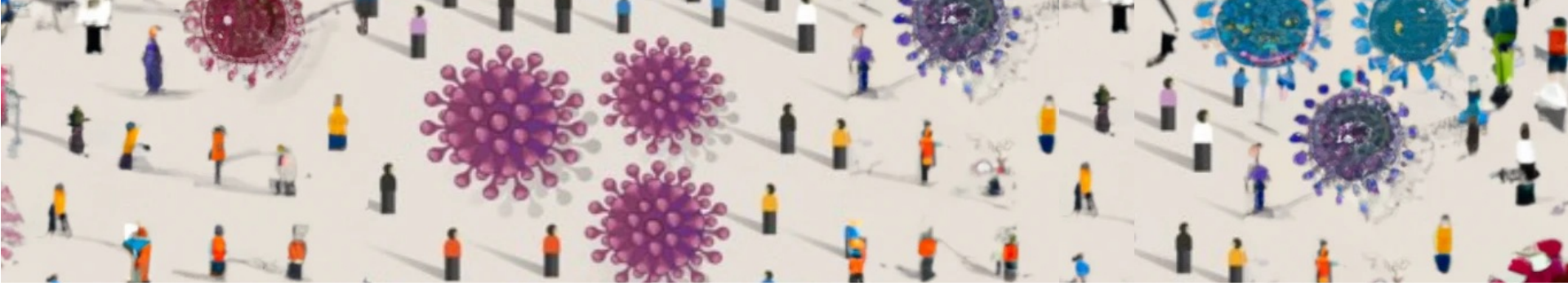

Using Approximate Bayesian Computation to Infer Disease Parameter Uncertainty in a COVID-19 Microsimulation

Molly Asher[1], Yannick Oswald[2], Nick Malleson[2]

[1] School of Earth and Environment, University of Leeds
[2] School of Geography, University of Leeds

This work: https://www.nature.com/articles/s41598-023-35580-z

Title image: https://www.camecon.com/blog/modelling-the-local-economic-impacts-of-the-coronavirus/

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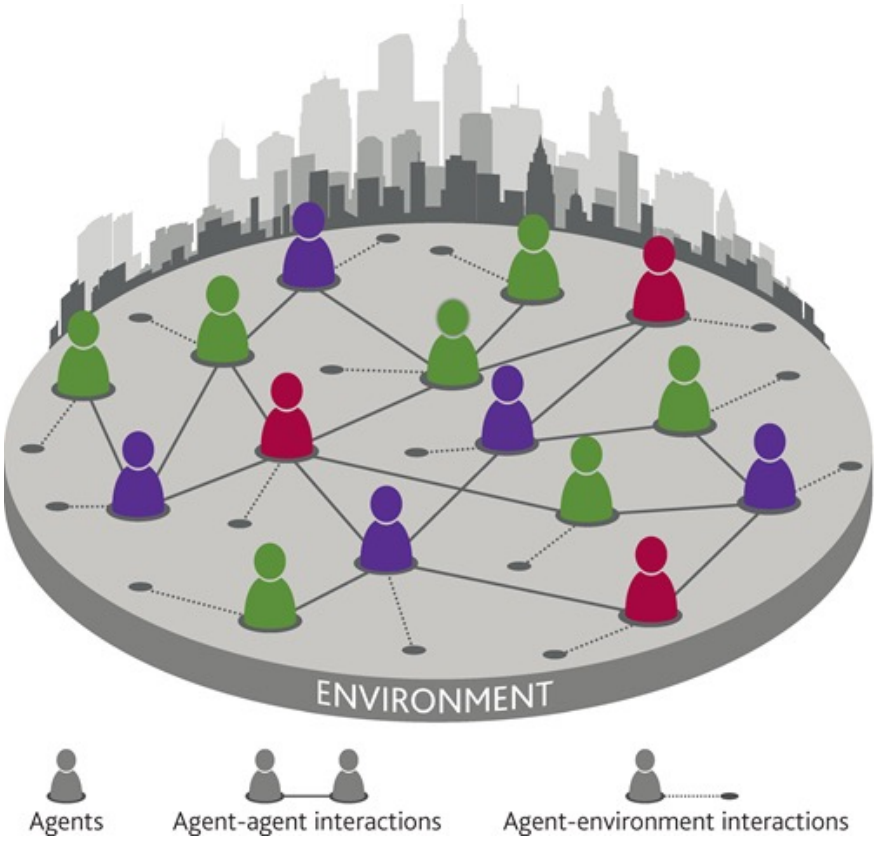
Individual based models

- e.g. Agent-based models, dynamic microsimulation
  - ➢ Oxford model, Imperial model

- A hope for escaping uncertainty that Covid-19 brought!



Challenges!

Model uncertainty

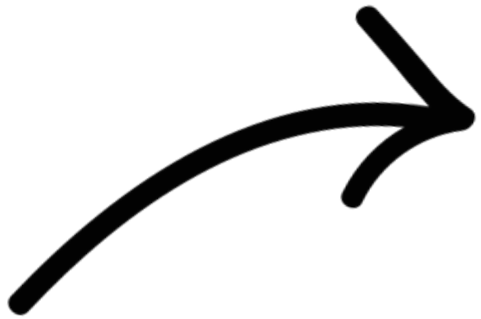
- Structural model uncertainty
  - System complicated
- Scenario uncertainty
  - Pandemic constantly evolving dynamics
    - Changing vaccination rates
    - New variants
    - Different testing approaches
    - Policy interventions
- Stochastic uncertainty
  - Even a perfectly calibrated model will diverge from reality
- Parameter uncertainty
  - Behaviour of Covid unknown; data limited

Challenges!

- Parameter uncertainty
  - Behaviour of Covid unknown; data limited

~~Challenges!~~ Solutions?

- Parameter uncertainty
  - Behaviour of Covid unknown; data ~~limited~~ increasingly available

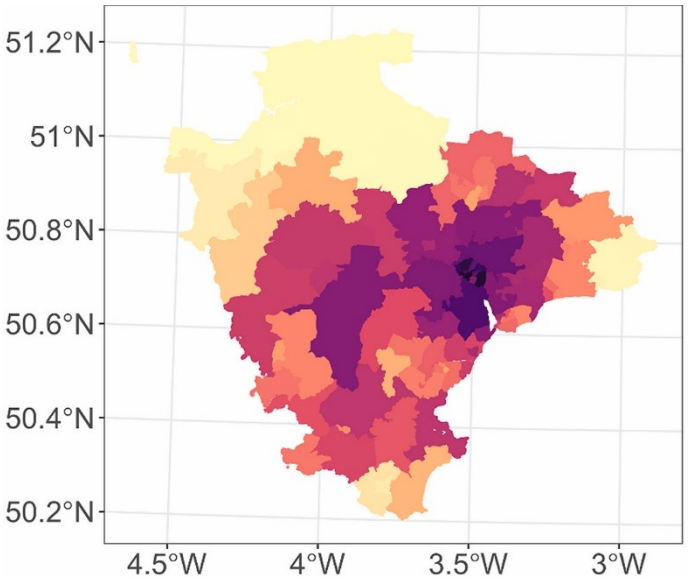


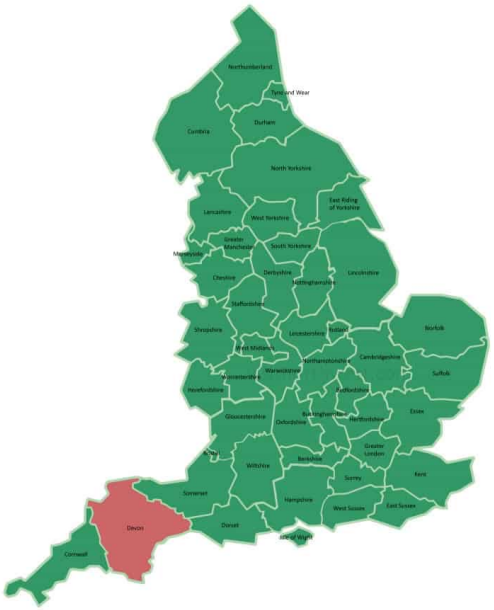
Approximate Bayesian Computation:

- Use data as it arises
- Better understand parameters and uncertainty
- Better quantification of uncertainty in predictions

DyME

Dynamic **M**odel of **E**pidemics (**DyME**)



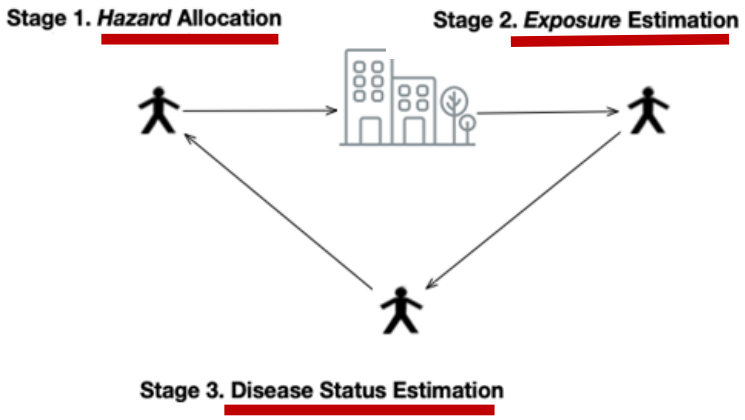


Spooner, F., Abrams, J.F., Morrissey, K., Shaddick, G., Batty, M., Milton, R., Dennett, A., Lomax, N., Malleson, N., Nelissen, N. and Coleman, A., 2021. A dynamic microsimulation model for epidemics. *Social Science & Medicine*, *291*, p.114461.

DyME

Dynamic **M**odel of **E**pidemics (**DyME**)

- Produce a synthetic population
  - Using census data
- Give the population characteristics
  - Using travel + health surveys
- Each model day…
  - Individuals visit locations (home, work, retail, school)
  - They give/receive risk
  - New disease states calculated daily



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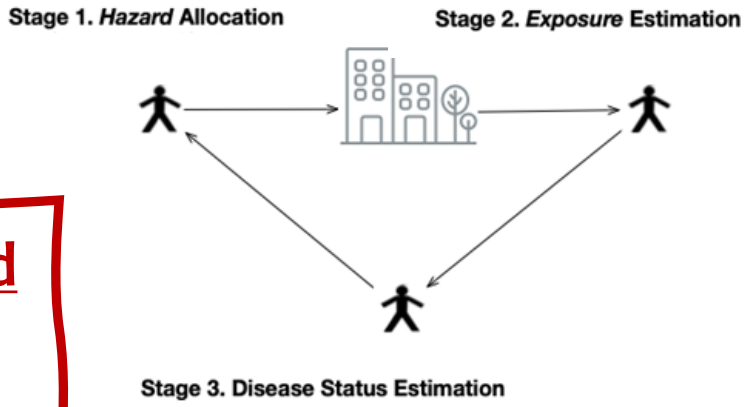
DyME

Dynamic Model of Epidemics (DyME)



Location parameters:

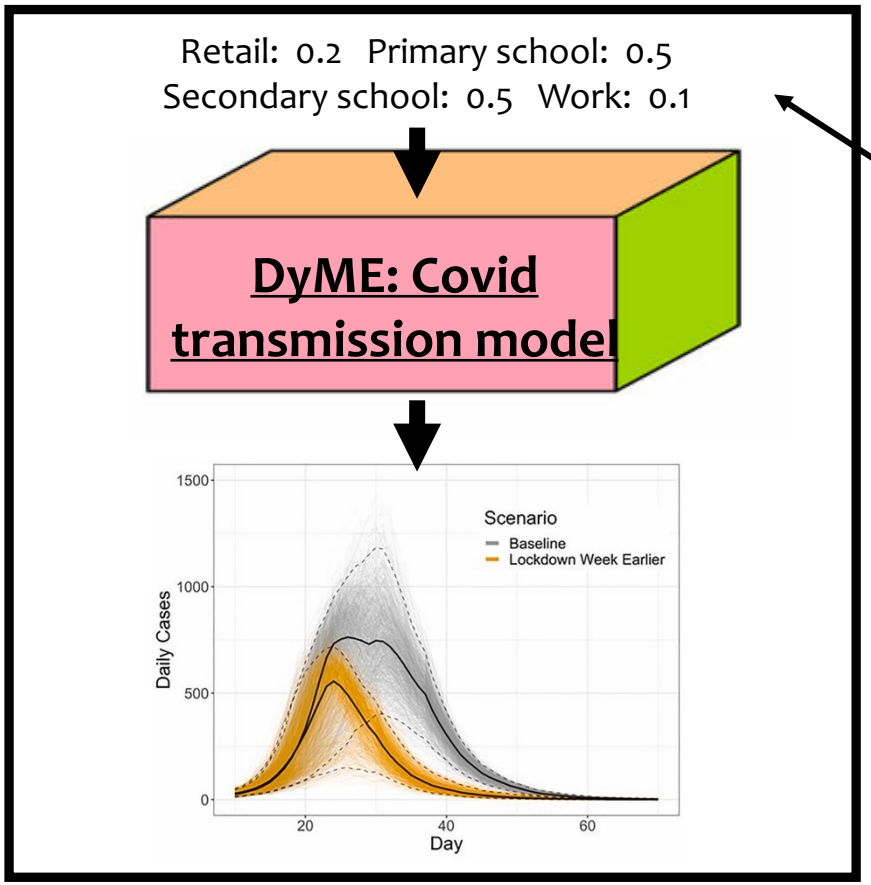
- Retail
- Primary school
- Secondary school
- Work
- Home

Individual hazard parameters:

- Presymptomatic
- Symptomatic
- Asymptomatic

Spooner, F., Abrams, J.F., Morrissey, K., Shaddick, G., Batty, M., Milton, R., Dennett, A., Lomax, N., Malleson, N., Nelissen, N. and Coleman, A., 2021. A dynamic microsimulation model for epidemics. *Social Science & Medicine*, *291*, p.114461.

DyME: Process



Parameters

e.g. location parameters (but there are more)

Generative model

Data

Spooner, F., Abrams, J.F., Morrissey, K., Shaddick, G., Batty, M., Milton, R., Dennett, A., Lomax, N., Malleson, N., Nelissen, N. and Coleman, A., 2021. A dynamic microsimulation model for epidemics. *Social Science & Medicine*, *291*, p.114461.

Dynamic recalibration: ABC

Approximate Bayesian Computation (ABC)

A method for estimating unknown parameter values, given the data

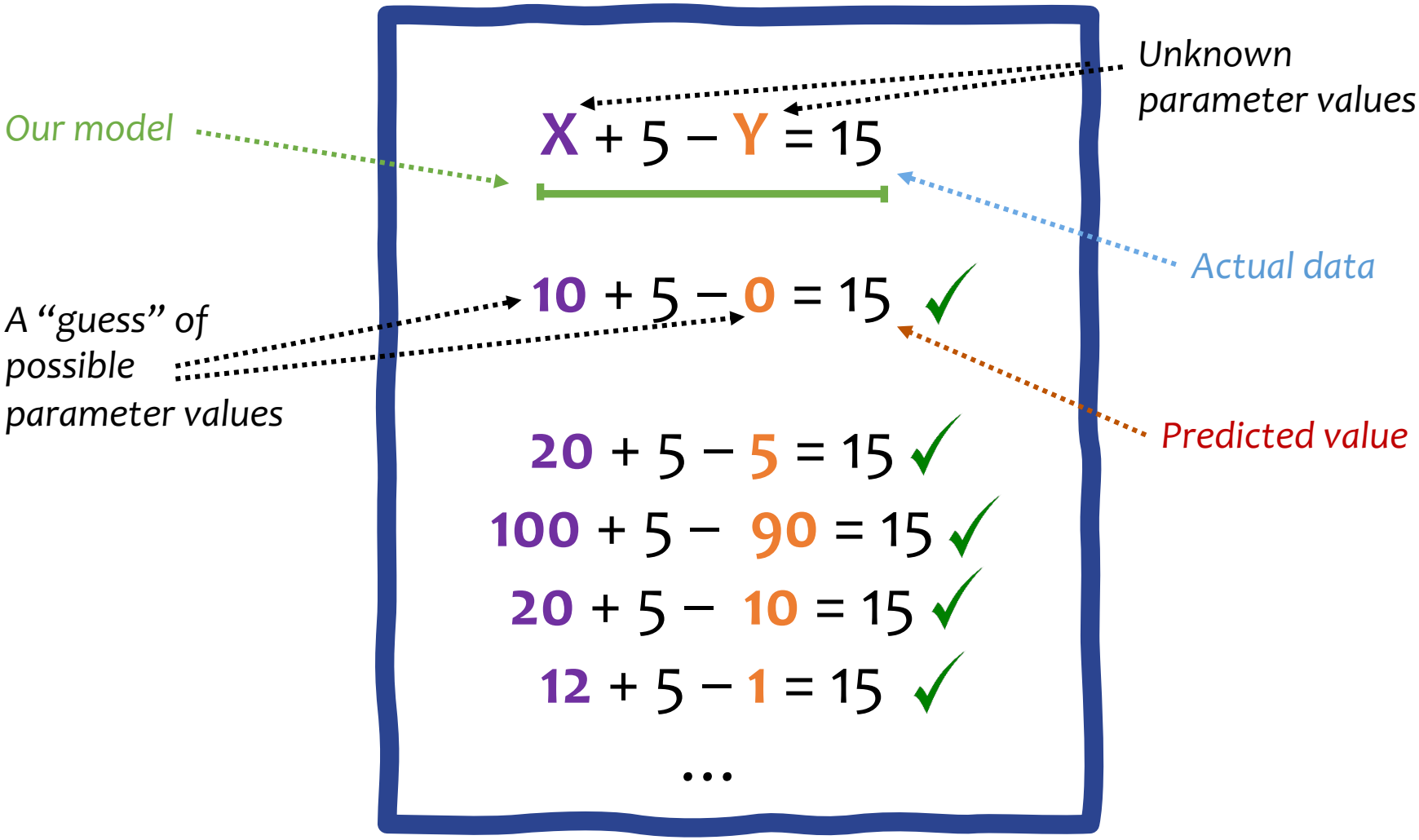
Parameters

e.g. location parameters (but there are more)

Generative model

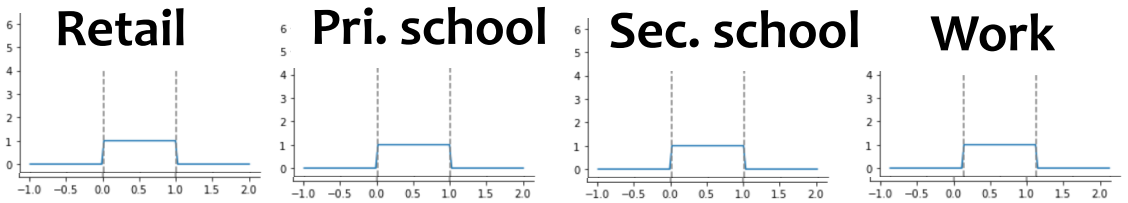
Data

Dynamic recalibration: ABC



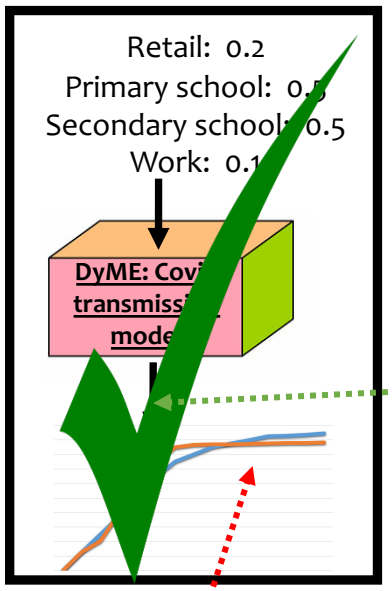
Dynamic recalibration: ABC

A "guess" of possible parameter values



Priors

Location parameters: a multiplier describing how likely someone is to get covid in that location

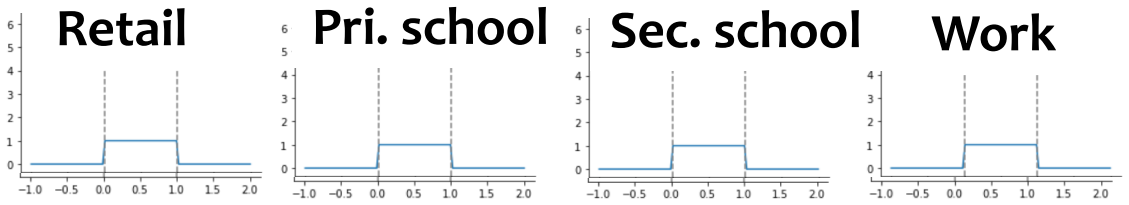


Accept or reject parameters based on similarity to observed data

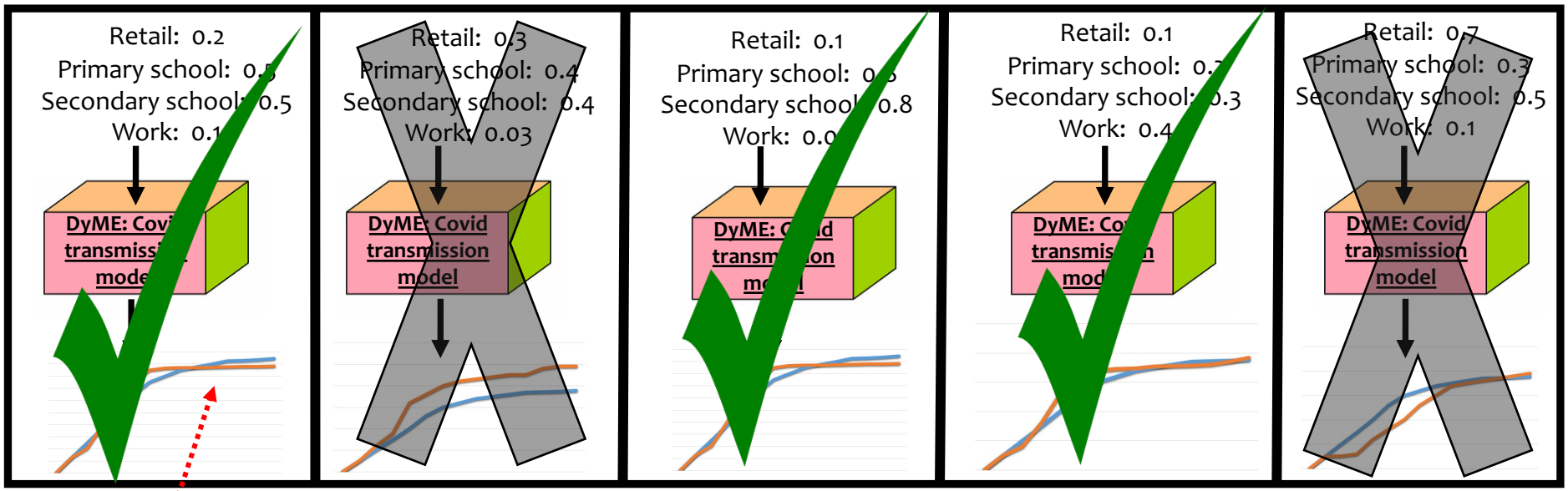
Similarity? Based on Euclidean distance

Dynamic recalibration: ABC

A "guess" of possible parameter values



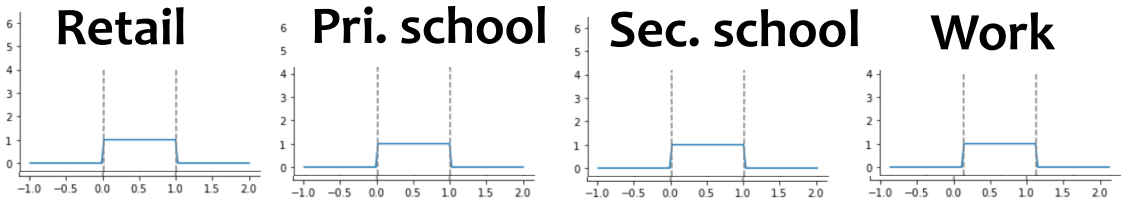
Priors



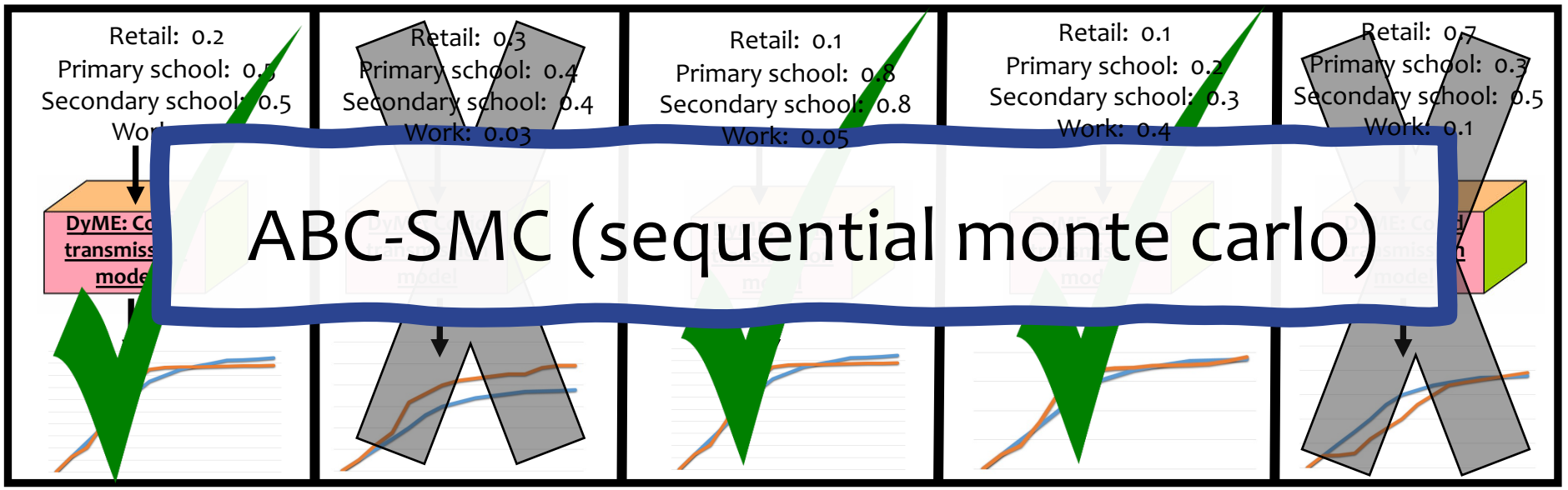
Similarity? Based on Euclidean distance

Dynamic recalibration: ABC

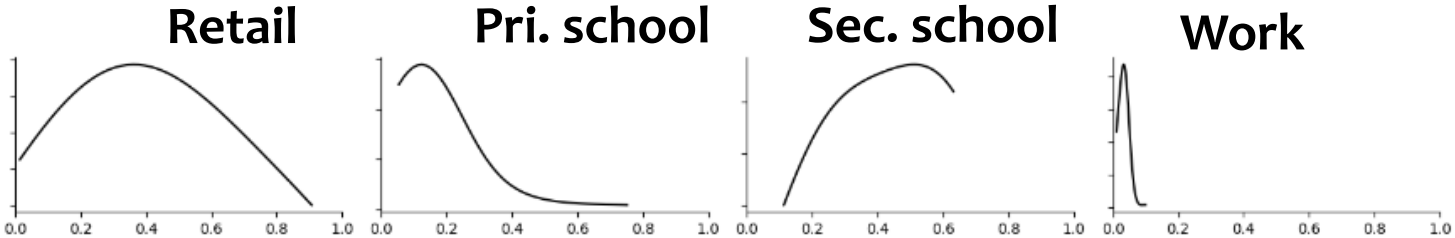
A "guess" of possible parameter values



Priors



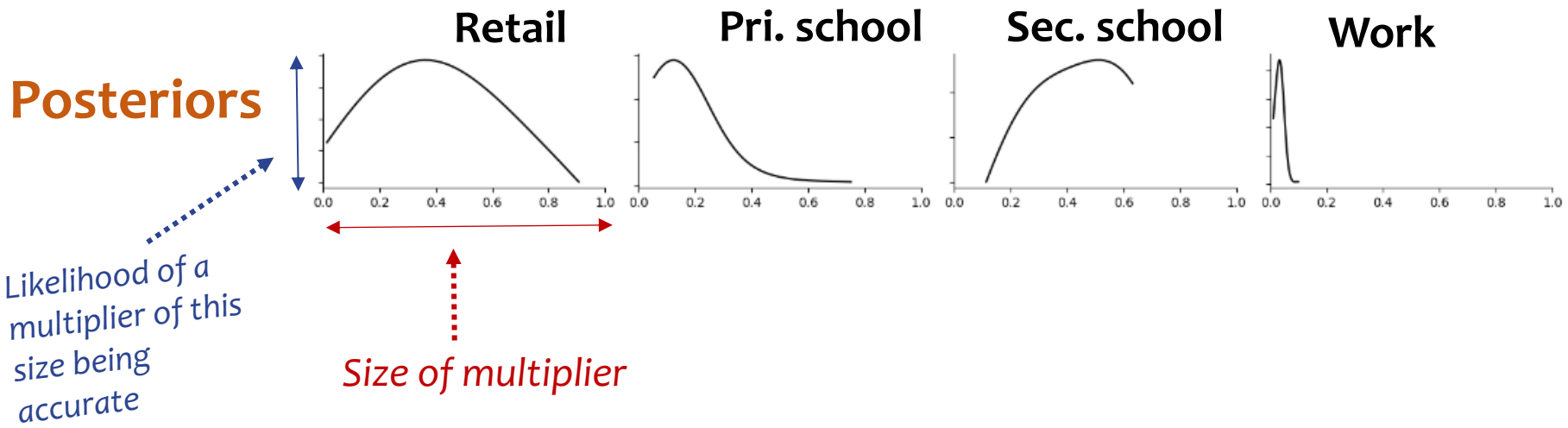
Posteriors



Uncertain parameters

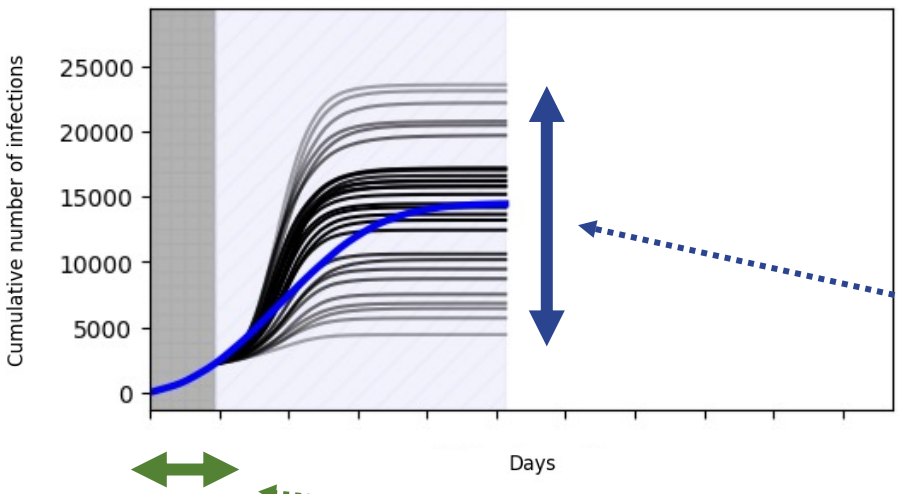
Each parameter value is:

A multiplier describing how likely someone is to get covid in that location



- Demonstrate **how uncertain** and **how important** each of the parameter values is

Uncertain predictions

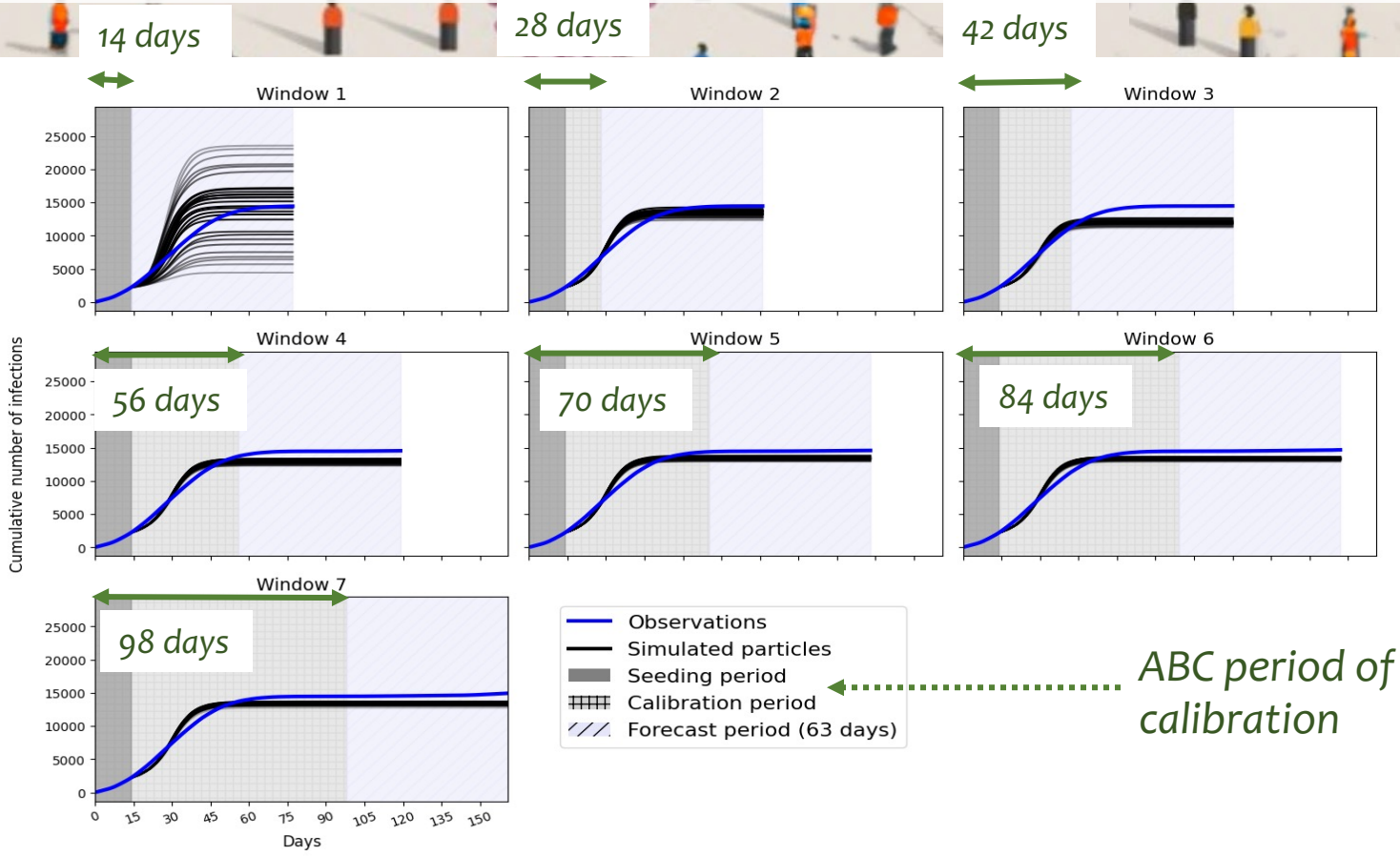


Spread of possible predicted values

14 days of data:
ABC period of parameter calibration

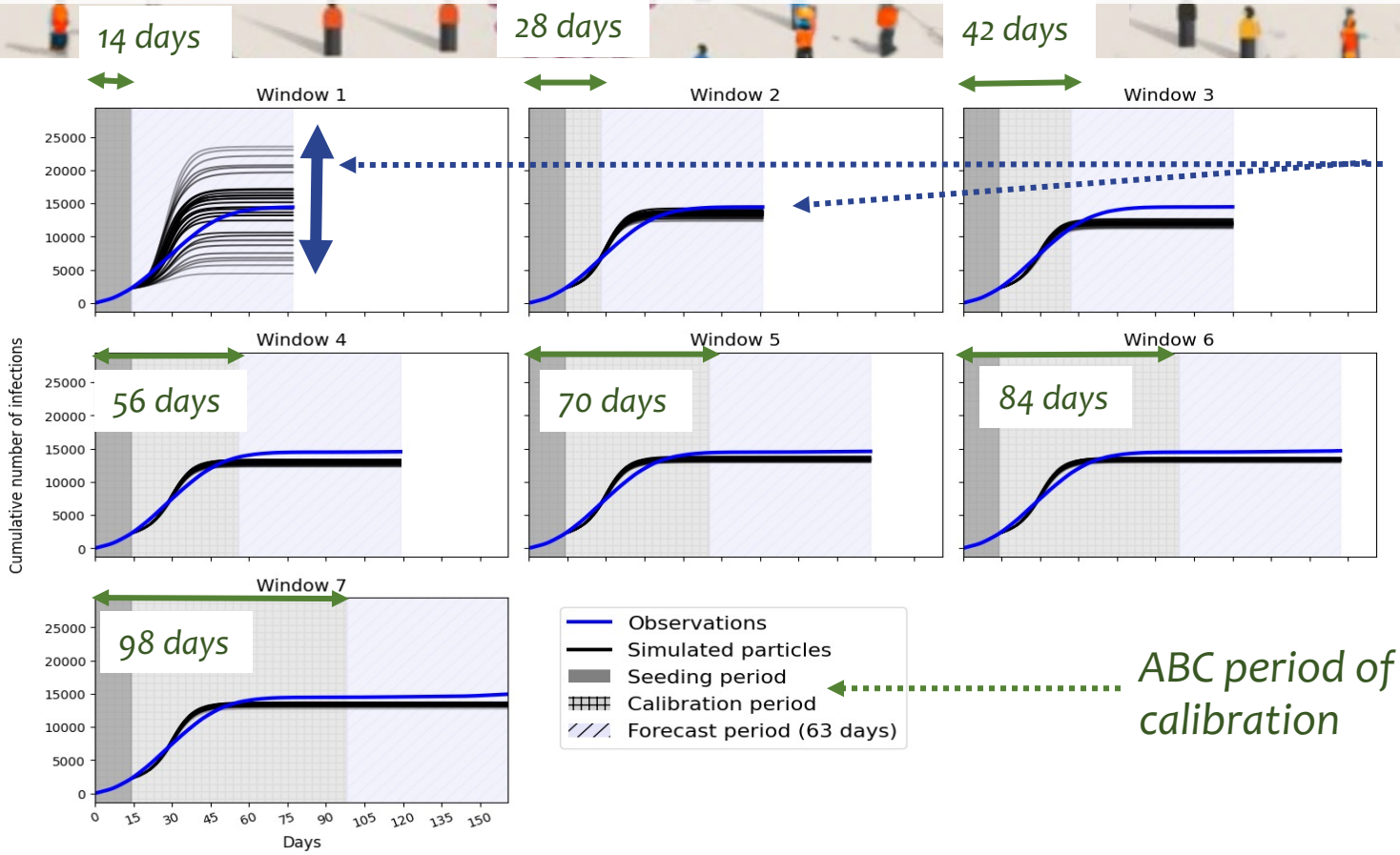
- Demonstrate how uncertain our predictions are

Uncertainty evolution



ABC period of parameter calibration

Uncertainty evolution

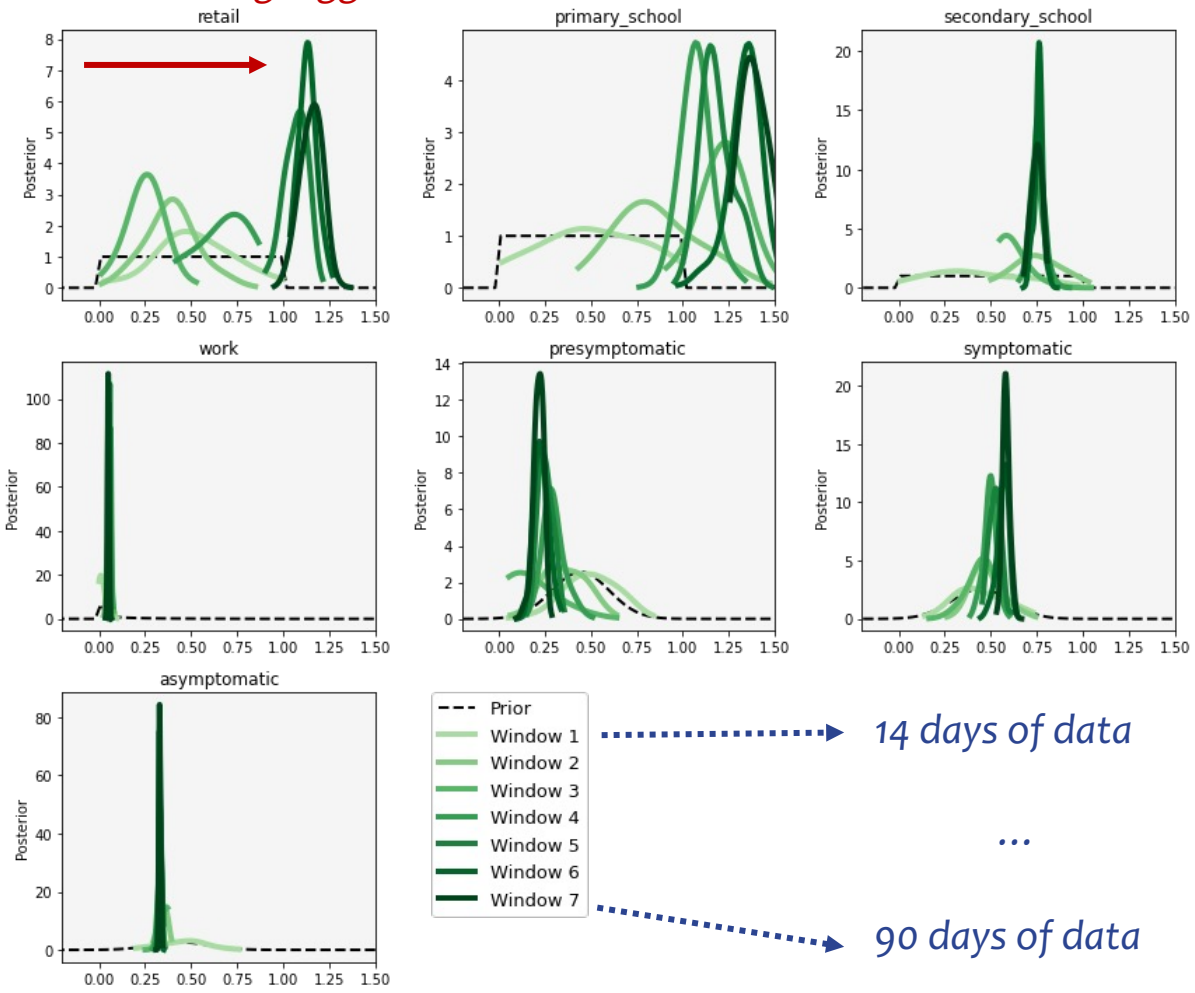


1. Illustration of how uncertainty changes over time (very uncertain at first, less certain as we get more data)

Parameter evolution

1. Show how importance of parameters change over time

Values becoming bigger

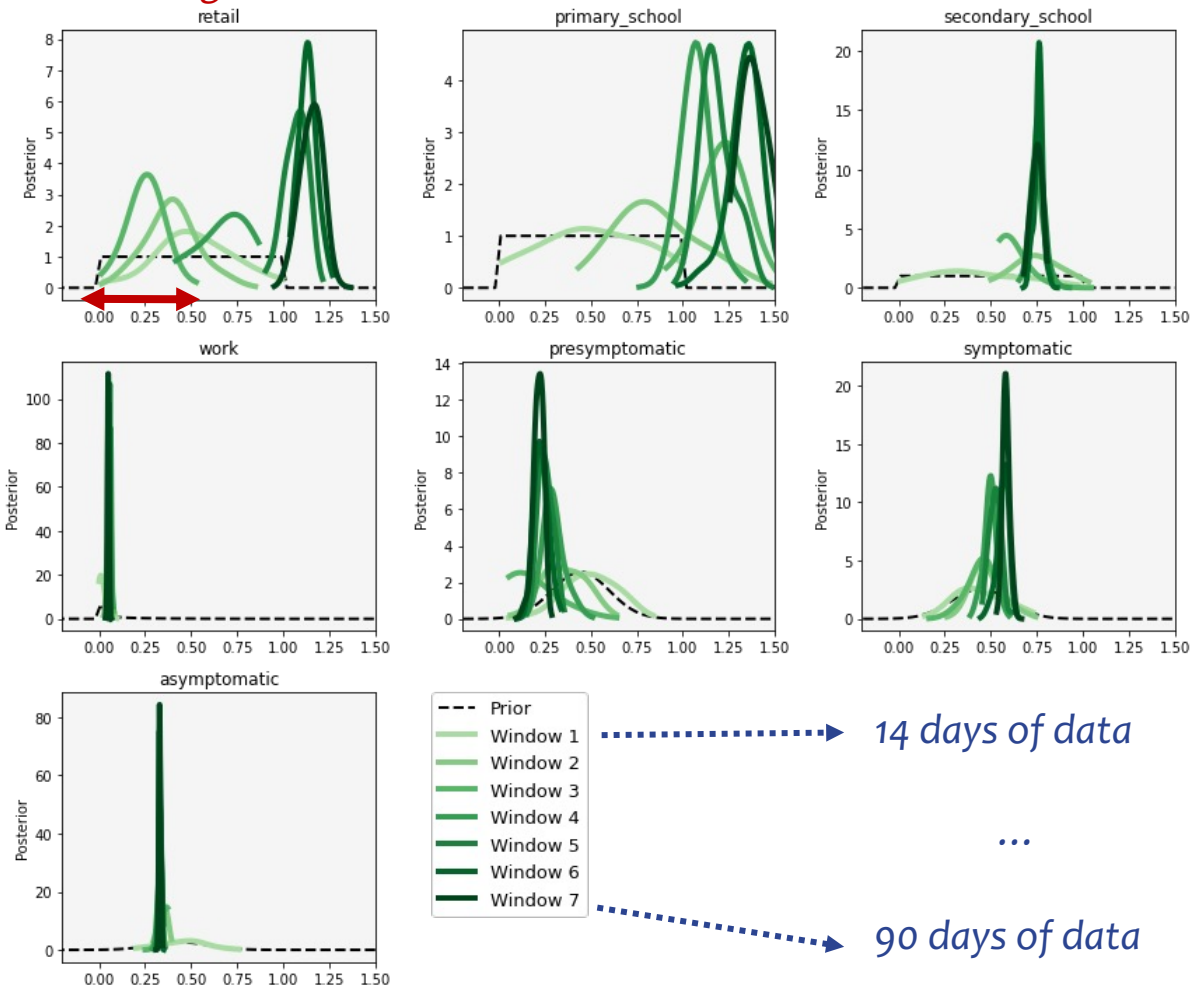


Parameter evolution

1. Show how importance of parameters change over time

2. Allow quantification of parameter uncertainty

Distribution gets narrower

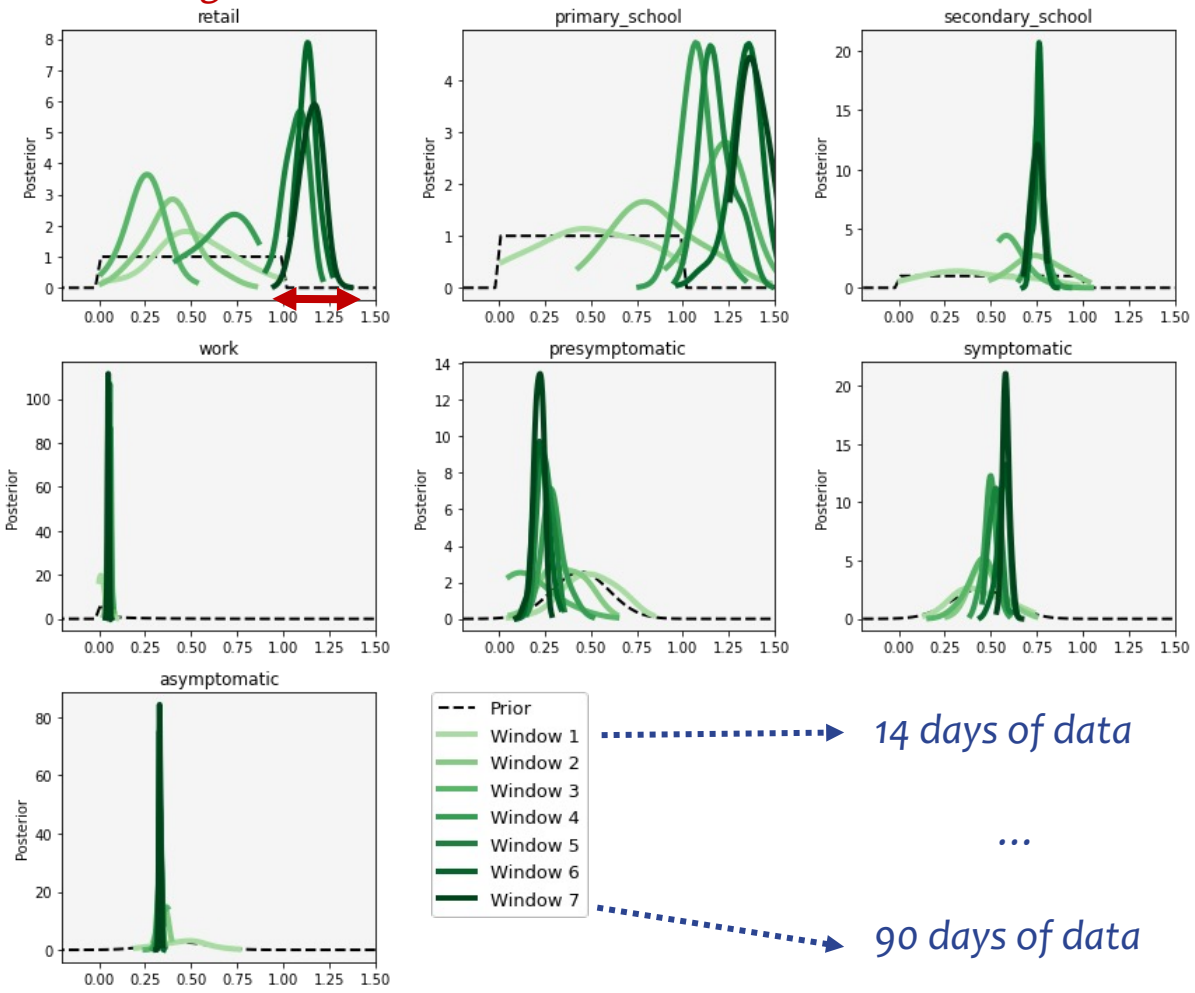


Parameter evolution

1. Show how importance of parameters change over time

2. Allow quantification of parameter uncertainty

Distribution gets narrower



Conclusions

Dynamic recalibration of an individual based model is possible, and:

- Preliminary results, but, proof of concept that ABC with ABM:
  - Allow new data to be used as it arises
  - Allows us to understand uncertainty in our predictions and the parameter values driving the model behind them