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Prediction of COVID-19 Pandemic Before The Latest Restrictions in Turkey by Using SIR Model

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Abstract: The ongoing CoVID-19 pandemic affected our lives dramatically. Many epidemiological models are developed by scientists to estimate the number of infected individuals and the transmission rate of the CoVID-19 pandemic. In this paper, we analyze the evolution of COVID-19 in Turkey over the period November 16 and December 9, 2020, using the SIR model. The estimation of the reproduction number is found as 1.38. The peak day of the pandemic based on the period used in the SIR model is estimated as the 13th of January. By that date, around a total number of 3530000 individuals would be affected according to the SIR model and among them, approximately 141000 people would be active cases. In total, approximately 35000 people would die, based on a mortality rate of 1%. These predictions are made according to the scenario, which assumes, the latest restrictions weren't announced by the Turkish Ministry of Health. The findings of this study can be used to understand the characteristics of the pandemic at a certain time and estimate the distribution of the disease but are not suggested for any policy change and strategies.

***Key words**:* SIR model, Covid-19, Pandemic, Epidemic prediction model

Türkiye'deki Son Kısıtlamalardan Önce COVID-19 Pandemisi'nin SIR Modeli Kullanılarak Tahmin Edilmesi

Özet: CoVID-19 salgını hayatımızı dramatik bir şekilde etkilemeye devam etmektedir. Birçok epidemiyolojik model, günlük vaka sayısını ve CoVID-19 pandemisi'nin bulaşma oranını tahmin etmek için bilim adamları tarafından geliştirilmiştir. Bu makalede, COVID-19 pandemisi'nin Türkiye'deki, 16 Kasım - 9 Aralık 2020 dönemindeki gelişimini baz alan SIR modeli kullanılarak pandemi analiz edilmiştir. Çalışmada üreme hızı 1.38 olarak bulunmuştur. SIR modelinde kullanılan döneme göre toplam vaka sayısının pik yapacağı tarih 13 Ocak 2020 olarak tahmin edilmektedir. O tarihe kadar, SIR modeline göre yaklaşık 3530000 kişi etkilenecek ve bunların arasında yaklaşık 141000'ini aktif vaka olacaktır. Toplamda, %1'lik bir ölüm oranı baz alındığında, yaklaşık olarak 35000 kişi vefat edecektir. Bu tahminler, son kısıtlamaların Türkiye Cumhuriyeti Sağlık Bakanlığı tarafından açıklanmadığını varsayan senaryoya göre yapılmıştır. Bu çalışmanın bulguları, belirli bir zamanda pandeminin özelliklerini anlamak ve hastalığın dağılımını tahmin etmek için kullanılabilir ancak herhangi bir politika değişikliği ve strateji için önerilmemektedir.

***Anahtar kelimeler**:* SIR model, Covid-19, Pandemi, Salgın tahmin modeli

1. Introduction

The CoVID-19 has become the most influential global pandemic since the 1918 influenza pandemic [1]. The virus began to spread in Wuhan in the first week of December 2019. Until the 5th of December 2020, it has contributed around 82.7 million confirmed cases and more than 1.81 million deaths according to the World Health Organization [2]. Nowadays, many countries are fighting to prevent the spread of the CoVID-19 pandemic. Turkey is one of the countries trying to prevent CoVID-19 pandemic. The pandemic of COVID-19 was firstly reported in Turkey on the 11th of March. After the first confirmed case, the government of Turkey started the fight against the virus and achieved successful results. For instance, although there was no case in Turkey in January, Turkey started to apply restrictions at airports from January 21, the Wuhan-Istanbul flights have been stopped on 22 January and all incoming flights from China are stopped. The borders between Turkey and Iran are closed on 23th of February. However, Turkey faced a massive number of daily cases at the end of the fall after releasing the restrictions in the 2020 summer.

The lockdown strategies cannot be prolonged due to the economic reasons for the countries. Therefore, we applied the infection, Susceptible-Infected-Removed (SIR) epidemiological model to evaluate the effectiveness of the latest response strategy and predict the spread of Covid-19 in Turkey. Recently, many studies have been carried out to estimate the spread of the pandemic by using epidemiological models. For instance, the time dependent SIR model is developed to estimate the impact of asymptomatic infections in CoVID-19 pandemic and illustrated how the social distancing can lead the reduction of infection ratio [3]. [4] used the susceptible-infected SI model and SIR model to examine the susceptible-infected deceased (SID) correlations. The presented models produced reliable results compared to similar epidemical model predictions. They also showed that the next few days of the infection can be critical for determining the future evolution of the death cases [4]. [5] used exponential and classic SIR models to make predictions on daily cases for India and examined the impact of social distancing.

The economic impact COVID-19 for emerging markets investigated using a SIR-multisector-small open economy model for Turkey and they reported that economic costs are higher without lockdown because of the amplification position of international linkages [6]. [7] illustrated the SIR model results and estimated the peak date of the maximum number of actively infected cases for Turkey.

It is critical that the mathematical models are developed to understand the disease characteristics and predict the new cases, deaths, infection ratio, and so on. To prevent highly infectious diseases, effective strategies and policies must be considered [8][9]. There are many other studies can be found that used the epidemiological models to estimate the outbreaks and to capture the dynamics of transmission of the pandemic from the dataset [10][11][12][13]. SIR and modified version of SIR approaches are also considered in several studies to predict the transmission ratio and new daily cases [14][15][16][17].

In this study, the SIR model is applied to the data of 25 days from the beginning of the second restriction in Turkey. Our aim is to predict the daily new cases for further days by using the SIR model to investigate the effect of the latest restrictions. The findings of the study based on the estimated reproduction rate and future predictions for the next 120 days are presented. The estimated peak day of the pandemic is examined and the impact of the restrictions is investigated and the comments are made.

2. Material and Method

2.1 Data

The data comprise many variables that represent the daily CoVID-19 statistics of the countries. However, the daily new cases and the daily cumulative cases of Turkey are used in the SIR model. All the observations are collected from John Hopkins University database. All the analyses were performed using R statistical software [18]. For visualization analysis, ggplot2 package [19], while for solving the differential equations for parameter estimation, deSolve package [20] were used. For the SIR model, the data of the daily cumulative cases for Turkey is extracted from 15th of November 2020 to 9th of December 2020.

2.2 SIR Model

In the SIR model, the total population is divided into three groups:

S: Individuals who are not infected but susceptible to the disease

I: Individuals who are infectious

R: Individuals who are recovered from diseases or died

It is assumed that the period of the SIR model is short. Therefore, births and deaths can be neglected in the analysis, and the number of individuals who are died from the virus is small compared to the living population [13]. In addition, the number of S reduce when the people are contaminated and the number of I decreases when the individuals recover or die from the virus. In addition, two parameters need to be estimated in order to describe the rates of change in each subset. Those are the infection rate β (controls the transition between S and I) and recovery rate γ (controls the transition between I and R). Ordinary Differential Equations (ODE) of the SIR model can be found below:

$$\frac{dS}{dt} = -\frac{\beta IS}{N} \tag{1}$$

$$\frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I \tag{2}$$

$$\frac{dR}{dt} = \gamma I \tag{3}$$

Here, N=S+I+R is the total population of the country. In the first equation, the number of S reduce with the newly infected people. The new infected individuals (βIS) can be found by multiplying infection rate β and the number of S who had a contact with I. In equation 2, ϒI is the recovery rate multiplied by the I. In equation 3, R increases with the ϒI and the final number of infected people assumed to be zero.

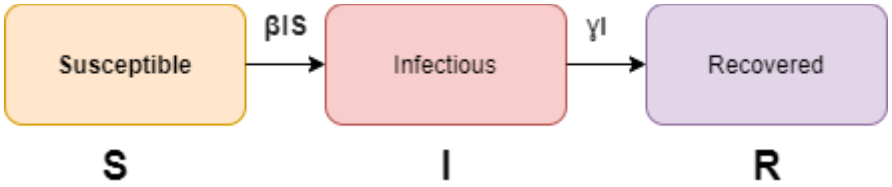

Figure 1. Illustration of the SIR model

ODE is applied in the simulation to estimate parameters β and ϒ. Our aim is to minimize sum of squares (RSS) between the number of infectious people at time t, I(t) and the number of predicted infectious people at time t, Iˆ(t). The equation for the RSS can be seen below:

$$RSS(\beta, \gamma) = \sum_{t} (I(t) - \hat{I}(t))^2 \quad (4)$$

The population of Turkey in 2019 was 83154997 according to Turkish Statistical Institute. So, the N was taken as the population of the Turkey. The vector of the daily cumulative cases for Turkey is created from 15th of November, 2020 to 9th of December 2020. The number of recovered and death cases are 353663 and 11507 respectively by the 15th of November 2020. The model fit and predictions are given in the next section. The reproduction number R_0 is calculated by using the produced parameters; β and ϒ. The reproduction number means that one infected individual causes the new infection(s). If R_0 is greater than 1, the disease become epidemic and an outbreak will occur in the future. In the case of R_0 is less than 1, the disease stops spreading in the population and die out. Reproduction number is the most important parameter for selecting interventions. R_0 can be calculated as follows:

$$R_0 = \frac{\beta}{\gamma} \quad (5)$$

Each value of N, S, I, R should initialize before application of SIR model. So far, all these values are mentioned above.

3. Results

In this study, the SIR model predicts the upcoming days based on the selected dates. The number of daily cases according to the scenario, in which, the latest restrictions weren't announced by the Turkish Ministry of Health, is estimated based on the SIR model. Figure 2 illustrates the distribution of the cumulative cases and the fitted values observed from the SIR model.

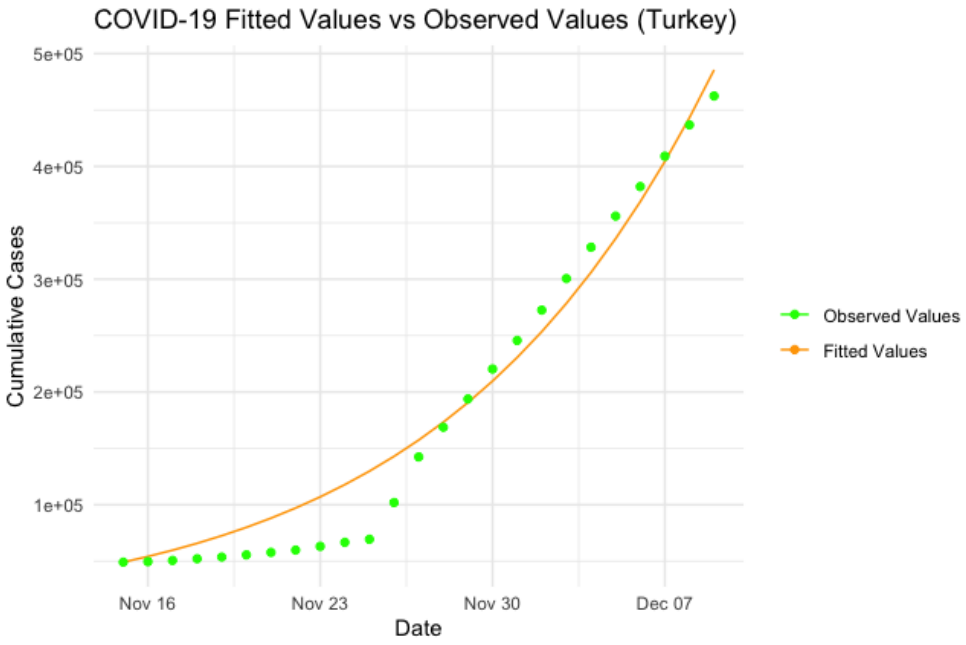

Figure 2. Fitted Values vs Observed Values based on the SIR model

Figure 2 illustrates the distribution of the cumulative cases and the fitted values observed from the SIR model. The sharp increase in daily cases after November 26 is seen in the graph. Therefore, the observed values up to this date do not fit well in the graph. However, The number of observed cases after 26 November follows the number of cases expected by our model. It is clearly seen from the graph that the pandemic has been in an upward trend since the beginning date of the SIR model. The similar plot can be seen in Figure 3. The difference of this graph is the cumulatice cases were calculated on logarithmic scale.

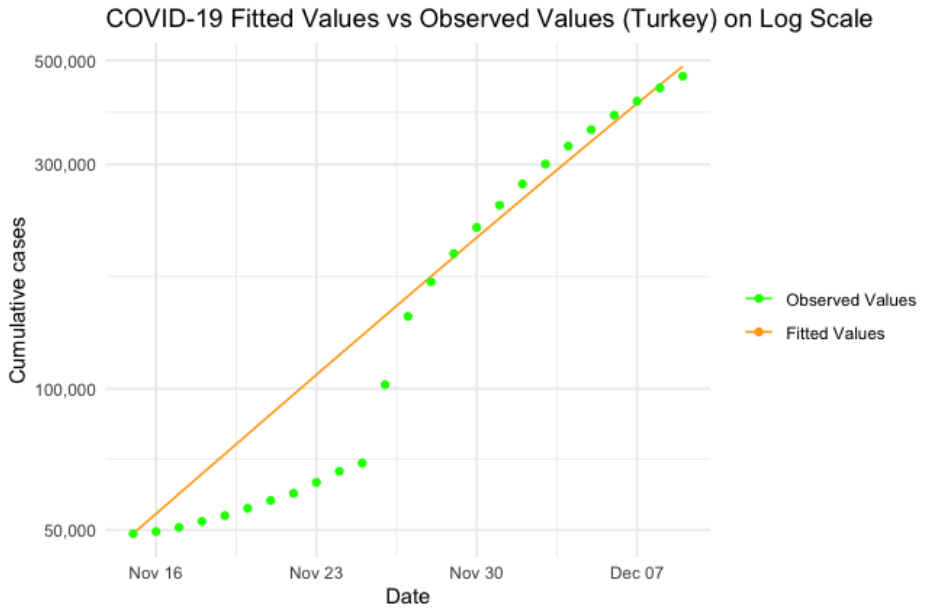

Figure 3. Fitted Values vs Observed Values based on the SIR model (Log Scale)

The sharp increase on November 26 is seen more clearly in this graph. The logarithmic transformation of the cumulative cases has the advantage to capture the difference between the observed and expected number of cases in the Figure 2. It is also possible that the low number of daily cases between November 16 and November 26 may be

due to the data collection problem. Furthermore, the estimate of reproduction number by the SIR model in Turkey is calculated as 1.38. Although the disagreement of different estimation methods, the basic SIR method is used to estimate the reproduction number in this study. The reason behind the reproduction number is higher than 1 can be that before December 2020 various containment measures haven't been strictly implemented, especially before the Turkish Ministry of Health announced to apply new COVID-19 restrictions. The value of reproduction number, 1.38, means that on average one person can spread the virus with the ratio of 1.38.

It can be useful to apply the fitted SIR model to the scenario, in which, the latest restrictions weren't announced by the Turkish government. The SIR graph can be seen in Figure 3.

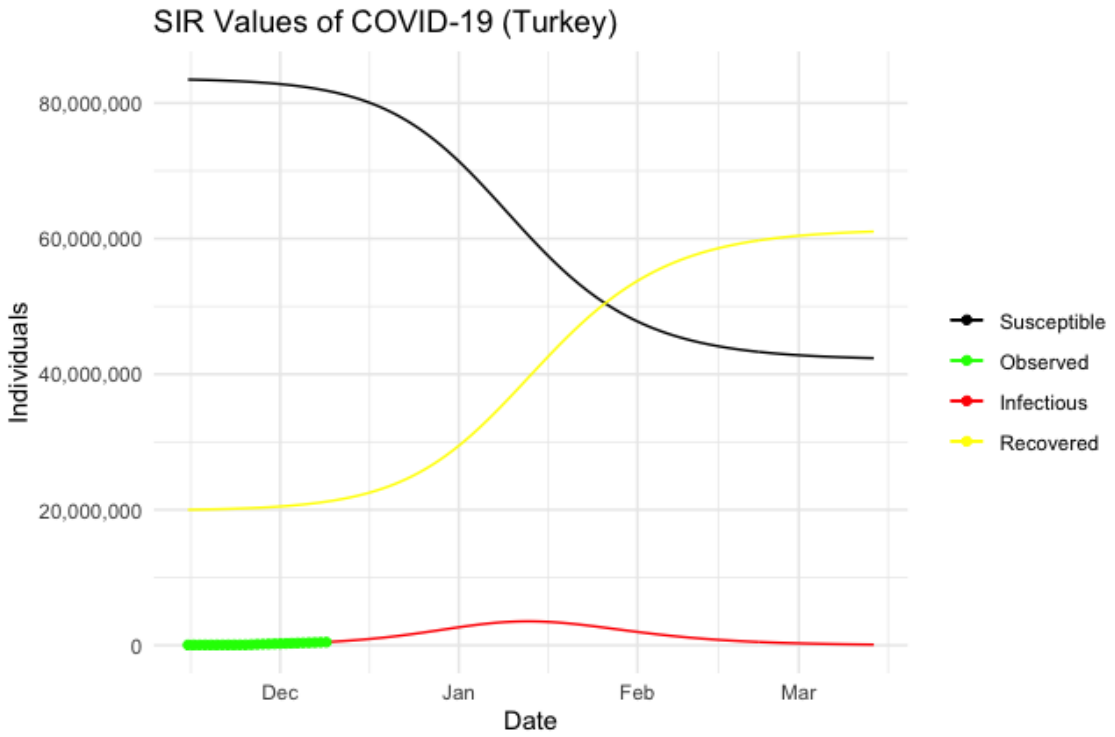

Figure 4. Illustration of the SIR model

The number of susceptible decreases over time until it stabilizes. The number of recovered cases rises rapidly after some time and it stabilizes. The number of individual who are infectious increases monotonically until reaches the peak and then reduce similarly.

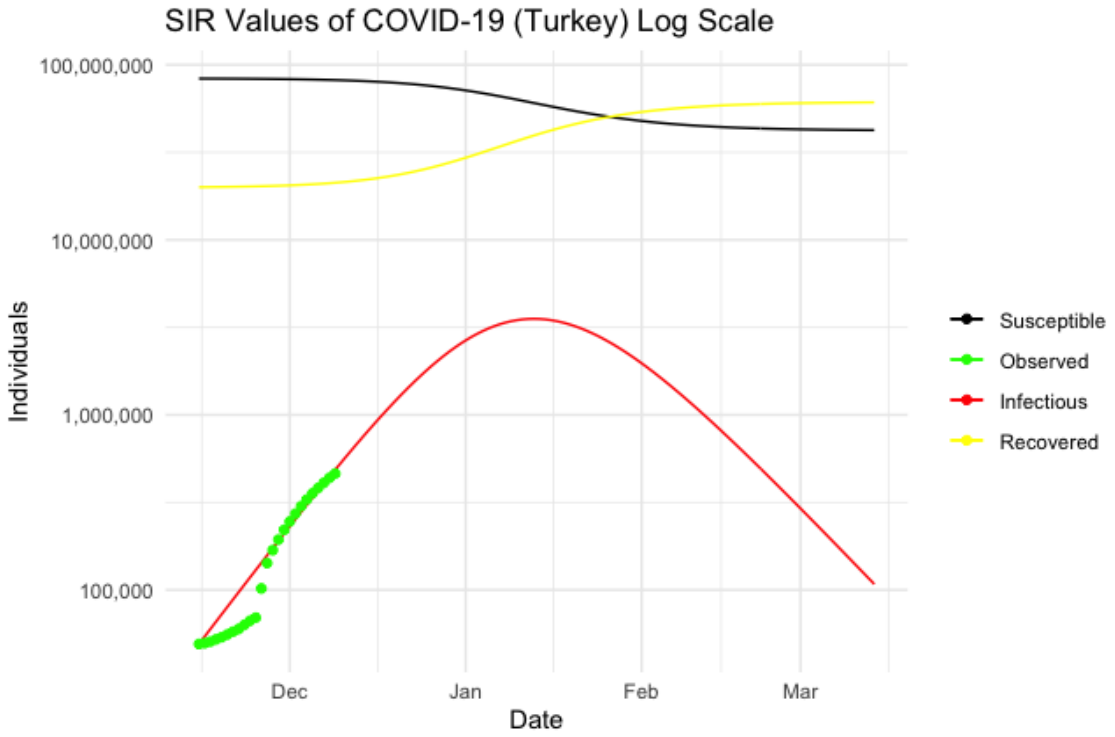

Figure 5. Illustration of the SIR model (log scale)

It may be easier to understand the characteristics of the pandemic from a logarithmic transformation of the cumulative cases in the SIR graph. Figure 5 shows the SIR model results. The sharp increase in late November 2020 can be seen clearly in Figure 5. Based on the predictions, the peak is estimated to be reached by the 13th of January in Turkey. It is important to note that these predictions are made according to the scenario, in which, the latest restrictions weren't announced by the Turkish government. Around a total number of 3530000 individuals would be affected according to the SIR model and among them, approximately 141000 people would be active cases. In total, approximately 35000 people would die, based on a mortality rate of 1%.

4. Conclusion and Comment

This paper is an explanatory study that estimates the daily cases and calculates the transmission rate of the COVID-19 in Turkey based on the SIR model between the dates, 15th of November, 2020 to 9th of December 2020. The estimates were made for 120 days after December 9. Along with the estimation of the daily cases, we estimate that the transmission rate and reproduction number for Turkey aren't in the expected range. The reason behind that might be the strong restrictions announced by the Turkish Government since December 2020. The SIR model has certain limitations. The most important one; It assumes that the entire population is a homogeneous mixture and each individual spreads the disease equally. However, the interaction of each individual in society cannot be the same. For example, individuals interact in much narrower groups, often shaped by business and social relations. Another limitation is that it does not cover the latent period between an individual's exposure to a disease and that individual becoming infected and contagious. Although it has limitations, the SIR model provides a reasonable estimate of peak and end dates in many countries, but care should be taken when interpreting these curves as any oversimplification can be misleading for policymakers.

The estimations in this study made using the scenario, in which, the latest restrictions weren't announced by the Turkish Ministry of Health. Therefore, the study would be invalid if any different event occurs. In addition, the findings of this study can be used to examine the characteristics of the pandemic at a certain time and predict the nature of the disease but are not recommended for any policy change and strategies.

Author Statement

Efehan Ulas: Original Draft Preparation, Investigation , Statistical Analysis

Acknowledgment

As the authors of this study, we declare that we do not have any support and thank you statement.

Conflict of Interest

As the authors of this study, we declare that we do not have any conflict of interest statement.

Ethics Committee Approval and Informed Consent

As the authors of this study, we declare that we do not have any ethics committee approval and/or informed consent statement.

References

[1] K. D. Patterson and G. F. Pyle, "The geography and mortality of the 1918 influenza pandemic," *Bull. Hist. Med*., 65(1), 4–21, 1991.

[2] World Health Organization, "Coronavirus disease 2019 (COVID-19): situation report, 82," 2020.

[3] Y.-C. Chen, P.-E. Lu, C.-S. Chang, and T.-H. Liu, "A time-dependent SIR model for COVID-19 with undetectable infected persons," *arXiv [q-bio.PE]*, 2020.

[4] C. Qi, D. Karlsson, K. Sallmen, and R. Wyss, "Model studies on the COVID-19 pandemic in Sweden," *arXiv [q-bio.PE]*, 2020.

[5] R. Ranjan, "Predictions for COVID-19 outbreak in India using epidemiological models," *bioRxiv*, 2020.

[6] C. Çakmaklı, S. Demiralp, Şebnem Kalemli-Özcan, S. Yesiltas, and M. Yildirim, "COVID-19 and emerging markets: An epidemiological model with international production networks and capital flows," *National Bureau of Economic Research*, Cambridge, MA, 2020.

[7] M. Özdinç, K. Şenel, S. Öztürkcan, and A. Akgül, "Predicting the progress of COVID-19: The case for Turkey," *Turk. Klin. J. Med. Sci.*, 40(2), 117–119, 2020.

[8] S. V. Scarpino and G. Petri, "On the predictability of infectious disease outbreaks," *Nat. Commun*., 10(1), 898, 2019.

[9] M. Chinazzi et al., "The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak," *Science*, 368(6489), 395–400, 2020.

[10] A. J. Kucharski et al., "Early dynamics of transmission and control of COVID-19: a mathematical modelling study," *Lancet Infect. Dis*., 20(5), 553–558, 2020.

[11] D. Fanelli and F. Piazza, "Analysis and forecast of COVID-19 spreading in China, Italy and France*," Chaos Solitons Fractals*, 134, 109761, 2020.

[12] L. Xue et al., "A data-driven network model for the emerging COVID-19 epidemics in Wuhan, Toronto and Italy," *Math. Biosci.*, 326, 108391, 2020.

[13] I. Cooper, A. Mondal, and C. G. Antonopoulos, "A SIR model assumption for the spread of COVID-19 in different communities," *Chaos Solitons Fractals*, 139, 110057, 2020.

[14] Q. Li, B. Tang, N. L. Bragazzi, Y. Xiao, and J. Wu, "Modeling the impact of mass influenza vaccination and public health interventions on COVID-19 epidemics with limited detection capability," *Math. Biosci*., 325, 108378, 2020.

[15] H. W. Hethcote, “The basic epidemiology models: Models, expressions for r0, parameter estimation, and applications,” in Lecture Notes Series, *Institute for Mathematical Sciences, National University of Singapore*, World Scientific, 2008, pp. 1–61.
[16] H. (howie) Weiss, “The SIR model and the Foundations of Public Health,” *Materials matemàtics*, 0001–0017, 2013.
[17] F. Ndaïrou, I. Area, J. J. Nieto, and D. F. M. Torres, “Mathematical modeling of COVID-19 transmission dynamics with a case study of Wuhan,” *Chaos Solitons Fractals*, 135, 109846, 2020.
[18] B. D. Ripley, “The R project in statistical computing,” *MSOR connect*., 1(1), 23–25, 2001.
[19] H. Wickham, “ggplot2: Ggplot2,” *Wiley Interdiscip. Rev. Comput. Stat*., 3(2), 180–185, 2011.
[20] K. Soetaert, T. Petzoldt, and R. W. Setzer, “Solving differential equations in R: Packagede solve,” J. *Stat. Softw*., 33(9), 1–25, 2010.