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.

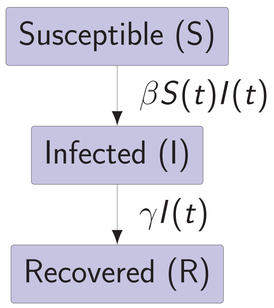

Figure: This flowchart depicts the standard SIR epidemiological model. It is accompanied by the system of differential equations 2.

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

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.

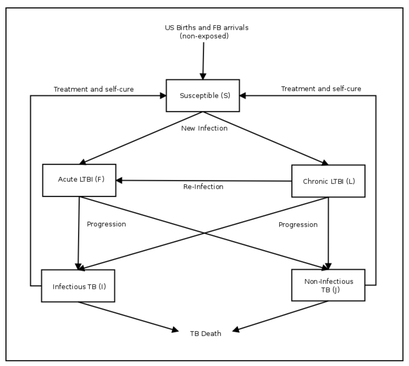

Figure: A flow chart representing the compartments of the Hill Model.

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

Intervention Analysis

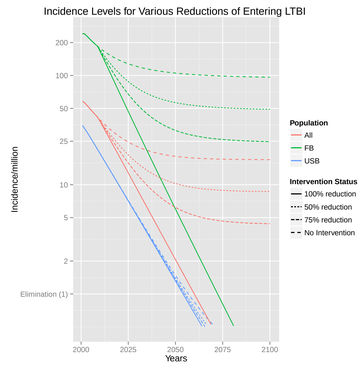

Figure: A graph of the projected incidence levels per million in the US-born, Foreign-born, and Total US population, given that LTBI rates in Foreign-born arrivals are reduced by 0%, 50%, 75%, and 100%.

Economic Modeling

We extended our basic implementation of the Hill model to incorporate economic data of treatment costs for Active and Latent Tuberculosis. In our model, we estimate the average heath care costs to be $14,014.90 and $403.45 to treat a single case of Active or Latent TB respectively. Given these costs and the average treatment rates for Active and Latent TB in the USA, we modeled the expected economic burden of Tuberculosis projected over the next hundred years.

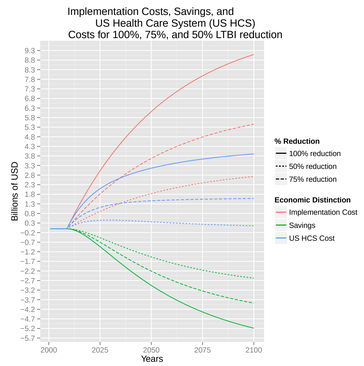

Figure: A graph of the cumulative implementation costs, savings, and net US health care system costs of reducing rates of LTBI in

An Agent Based Implementation

In addition to the extended Hill model (implemented in R), we also created a stochastic agent-based counterpart in both NetLogo and C++. Stochastic models add notions of uncertainty into the model structure, while agent-based models simulate global behavior of the system by describing local behavior of individual agents in the population.

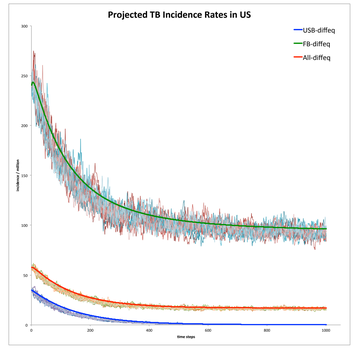

Figure: Incidence per million for R and NetLogo models (12 runs)

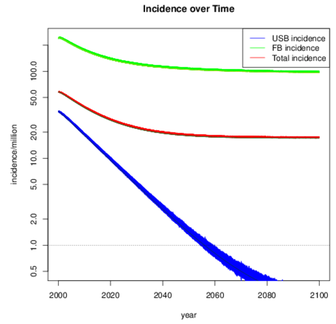

Figure: Incidence per million for R and C++ models (2100 runs)

Stochastic Models as a Measure of Variability

Future Extensions

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