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Modeling of covid-19 cases and death numbers in Malta with Gompertz and Brody nonlinear models

Şenol Çelik
Agricultural Faculty, Department of Animal Science, Biometry and Genetics Unit Bingöl University Bingol Turkey

Abstract
This study was conducted to determine the number of covid-19 cases and death numbers in Malta from 8 April 2020 to 11 October 2021 with different growth curve models and compare them in terms of growth curve parameters. It was seen that the Gompertz model better explains the growth performances in both the number of cases and the number of deaths. While the coefficient of determination (R^2) of the Gompertz and Brody models examined in estimating the number of cases was 0.993 and 0.944, respectively, the R^2 values of the Gompertz and Brody models in the death number toll model were found as 0.997 and 0.923, respectively. As a result, it has been revealed that the Gompertz model fits better than the Brody model in estimating the number of cases and deaths.

Keywords: *Growth curve, case, death*

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I. INTRODUCTION

The earliest evidence of human presence in Malta goes back to about 5000 BC. The first inhabitants were descendants of the migration movement that began in the East in 9500 BC and reached southern Italy and Sicily between 6000 and 5000 BC [1].

A significant prehistoric Neolithic culture marked by Megalithic structures, which date back to 3600 BC, existed on the islands, as evidenced by the temples of Bugibba, Mnajdra, Ggantija and others. The Phoenicians colonised Malta between 800 and 700 BC, bringing their Semitic language and culture [2].

Towards 2500 BC the Temple Culture collapsed rapidly, because of an epidemic, mass desertion, famine resulting from the excessive exploitation of the land, or a merciless invasion by a warring people. Moreover, the total absence of the previous culture's characteristics seems to point to a massacre or some form of hiatus for a certain period of time [3].

Malta, officially known as the Republic of Malta, is a Southern European island country consisting of an archipelago in the Mediterranean Sea [4]. It lies south of Italy, east of Tunisia [5], and north of Libya [6]. With a population of about 515,000 [7] over an area of 316 km^2 [8], Malta is the world's tenth smallest country in area [9, 10] and fourth most densely populated sovereign country. Its capital is Valletta, which is the smallest national capital in the European Union by area at 0.61 km^2.

The COVID-19 pandemic in Malta is part of the worldwide pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case of the disease in Malta was reveal on 7 March 2020 [11].

Malta's second wave of the virus, which was more severe, began in the summer of 2020 [12].

As of 22 October 2021, Malta has reported 37,535 confirmed cases, 36,444 recoveries and 460 deaths, while 251 cases remain active. [13]

The objective of this study is to compare the several nonlinear models (Gompertz and Brody) in describing the course of the COVID-19 outbreak in Malta. In order to present this, it was focused on 2 indicators such as the number of total cases and the number of deaths.

II. MATERIAL AND METHOD

Material

It was obtained daily updates of the cumulative number of reported confirmed cases and deaths for the 2019-nCoV pandemic of Malta between April 8, 2020 and October 11, 2021, from Worldometer and WHO websites [14].

Method

The general differential form of a growth function is dW/dt = f(W, t). The use of growth functions is often empirical, and the form of the function is chosen by its ability to fit the data. A growth function, however, can characterize some underlying physiological or biological mechanism or constraint [15].

Brody growth function is defined [16] as

$$Y = A(1 - b\exp(-kt))$$

The Gompertz function [17] is defined as

$$Y = A\exp\left(-b\exp(-kt)\right)$$

Inflection point of Gompertz function is defined [18-20] as

$$IP_T = \ln(b)/k$$
$$IP_W = A/e$$

IPT is point of inflection time and IPW is point of inflection case or death.

III. RESULTS

The models examined in the study and the compliance levels of these models with the model performances of covid-19 cases and numbers in Malta are presented in Table 1.

Table 1. Compliance levels of different models to the number of cases and deaths

Model	Equation	R^2 (for case)	R^2 (for death)
Gompertz	$Y = A\exp\left(-b\exp(-kt)\right)$	0.993	0.997
Brody	$Y = A(1 - b\exp(-kt))$	0.944	0.923

R of the Gompertz and Brody models used for case numbers in Malta.[2nd] values were calculated as 0.993 and 0.944, respectively. Similarly, for the number of dead, the Gompertz and Brody models' R^2 values were found to be 0.997 and 0.923, respectively. Considering the model performance, it has been seen that the Gompertz model, which has a better fit value which has higher R^2 values in both the number of cases and the number of deaths value.

Table 2. Estimated Gompertz and Brody model parameters values for cases and deaths

Model		A	b	k	R^2
Gompertz	Case	38 442	16.406	0.011	0.993
	Death	453	40.311	0.015	0.997
Brody	Case	13 137 622.89	1.001	0.0000065	0.944
	Death	62 693.822	1.001	0.000018	0.923

Gompert model for number of cases

$$Y = 38442\exp\left(-16.406\exp(-0.011t)\right)$$

Gompertz model for death toll

$$Y = 453\exp\left(-40.311\exp(-0.015t)\right)$$

is expressed as.

The A values found in the Gompertz and Brody models define the maximum number of cases and deaths. There was a difference between the methods in terms of A parameter calculation. The Brody model estimated the number of cases and deaths higher (Table 2). In the appropriately estimated Gompertz model, parameter A was found to be 38442 for the number of cases and 453 for the number of deaths. In terms of the parameter k, which gives information about the rate of increase, very close values were obtained for the number of cases and deaths. Case and death rates were estimated at 0.011 and 0.015 levels, respectively. Briefly, in the period examined, the rate of increase in cases was 1.1% and the rate of increase in deaths was 1.5%. The death rate increase is slightly higher than the case increase rate. According to the Gompertz model, the inflection point in the number of cases was calculated as follows.

$$IP_T = \frac{\ln(16.406)}{0.011} = 254$$
$$IP_W = \frac{38442}{e} = 14142$$

The time at the inflection point is day 254 and the number of cases at the inflection point is 14142. Similarly, the inflection point of the dead number was calculated, and the IP_T=246 and IP_W=167 were found.

The growth curves estimated by the Gompertz and Brody models for cases and deaths are shown in Figure 1 and Figure 2, respectively.

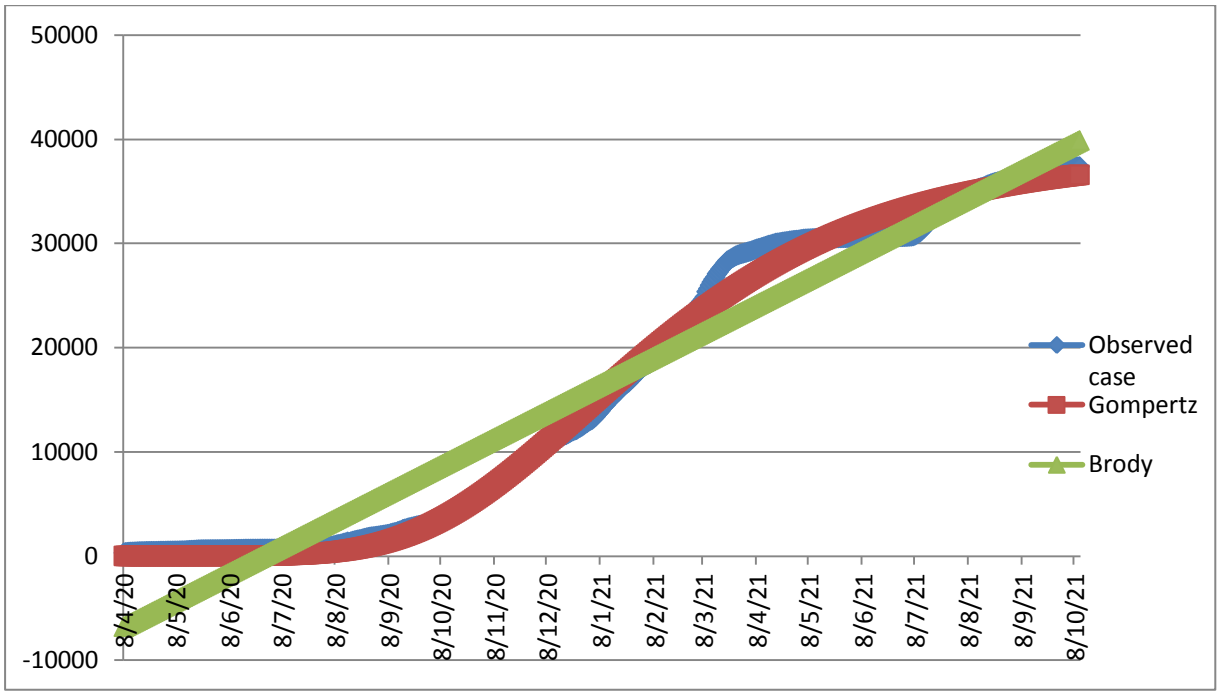

Figure 1. Growth curves of the number of cases with different models

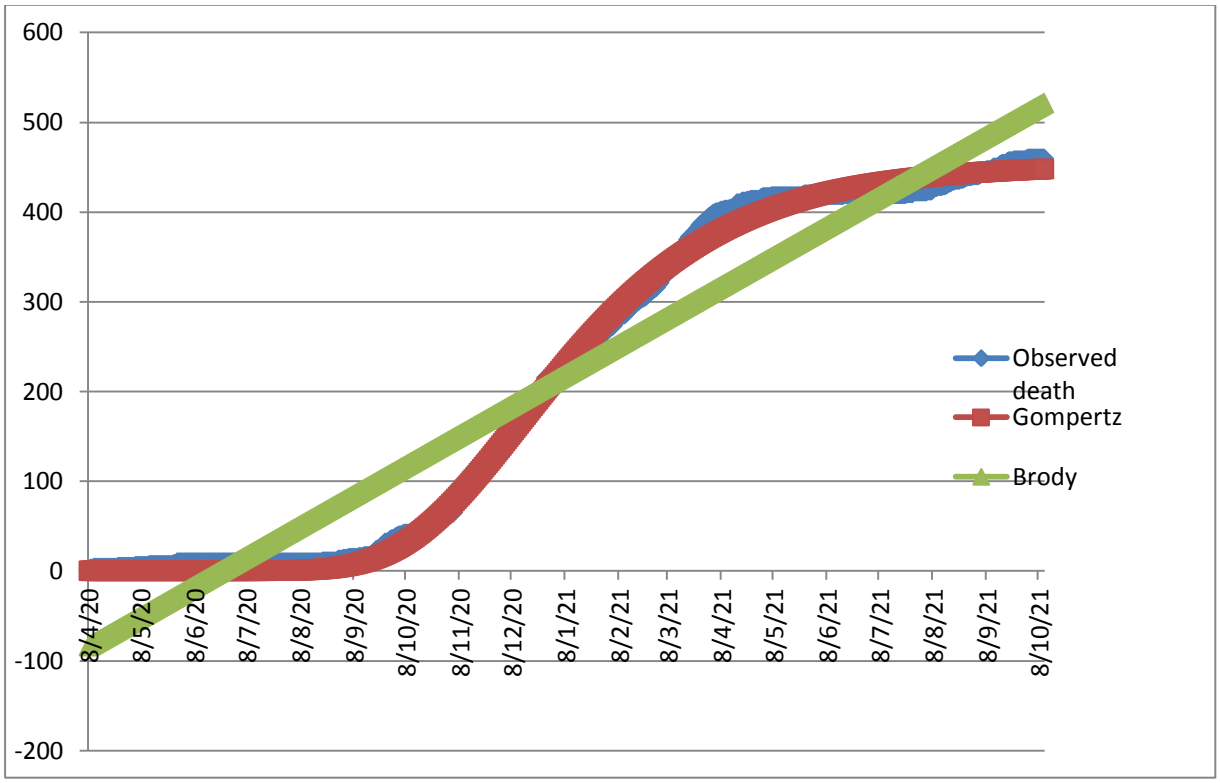

Figure 2. Growth curves of the death toll with different models

IV. DISCUSSION

In a research, it was displayed a suitable ARIMA (5, 1, 1) model which can be using to statistically forecast the actual number of confirmed cases of COVID-19 recorded in ECOWAS (Benin, Burkina Faso, Cabo Verde, Core D'Ivoire, Gambia, Ghana, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo) as a whole. A forecast of 235 days from 11th May 2020 to 31st December 2020, was conducted using the fitted model, and it was discovered that the COVID-19 daily confirmed cases may most likely incline over the next six months [21]. [22], publicly available data sets of 10 countries in the world used to build the fuzzy model with time series in a fixed period. Then, they other periods of time used to verify the effectiveness of the

proposed approach for the forecasted values of the 10 countries. Forecasting windows of 10 and 30 days ahead were used to test the put forwarded approach. Forecasting average accuracy was obtained 98%. The proposed approach can help people in charge of decision making to fight the pandemic can use the information of a short window to decide immediate actions.

V. CONCLUSION

As a result of the research carried out to predict the number of cases and deaths as a result of the covid-19 virus that occurred in Malta in the years 2020-2021 with the Gompertz and Brody models, it was seen that the Gompertz model made a more successful prediction. According to the suitable Gompertz model, the maximum number of cases and deaths were found to be 38442 and 453, respectively. The rate of increase in the number of cases and deaths was estimated as 0.011 and 0.015, respectively. The b parameters of the Gompertz model for cases and deaths are 16.406 and 40.311, respectively. It can be suggested that growth models will be the preferred methods for estimating the number of cases and deaths.

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