Applications Software for Information Management

EST 305

Final Project

Understanding the Effects of Vaccination on COVID

May 2021

1. Application Description
2. Mathematical Model
3. VBA Application

1 Application Description

2 Mathematical Model

3 VBA Application

Description

Although COVID vaccines are free, at least in the U.S., and available to the general public now, many people are still hesitant about the COVID vaccine. This application will model the Covid pandemic with given parameters inputed by the user, and display the effectiveness of vaccines on ending this pandemic, and, essentially, to convince them to take the vaccine.

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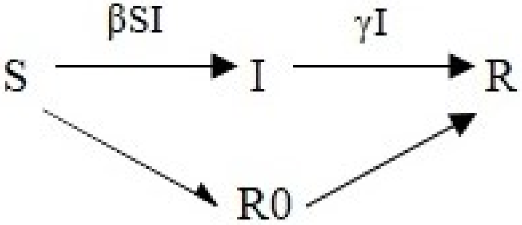
SIR Model with Vaccination

Schematic Diagram



- S:Susceptible; those who could become infected
- I:Infective; infected and can pass the disease to others
- R:Removed; not susceptible nor infective, do not play a direct role in disease progression, those who died or immune to this virus

SIR Model with Vaccination

- $R_0(V_r)$:Vaccination Rate; number of individuals who gained immunity through vaccination per day
- β:Infection Rate; the likelihood that a single infective individual would pass the disease to an arbitrary susceptible, unit of β is per individual per day
- γ:Recovery Rate; gamma represents the proportion of Infective population that will be placed into Removed population(either died or became immune). Statistically, the expected value of $\gamma = 1/k$, where k is average number of days that infection lasts

SIR Model with Vaccination

- Mathematical Equations

Without Vaccination	With Vaccination
$\frac{dS^f}{dt} = -\beta N I^f S^f$	$\frac{dS^f}{dt} = -(\beta N I^f + V_r) S^f$
$\frac{dS^f}{dt} = (\beta N S^f - \gamma) I^f$	$\frac{dS^f}{dt} = (\beta N S^f - \gamma) I^f$
$\frac{dI^f}{dt} = \gamma I^f$	$\frac{dI^f}{dt} = \gamma I^f + V_r S^f$

- where superscript f means fractional population, and this set of differential equations can be analyzed by Forward Euler's Method, which is a discretization method that can be implemented in Excel VBA by iteration.

Iteration

- In each iterative step:

Without Vaccination	With Vaccination
$S = S + dS/dt$	$S = S + dS/dt - V_r S$
$I = I + dI/dt$	$I = I + dI/dt$
$R = R + dS/dt$	$S = S + dS/dt - V_r S$
$D = D + 0.03 \cdot dR/dt$	$D = D + 0.03 \cdot dR/dt$

- Each iterative step gives us the data for the next day.
- Here S, I, and R are in their fractional form, and 0.03 is the death rate that is fixed in this program.

VBA Iteration Implementation

- Without Vaccination:

```
With .Range("C11")
    For k = 1 To 365
        rowoff = rowoff + 1
        .Offset(rowoff, 0).Value = k
        .Offset(rowoff, 1).Value = Round(S * PopSize)
        .Offset(rowoff, 2).Value = Round(I * PopSize)
        .Offset(rowoff, 3).Value = Round(R * PopSize)
        .Offset(rowoff, 4).Value = Round(D * PopSize)
        dSdt = -b * PopSize * I * S
        dIdt = ((b * PopSize * S) - g) * I
        dRdt = g * I
        S = S + dSdt
        I = I + dIdt
        R = R + dRdt
        D = D + 0.03 * dRdt
    Next
End With
```

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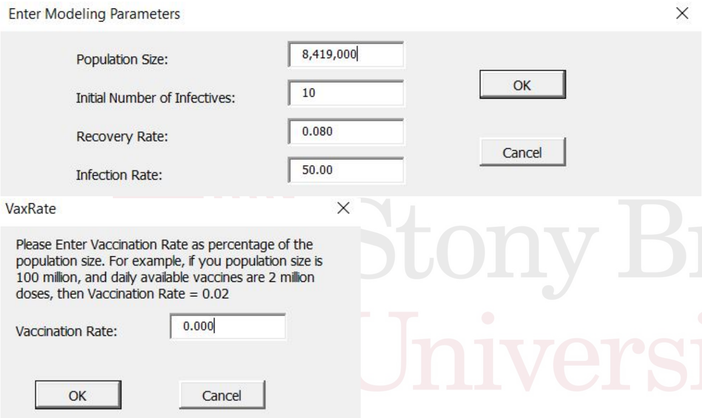
User Form: Inputs

- This program has multiple User Forms asking for user inputs. It will ask **which model the user wants to perform; constant or probabilistic.** The probabilistic model will have random rates. However, statistically, the expected values of these rates will still be of the same values as what the user enters. It will ask for modeling parameters including **population size, initial numbers of infectives, recovery rate, infection rate, and vaccination rate.**
- Details will be shown during Demo

Example Input User Form



Error Trapping for Inputs

- Multiple attempts of error trapping are included in the code to make sure that those values are valid, reasonable, and mathematically feasible. For example:

```
' Enter some labels and clear the table from a previous run, if any.
With .Range("C11")
    Range(.Offset(1, 0), .Offset(1, 4).End(xlDown)).Clear
End With

If IniInf > PopSize Then
    MsgBox "Initial number of infectives cannot exceed population si
        vbInformation, "Improper input"
    Exit Sub
End If
If RecR > 0.3 Or RecR < 0.03 Then
    MsgBox "Reasonable recovery Rate(%) is between 0.03 to 0.3", _
        vbInformation, "Improper input"
    Exit Sub
```

Error Trapping for Inputs

```
'Error trapping, make sure that each box is filled with correct
For Each ctl In Me.Controls
    If TypeName(ctl) = "TextBox" Then
        If ctl = "" Or Not IsNumeric(ctl) Then
            MsgBox "Enter a positive number in each box.", _
                vbInformation, "Improper input"
            ctl.SetFocus
            Exit Sub
        End If
    End If
Next
```

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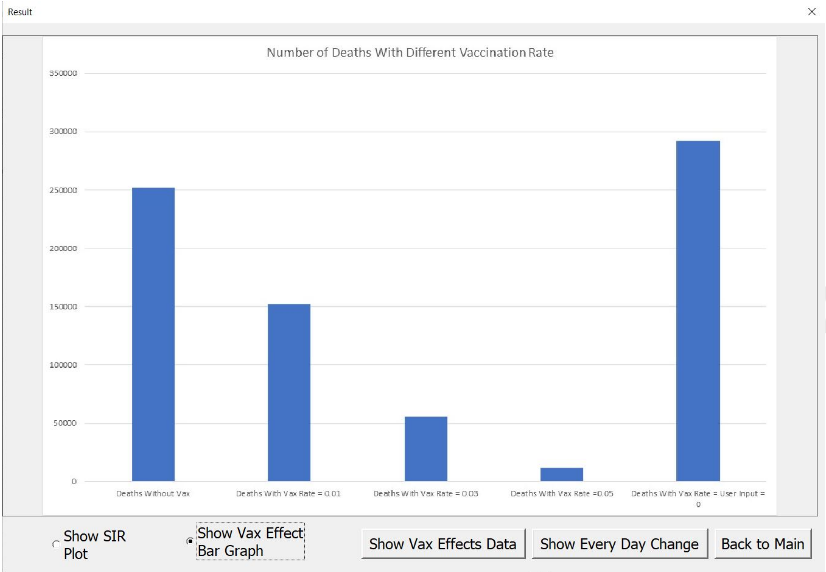
Example Output User Form

- In the next slide, we will show you the result we get from modelling with NYC population size(approximately 8.5 million), 1000 initial number of infectives(1000 people carrying the virus), Removal/recovery rate 0.08(assuming 12.5 days to recover or die on average), and infection rate 50.00(50 chances for an infective individual to pass the disease to a random susceptible). And this will actually be the default input values when the user runs the program.

Example Output User Form



Example Output User Form

- The first bar is the number of deaths without vaccination, over 250,000 people would die in NYC along(our program does not consider the effects of wearing masks, quarantine, etc.., so it experiences higher death toll than the reality). Significant decreases in number of deaths are observed when the rate of vaccination increases. If we can just vaccinate 3 percent of the population everyday, we can save almost 200,000 lives.