Optimal vaccination strategies and rational behaviour in seasonal epidemics

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We consider a fixed size population divided in three different classes: **S**usceptible, **I**nfeccious and **R**ecovered. In particular, we consider a classical SIR dynamics: ($S + I \xrightarrow{\beta} 2I$, $I \xrightarrow{\gamma} R$, $R \xrightarrow{\alpha} S$) where the infecctious term $\beta(t)$ is a periodic function. We include in the model a periodic *vaccination function* $p(t)$, such that the trasition $S \xrightarrow{p} R$ is also allowed.

We show the existence of an optimal vaccination $p_{\rm opt}$, in the sense that it can be approximated by vaccination functions able to prevent outbreaks and all these other functions will necessarily imply the existence of a vaccination effort at least equal to the vaccination effort of $p_{\rm opt}$. For some examples, we are able to show explicitly $p_{\rm opt}$ as a function of β.

Finally, we introduce a population of rational individuals and we will show how the *voluntary vaccination* affects the dynamics. In particular, we consider that each individual is *rational*, i.e., each individual decides freely, according the the available information, if he or she is willing or not to be vaccinated. To this end, we will couple a system of differential equation with principles from game theory. We prove the existence of a Nash-equilibrium vaccination function $p_{\rm Nash}$ (i.e., when all individuals in the population are rational) and, for some simple examples, we show explicit formulas for $p_{\rm Nash}$.