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COVID-19 Predictions Using Regression Growth Model in Ireland and Israel

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ABSTRACT

The World Health Organization (WHO) asserted the recently discovered severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as COVID-19, a pandemic on March 11, 2020. Since the genesis and growth mechanisms of this virus are unclear and impossible to detect, there are still many uncertainties concerning it and no vaccination or effective treatment. The main goal is to halt its global spread. This paper employed a regression growth model with an extended Weibull function on the dynamics of COVID-19 to make predictions about its spread. Our findings demonstrate the viability of using this model to forecast the spread of the virus. Using a logistic growth regression model, the note tabulates the COVID-19-related final epidemic sizes for a few sites, including Ireland and Israel.

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A. INTRODUCTION

There is no specific medication or vaccination approved by the medical community to treat or prevent the novel coronavirus SARS-CoV-2 that causes COVID-19. This disease, which is spread through inhalation or contact with contaminated droplets or fomites, has a retention duration of one to two weeks (Singhal, 2020).

Even though the case fatality rate is estimated to range from 2 to 3% (Yang et al., 2020), the disease can be fatal to older people (about 20% for age groups of 50+) and those with an underlying comorbid condition. The first quick growth is a representation of the cases between January 22 and the end of January, highlighting the growing case load in China. The pinnacle that developed at the end of January and February 10 illustrates how effective China's strict lockdown, which was put in place to halt the spread.

During this time, there were very few officially recognized cases anywhere else in the world. The gradual global spread of COVID-19 cases is correlated with the slow exponential rise that occurred from the middle of February until March 10. At the moment, South Korea, Iran, Italy, etc. are among the countries, where the sickness is having the most serious effects. As the virus spreads to the US and other European countries like Spain around March 11. As a result of the early suspension of international fights and strict social segregation laws, nations like Pakistan exhibits extremely slow growth over the period. An epidemic's overall size and peak period should be of particular concern.

For governments and health institutions to properly manage the problem, accurate COVID-19 dynamics forecast is essential. Numerous papers reported exact SIR model solutions, however these solutions barely seemed to match the data from real pandemics. An excellent study on the precise solution of (Bailey, 1975) SIR model was published by (Bohner et al., 2019).

The recovered (R) population is not considered in such methods when susceptible (S) and infectious (I) equations are solved; as a result, we were unable to fit the COVID-data using the explicit formulations given. Although Harko et al. (2014) published precise solutions to the SIR model taking birth and death rates into account, these solutions were never validated with actual epidemic data. Exact solutions to the SIS and SIR original ODE equations described by (William Ogilvy Kermack and A. G. McKendrick, 1927) have been reported by (Shabbir et al., 2010) and (Maliki, 2011). Only (S) and (I) equations were included in these unique models.

Analytical (Barbarossa et al., 2015; Brauer, 2019; Danby & John Michael Anthony, 1985; Wu et al., 2020) stochastic (Miller, 2012), and phenomenological (Pell et al., 2018a) models, among others, are used to explore this topic. Read et al estimation is supported by data. On February 4, 2020, there will have been 132751 to 273649 illnesses worldwide since January 2020 (Pell et al., 2018b).

The epidemy would eventually have 115022 diseases, according to (Xiong & Yan, 2020), who employed the SEIR model and data up until February 7, 2020. Additionally, Read et al. forecast that there will be between 9821 and 16, 419 diseases on January 30, 2020, (Read et al., 2021). The epidemy's final magnitude would be 83, 756 infections, according to Milan Batista (Batista, 2020), who utilized a logistic growth regression model and data up to February 24, 2020. We estimate the eventual epidemic magnitude for Israel and Ireland in this study, which has been significantly influenced by this outbreak. Since even with the same underlying data, the outcomes of epidemiological models might differ depending on how the models are implemented to estimate parameters, the starting condition, etc., we use logistic regression models to compare the findings. Alternatives to the logistic and basic SIR models include an extended SEIR model that takes quarantined and deceased patients into account. We will try to predict the eventual epidemic extent and its peak using the phenomenological model, which is the logistic growth regression model (Anastassopoulou et al., 2020; Batista, 2020; Nesteruk, 2020; Pell et al., 2018b; Read et al., 2021). We first fit daily data to the logistic model, which yields several estimates, and then fit the Weibull function to complete the estimation.

These models are fully addressed in Section 3, and the sources listed in the appendix are where you can learn more about how they were used. Modifications made to account for the slower drop in infections than that seen in Ireland and Israel are detailed in section 3:1 and 3:2 respectively. The models' scripts are open source; however, it is anticipated that readers would use them to estimate the final epidemic magnitude for regions that were excluded from this study. It should be emphasized, however, that the epidemic will enter a new stage if the reported patient count begins to frequently surpass the anticipated end state. To take the effects of the changed parameters into account, a new estimate must be created.

B. METHODS

Any new pandemic outbreak, like COVID-19, needs a quick and reliable mathematical model solution to minimize calamitous effects and equip with the necessary defenses. The COVID-19 revealed the vulnerability of humans in dealing with biological emergencies. Here, we first give the Regression Growth Model's formulation based on the infected population.

1. The Logistic Growth Model

Population dynamics is where logistic growth models first appeared (Haberman & Kolkka, 1977). The model's fundamental premise is that the rate of change in the quantity of new instances per inhabitant declines linearly as cases increase. Therefore, the model is where r is the infection rate and K is the final epidemic extent, where C is the number of cases and t is the period.

$$\mathbf{\frac{1}{C}\frac{dC}{dt} = r\left[1 - \frac{C}{K}\right]} \quad (1)$$

While the initial spread of the pandemic is predicted by exponential and other models, the final decay and flattening of the curve are not considered. On the other hand, logistic models may not succeed at the first stage but can forecast subsequent decline. The growth in the logistic model is given by (Ma, 2020). Considering that,

$$\mathbf{C(t) = \frac{K}{1+Aexp^{-rt}}} \quad (2)$$

with $A = \frac{K-C_O}{C_O}$

Now, assuming when K >>C_0 and t <<1 therefor A >>1 We possess expansion.

$$\mathbf{C = \frac{Ke^{rt}}{e^{rt}+A} \approx C_o e^{rt}} \quad (3)$$

when indefinite bell chimes, $t \rightarrow \infty$

$$\mathbf{C = K(1 - Ae^{-rt} + \cdots)\left[1 - e^{-r(t-t_o)}\right]} \quad (4)$$

When the second derivative of $\frac{dC}{dt}$ equals 0, the growth rate $\frac{dC}{dt}$ reaches its maximum value. Because of this circumstance, we can infer that the growth rate peak occurs at time,

$$\boldsymbol{t_p = \frac{\ln A}{r}} \quad (5)$$

The number of cases and growth rate are currently,

$$\mathbf{C_p = \frac{K}{2}, \left[\frac{dC}{dt}\right]_p = \frac{rK}{4}} \quad (6)$$

Regression Model. When making predictions regarding a categorical variable as opposed to a continuous one, logistic regression is used to evaluate the connection between a dependent variable and one or more independent variables. We estimate the parameters of the logistic model using the logistic regression model. Using (2), we can construct the regression model as follows,

$$\mathbf{C} = \frac{\mathbf{b_1}}{\mathbf{1+b_2 exp^{-b_3 t}}} \tag{7}$$

Where b_1, b_2, and b_3 are unknown parameters that must be inferred from the data. The parameters of the logistic model are constants, but the parameters of the regression model vary on the data at hand. In other words, if $C_1, C_2, C_3, \ldots, C_n$ are the cases in times $t_1, t_2, t_3, \ldots, t_n$. Then $b_i^{(n)} = b_i^{(n)}(C_1, C_2, C_3, \ldots, C_n)$ are the parameters in times (i = 1, 2, 3),

$$\mathrm{b}_i = \mathrm{b}_i(t)(\mathrm{i} = 1, 2, 3) \tag{8}$$

$b_i = b_i(t)$ should eventually converge to some definite values if we presume that the epidemy has an ultimate size. The Shanks transformation (Shanks, 1955) for epidemy size is

$$\mathbf{K(K_n)} = \frac{\mathbf{K_{n+1}K_{n-1} - K_n^2}}{\mathbf{K_{n+1} - 2K_n + K_{n-1}}} \tag{9}$$

where the time estimate is given by Kn. We might get a more accurate idea of the ultimate value of K by repeatedly applying (7). As an adjunct, we can use the Weibull function to fit the fragment b_i^k, $k = n_0, n_1, \ldots n$ (or any other appropriate role)

$$\mathbf{b_1 = K[1 - exp[-k(t - t_o)^p]]} \tag{10}$$

We compute a final estimation of K, or the extent of the epidemy. The regression coefficients are k, p, and t_0.

2. Data

For Ireland and Israel, we conduct a regression analysis using a separate set of data. We use the dates from September 26, 2020, through December 12, 2020, for Ireland, and from June 14, 2021, through August 3, 2021, for Israel. Prior to hitting the link to the coronavirus world meter, we first get the necessary information from (Coronavirus World meter Website. https://www.worldometers.info/ coronavirus/, n.d.).

C. RESULTS

We employ MATLAB's lsqcurvefit and fittnlm tools for practical calculation.

1. Ireland.

The epidemy peaked on October 26, 2020, based on data that is currently accessible (up to December 31, 2020), and its expected final size is 56889 cases (see Table 1, Figure 1 and Figure 2). According to the data, the regression has a strong estimation coefficient of 0.0973 and all parameters are attainable (p-value <<< 0000). With the new data, these estimates will change predictably in a timely manner. The trend of the model's parameters is shown in Table 2, and the epidemy's finalize is assessed using the bar graph in Fig 3. At this time, 56890 cases are thought to be involved in the epidemic. As shown in Table 1 and Figure 1.

Table 1. Calculate the Logistic Model's Parameters

	Estimate	SE	t-Stat	p-Value
b1	56890	871.25	65.297	4.0792e-80
b2	0.052289	0.0023658	22.102 5	5.2379e-39
b3	4.5983	0.25634	17.938	1643e-32

Number of observations: 97, Error degrees of freedom: 94 Root Mean Squared; Error:2.53e+03, R-Squared: 0.973, Adjusted R-Squared: 0.972; and F-statistic vs. zero model: 8.26e+03, p-value = 1.1e-113.

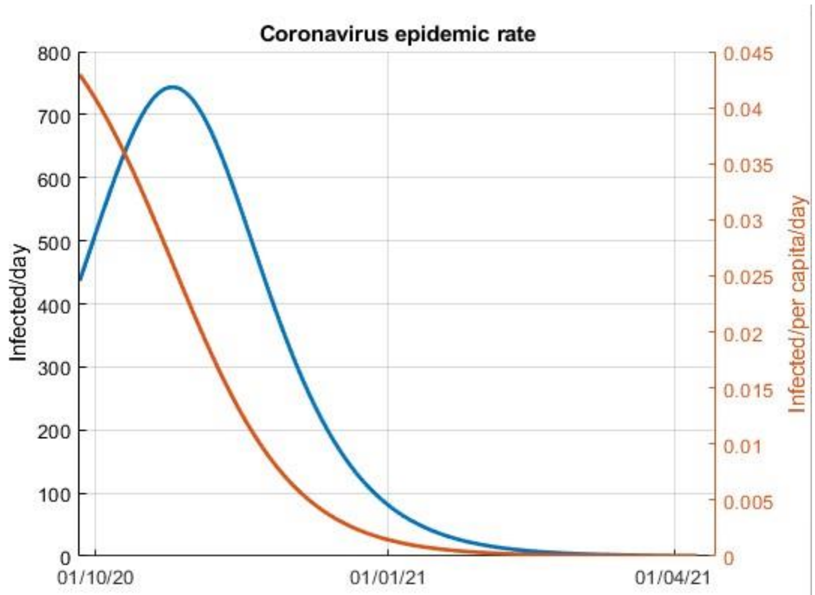

Figure 1. Evaluation into the projected coronavirus epidemic. Table 4 contains the data for the regression

Figure 1 depicts the infected population over time. As we can see, it starts out rising, but after a short period of time, the curve fitting quickly falls. Therefore, using the provided data, we can simply examine the coronavirus epidemic rate over time, as shown in Figure 2.

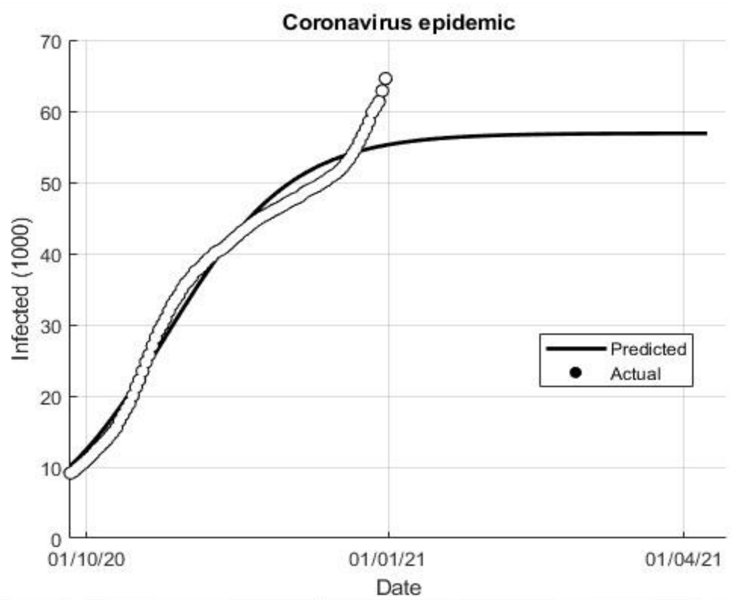

Figure 2. Overview of the envisaged coronavirus epidemic rate

We exhibit the actual data in figure 2 and compare it to the projected data. The results are highly accurate, and the coronavirus outbreak has eased since its peak, as shown in Table 2.

Table 2. Results of statistics and logistic regression (see Eq. 2, 3, 4)

Date	C(cases)	Data day	K(cases)	r(1/day)	A	Day	d-Cdt	Peak date
10/10/2020 4:23	15518	15	450593965	0.432	8536802.935	36	48630500	02-Nov-2020
10/11/2020 4:23	16526	16	524626335	0.334	3369622.000	44	43827624	10-Nov-2020
10/12/2020 4:23	17338	17	634868039	0.313	3840040.995	48	49620612	14-Nov-2020
10/13/2020 4:24	18160	18	7849017	0.378	184559.395	32	741289	29-Oct-2020
10/14/2020 4:24	18965	19	360721648	0.283	2177970.741	51	25533668	17-Nov-2020
10/15/2020 4:24	20044	20	20867297	0.275	136203.979	42	1435112	08-Nov-2020
10/16/2020 4:24	21227	21	517207688	0.230	1755432.649	62	29796386	28-Nov-2020
10/17/2020 4:24	22222	22	524227287	0.224	1875121.751	64	29404204	30-Nov-2020
10/18/2020 4:24	23465	23	670958486	0.207	1972451.704	69	34762929	05-Dec-2020
...	...	...	...	...	...	...	...	...
12/31/2020 5:22	64567	97	56889	0.052	4.598	29	743	26-Oct-2020

The Weibull model (8), which assesses the size of the epidemy for data up to October 10, 2020, has values in Table 3 with p = 1. Our predictions show that the epidemy would peak on November 20, 2020, with a final size of 105378 illnesses. However, a novel approach to data collection undermines this hypothesis. The epidemy's final size, calculated using the Weibull model, is around $1{:}5173e^{+08}$ illnesses (see Table 4). We underline that this prediction should be viewed with some care because there are not yet enough data to apply the Weibull model to make a definitive prediction regarding the severity of the epidemy. As seen in Table 4, the R^2 is not very high ($-4.44e^{-16}$), but the regression coefficients for k have a p-value of 0, rendering them statistically insignificant. The epidemy peak phase at the time of writing (Fig 4) happened on day 83, or on November 4, 2020, according to Weibull regression. Each parameter in this regression is significant when the p-value < 0. As shown in Figure 3.

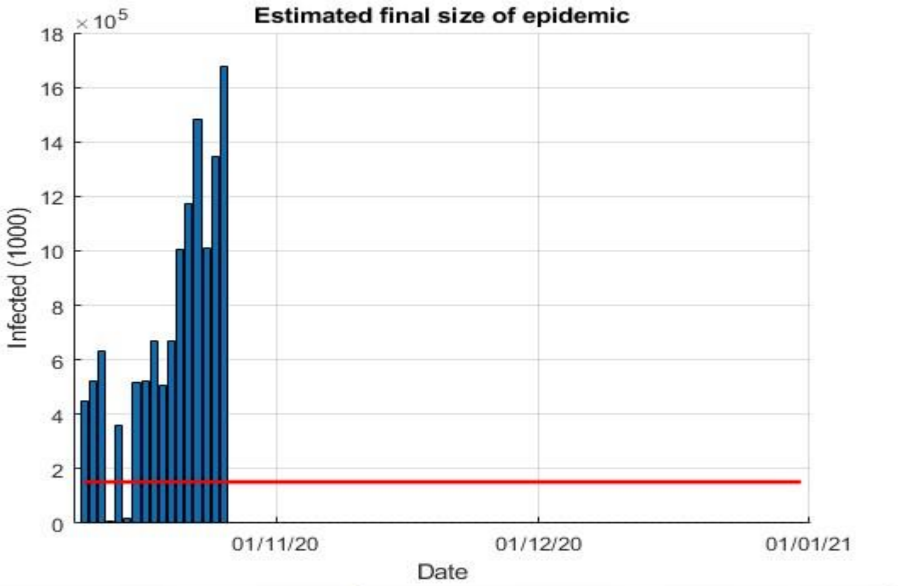

Figure 3. Appraisal of the estimated final extent of the coronavirus pandemic (bars). Data for Weibull regression are in Table 4 (red line).

The red line in Figure 3 represents the anticipated epidemic peak rate because of Weibull regression, whereas the blue bar represents the actual data, as shown in Table 3.

Table 3. Estimated final scale of the epidemic, based on information as of October

	Estimate	SE	tStat	pValue
b1	1.35e+05	3.96e-06	3.41e+10	4.47e-131
b2	0.041925	0.000281	149.33	2.05e-22
b3	13.853	0.036037	384.41	9.43e-28

Number of observations: 15, Error degrees of freedom: 13 Root Mean Squared; Error: 50.5, R-Squared: 0.999, Adjusted R-Squared: 0.999; and F-statistic vs. zero model: 4.38e+05, p-value = 4.1e-32.

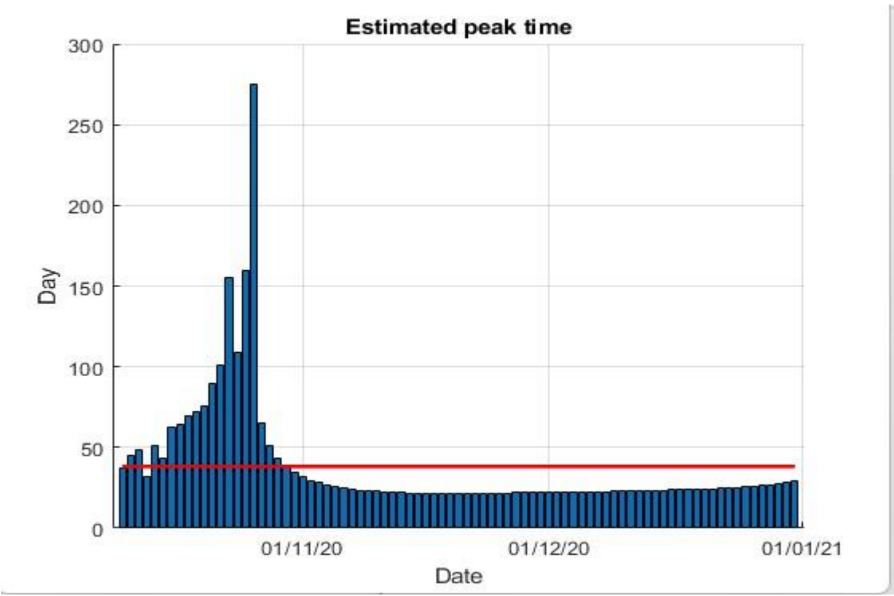

Figure 4. Estimating the peak period of the coronavirus epidemic (bars). Weibull regression data (red line) (Table 5)

Figure 4 uses Weibull regression to provide data on the coronavirus estimated peak time of infection. Table 4 and Table 5 shows that the peak date is 4 November 2020.

Table 4. The final epidemy size predicted by the Weibull model (8) is (see Figure 3)

	Estimate	SE	tStat	pValue
b1	1.52e+08	4.03e+07	3.7668	0.00031
b2	1072.7	0	Inf	0
b3	-27648	0	-Inf	0
b4	3877.4	0	Inf	0

Number of observations: 83, Error degrees of freedom: 82; Root Mean Squared Error: 3.67e+08 R-Squared: -4.44e-16, Adjusted R-Squared -4.44e-16; and F-statistic vs. zero model: 14.2, p-value = 0.00031.

Table 5. The Weibull model's (8) predicted peak time size for the Epidemy using data up to January 1, 2021. (See Fig4))

	Estimate	SE	t-Stat	p-Value
b1	38.197	4.1156	9.281	1.99e-14
b2	226.57	0	Inf	0
b3	-1998.5	0	-Inf	0
b4	344.79	0	Inf	0

Number of observations: 83, Error degrees of freedom: 82; Root Mean Squared Error: 37.5; R-Squared: 1.11e-16, Adjusted R-Squared 1.11e-16; F-statistic vs. zero model: 86.1, p-value = 1.99e-14; Peak date 04-Nov-2020

2. Israel.

The epidemy peaked on August 21, 2021, based on data that is currently accessible (up to August 3, 2021), and its expected final size is 1:0602e+05 cases (see Table 6 and Fig 5 and Fig 6). According to the data, the regression has a strong estimation coefficient of 0:0997 and all parameters are attainable (p-value <<<0000). With the new data, these estimates will change predictably in a timely manner. The trend of the model's parameters is shown in Table 7, and the epidemy's final size is assessed using the bar graph in Figure at this time, 103984 cases are thought to be involved in the epidemic, as shown in Table 6 and Figure 5.

Table 6. Calculate the logistic model's parameters

	Estimate	SE	tStat
b1	1.06e+05	0.01451	7.31e+06
b2	0.079714	0.000884	90.221
b3	224.01	8.6034	26.038

Number of observations: 51, Error degrees of freedom: 49; Root Mean Squared Error: 306; R-Squared: 0.997, Adjusted R-Squared 0.997; F-statistic vs. zero model: 1.74e+04, p-value = 1.42e-70.

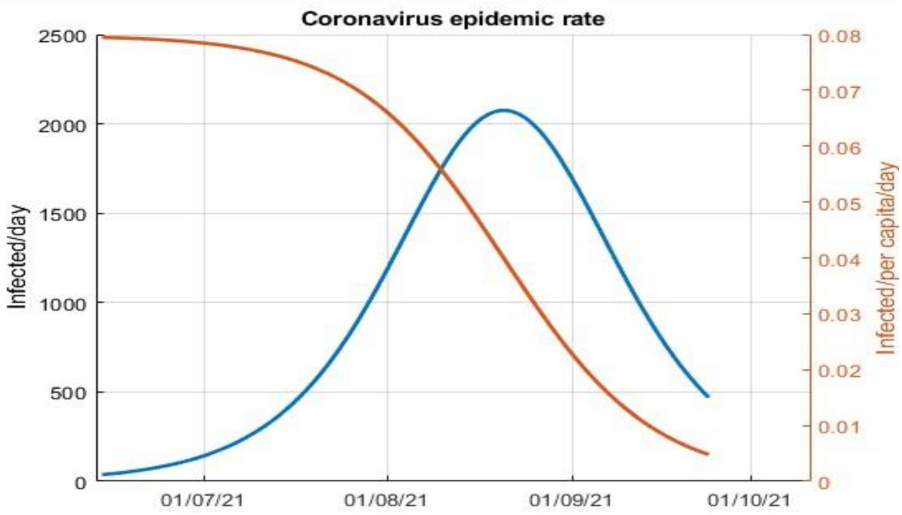

Figure 5. Evaluation into the projected coronavirus epidemic. Table 4 contains the data for the regression

The infected population is shown over time in Figure 5. As we can see, it first rises before the curve fitting quickly lowers after a brief length of time. Therefore, we may easily track the coronavirus epidemic rate over time using the available data, as shown in Figure 6.

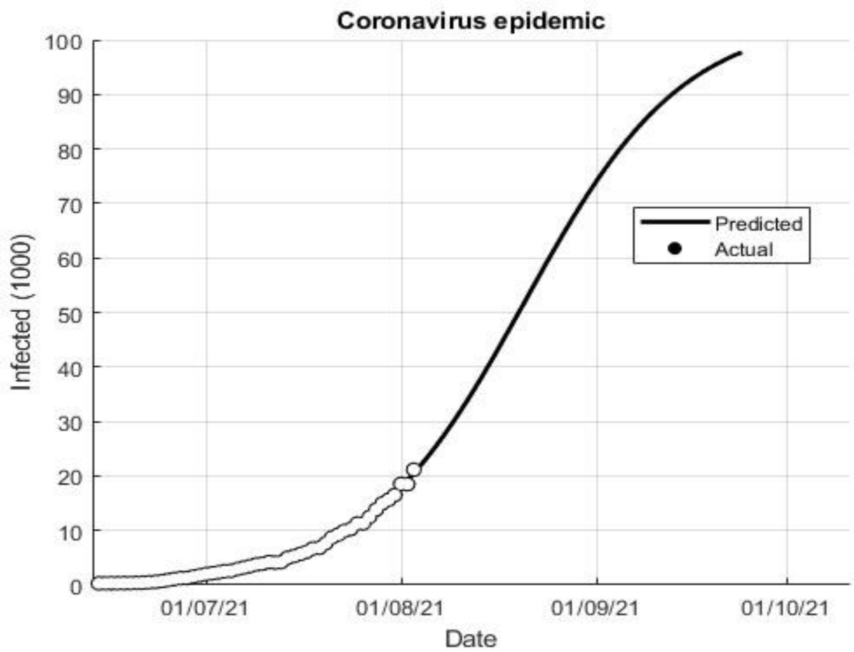

Figure 6. Overview of the envisaged coronavirus epidemic rate

Figure 6 shows the actual data, which we contrast with the projected data. The findings are very accurate, and since its peak, the coronavirus outbreak has subsided, as shown in Table 7.

Table 7. Results of statistics and logistic regression (see Eq. 2, 3, 4)

Date	C(cases)	Data day	K(cases)	r(1/day)	A	Day	dCdt	Peak date
6/28/2021 4:21	1290	15	4728288	0.491	2635763	30	580290	15-Jul-21
6/29/2021 4:21	1539	16	52881971	0.284	2004596	51	3748740	5-Aug-21
6/30/2021 4:21	1764	17	84372111	0.227	1578976	62	4795622	16-Aug-21
7/1/2021 4:21	1986	18	45851812	0.248	1318278	56	2846238	10-Aug-21
7/2/2021 4:21	2142	19	48147030	0.228	1104921	61	2745709	15-Aug-21
7/3/2021 4:21	2319	20	328236	0.194	4709.459	43	15960	28-Jul-21
7/4/2021 4:21	2529	21	122409	0.183	1555.685	40	5614	25-Jul-21
7/5/2021 4:21	2595	22	420720	0.199	8081.78	45	20907	30-Jul-21
7/6/2021 4:21	2925	23	73943905	0.204	1805751	70	3780233	24-Aug-21
7/7/2021 4:21	3206	24	63943979	0.181	1041900	76	2889406	30-Aug-21
...	...	...	...	...	...	...	...	...
8/3/2021 4:21	21156	51	103984	0.08	220.354	67	2075	21-Aug-21

The Weibull model (8), which assesses the size of the epidemy for data up to June 28, 2021, has values in Table 3 with p = 1. Our predictions show that the epidemy would peak on September 17, 2020, with a final size of 1:8578e+09 illnesses. However, a novel approach to data collection undermines this hypothesis. The epidemy's final size, calculated using the Weibull model, is around 2:7596e+07 illnesses (see Table 4). We underline that this prediction should be viewed with some care because there are not yet enough data to apply the Weibull model, as shown in Figure 7.

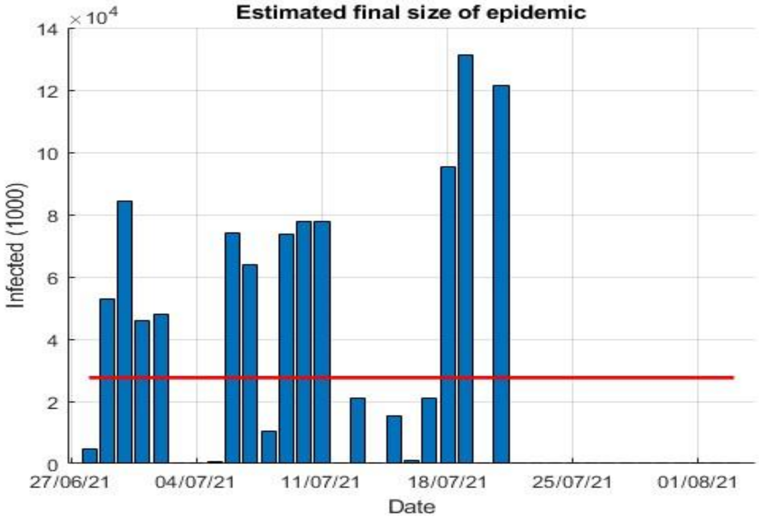

Figure 7. Evaluation into the projected coronavirus epidemic. Table 4 contains the data for the regression

In Figure 7, the blue bar reflects the actual data, whereas the red line in Figure 7 depicts the predicted epidemic peak rate as a result of Weibull regression, as shown in Table 8.

Table 8. Estimated final scale of the epidemic, based on information as of June 28, 2021

	Estimate	SE	tStat	pValue
b1	1.86e+09	1.09e-13	1.70e+22	1.29e-304
b2	0.14002	0.002425	57.75	4.68e-18
b3	9.85e+06	2.06e-11	4.78e+17	6.72e241

Number of observations: 15, Error degrees of freedom: 14; Root Mean Squared Error: 75.3; R-Squared: 0.956, Adjusted R-Squared 0.956; F-statistic vs. zero model: 1.28e+03, p-value = 3.7e-15.

Table 9. The final epidemy size predicted by the Weibull model (8) is (see Fig 3))

	Estimate	SE	tStat	pValue
b1	2.76e+07	6.45e+06	4.2783	0.00013
b2	4.0154	0	Inf	0
b3	-9479.3	0	-Inf	0
b4	2233.8	0	Inf	0

Number of observations: 37, Error degrees of freedom: 36; Root Mean Squared Error: 3.92e+07 R-Squared: 0, Adjusted R-Squared 0; F-statistic vs. zero model: 18.3, p-value = 0.000133.

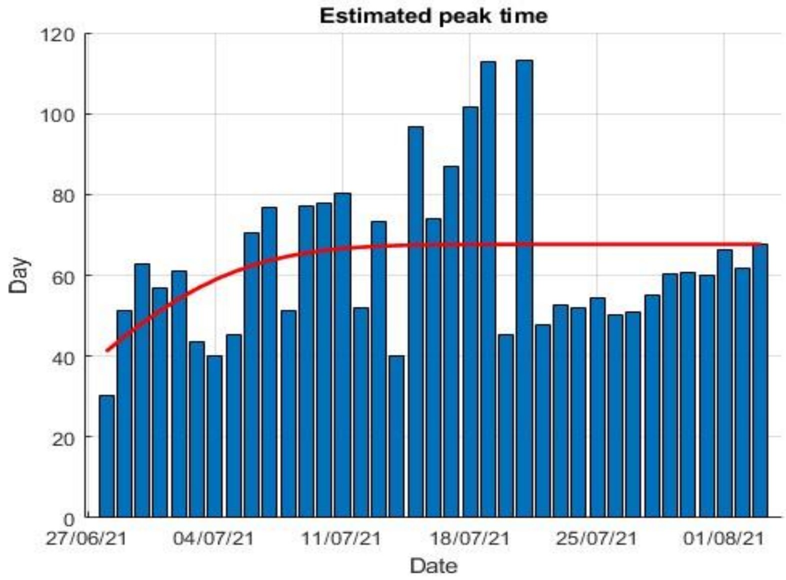

Figure 8. Evaluation into the projected coronavirus epidemic. Table 4 contains the data for the regression

Data on the estimated peak period of infection for the coronavirus are shown in Figure 8 using Weibull regression. According to Table 5, the peak date is August 21, 2021.

Table 10. The Weibull model's (8) predicted peak time size for the epidemy using data up to August 4, 2021. (See Figure 4)

	Estimate	SE	tStat	pValue
b1	67.667	4.404	15.365	1.34e-16
b2	0.00011	0.017073	0.006438	0.9949
b3	-6.273	293.65	-0.02136	0.98309
b4	3.0077	36.439	0.082543	0.93471

Number of observations: 37, Error degrees of freedom: 33; Root Mean Squared Error: 19.1; R-Squared: 0.128, Adjusted R-Squared 0.0492; F-statistic vs. zero model: 104, p-value = 3.27e-18; Peak date 21-Aug-2021.

D. CONCLUSION AND SUGGESTIONS

More accurate estimates of the coronavirus epidemic's eventual size can be made using the now-available data from Ireland and Israel: 56890 and 103984 cases, respectively. While Ireland's outbreak peaked on October 26, 2020, Israel's occurred on August 21, 2021. The next Weibull function prediction is less reliable; it states that the infection rate will ultimately be around 1.5173e+08 for Ireland and that its peak occurred after 83 days, and 2.7596e+07 for Israel and that its peak occurred after 37 days, i.e., on November 4, 2020 and August 21, 2021, respectively. If data collection does not change, the epidemic is entering the saturation phase, according to the aforementioned studies. To make a sound choice, further data files and numerical analyses on the COVID-19 pandemic are required, although thus far, the Regression Growth model and Weibull function have produced encouraging results. Weibull-SIRD model will be used to continue the study in the future.

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