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Research Paper

Modeling of Covid-19 cases and deaths in Uruguay with different, nonlinear growth models

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ABSTRACT
This study was carried out to reveal the number of cases and deaths resulting from the Covid-19 epidemic in Uruguay between January 1st and November 2nd, 2021 with different growth models and to compare the number of cases and deaths in terms of growth curve parameters. In a 305 days period, compatibility of the Logistics, Gompertz, and Von Bertalanffy models to the growth data was examined. It has been discovered that the increase performance of cases and deaths in both the number of cases and the number of deaths are best explained by the Gompertz model. The coefficient of determination of the logistic, Gompertz and Von Bertalanffy models (R^{2nd}) were respectively 0.934, 0.984 and 0.977 in the cases and deaths were calculated as 0.949, 0.989 and 0.975. It has been concluded that nonlinear growth models are convenient models that can be used to model epidemic disease cases and deaths.

KEYWORDS: *Non-linear Models, Growth Curve, case, death*

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I. INTRODUCTION

COVID-19 has disrupted many countries world, crushing their healthcare systems. It has been associated with a death rate higher than any other respiratory viral infection. So, it has turn into important to identify reliable predictors of disease severity and morbidity which would streamline healthcare resources into improving efficiency of management and thus improving the clinical burden and overall outcome (Sheshan et al., 2021).

Nowadays, epidemic diseases continue to spread under different forms and affect the social, economic, and lifestyles of countries. The current outbreak, which started in Wuhan, China in 2019 and was declared a "Pandemic" by the World Health Organization (WHO) in 2020, spread rapidly all over the world with the effect of globalization (WHO, 2020).

The COVID-19 crisis has led to on the process of rethinking health and quality of life issues. To be healthy is to live under good conditions as a physical, mental, and social being, and the whole environment plays an active role in a person's mental and physical health (Curtis et al., 2010).

Uruguay is a high-income country with 3.5 million inhabitants, located in the southeastern part of South America. The first cases of COVID-19 in the country were detected on March 13th, 2020 (Nacional de Emergencias, 2020).

In the context of the COVID-19 pandemic, countries performed different types of social distancing measures. In the specific case of Latin America, measures ranged from nationwide curfews and lockdowns such as Argentina, Chile and Peru to softer restrictions that combined closure of educational institutions, mass gathering cancellations and stay-at-home recommendations (e.g. Uruguay and Brazil) (Costa et al., 2020).

In a work showed that the social distancing measures implemented to contain the COVID-19 outbreak in Uruguay caused a major disruption in daily habits, which were mostly attributed to changes in work-related activities and the closure of educational institutions. Difficulties to cope with such changes and the fear and uncertainty caused by COVID-19 were identified (Ares et al., 2021).

The target of this study is to compare such as Logistic, Gompertz and Von Bertalanffythe several nonlinear models in describing the course of the COVID-19 outbreak in Uruguay. To makes this, it was focused on the number of total cases and the number of deaths indicators.

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 January1, 2021 and November02, 2021, from owid/covid-19-data websites.

Method

The analysis of growth curves used is nonlinear growth curve with the model of von Bertalanffy, Logistic, and Gompertz for modeling of number of case and death. The form of mathematical equations and some of the rules is given in Table 1.

Table 1. Mathematical Model of Growth Curve

Model	Equation	M	References
Logistic	$Y = A/(1 + be^{-kt})$	-	Nelder (1961) Korstanje (2020)
Gompertz	$Y = Aexp(-be^{-kt})$	∞	Blasco et al. (2003)
Von Bertalanffy	$Y = A(1 - be^{-kt})^3$	3	Brown et al. (1976)

A=asymptotic number of case/death, namely the value of t approaches infinity; b=scale parameter (the value of integral constant); e=logarithm base (2.718282); k=the average rate of growth of the case/death; M=value of the function in the search for the inflection point (curve shape); U_t: Represents the proportion of case compared to the mature case at the day. t=time in units of the day

The inflection time and value for the various models of the growth curve are displayed in Table 2.

Table 2. Inflection Point on the Non Linear Models

Model	Growth at inflection point (U_t)	Inflection Time
Logistic	A/2	(ln M)/k
Gompertz	A/e	(ln b)/k
Von Bertalanffy	A(8/27)	(ln 3b)/k

III. RESULTS

The non-linear models', Logistics, Gompertz and Von Bertalanffy models, compatibility values of Covid-19 cases and deaths in Uruguay are presented in Table 3.

Table 3. Concordance values for Covid-19 cases and deaths of different models (R^2)

Model	Cases	Death
Logistic	0.934	0.919
Gompertz	0.984	0.989
Von Bertalanffy	0.977	0.975

When the nonlinear models were compared among themselves in terms of compatibility, it was observed that the Gompertz model gave the best compatibility with the coefficient of determination of 0.984 and 0.989, respectively, in the number of cases and the number of deaths. The second convenient model was the Von Bertalanffy model, while the Logistic model showed the lowest compatibility (Table 3).

Nonlinear models were applied to the number of Covid-19 cases and deaths for January 1 to November 2, 2021 period, and the obtained growth curve parameter estimates are presented in Table 2. The growth curves estimated by nonlinear models in the number of Covid-19 cases and deaths are shown in Figure 1 and Figure 2, respectively.

Parameter A in the logistics, Gompertz and Von Bertalanffy models predicts the maximum number of cases and deaths. There were differences between the methods in terms of estimating the A parameter. For example, the Logistics model estimated the maximum number of cases and deaths at the highest levels, while the Gompertz model estimated the lowest (Table 4). When evaluated according to the Gompertz growth model, which gives the best compability, the A parameter was approximately 410727 in the number of cases and approximately 6269 in the number of deaths.

There was a difference between the number of cases and deaths in terms of the k parameter, which provides information about the growth rate. According to the Gompertz model, the growth rate was -0.021 and -0.026 in cases and deaths, respectively. The growth rates in the number of cases and deaths were found to be 0.004 and 0.003 in the Logistic model, and 0.016 and 0.015 in the Von Bertalanffy model, respectively. In the comparison of cases and deaths within the model, the growth rate values were disclosed to be very close to each other in all examined models.

Table 4. The results of the nonlinear model parameters estimated over the number of cases and deaths

Model	Case/death	A	b	k	R^2
Logistic	Case	631509±36757.6	-1.077±0.015	0.004±0.001	0.934
	Death	11982.6±1167	-1.082±0.017	0.003±0.001	0.919
Gompertz	Case	410726.9±2726.4	7.712±0.375	-0.021±0.001	0.984
	Death	6269.1±32.4	18.8±1.2	-0.026±0.001	0.989
Von Bertalanffy	Case	425745±3983.2	1.32±0.049	0.016±0.001	0.977
	Death	6839±69.8	1.446±0.04	0.015±0.001	0.975

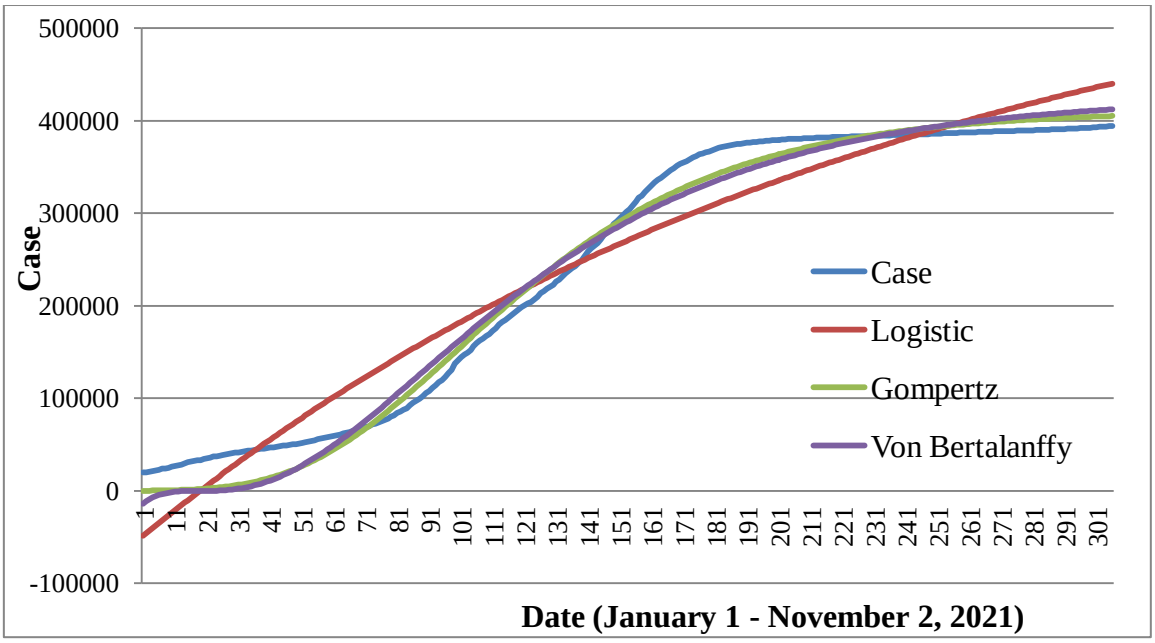

Figure 1. Growth curves of the number of cases estimated by different models

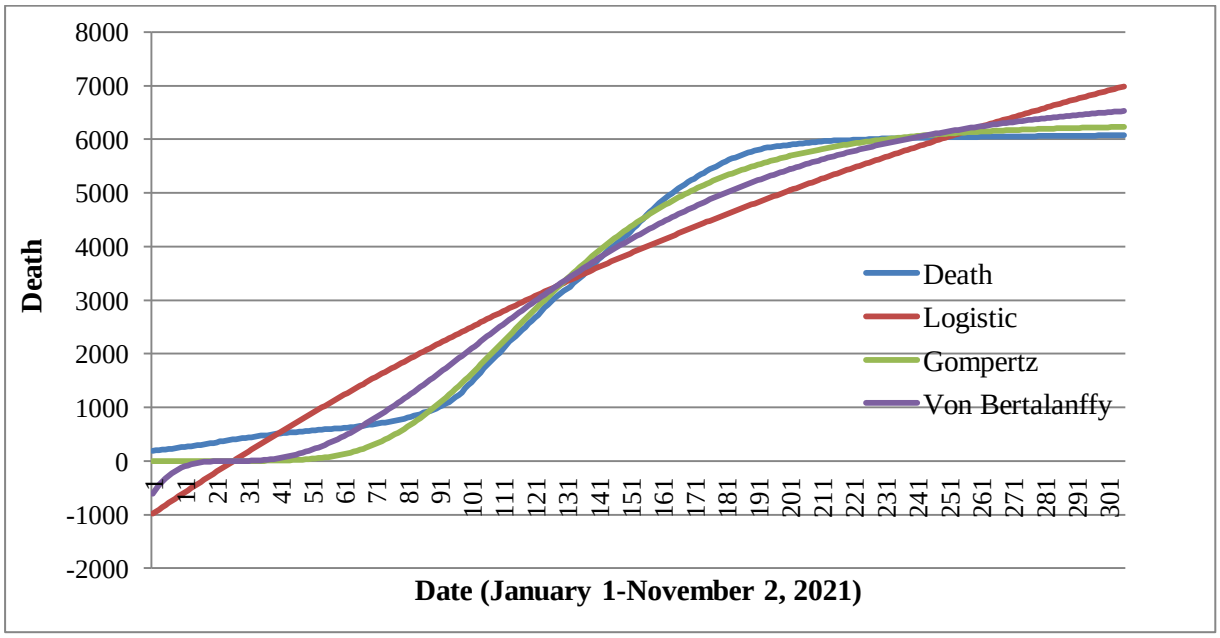

Figure 2. Growth curves of death tolls estimated by different models

As presented in Figure 1 and Figure 2, it is observed that the results estimated from the Gompertz model in estimating the number of cases and deaths are closer to the observed values.

IV. DISCUSSION

One study surveyed 1725 people in Uruguay in 2020.Participants were diverse in terms of gender, age, educational level and socio-economic status. The largest proportion of the participants were female, aged

between 26 and 45 years old, and from low socio-economic status. Chi-square test results showed that participants experienced major changes in their daily routines and family life. The percentage of participants who reported having experienced changes in different aspects of their life since the implementation of social distancing measures did not significantly differ between participants from low and medium socio-economic status (Ares et al., 2021).

According to results be obtained in another study, suggest that COVID-19 caused changes in the eating habits of Uruguayan middle and high-income citizens, even though no mandatory curfews and quarantines were in place. Household income, perceived healthiness of the diet and coping strategies were associated with different perceived changes in eating habits due to COVID-19 (Vidal et al., 2021).In another study, Gompertz model, the maximum number of cases and deaths were found to be 38442 and 453, respectively in Malta. 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 (Çelik, 2021).

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 Uruguay in the year 2021 with the Logistic, Gompertz and Von Bertalanffy models, it was seen that the Gompertz model made a more successful prediction. As a result of the suitable Gompertz model, the maximum number of cases and deaths were found to be 410727 and 6269, respectively. There was a decrease in the rate of increase in cases and deaths. It has been revealed that growth models show good results in estimating the number of cases and deaths.

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