Chapter 6

Tracking of COVID-19 Pandemic for Multi-Waves Using a Compartmental Model With Time-Dependent Parameters:
A Sum of Logistic Branches

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ABSTRACT

Estimating and controlling the COVID-19 pandemic is essential to reduce the spread of the disease and help decision-making efforts in combating public health crises. However, the potential presence of multiple dynamic changes in the reported count data or the occurrence of another wave of the pandemic emerges as a challenge for simulating the evolution of the disease over a long period. In this chapter, to account for the dynamic changes in the COVID-19 curves, the authors propose a rate function based on multiple branches of a logistic function. They assumed in a compartmental model that the recovery

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and disease transmission rates are time-dependent, and they assign to each the rate function. Then, they apply the model to daily COVID-19 data on infection counts in Morocco between March 2, 2020 and December 31, 2021 using curve fitting through the Nelder-Mead optimization method. The simulation outcomes demonstrate the model's ability to replicate the COVID-19 pandemic in Morocco over two waves, with the goodness of fit depending on the number of logistic branches composing the rate function.

1. INTRODUCTION

Coronavirus disease 2019 (COVID-19), an illness caused by the novel SARS-CoV-2 virus, was first reported in Wuhan, China, on December 31, 2019. As of July 5, 2023, the worldwide count of confirmed infections exceeded 767 million, with more than 6 million deaths recorded (WHO Coronavirus Dashboard, 2023). Faced with the growing risk of a pandemic, governments have started implementing targeted policies aimed at slowing the transmission of infection, easing the strain on public healthcare systems, and lowering the mortality rate. Combating COVID-19 has encountered increased challenges due to the re-emergence of consecutive waves, following periods of partial containment, in new infection cases, hospitalizations, or fatalities.

In the COVID-19 pandemic, the re-emergence of a new wave of infection in a population is not primarily due to seasonal variations. On the contrary, the way the virus spreads and the subsequent impact on waves is influenced by human behavior, such as adherence to preventive measures, compliance with public health guidelines, mobility patterns, and social interactions. Further, the effectiveness or lack of interventions implemented by local health authorities can contribute to the occurrence and severity of successive waves. When relaxing restrictions, the transmission of the virus tends to increase, whereas reintroducing or strengthening control measures can lead to a decrease in the transmission rate of the virus. A COVID-19 wave typically starts with a gradual rise in cases, reaches a peak where infection rates are at their highest, and then experiences a gradual decline in cases. Similarly, when examining the impact on healthcare systems, such as hospitalizations, intensive care unit (ICU) admissions, or healthcare resource utilization, a significant increase in hospitalizations or overload of healthcare capacity during a specific period indicates the presence of a COVID-19 wave.

Identifying multiple dynamic changes or waves in epidemic count data provides valuable insights into the trajectory of the outbreak, helps evaluate interventions, guides resource allocation, informs public health strategies, and aids in monitoring and forecasting. It is a crucial phase in understanding and effectively responding to an ongoing epidemic and guiding decision-making for future waves or similar outbreaks. This requires a dependable mathematical model and numerical technique to depict the intricate patterns of epidemic curves that exhibit multiple waves. In response to the subsequent waves of the COVID-19 disease observed in many countries, researchers have examined various models in the literature to represent the dynamic changes in COVID-19 curves. These include growth models or diffusion models (Brum et al., 2023; Vasconcelos et al., 2021; Eryarsoy et al., 2021) and compartmental models (Alshammari, 2023; Cacciapaglia et al., 2020) with time-dependent parameters. Our interest goes to compartmental or mechanistic models that consider the key biological features of infectious diseases. The epidemiological parameters of these models can be viewed as constant (time-invariant) or time-dependent.