

FIG. 6 Convergence of unaware susceptible and chronically infected populations (S_u and C) to their desired values (S_{u_d} and C_d).

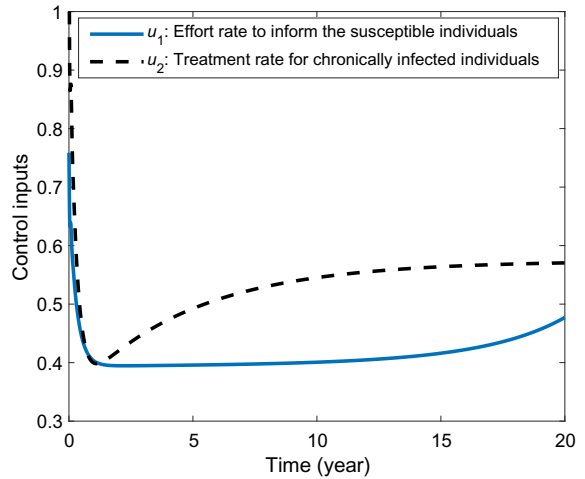


FIG. 8 Control inputs (u_1 and u_2) during the treatment period of HCV epidemic.

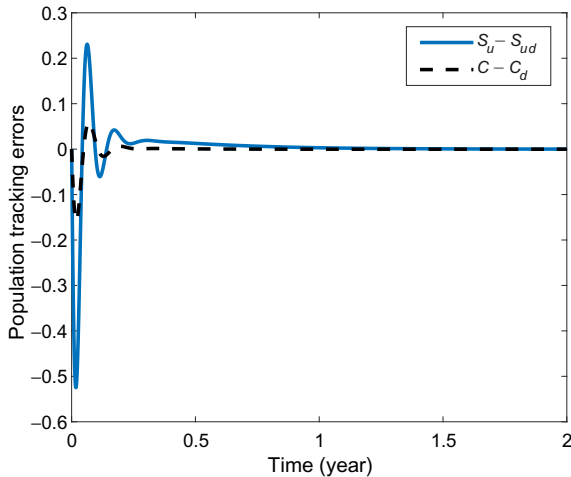


FIG. 7 Tracking errors between the desired and real values of unaware susceptible and acutely infected compartments.

As described, two control inputs are adjusted according to the proposed nonlinear adaptive strategy in order to prevent the HCV outbreak. The first control input $u_1(t)$ denotes the effort rate to inform the susceptible individuals from the HCV and the second one $u_2(t)$ is the treatment rate for chronically infected individuals. These control inputs are considered to be normalized in Eq. (1) to be in the range of $[0, 1]$. The obtained values for these inputs using the proposed control strategy are shown in Fig. 8, which satisfy the physiological constraint ($u_1 \in [0, 1]$). This implies that the considered

desired scenarios (20), (21) for the reduction of unaware susceptible and chronically infected compartments comply with the control input limitations. Fig. 9 illustrates the tuning of estimated parameters (θ_1 and $\hat{\theta}_2$) based on the designed adaptation laws (15), (16) in the presence of 20% uncertainty.

5.1. System Response to Different Uncertainty Levels

In this section, the effects of different uncertainty levels are investigated for the HCV epidemic dynamics. For this purpose, 50%, 70%, and 90% uncertainties are considered on the initial guess of parameters in θ_1 and θ_2 (defined in Eqs. 7, 8). Performance of the adaptation laws (15), (16) on the tuning of estimated model parameters is investigated in Fig. 10. As discussed and proven in Section 4, these adaptation laws guarantee that the estimation errors of the HCV dynamic parameters remain bounded against different uncertainty levels.

Fig. 11 shows the population errors of unaware susceptible and chronically infected classes in tracking their desired value ($\tilde{S}_u = S_u - S_{u_d}$ and $\tilde{C} = C - C_d$).

As observed in Fig. 11, the increment of parametric uncertainties increases the magnitude of errors (\tilde{S}_u and \tilde{C}) and their initial variations. However, after a period of time (about 0.2 year), the error magnitudes have reached zero, which means that the tracking convergence has been achieved for different values of uncertainties. In other words, the population of unaware susceptible and chronically infected compartments converged to their desired values ($S_u \rightarrow S_{u_d}$ and $C \rightarrow C_d$) in the existence of different levels of uncertainty.