

# 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.

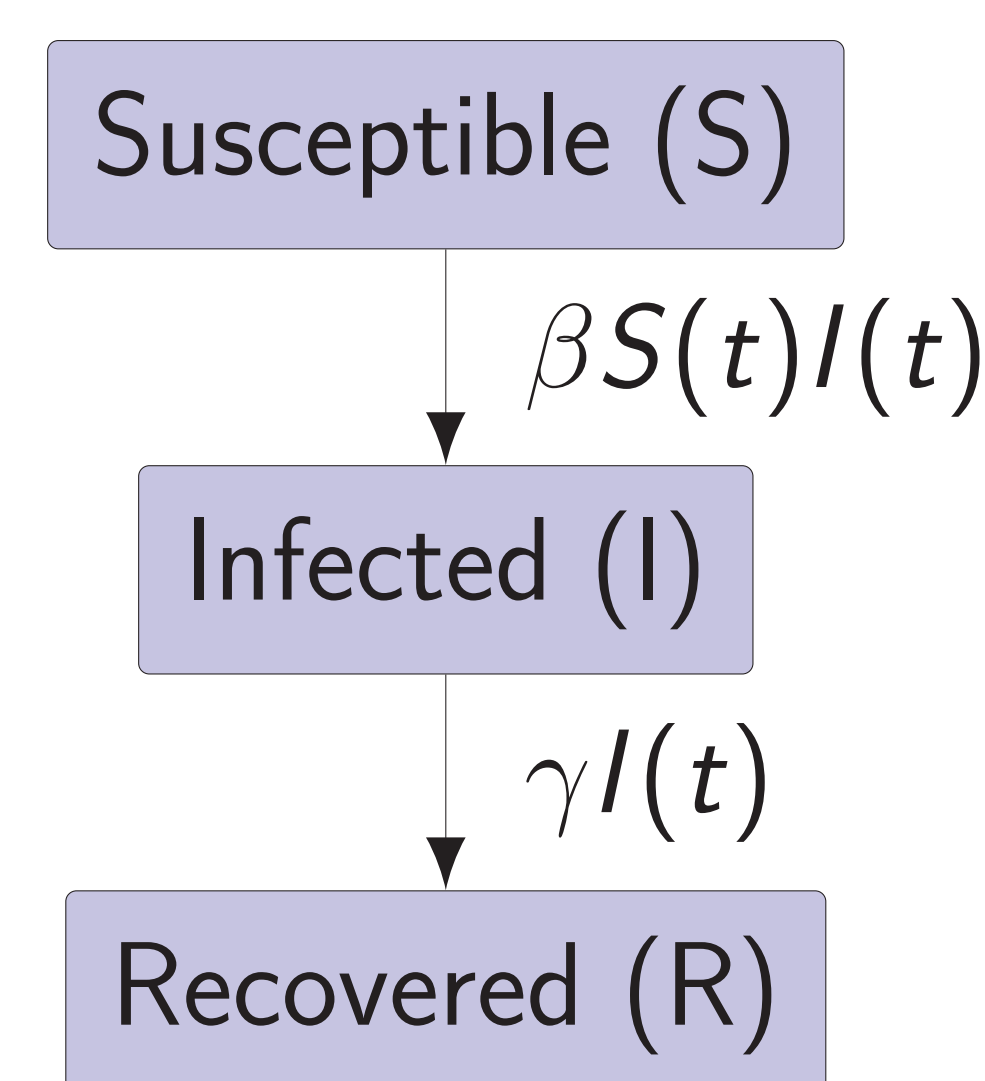


Figure: This flowchart depicts the standard SIR epidemiological model. It is accompanied by the system of differential equations 2.

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

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.

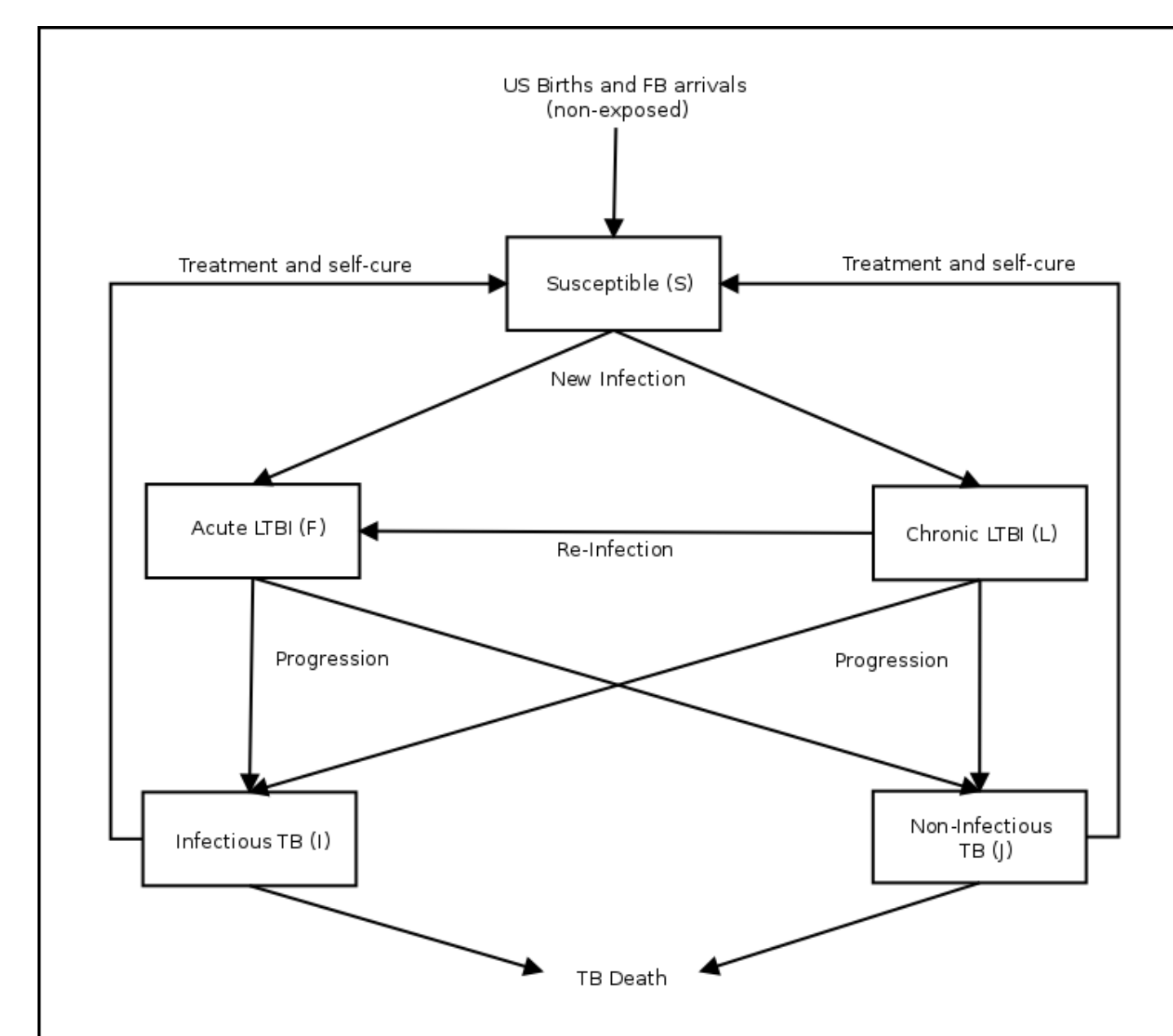


Figure: A flow chart representing the compartments of the Hill Model.

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

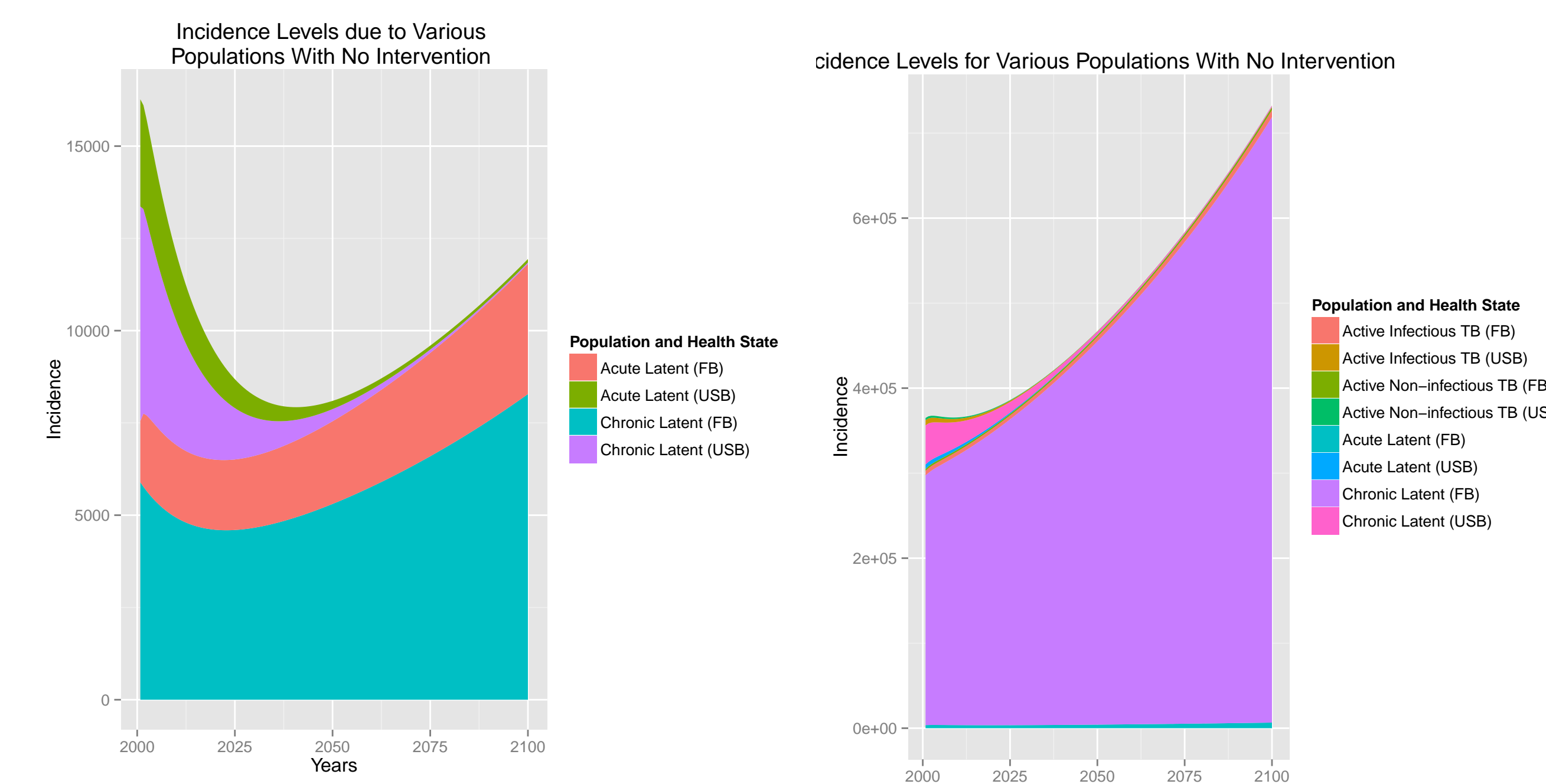


Figure: A plot showing the source population of yearly US TB incidence.

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

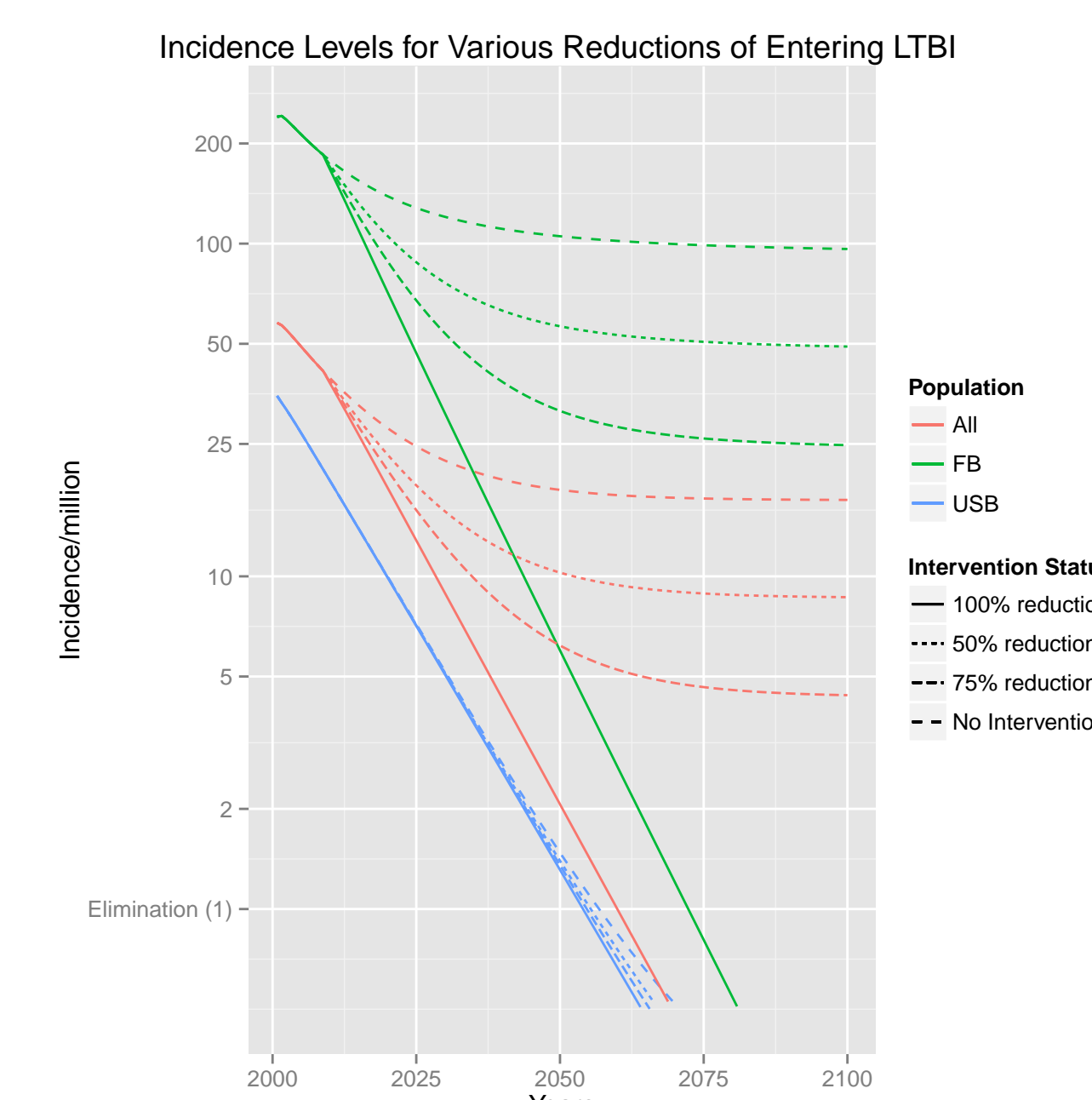


Figure: A graph of the projected incidence levels per million in the US-born, Foreign-born, and Total US population, given that LTBI rates in Foreign-born arrivals are reduced by 0%, 50%, 75%, and 100%.

## Economic Modeling

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

Implementation Costs, Savings, and US Health Care System (US HCS) Costs for 100%, 75%, and 50% LTBI reduction

## An Agent Based Implementation

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

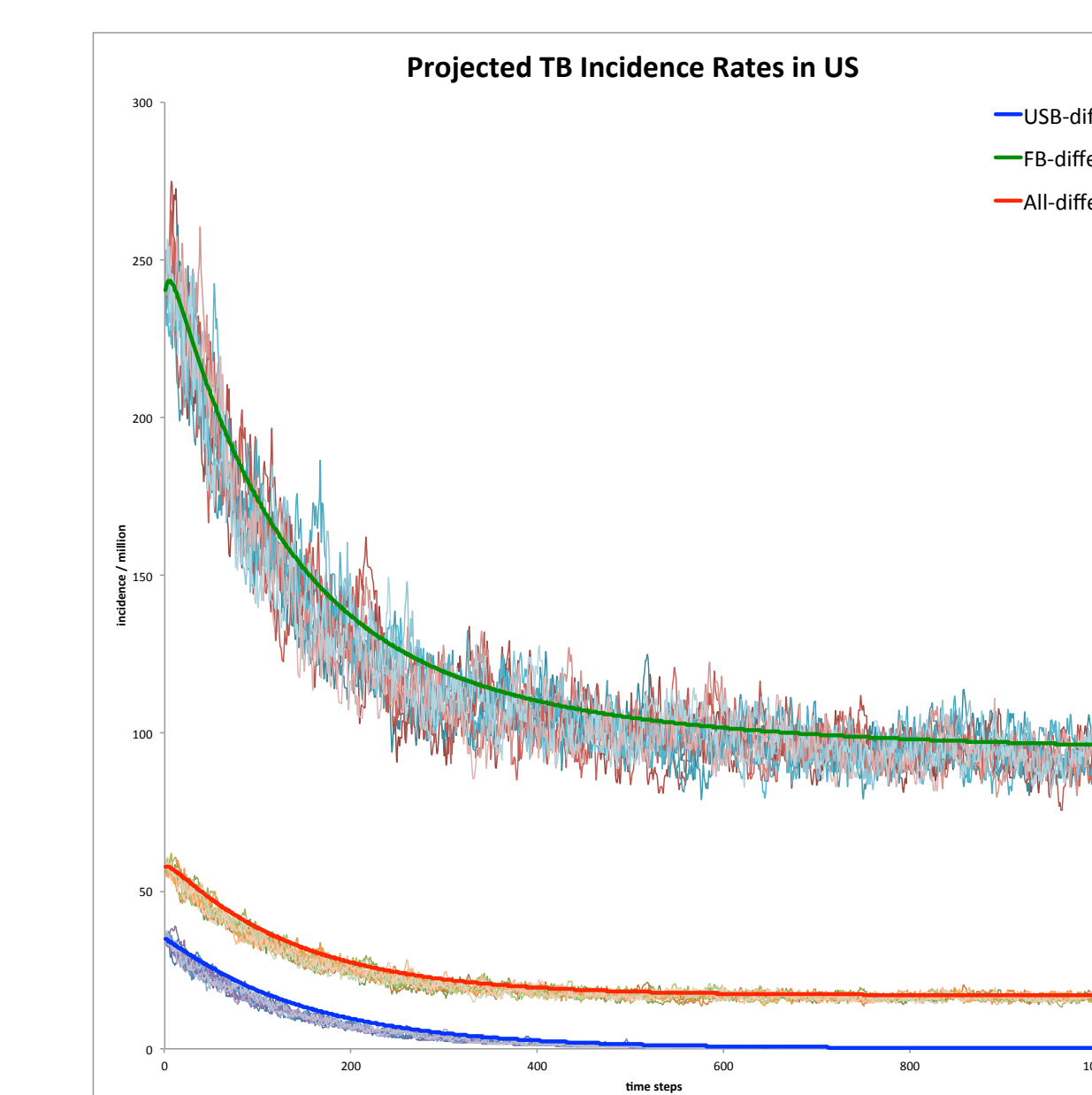


Figure: Incidence/million for R and NetLogo models (12 runs,  $\Delta t = 0.1$ , popConst = 100)

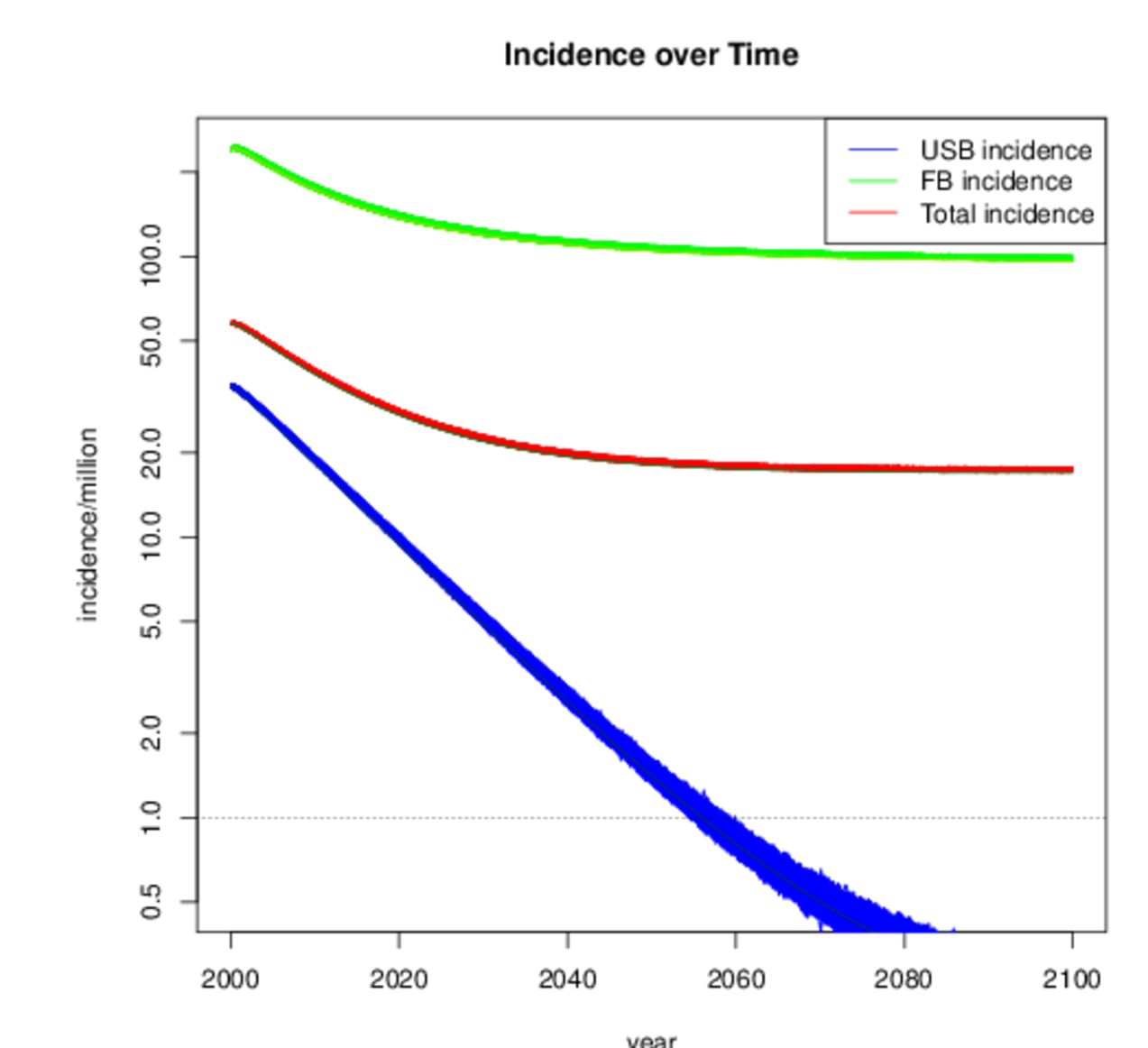


Figure: Incidence/million for R and C++ models (2100 runs,  $\Delta t = 0.01$ , popConst = 1)

## Stochastic Models as a Measure of Variability

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

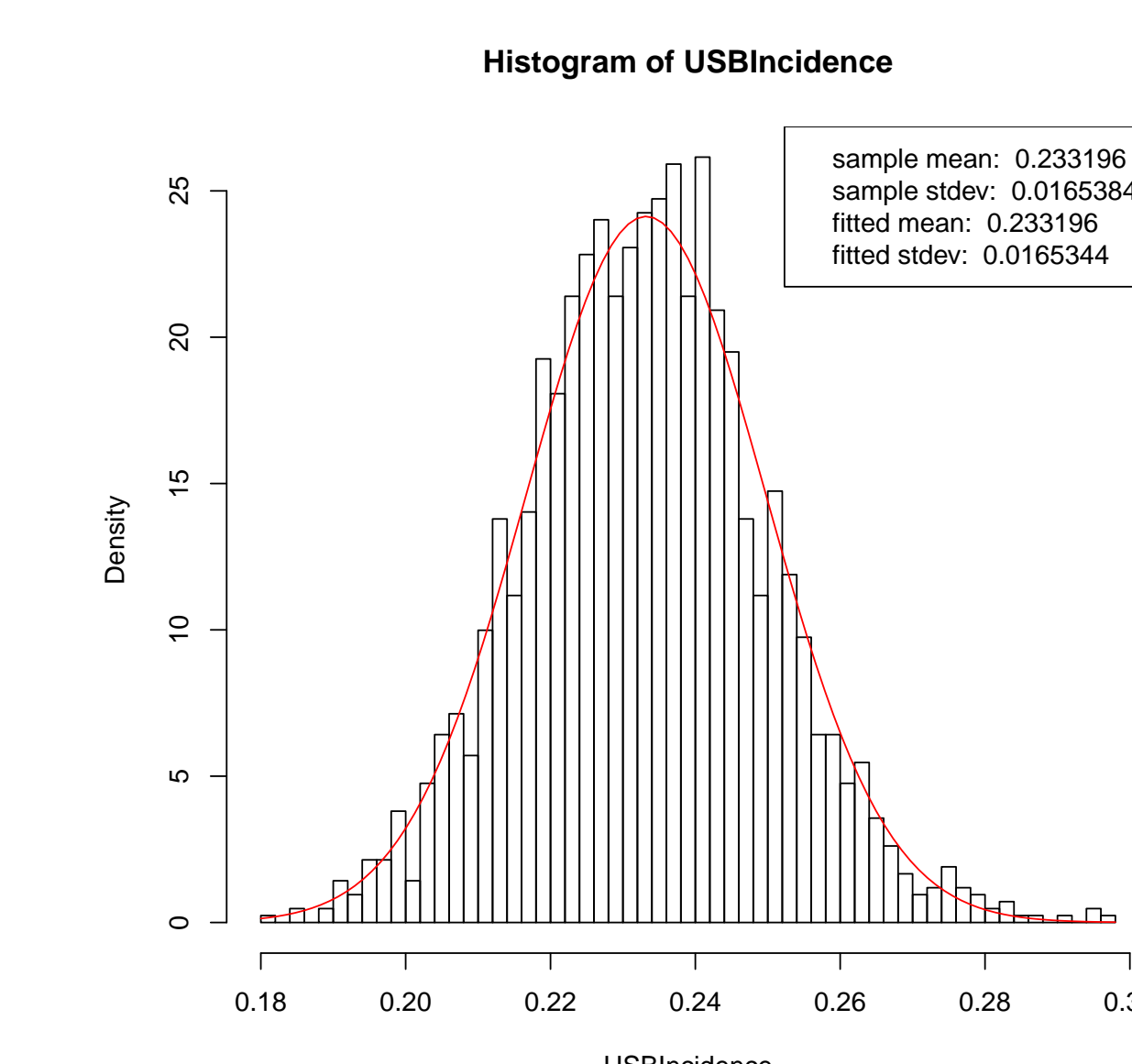


Figure: Distribution of USB Incidence (C++) with fitted Normal curve

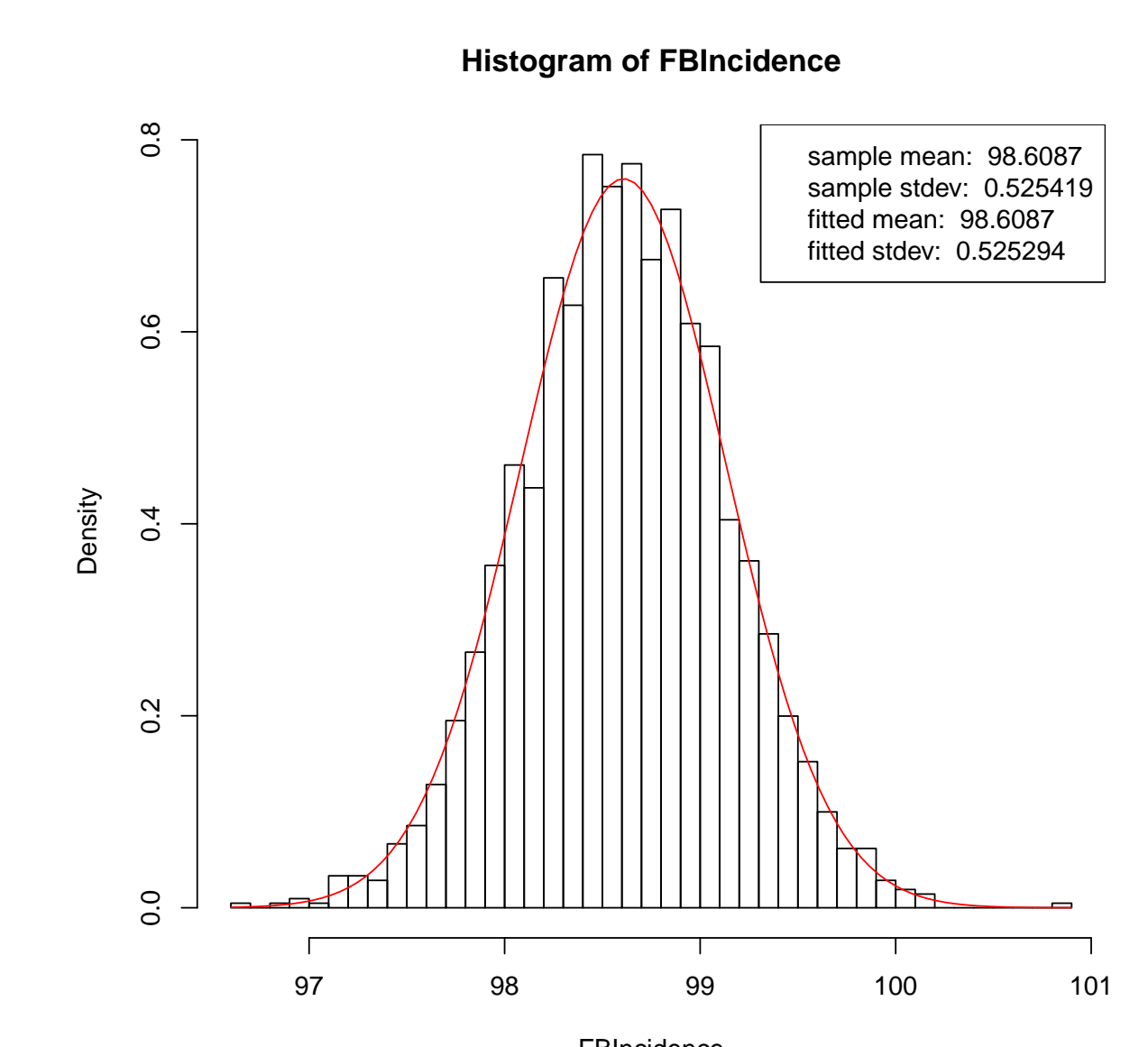


Figure: Distribution of FB Incidence (C++) with fitted Normal curve