Assessing Vaccine Efficacy of Influenza Spread in Urban vs. Rural North Carolina using an SVIR model

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I. Introduction

The spread of infectious diseases such as influenza is influenced by various factors, one of the most significant being the efficacy of a vaccine. This is particularly relevant when comparing rural and urban populations, where access to vaccination can differ substantially. Then, using an SVIR model, observations about the possible repercussions of this discrepancy can discern what impacts the spread of a virus such an influenza throughout different populations.

II. Assumptions

- Two strains of flu present in one season
- No mutations between the strains
- No deaths from the infection
- Strain 2 has a higher transmission rate and a longer recovery time
- Homogenous mixing
- No age structure, no loss in immunity
- Someone who has had strain 1 cannot be infected with strain 2
- No addition to initial population (No birth rate / no migration)
- Transmission rates, β1 and β2, are assumed not to change
- If vaccinated, there is still a smaller chance of infection
- If recovered, there is no chance of re-infection

III. The Model

- S_t → number of susceptible individuals at time t
- $I_{1,t}$ → number of infected individuals with influenza strain i at time t
- V_t → number of vaccinated individuals at time t
- $R_{i,t}$ → number of recovered individuals at time t of influenza strain i
- β_i → transmission/infection rate of influenza strain i
- θ → vaccination rate
- ε_i → vaccine efficacy of influenza strain i
- α_i → recovery rate of infected individuals of strain i
- q_i → proportion of initial susceptible (S0) that have not been infected with strain i

IV. Results

The model below was analyzed through simulations toggling previously discussed parameters, aimed at modeling the spread of flu throughout distinct populations.

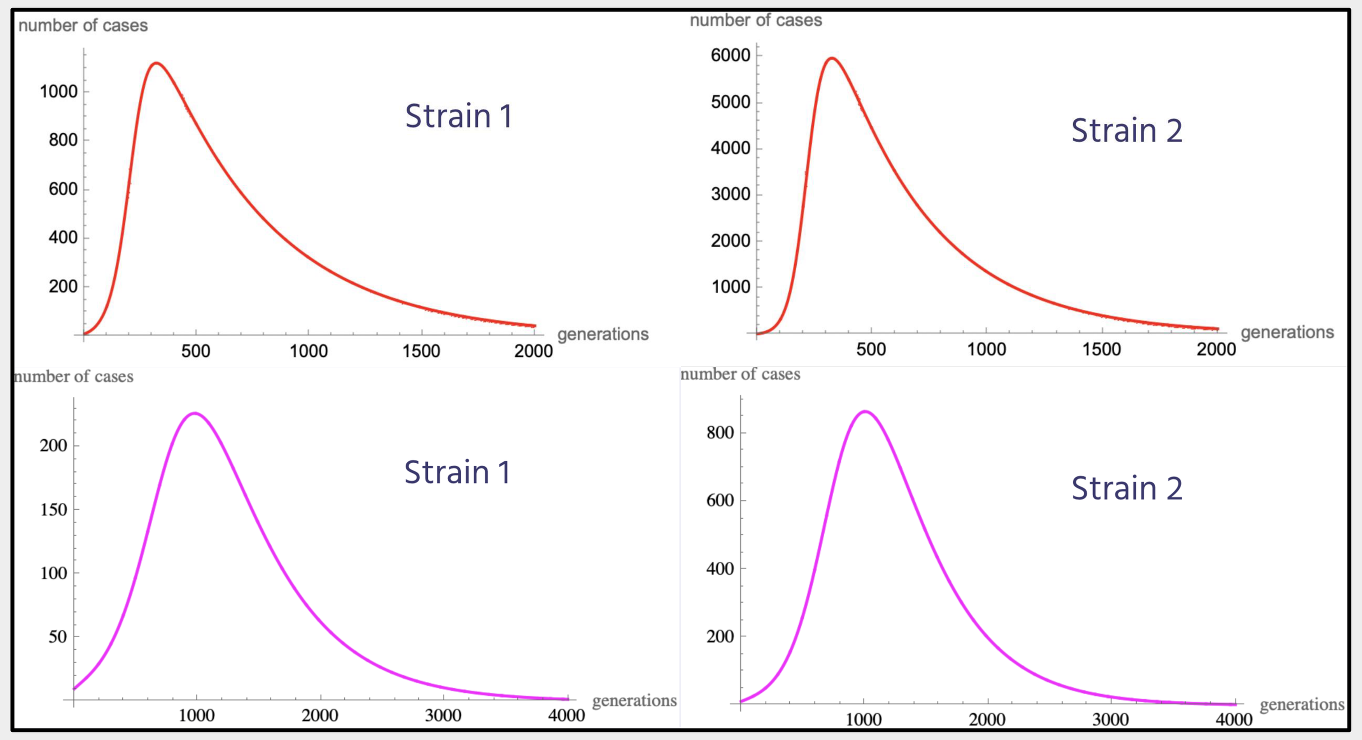

Figure 1. Comparing number of influenza cases vs. time for strain 1 and strain 2 in urban (red) vs. rural (magenta).

- Strain 1 has lower transmission rate, recovery rate, and starting infected population compared to Strain 2

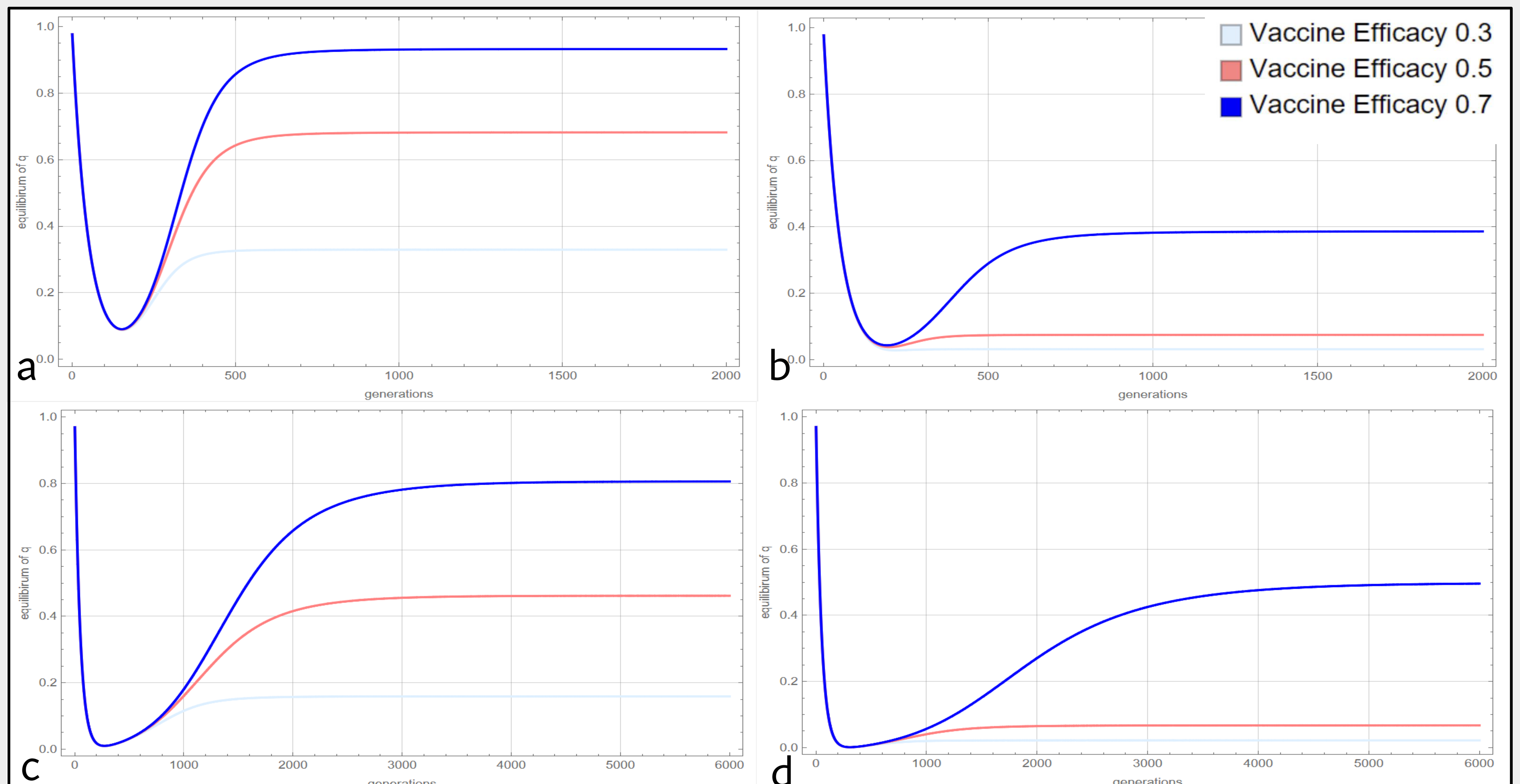

Figure 2. Vaccine efficacy on the equilibrium proportion of initial susceptibles that have not been infected (q) for strain 1 (*a, c*) and strain 2 (*b, d*) for urban (*a, b*) vs. rural (*c, d*) populations.

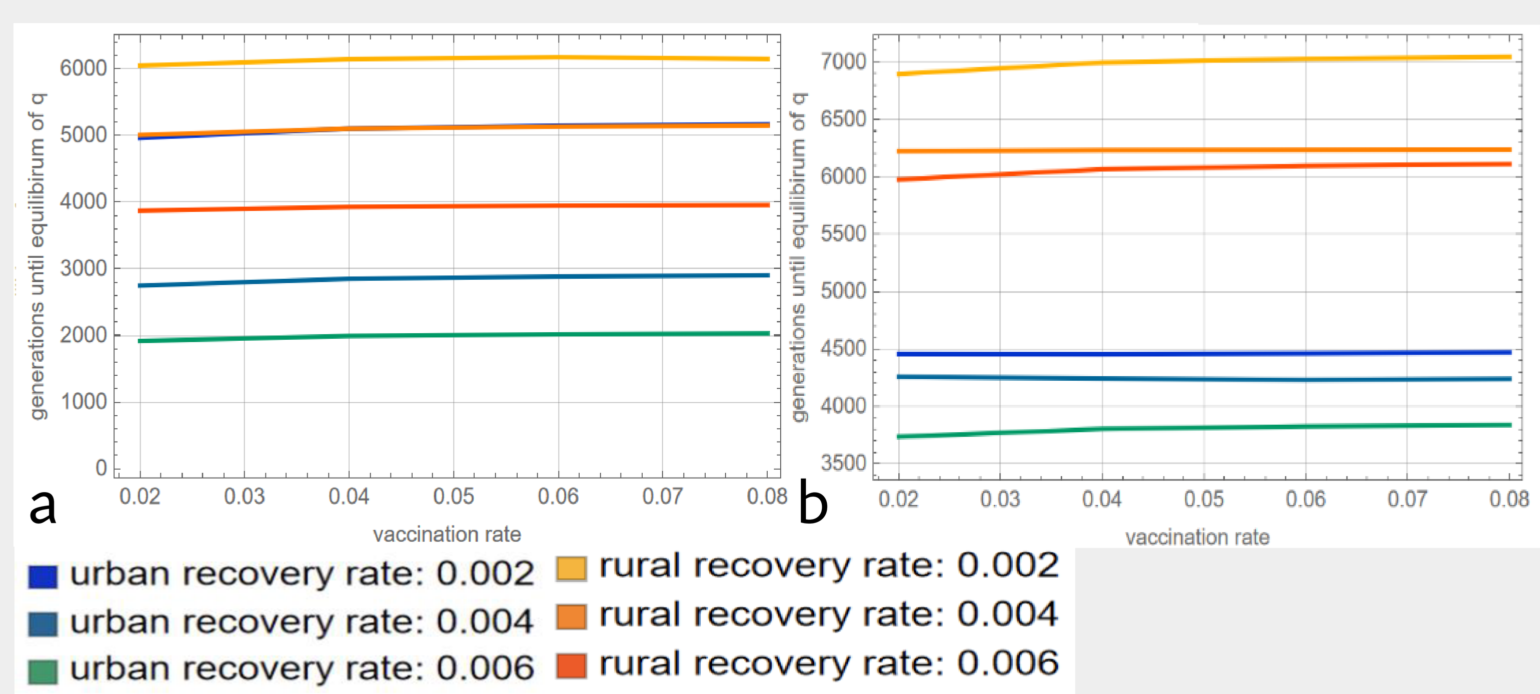

Figure 3. Vaccination and recovery rates on the generations until equilibrium of the proportion of initial susceptibles that have not been infected (q) by strain 1 *(a)* and strain 2 *(b)* viruses is reached.

V. Discussion

- Understanding infection spread and vaccination efficacy is crucial for public health.
- Figure 1 reveals that strain 1 infected a significantly smaller number of people compared to strain 2.
- The peak in the rural population took much longer to achieve compared to the peak in the urban population
- Increasing vaccine efficacy increases the proportion of individuals not infected (q).
- Urban areas, with higher vaccination rates and transmission rates, exhibit higher q values compared to rural areas.
- Increasing recovery rates in both rural and urban simulations increase q.

VI. Limitations & Conclusions

- We assumed homogeneous mixing and the absence of mutations between strains, which may oversimplify real-world dynamics.
- There is a lack of consideration for demographic factors such as race and age, or socioeconomic disparities which limits the generalizability of our findings.
- Human behavioral aspects, such as varying decision-making processes and healthcare-seeking behaviors.
- Specific regional considerations, such as military bases, industrial areas, and agricultural communities.
- The variability among urban and rural vaccination and recovery rates, as well as among different possible strands, indicates the need for more targeted interventions to improve vaccine efficacy
- Rural populations are affected more significantly than urban

VII. References and Acknowledgements

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