

Modeling Intervention Strategies for United States TB Control

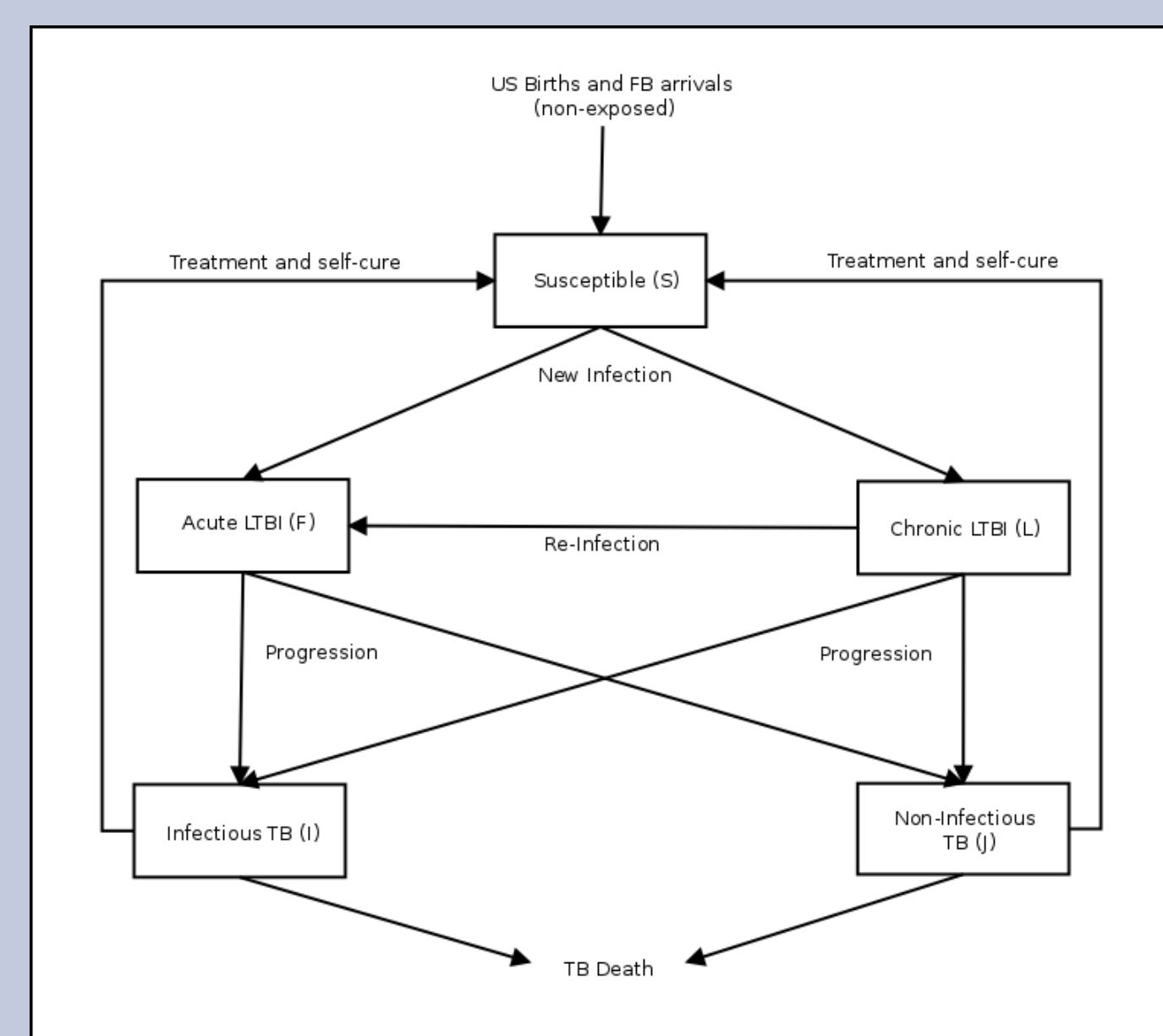
Jessica Ginepro, Emma Hartman, Ryo Kimura, Matthew McDermott, Colin Pawlowski, & Dylan Shepardson

Mathematical Modeling Group, Mount Holyoke College, South Hadley, MA, USA

Introduction

Epidemiological models offer insight into the structure of disease outbreaks and the merits of various interventions. Compartmental differential equation models are a common model in which populations move between various health states, or compartments, according to predetermined rates. This work is an extension of the Hill Model, a complex compartmental model of tuberculosis (TB) in the United States.

The Basic Hill Model



Populations:

- US Born (USB)
 - Foreign Born (FB)
- Individuals also leave the model due to natural death.

Figure : The Hill Model schematic

- USB TB incidence rates are declining
- FB latent TB infection (LTBI) arrivals remain high
- TB elimination in total population not projected by 2100
- TB cases and costs dominated by FB LTBI individuals

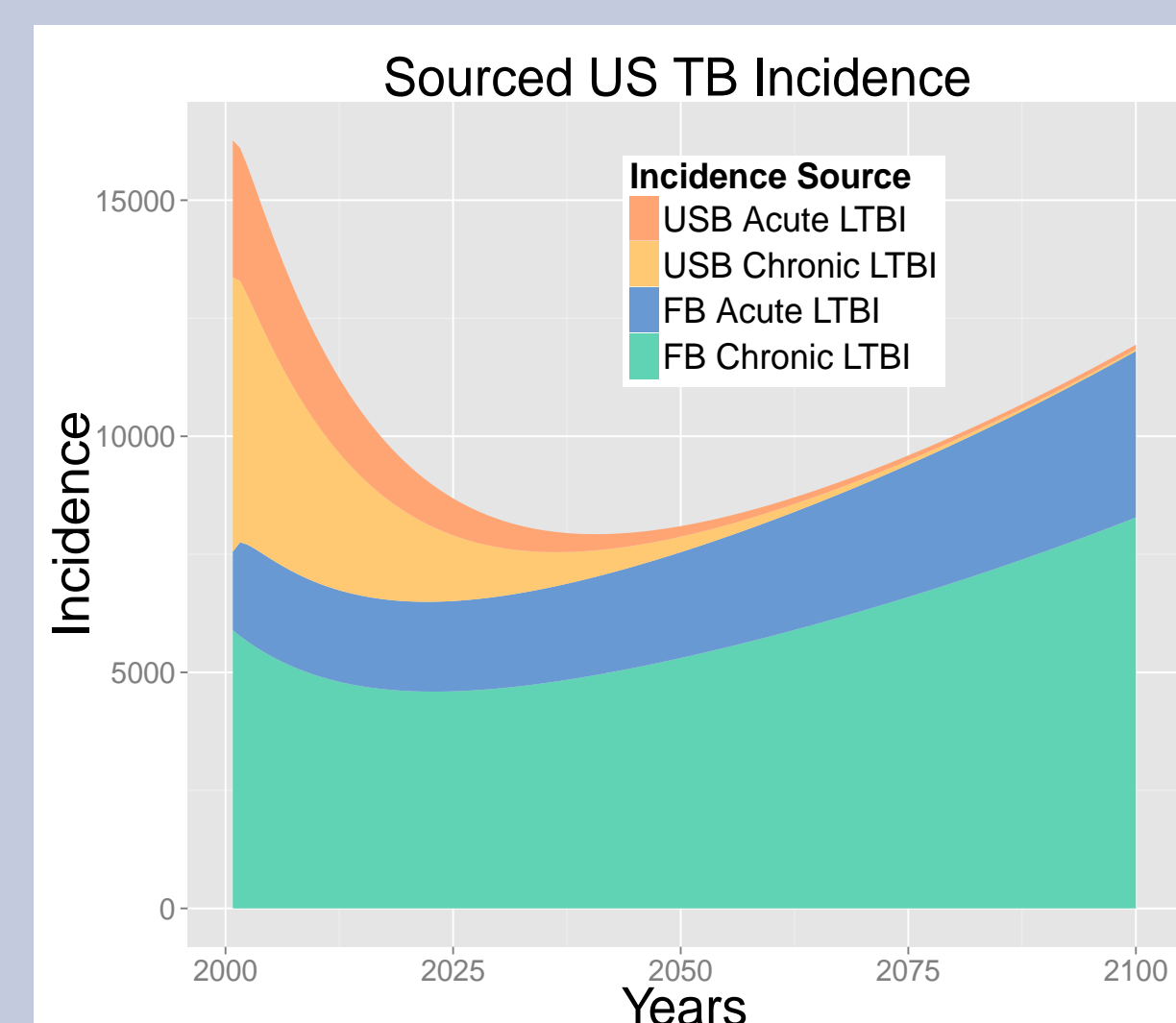


Figure : Source population of US TB incidence

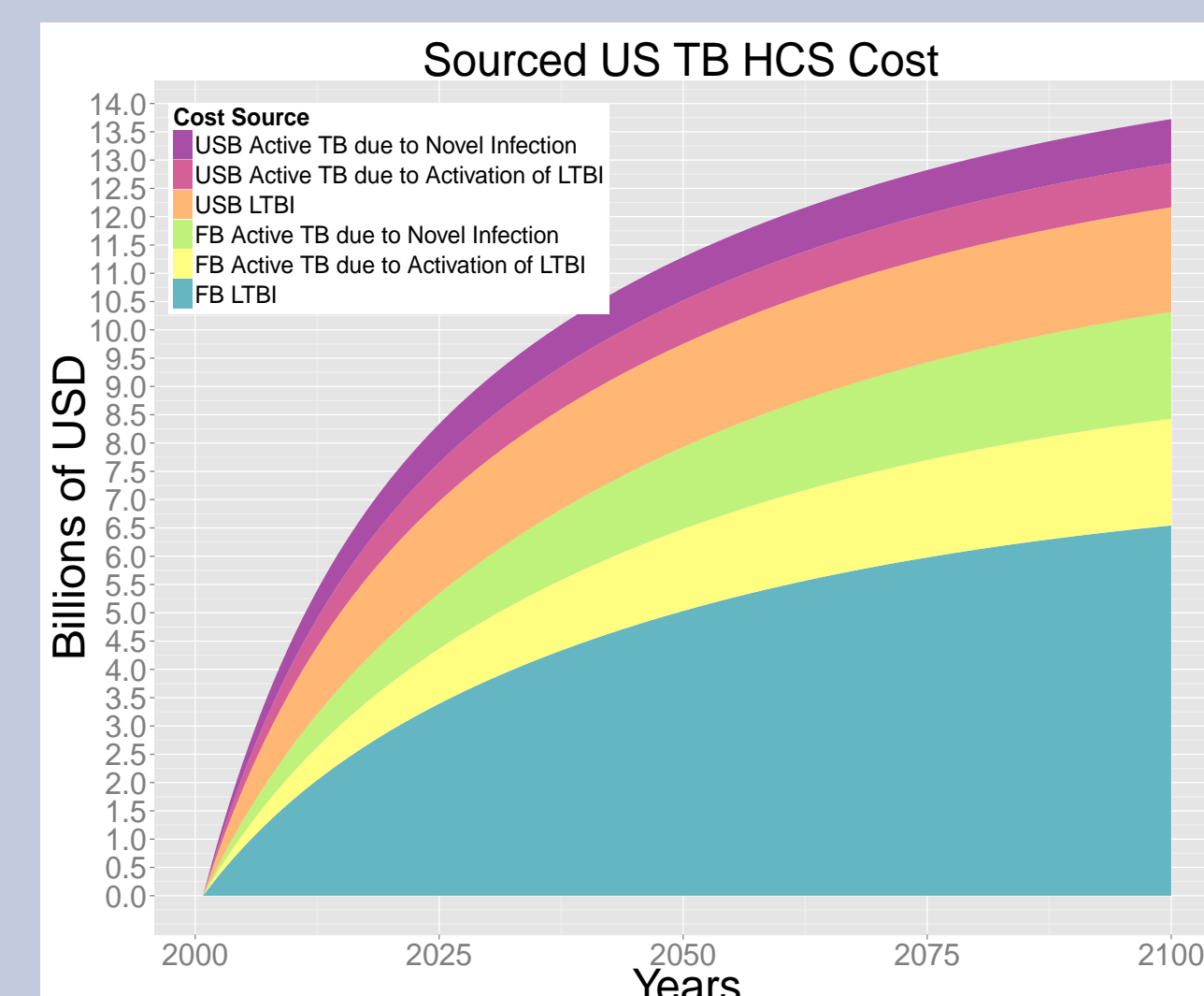


Figure : Source population of US HCS TB cost

Analyzing US TB Reduction Strategies

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

Intervention Analysis

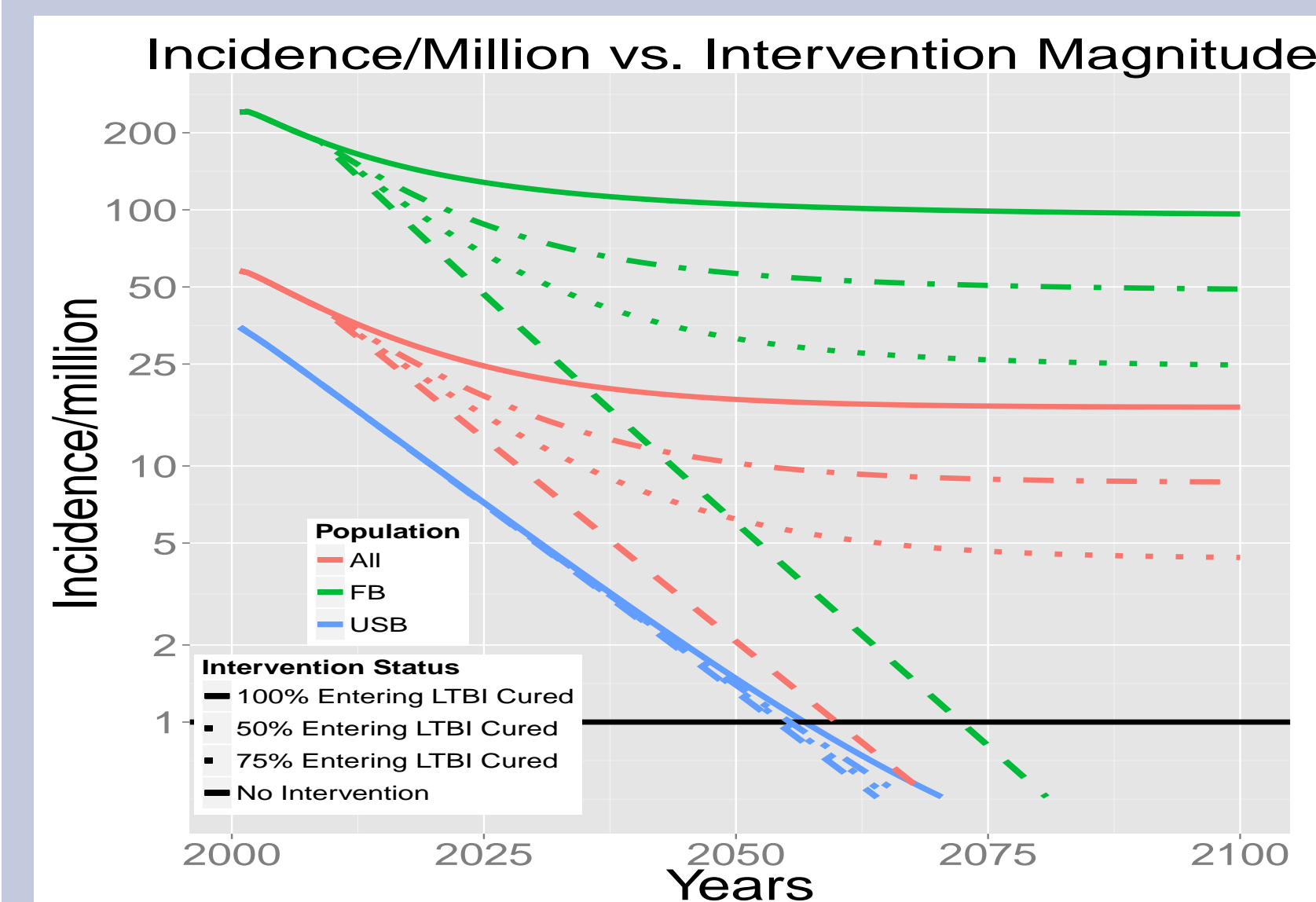


Figure :

Incidence/million in USB, FB, and total populations, given 0%, 50%, 75%, or 100% treatment of incoming LTBI

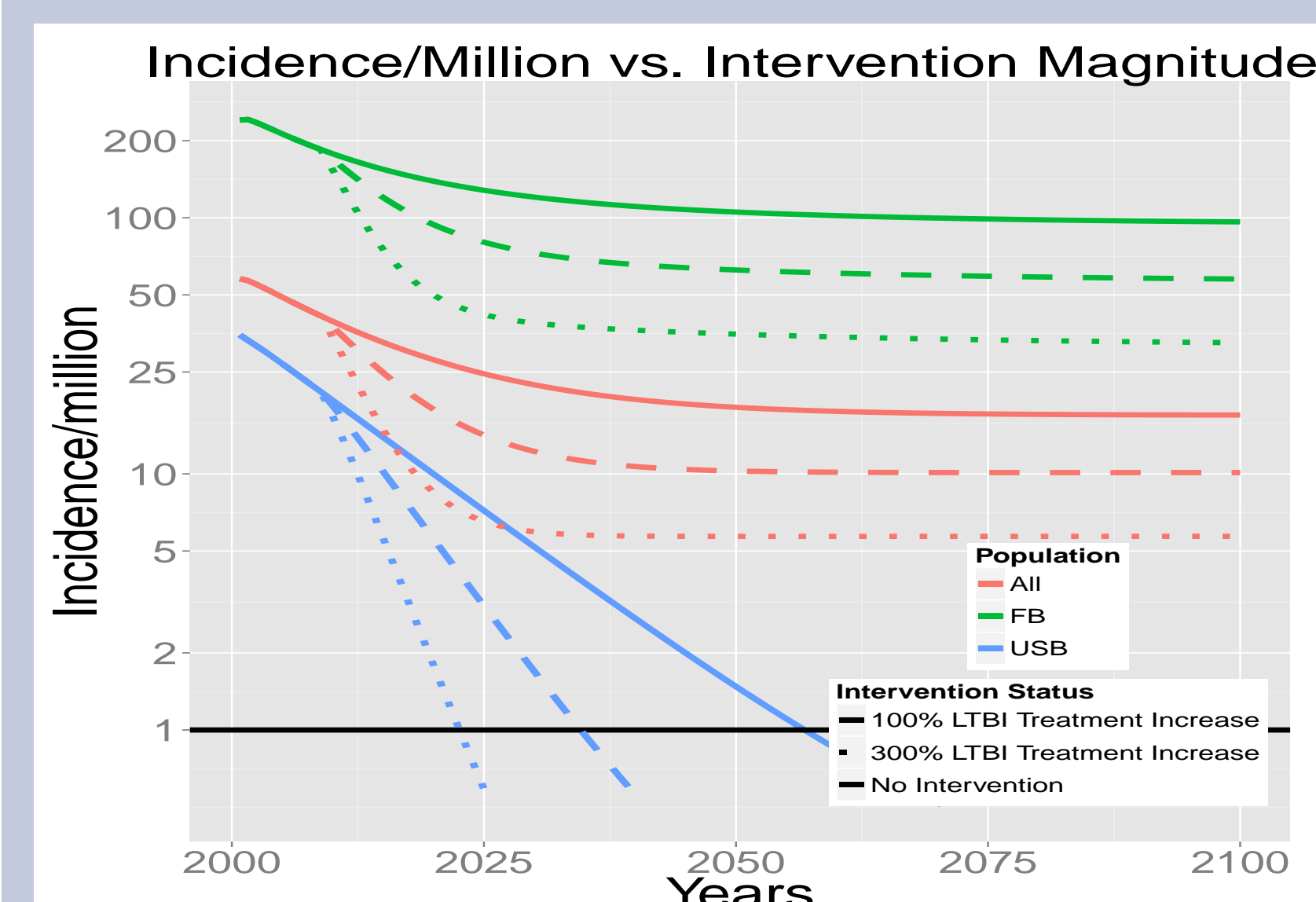


Figure :

Incidence/million in USB, FB, and total populations, given 0%, 100%, or 300% LTBI treatment increase

Economic Modeling

- Tracks treatment costs for various disease states
- Estimates implementation cost of intervention
- Active TB Costs: \$14,014.90 LTBI Costs: \$403.45

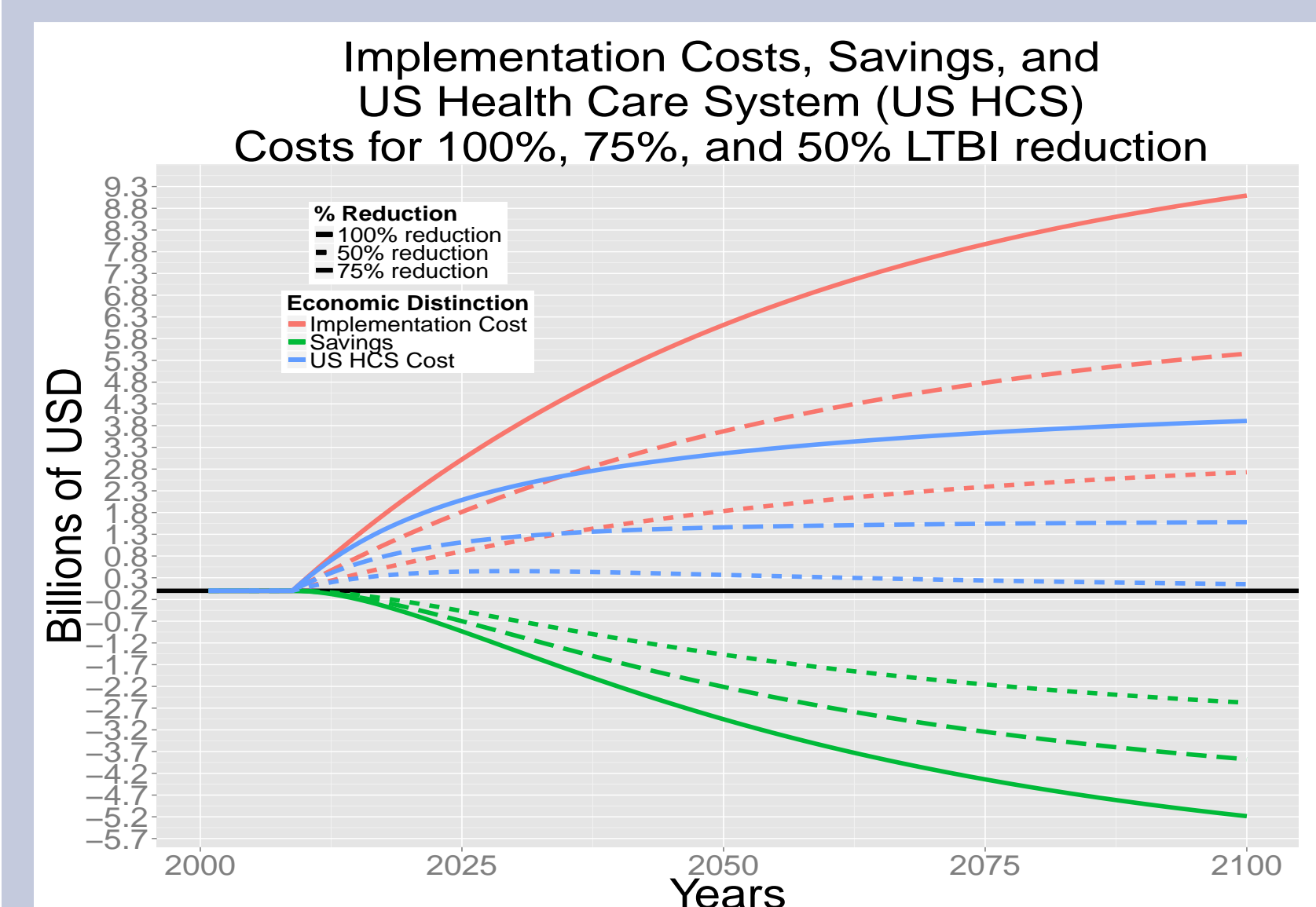


Figure : Cumulative implementation costs, US HCS savings, and net US costs of LTBI arrival cure rates. Cost/case cured was \$600, \$800, and \$1000 for 50%, 75%, and 100% cured

An Agent-Based Implementation

Agent-based models capture disease dynamics on the individual level and reflect stochasticity and granularity lost in compartmental models. Agent-based counterparts to the Hill model were implemented in Netlogo and C++.

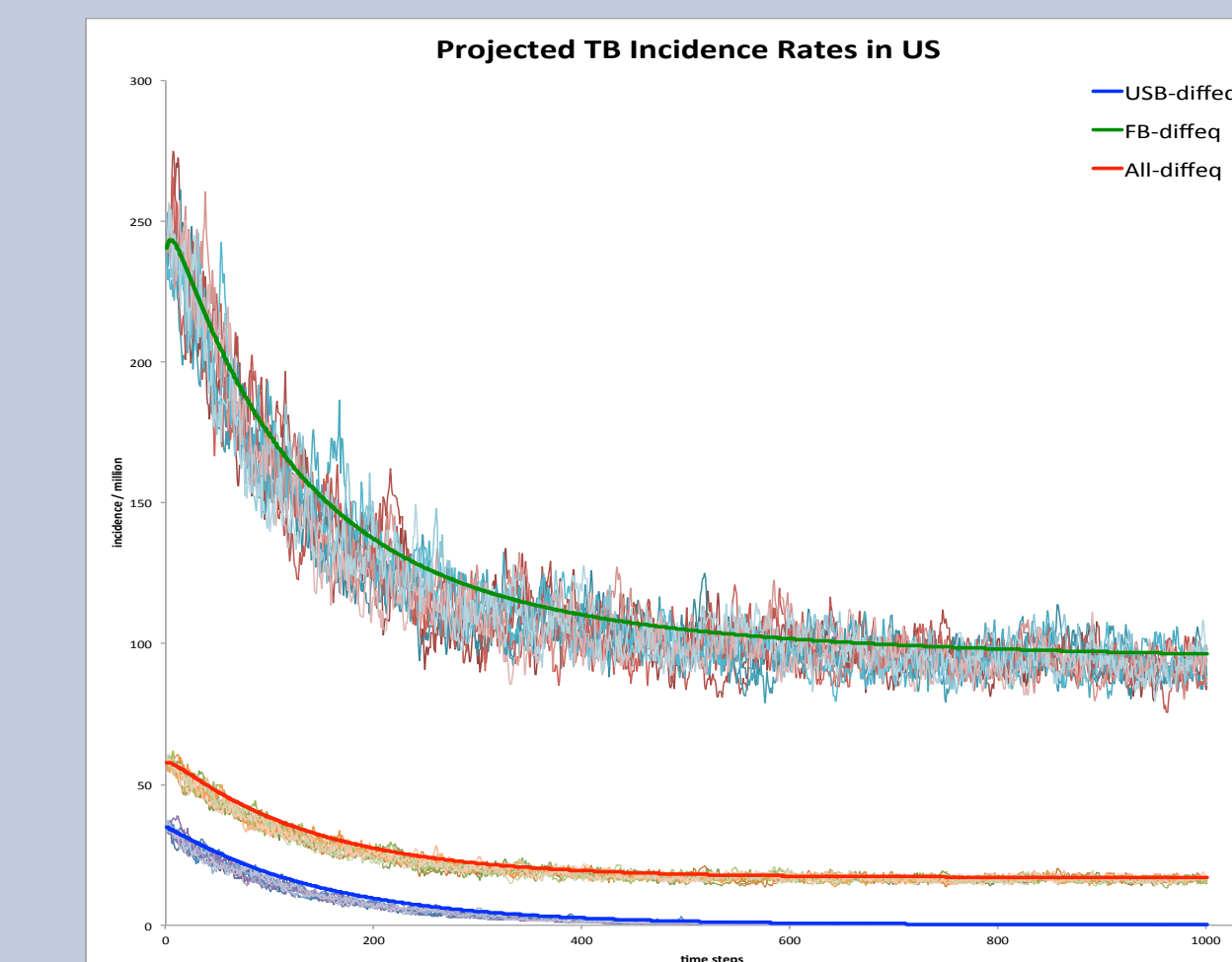


Figure : Incidence/million for R and NetLogo models (12 runs, $\Delta t = 0.1$, popConst = 100)

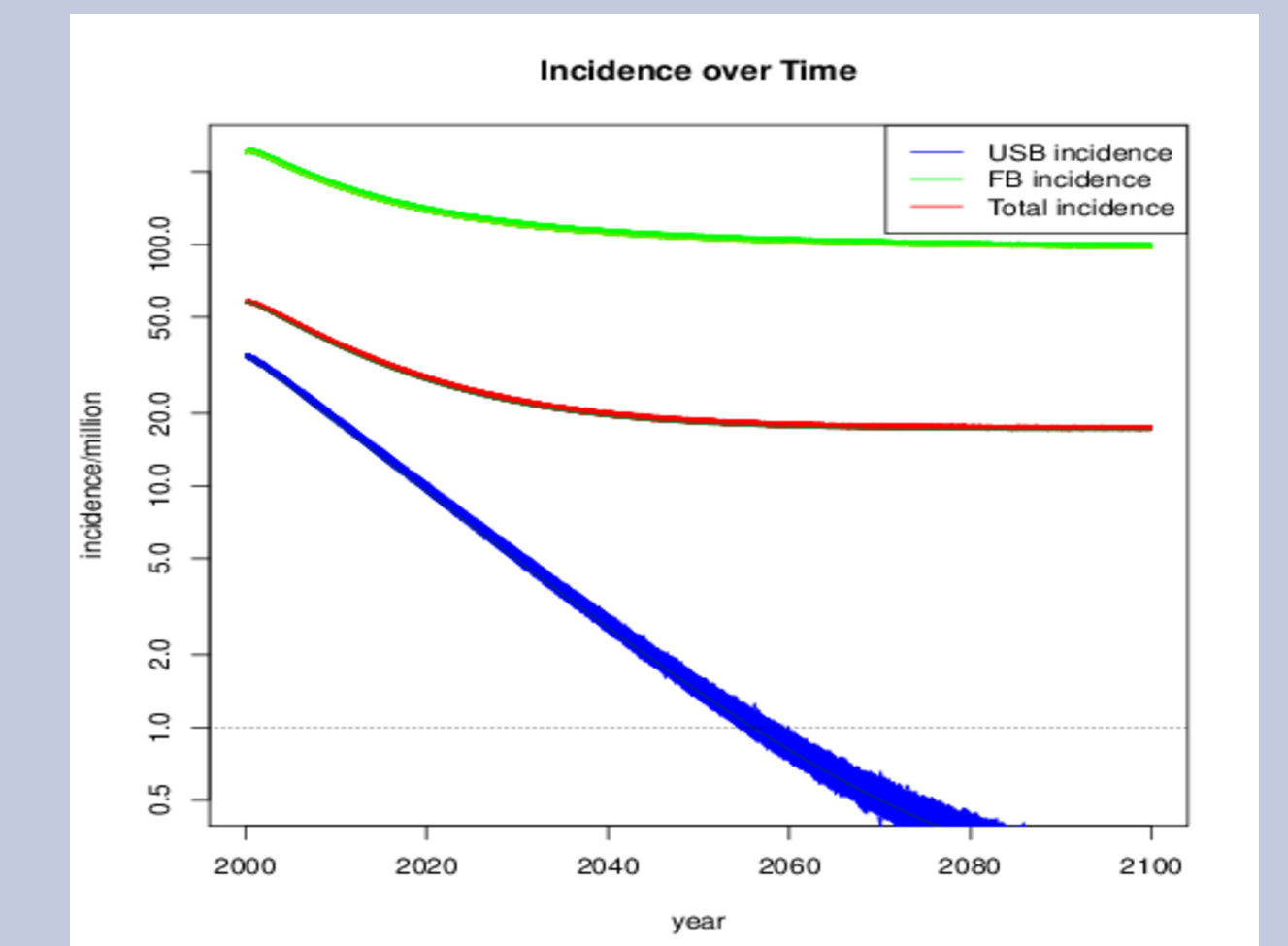


Figure : Incidence/million for R and C++ models (2100 runs, $\Delta t = 0.01$, popConst = 1)

Stochastic Models as a Measure of Variability

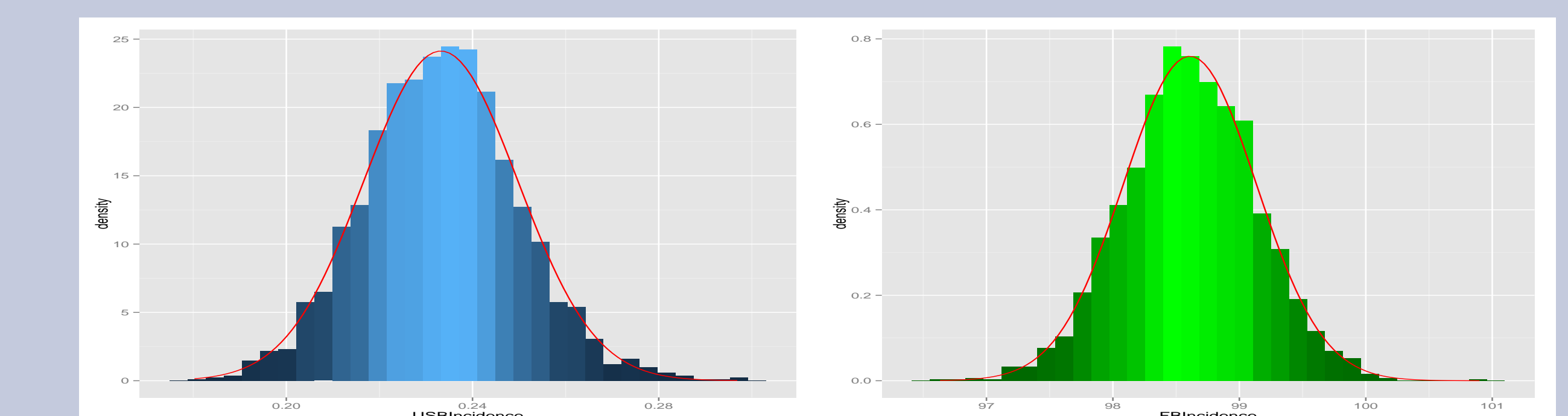


Figure : USB and FB Incidence (c++) with fitted Normal curves (USB: $\mu = 0.233$, $\sigma = 0.016534$, FB: $\mu = 98.6$, $\sigma = 0.525294$)

Summary

- TB elimination is possible
- new framework for disease modeling
- something else

References & Acknowledgments

This research was supported via an NSF REU grant. [1] Hill, A. N., Becerra, J. E., & Castro, K. G. (2012). Modelling tuberculosis trends in the USA. *Epidemiology and infection*, 140(10), 1862.