Quantification of transmission and distinguishment of transmission modes

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Background

Transmission mechanisms of infectious diseases involve many possible routes and the relative contribution of the different routes are not fully understood. However, a good understanding of transmission is a prerequisite for improving interventions in public health issues. Modellers and epidemiologists used different approaches to understand transmission. However, classical epidemiological model do not relate risk to source of infection and inverse modelling might fail to give incorrect parameter estimation due to unidentifiability.

Objective

- To discuss the third way to quantify transmission which considers both disease dynamics and source of infection.
- Compare inverse modelling with this epidemiological dynamic model by using three simple transmission examples.
- Have a better understanding of environmental transmission and provide a method to quantify it

Method

Simulation for 3 transmission models

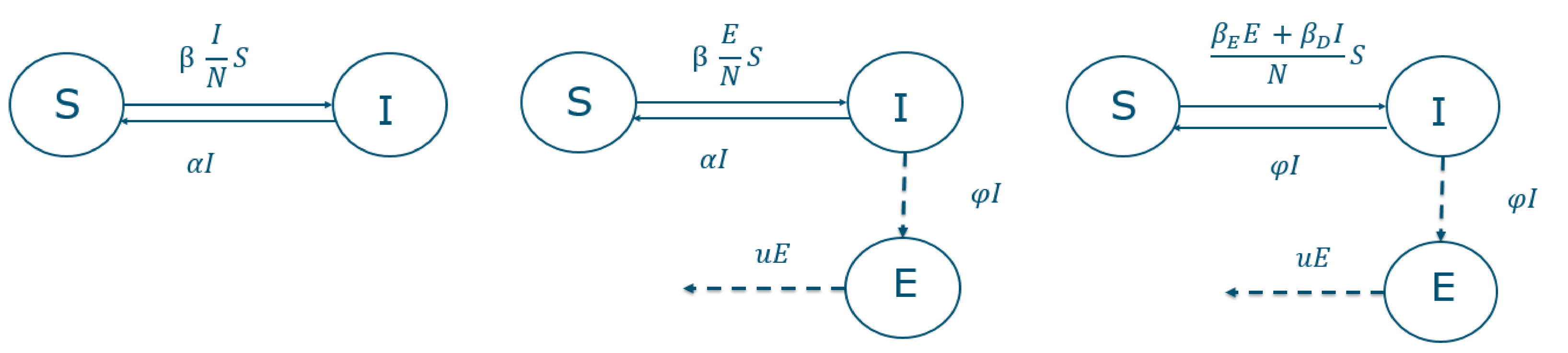

Figure 1. Schematic representation of the direct transmission (SIS), environmental transmission (SISE) and multiple transmission models (SIS+SISE).

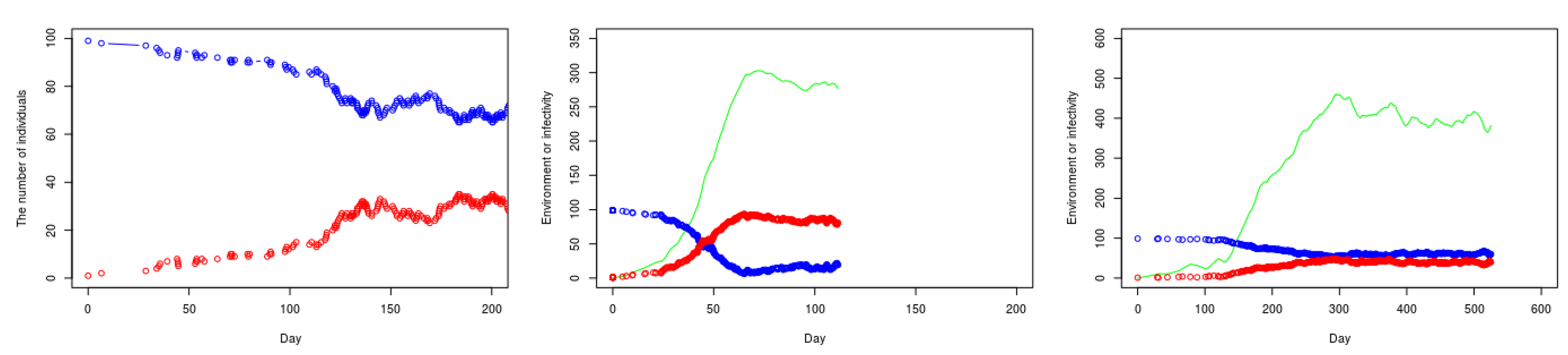

Figure 2. Representations of simulations: the number of Infected number, susceptible number and environmental infectivity

Statistical models

Inverse modelling:

Using Least squares, maximum likelihood, assuming Gaussion, binomial distribution, using a Nelder-Mead search by using FME, Pomp in R

Epi-dynamic model:

$$\text{cloglog}\left(\frac{\text{case}}{S}\right) = \log(\beta_D) + \log\left(\frac{I\,(t)}{N}\Delta t\right)$$

$$\text{cloglog}\left(\frac{\text{case}}{S}\right) = \log(\beta_E) + \log\left(\frac{E\,(t)+I(t)}{N}\Delta t\right)$$

$$\text{cloglog}\left(\frac{\text{case}}{S}\right) = \log(\beta_E) + \text{fracE} * \log\left(\frac{\beta_D}{\beta_E}\right) + \log\left(\frac{E(t)+I(t)}{N}\Delta t\right)$$

Results

Compare the accuracy and bias of GLM and ODE method

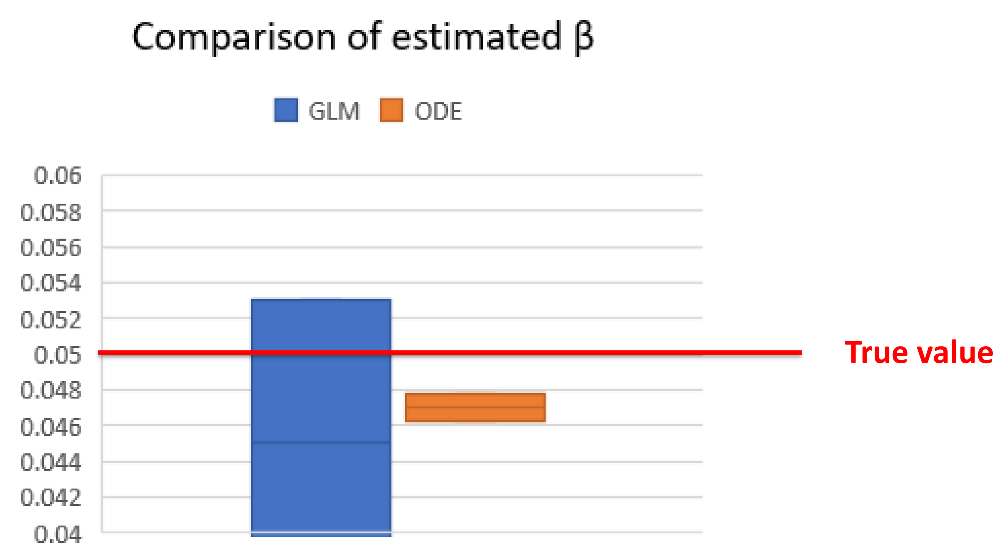

Figure 3. Estimated parameter for SIS simulation

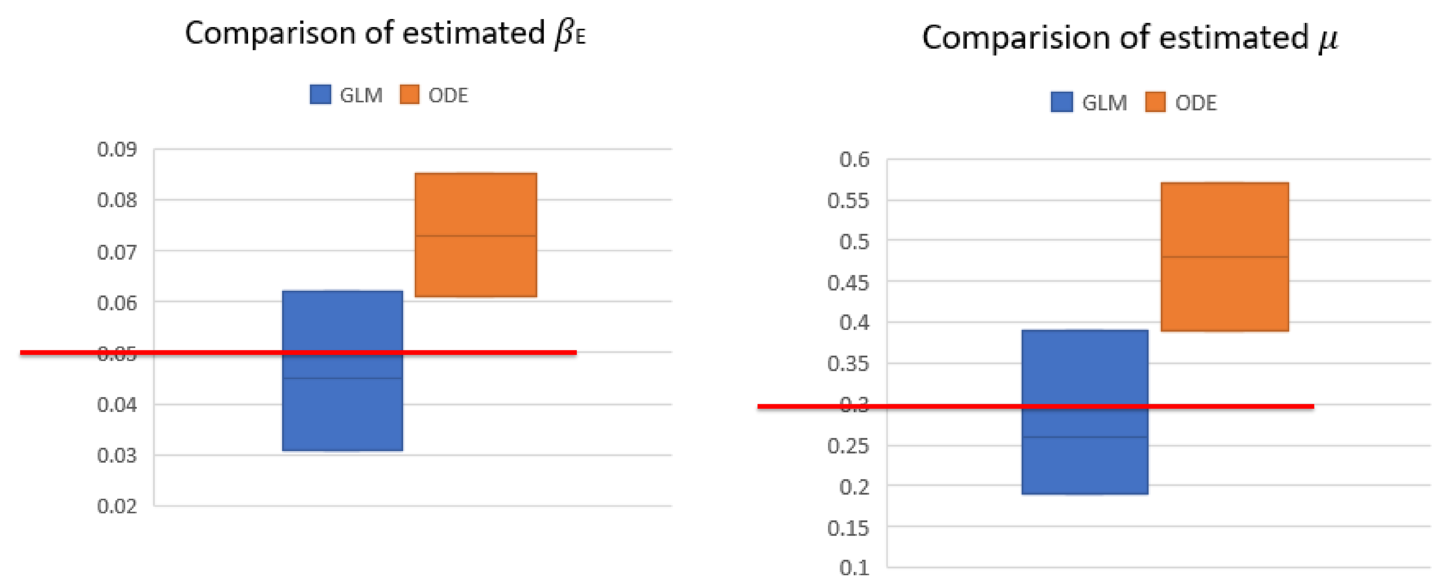

Figure 4. Estimated parameters for a SISE simulation

Distinguish mechanism by model fit measure

Table 1. Distinguish transmission modes by AIC

Simulated data	Statistical model	$\hat{\mu}$	$\widehat{\beta_E}$	CI	$\widehat{\beta_D}$	CI	$\widehat{R_0}$	AIC
SIS+SISE $\beta_E = 0.002$, $\beta_D = 0.02$, $\mu = 0.1$	Only environmental transmission	0.27	0.01	(0.0102 ,0.011)	--	--	1.85	9203 ★
	Environmental and direct transmission	0.22	0.007	(8e-5,0.54)	0.011	(0.002, 0.538)	4	9206

Conclusions

- Inverse modelling fails to estimate transmission parameters correctly in these three simple stochastic transmission model. We doubt this method can estimate parameters in other more complexed models.
- GLM model can quantify direct transmission, and environmental transmission by imputing environmental data.
- A good model fit does not mean the right model. Only by using statistical measure can not infer to the transmission mechanism.

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