred thousand: United Kingdom.

IV. DISCUSSION

The statistical model used to analyze the COVID-19 time series data for these five countries provides some insights about the nature of the virus's transmission mechanism. The model suggests that it is the individuals who are infected with the virus but show no symptoms are the carriers of the disease. This is consistent with the studies of [7] and [8]. One of the benefits of the methodology employed here is that it provides a procedure for dealing with asymptomatic carriers of the disease. Reference [11] noted the difficulties associated with the unobservable component in new cases and opted for the analysis of COVID-19 deaths as an alternative.

This result also holds for versions of the model applied to the data for the beginning of the pandemic (day 1 to day 60) when there were no vaccines available, and the total number of cases was initially very small. The conclusion that COVID-19 cases were generated by contact with asymptomatic individuals still stands for this early data. This was a time when experts and agencies like WHO, the American CDC, and the Public Health Agencies of Canada and the United Kingdom were telling the public that there was no need for people to wear masks. This advice was simply wrong and would not have been given had the agencies in question examined the data that was available by the end of March 2020 or were aware of the two papers noted at the beginning of this section. This was a costly mistake and there were many unnecessary deaths because of it.

In the econometric model used to analyze new cases, the mean of the distribution of infected individuals is $\mu = \lambda/(1-\lambda)$. Estimates of μ vary by country but Italy is not unusual and has an average of 11.3 days and a standard deviation of 3.5 days. Unfortunately, this result is not informative about the COVID-19 incubation period as it would be if all COVID-19 carriers tested positive when they were first infected. However, it does provide some information on the duration of COVID-19 infectiveness. In Italy, for example, only 5% of new cases can be attributed to individuals who were infected more than 19 days prior to the current date. This is consistent with results from Israel by [12] who showed that some symptoms had similar durations.

Vaccines appear to have some effect, eventually. All the five countries examined here showed significant declines in new COVID-19 cases as the vaccines were rolled out. New cases started to increase when the new δ variant arrived on the scene. Its arrival coincided with the opening of these economies and relaxing the restrictions involving contact between individuals. In the United Kingdom the arrival of the new delta variant and the relaxation of restrictions have led to a significant third wave despite a 68% first dose vaccination rate of the Astra-Zeneca vaccine. However, the delta cases are much more prevalent among younger and unvaccinated adults

It is well known that social distancing and mask use have a major impact on the spread of the disease. See, for example, [9] and [10] on the issue of masks. Unfortunately, it was difficult to account for the effects of these policies in the econometric model used here. Many of them were operating before the arrival of vaccines making it difficult to assess their effects. In some countries, these policies were organized differently depending on which region, state, or province was responsible for managing them. In the United States whether

masks were required was determined by state level political considerations. In Israel, for example, what individuals were supposed to do and what they did were not the same. As a result, one of the lock-down policies initiated in January-February 2021 when it was represented by a dummy variable for the time period in question appeared to have no effect on new cases.

The main result of this study is that the vaccines were effective against the α variant. What will happen with respect to the δ variant is an open question. Governments should continue with their vaccination programmes, in spite of the uncertainty about how effective they will be in dealing with the δ variant since there is no obvious alternative. Resistance from individuals opposed to COVID-19 vaccinations should not prevent the population from getting the protection it deserves.

V. DISCLOSURES

There was no external funding for the project and the author has no conflicts of interest.

REFERENCES

- [1] New York Times report on May 25, 2021, by Carl Zimmer, Jonathan Corum, and Swi-Lee Wee.
- [2] Mathieu E., Ritchie H., Ortiz-Ospina E., Roser M., Hasell J., Appel C. et al. A global database of COVID-19 vaccinations. *Nature human behaviour*. 2021, 1-7.
- [3] Greene, W. H. (2008) *Econometric Analysis 6th Edition*. Pearson Education Inc. Upper Saddle River NJUSA.
- [4] Hethcote HW. The Mathematics of Infectious Diseases. *SIAM Review*. 2001; 42: 599-563.
- [5] Britton T., Pardoux E., Ball F., Laredo C., Sirl D., Tran, VC. (2019). *Stochastic epidemic models with inference*. Cham, Switzerland: Springer.
- [6] Lavezzo E., Franchin E., Ciavarella C., Cuomo-Dannenburg G., Barzon L., Del Vecchio C., et al. Imperial College COVID-19 Response Team. *Suppression of a SARS-CoV-2 outbreak in the Italian municipality of Vo'.* *Nature*. 2020; 584(7821): 425-429.
- [7] Day M. Covid-19: four fifths of cases are asymptomatic, China figures indicate. *BMJ* 2020; 369: M1375.
- [8] Greenhalgh T., Schmid MB., Czypionka T., Bassler D., Gruer L. Face masks for the public during the covid-19 crisis. *BMJ*. 2020; 369.
- [9] Howard J., Huang A., Li Z., Tufekci Z., Zdimas V., van der Westhuizen H. M., et al. Evidence reviews of face masks against COVID-19. *Proceedings of the National Academy of Sciences*, 2021; 118(4).
- [10] Goliński A., Spencer P. Modeling the Covid-19 epidemic using time series econometrics. *Health Economics*. 2021; 30(11): 2808-2828.
- [11] Klein H., Asseo K., Karni N., Benjamini Y., Nir-Paz R., Muskat M., et al. Onset, duration and unresolved symptoms, including smell and taste changes, in mild COVID-19 infection: a cohort study in Israeli patients. *Clinical Microbiology and Infection*. 2021; 27(5): 769-774.
- [12] Pfizer-BioNTech (2021). Statement of Clinical Trial Results. April 1, 2021.
- [13] Thompson MG., Burgess JL., Naleway A., Tyner H., Yoon SK., Meece J., et al. Prevention and Attenuation of COVID-19 by BNT162b2 and mRNA-1273 Vaccines. medRxiv. 2021.
- [14] Goliński A., Spencer P. Modeling the Covid-19 epidemic using time series econometrics. *Health Economics*. 2021; 30(11): 2808-2828.