Modeling Intervention Strategies for TB Control in the United States

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Introduction

Epidemiological models offer insight into the structure of disease outbreaks and the merits of various interventions. The most common epidemiological models are compartmental differential equation models, such as the SIR system, illustrated in figures 1 and 2.

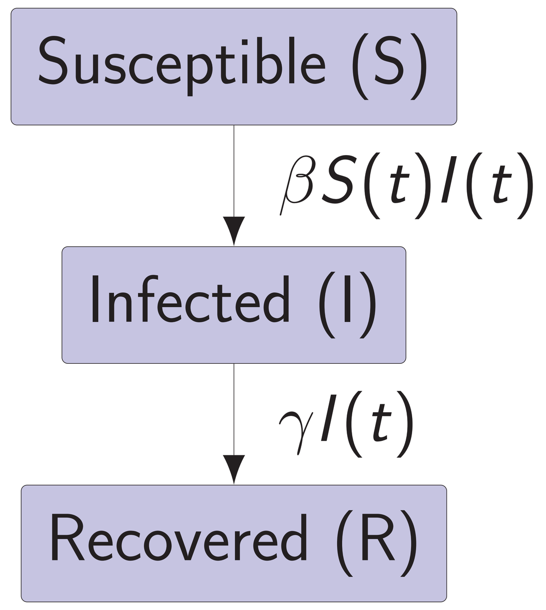

Figure : This flowchart depicts the standard SIR epidemiological model. It is accomponanied by the system of differential equations 2.

$$\frac{dS}{dt} = -\beta S(t)I(t)$$
$$\frac{dI}{dt} = \beta S(t)I(t) - \gamma I(t)$$
$$\frac{dR}{dt} = \gamma I(t)$$
$$N = S(t) + I(t) + R(t)$$

Figure : The system of differential equations governing the SIR model.

The Basic Hill Model

In order to model tuberculosis (TB) in the United States (US), Hill, Becerra, and Castro designed a complex compartmental model called the hill model.

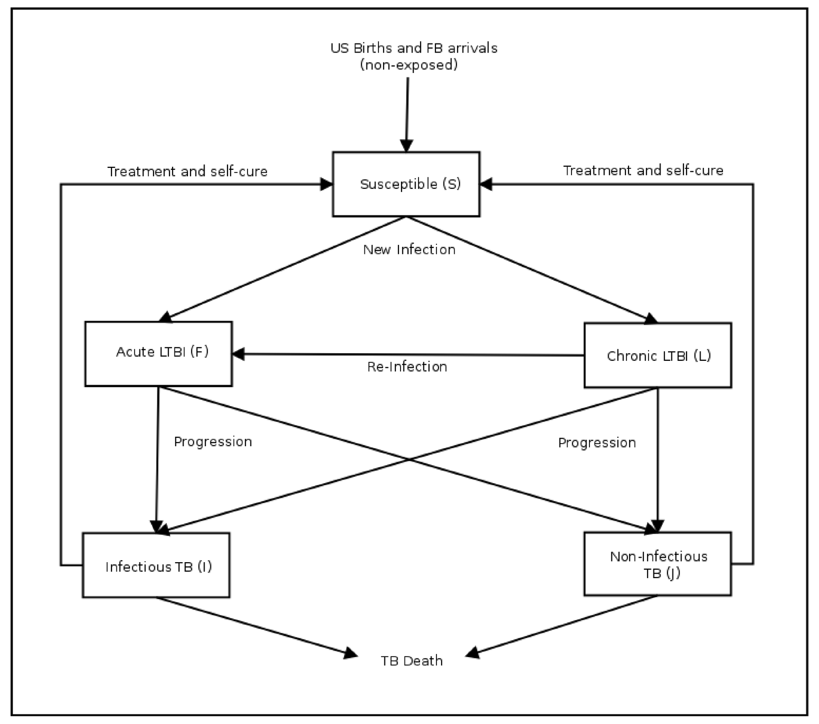

Figure : A flow chart representing the compartments of the Hill Model.

Populations:

- US Born Individuals (USB)
- Foreign Born Individuals (FB)

Individuals also leave the model due to natural death.

TB Reduction Strategies for the United States

From the Hill model, we

Intervention Analysis

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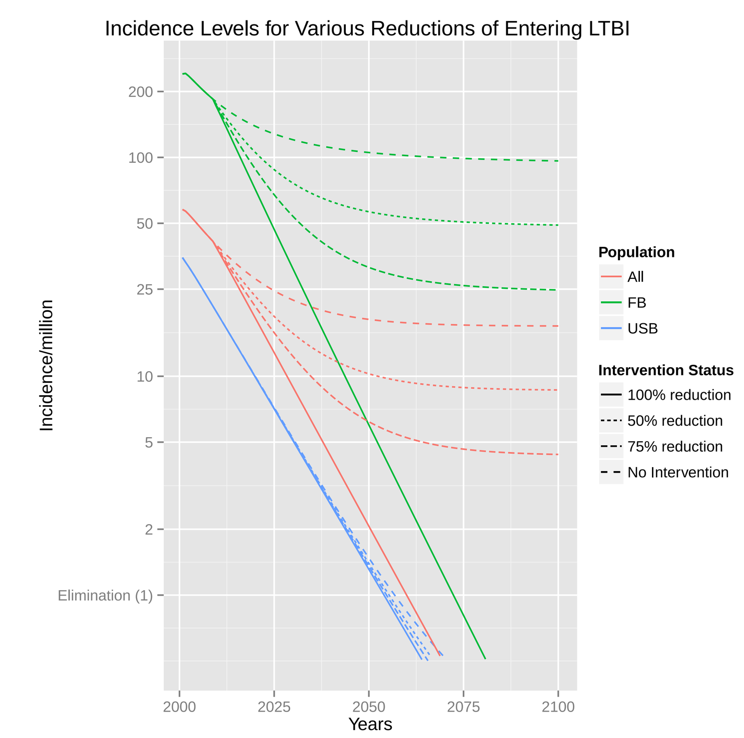

Figure : A graph of the projected incidence levels per million in the US-born, Foreign-born, and Total US population, given that LTBI rates in Foreign-born arrivals are reduced by 0%, 50%, 75%, and 100%.

Economic Modeling

We extended our basic implementation of the Hill model to incorporate economic data of treatment costs for Active and Latent Tuberculosis.

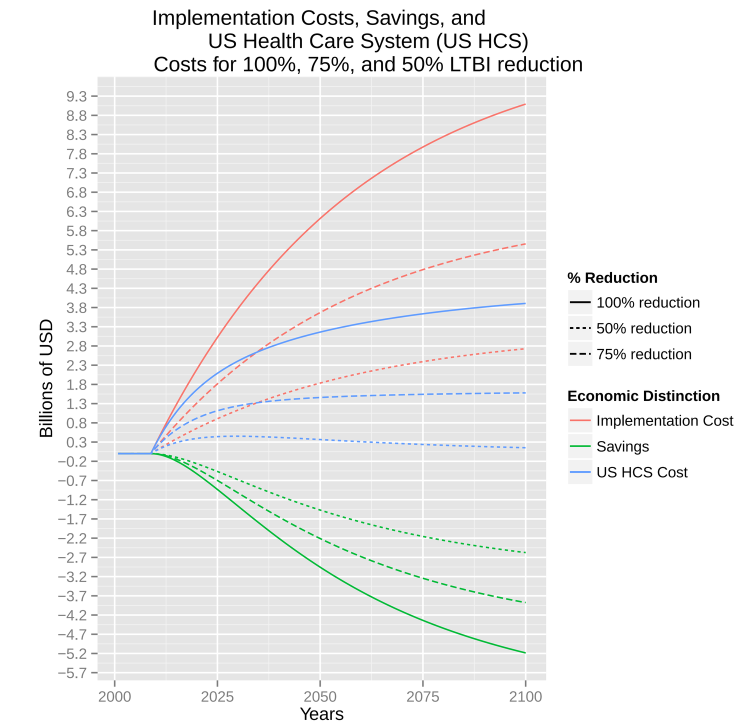

Figure : A graph of the cumulative implementation costs, savings, and net US health care system costs of reducing rates of LTBI in Foreign-born arrivals by 50%, 75%, and 100%. To determine the implementation cost for each intervention, the average cost to identify and treat entering Foreign-born individuals with LTBI was set to be \$600, \$800, and \$1000 for the 50%, 75%, and 100% reduction strategies respectively.

An Agent Based Implementation

We also wrote a stochastic agent-based version of the Hill model in both NetLogo and C++.

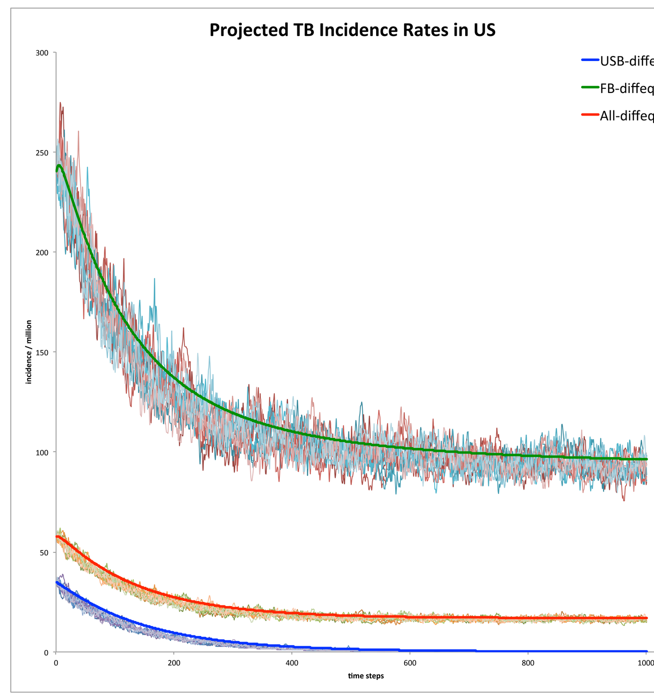

Figure : Incidence/million for R and NetLogo models (12 runs, $\Delta t = 0.1$, popConst $= 100$)

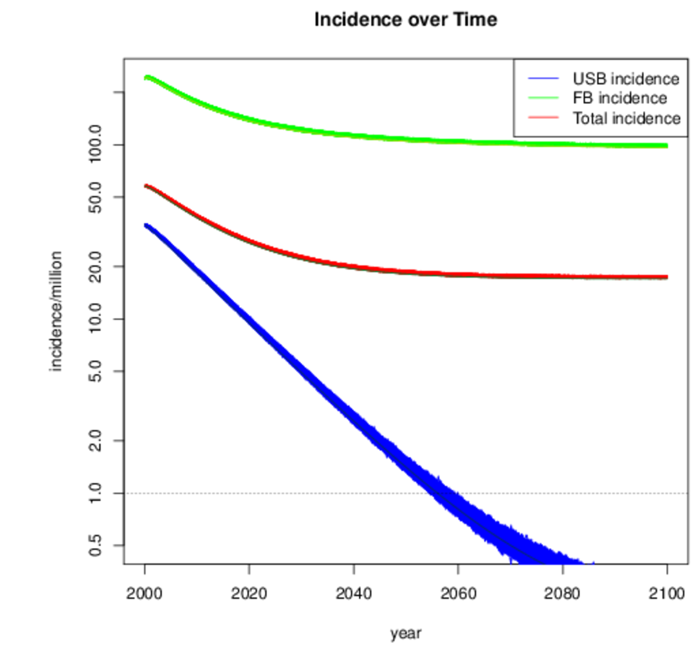

Figure : Incidence/million for R and C++ models (2100 runs, $\Delta t = 0.01$, popConst $= 1$)

Stochastic Models as a Measure of Variability

The stochastic model gives us a sense of the variability of the results of the deterministic model.

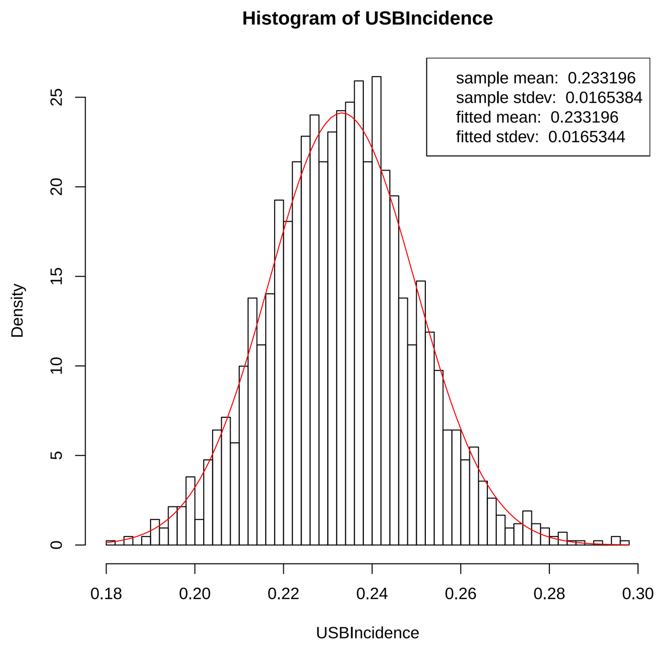

Figure : Distribution of USB Incidence (C++) with fitted Normal curve

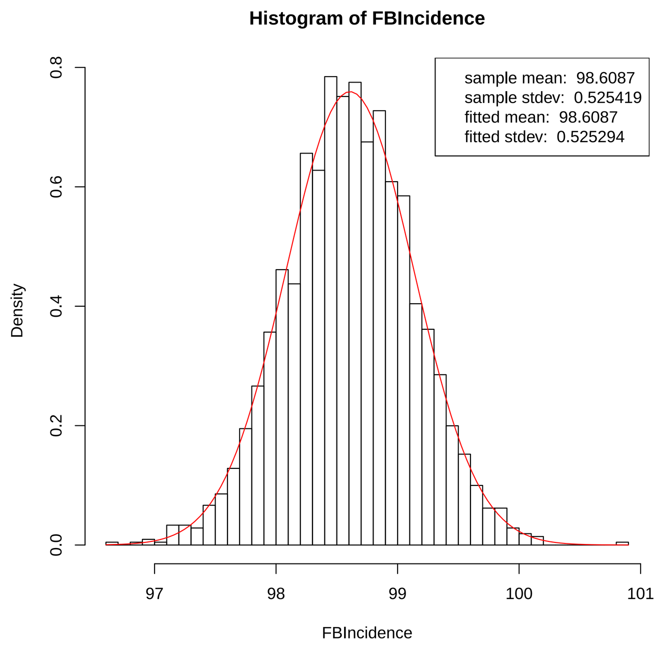

Figure : Distribution of FB Incidence (C++) with fitted Normal curve

Future Extensions

Possible extensions to our model include the incorporation of non-homogeneous contact structures and MDR (multi-drug resistant) TB.

https://www.github.com/mmcdermott/disease-modeling