Data-informed parameter estimation in behavioral epidemic models

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Motivation

Behavioral epidemic models capture the feedback loop between human risk response and disease transmission. Accurate parameter estimation through model calibration is vital for making projections. However, few studies estimate behavior-related parameters using available data.

Objective: Examine parameter estimation challenges in behavioral epidemic models.

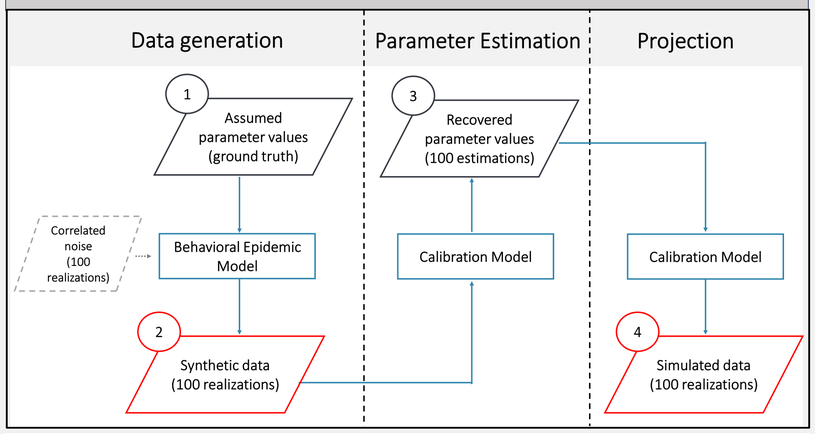
Hypotheses

- ***H1: Effect of Observation Time:*** Parameters can be accurately estimated throughout the pandemic using an accurate model and data, improving as disease outbreak progresses.
- ***H2: Effect of Model Structure:*** Parameter estimation is unreliable with improper model structure.
- ***H3: Effect of Behavior Data:*** Using public behavior data improves estimation accuracy.

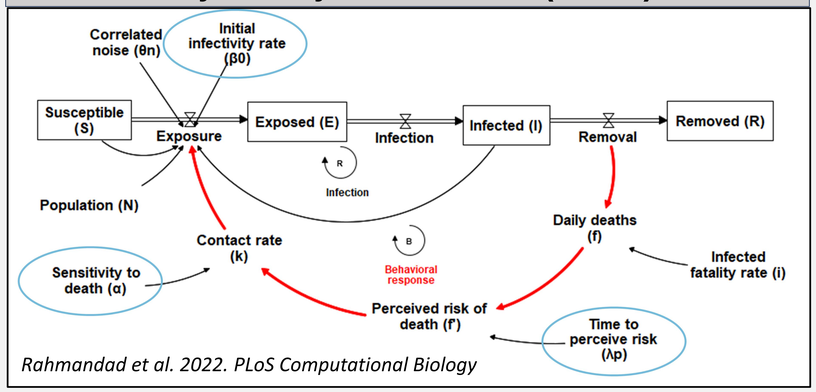
Key Insights & Results

- ✓ **Accurate behavior parameter estimation**
  - ○ **is challenging early on, even with accurate data and a well-structured model.**
  - ○ **improves with additional data on human behavior.**
  - ○ **requires data of at least half of a wave, due to the behavioral response delay.**
- ✓ **Absent behavioral loop (conventional SEIR)**
  - ○ **models may fit well initially but exhibit significant errors after the first wave.**
  - ○ **having extensive data does not correct the model's structural deficiencies.**

Research Procedure



System dynamics model (SEIRb)



Rahmandad et al. 2022. PLoS Computational Biology

Data Generation & Calibration Method

$$\frac{dE}{dt} = \beta \frac{SI}{N} \theta_n - \frac{E}{\lambda_e}$$

θ_n: correlated noise for synthetic data generation

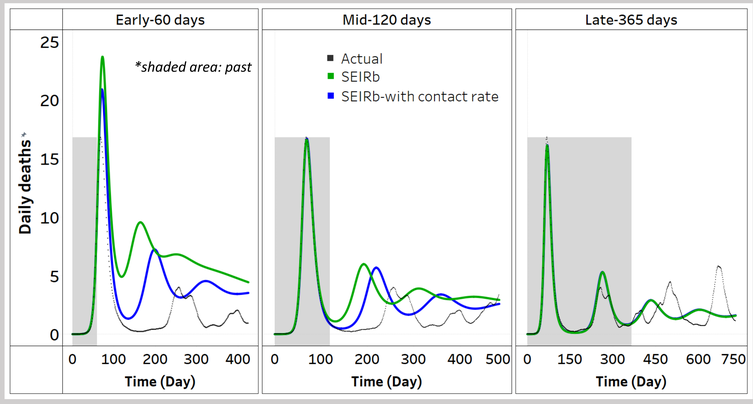
$$Min_p \left(\sum_{i=1}^{n} w_i \sum_{t=t_o}^{t_f} (\hat{y}_{it} - y_{it})^2 \right)$$

$$Subject\ to\ \hat{y}_t = c(s_t, p), \quad lp \le p \le up$$

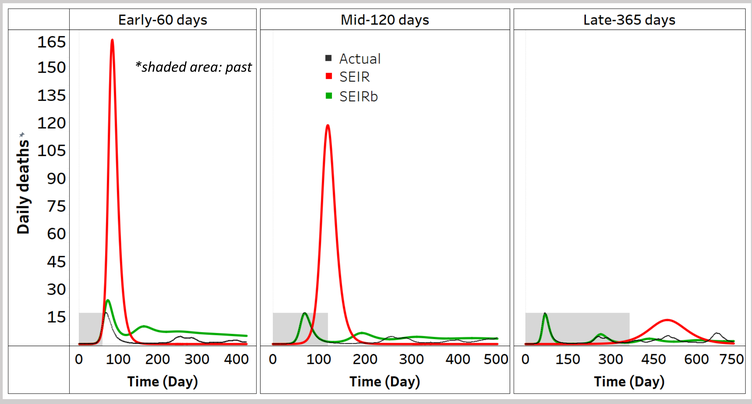
We use the Vensim built-in Powell method for calibration.

Results

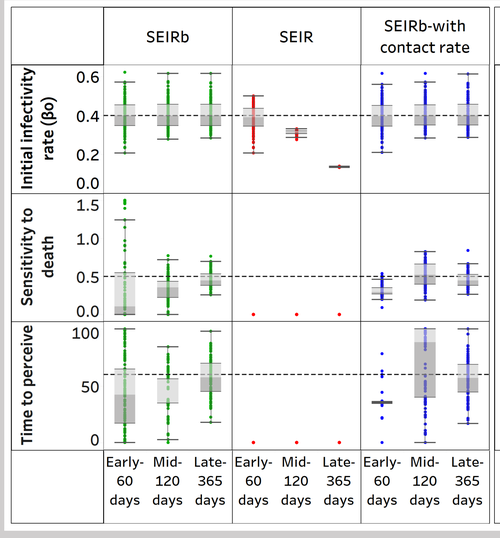
Effect of estimation time, and behavior data availability on projection



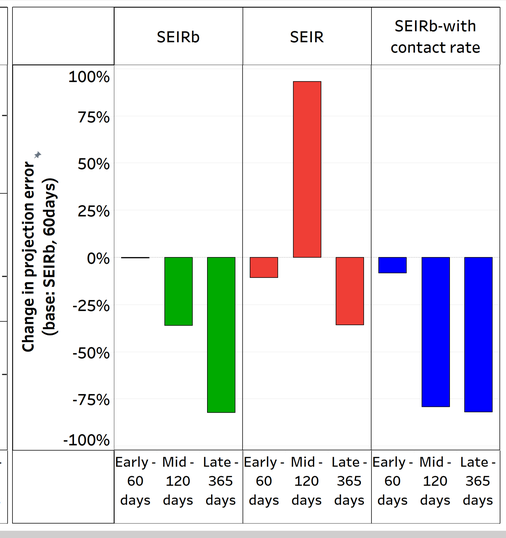
Effect of structural deficiency on projection



Parameter estimation accuracy



Cumulative projection error (normalized)



Conclusion

- We point to estimation challenges of behavioral parameters in an inverse process.
- Estimating behavior parameters is prone to bias during the early stages of the pandemic.
  - Projection errors reduce as the pandemic progresses.
  - Use of behavioral data can help after the first peak of the pandemic.
- The use of a proper model structure is a must.

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