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.

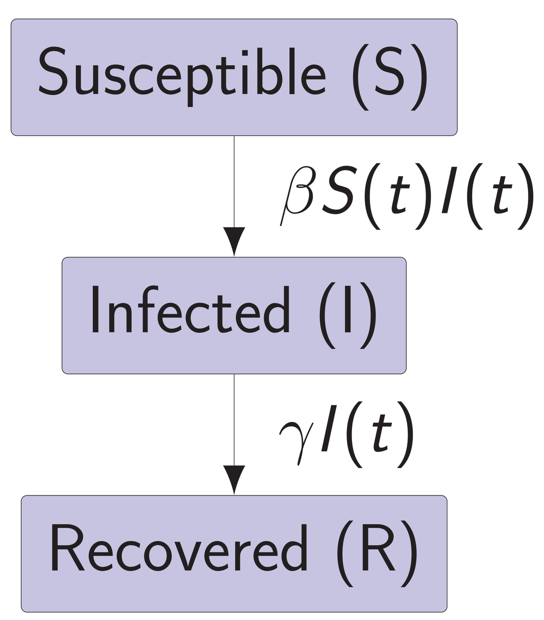

Figure: This flowchart depicts the standard SIR epidemiological model. It is accomponanied by the system of differential equations 2.

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

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.

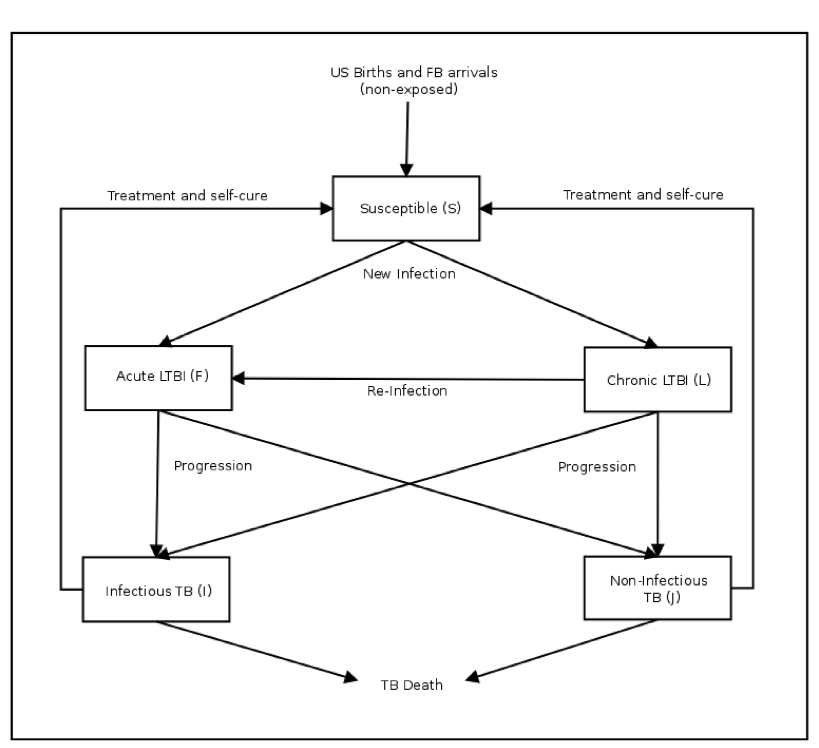

Figure: A flow chart representing the compartments of the Hill Model.

Populations:

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

Individuals also leave the model due to natural death.

Analyzing US TB Reduction Strategies

1. Implemented in R, with various numerical DE solvers.
2. Tracks US Health Care System (HCS) cost.
3. Tracks statistics about various health states.

Basic Hill Behaviour

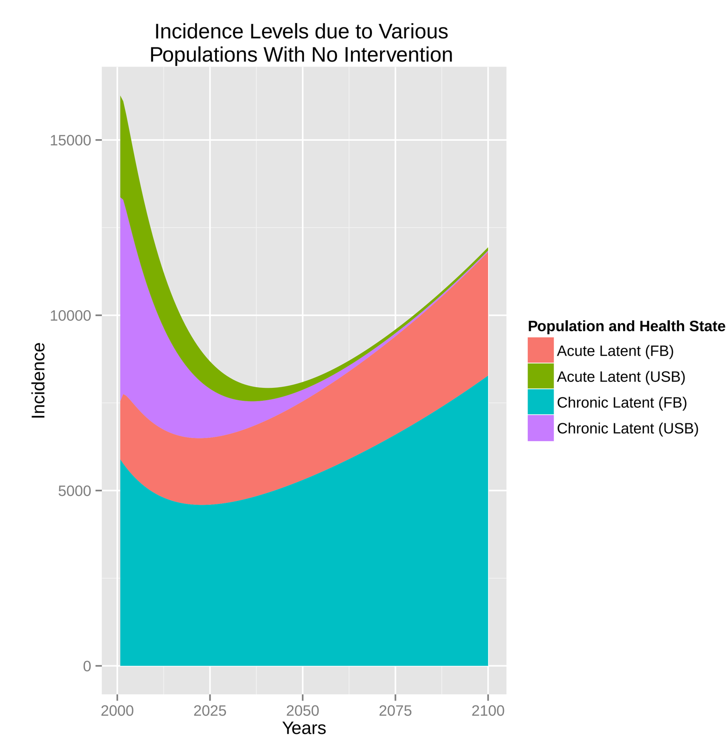

Figure: A plot showing the source population of yearly US TB incindecence.

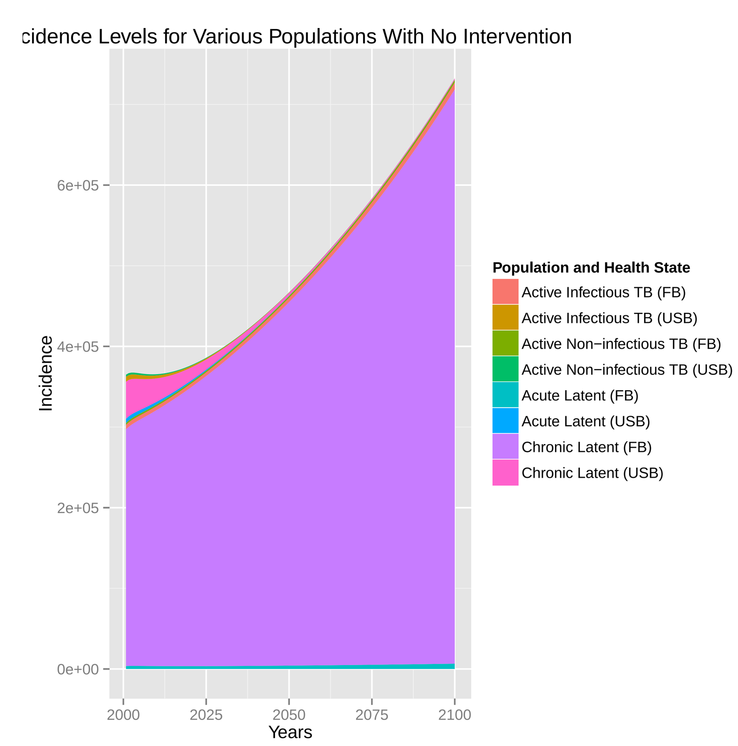

Figure: New cases per year of various types of TB in the US.

Intervention Analysis

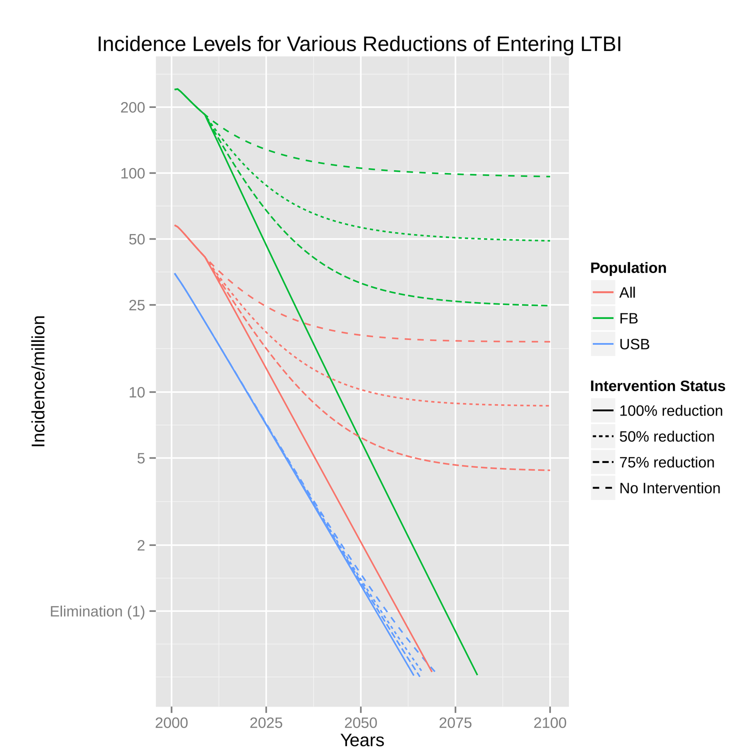

Figure: The projected incidence levels per million in USB, FB, and total populations, given 0%, 50%, 75%, or 100% of incoming LTBI cases are cured.

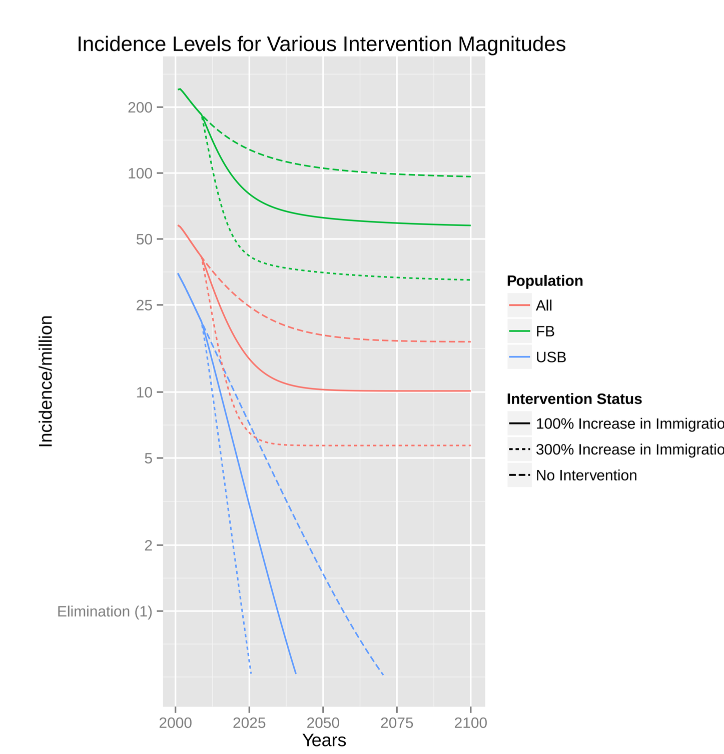

Figure: The projected incidence levels per million in USB, FB, and total populations, given 0%, 100%, or 300% increase in LTBI treatment.

Economic Modeling

We extended our basic implementation of the Hill

An Agent Based Implementation

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

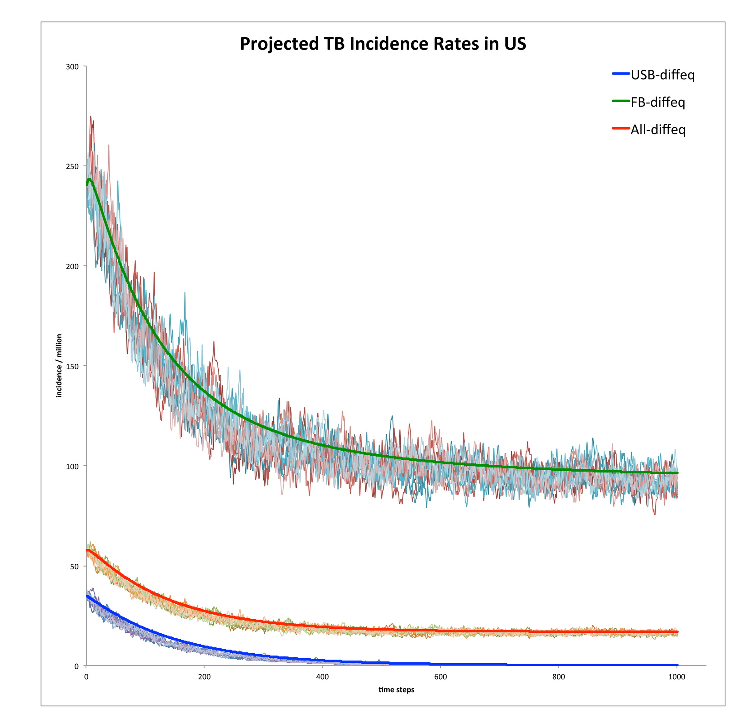

Figure: Incidence/million for R and NetLogo models (12 runs, $\Delta t = 0.1$, popConst $= 100$)

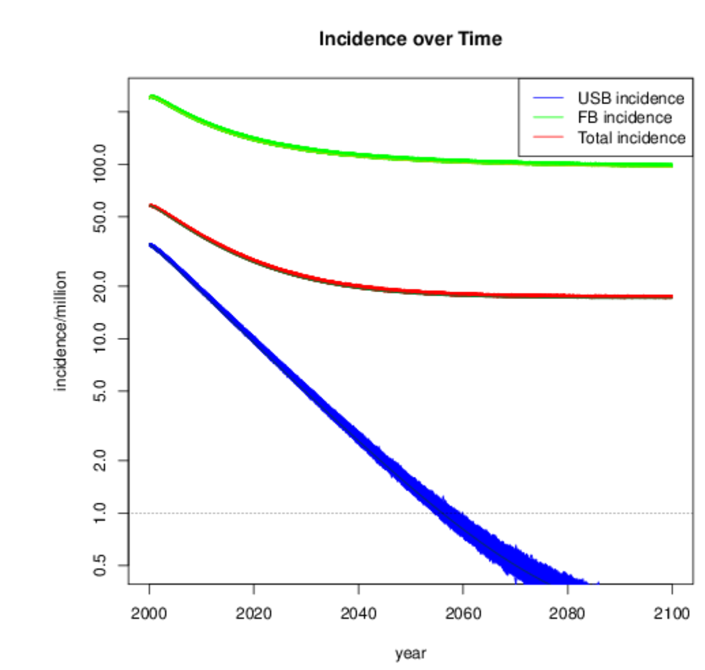

Figure: Incidence/million for R and C++ models (2100 runs, $\Delta t = 0.01$, popConst $= 1$)

Stochastic Models as a Measure of Variability

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