**Supporting Information Table S1**

**Model structure**

The following set of partial differential equations defines the rates at which the simulated population moves between model states:















In which:

* NS, NC, LS, LC, HS, HC, and D, are population states, where N=No protection, L = Low protection, H = High protection, S = Susceptible, C = Colonized, and D = Diseased; X(t) is the total population.
* μ(t,a) and ν(t) are time-dependent birth and death rates, respectively. Birth rate also depends on age as individuals are only born into the age=0 group
* ωL(a) is the age-dependent rate at which low protection wanes to no protection and ωH(a) is the age-dependent rate at which high protection wanes to low protection
* λ(t,a) is the time- and age-dependent force of infection
* γ(t,a) is the time- and age-dependent rate of vaccination
* σ(a) is the age-dependent rate of invasive disease among colonized persons
* αL and αH are the efficacy of low and high antibody at preventing colonization
* βL and βH are the efficacy of low and high antibody at preventing invasive disease
* ρC and ρD are the rates of recovery from colonization and invasive disease, respectively