

Supplementary Materials for “Incorporating Interventions to an Extended SEIRD Model with Vaccination: Application to COVID-19 in Qatar”

ELIZABETH B AMONA¹, RYAD A GHANAM², EDWARD L BOONE¹, INDRANIL SAHOO^{1,*},
 AND LAITH J ABU-RADDAD³

¹*Department of Statistical Sciences and Operations Research, Virginia Commonwealth University, Richmond, Virginia, 23284, USA*

²*Department of Liberal Arts and Sciences, Virginia Commonwealth University in Qatar, Education City, Doha, Qatar*

³*Weill Cornell Medicine, Qatar*

Abstract

This supplementary material contains the functional form of the posterior distribution of the model parameters, a discussion on the behaviour of $\mathfrak{R}_e(t)$ over time, some trace plots validating convergence of model parameters and details about the data and code used for this project.

1 Posterior distribution of the model parameter

The posterior distribution obtained from the likelihood (6) and prior distribution (7) is given by

$$\begin{aligned} \pi(\boldsymbol{\alpha}, \beta^*, \beta, \boldsymbol{\gamma}, \zeta, \rho | \mathbf{D}) &\propto \frac{\pi(\boldsymbol{\alpha})\pi(\beta^*)\pi(\beta)\pi(\boldsymbol{\gamma})\pi(\zeta)\pi(\rho)L(\mathbf{D}|\boldsymbol{\alpha}, \beta^*, \beta, \boldsymbol{\gamma}, \zeta, \rho)}{e^{-\sum_i \alpha_i - \beta^* - \beta - \sum_j \gamma_j - \zeta - \rho}} \\ &\propto e^{\sum_i \alpha_i + \beta^* + \beta + \sum_j \gamma_j + \zeta + \rho} \\ &\times \prod_{t=1}^T \frac{\phi_I(t)^{I(t)} \phi_{R_I}(t)^{R_I(t)} \phi_D(t)^{D(t)} \phi_V(t)^{V(t)} e^{-\phi_I(t) - \phi_{R_I}(t) - \phi_D(t) - \phi_V(t)}}{I(t)! R_I(t)! D(t)! V(t)!}. \end{aligned}$$

2 Behavior of $\mathfrak{R}_e(t)$ over time

Figure 1 shows the estimated time varying effective reproduction number, $\mathfrak{R}_e(t)$, along with 95% confidence bands (colored green). Until about day 90, the entire band is above 1, showing that the system was in a pandemic state at the beginning of the study period. The estimated $\mathfrak{R}_e(t)$ in this period is about 2.6, which indicates that the number of secondary infections was high and more people could get infected since the population was well mixed. For the time period when the band is close to or contains 1, it is difficult to conclude whether the system was in a pandemic state or not. But after the introduction of vaccines on day 420, $\mathfrak{R}_e(t)$ goes below 1, showing that the system was then in the endemic or declining state.

Additionally, we can visualize the impact of the intervention strategies by the Qatari government using the time varying effective reproduction number. With an intervention on day 48, $\mathfrak{R}_e(t)$ declines from about 2.6 to about 2.4. This shows that the intervention on 48 was helpful in reducing the spread of secondary infections. Similarly, the intervention implemented on day 60 was also effective in controlling the spread of COVID-19, as reflected in the drop of $\mathfrak{R}_e(t)$

*Corresponding author. Email: sahooi@vcu.edu.

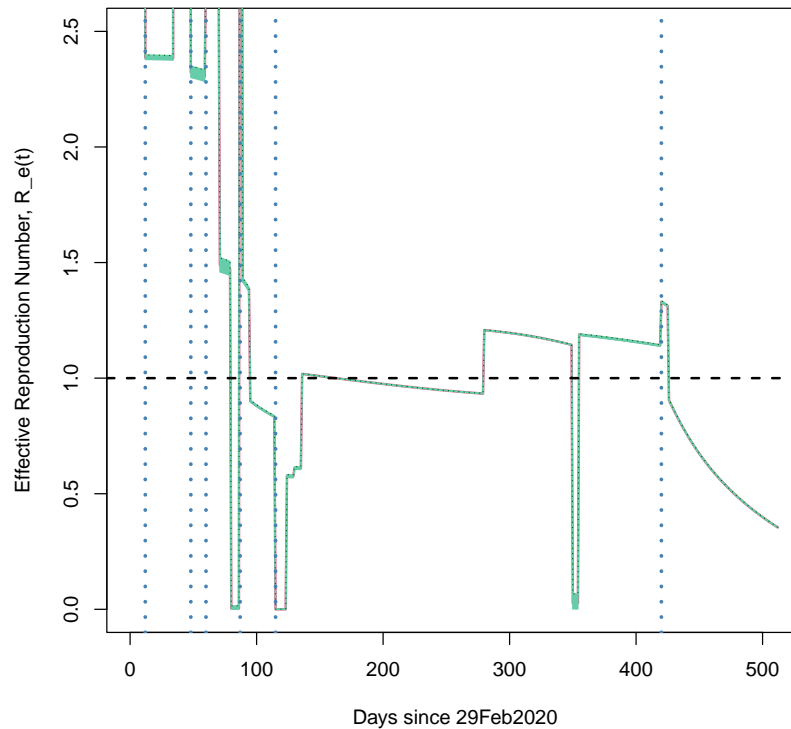


Figure 1: Plots of Time Varying Effective Reproduction Number for the State of Qatar for the days since 29 February 2020 until until 13 October 2021 with the 0.025 and 0.975 Quantiles .

from about 2.4 to 1.5. These conclusions consistent with the results in Table 5 in the main manuscript. After the introduction of vaccination on day 420, $\mathfrak{R}_e(t)$ drops drastically to about 0.4, showing the importance of getting vaccinated. This is also evident from Figure 3(b) in the main manuscript, where the number of infected dropped drastically when vaccination was introduced. Between days 126 and 420, we could not decide whether the system was in the pandemic state, which reflects the government’s decision to lift restrictions on June 15, 2020 (day 126) and to not implement any major intervention measures until April 29, 2021 (day 420), when vaccines were introduced in Qatar.

3 Trace plots for validating convergence of model parameters

For details on the posterior sampling scheme, please see the main manuscript.

4 Data and code availability

The dataset and code used for this project can be found at <https://github.com/elizabethamona/SEIRDV-model>.

