Quasi-Spatial Mixing Patterns for COVID-19

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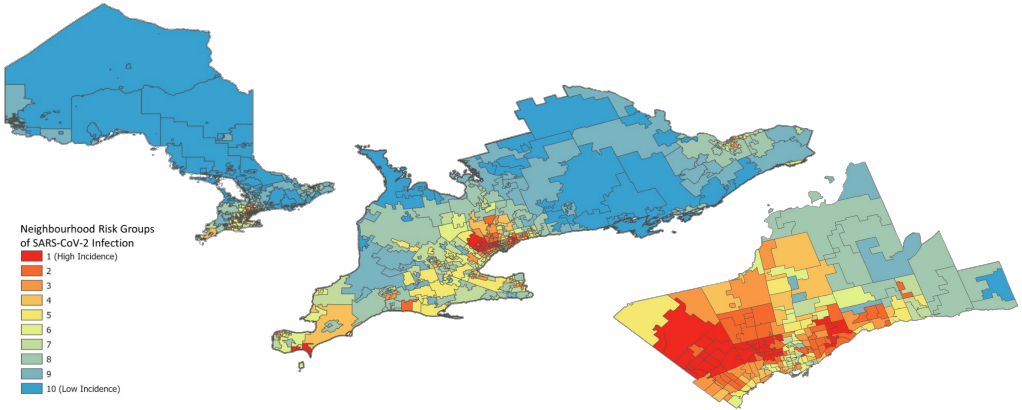
Modelling Research Question

- **Research Question:** impact of **hotspot** vs **non-hotspot** COVID-19 vaccine prioritization in Ontario

- **Transmission Model:**
  - 513 FSA (first 3 postal code) $\rightarrow$ **10 deciles** by cases
  - **12 age** groups: [0–11, 12–15, 16–39, 40–44, 45–49, …, 80+]
  - **2 contact types**: home, travel[1]
  - COVID-19 stuff …

[1] travel = work + school + transport + leisure + other

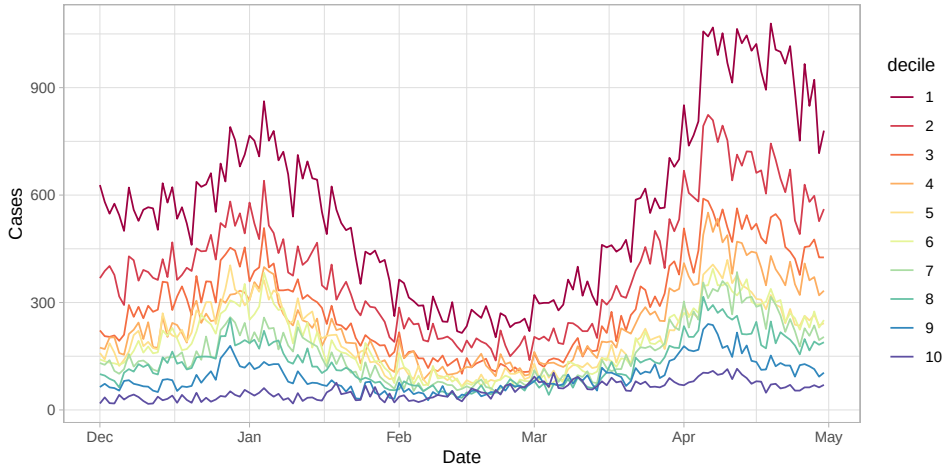
513 FSA by Cumulative Covid-19 Cases Deciles



[2]

[2] Brown 2021

Covid-19 Cases by Decile (t)



Objective

Develop a **mixing matrix** (number of contacts formed, and with whom) stratified by:

- self decile, g
- self age, a
- other decile, g'
- other age, a'
- contact type, y
- calendar month, t

Dimensions: $10 \times 12 \times 10 \times 12 \times 2 \times t$

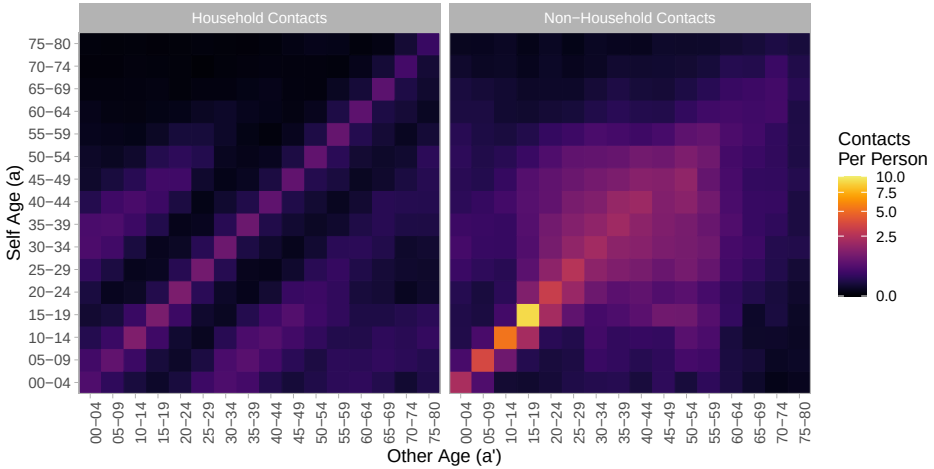
Two versions:

- X: total number of contacts in the model
- χ: contacts formed per person, $\chi = X/P$

Methods Overview

1. Contact Rates & Age Mixing
2. Mobility Patterns
3. Complete Mixing

Polymod Contact Matrices, for Canada (Prem 2017)



Age Mixing: Three Challenges

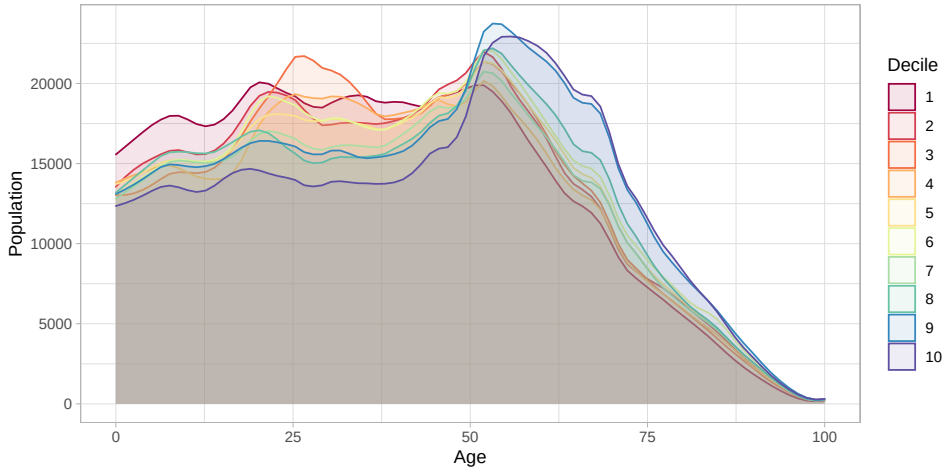
1. Polymod study did not include Canada → Prem 2017
2. Each decile: unique age distribution
3. Age stratification not aligned

Age Mixing 1: Canada-Specific

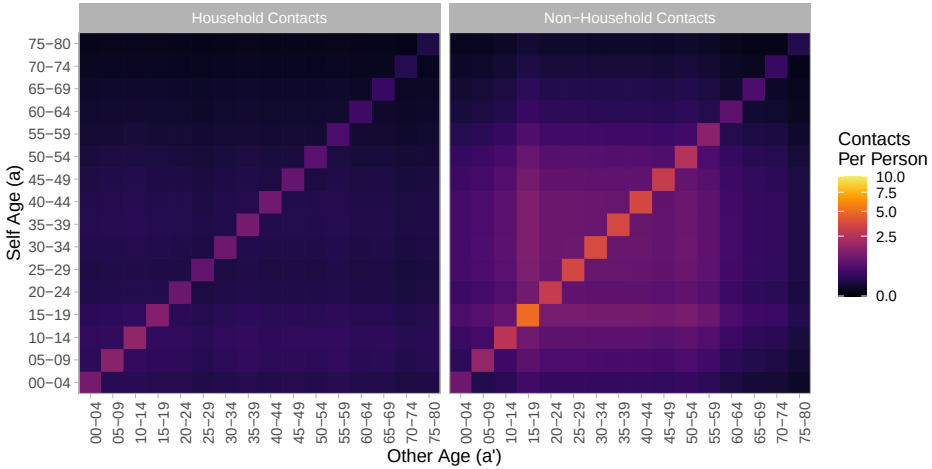
Prem et al. (2017): project POLYMOD contact matrices onto 152 countries, using:

- age pyramid → all types
- labour force participation → work
- school participation & teacher-student ratio → school
- household age structure & socio-demographic factors → home

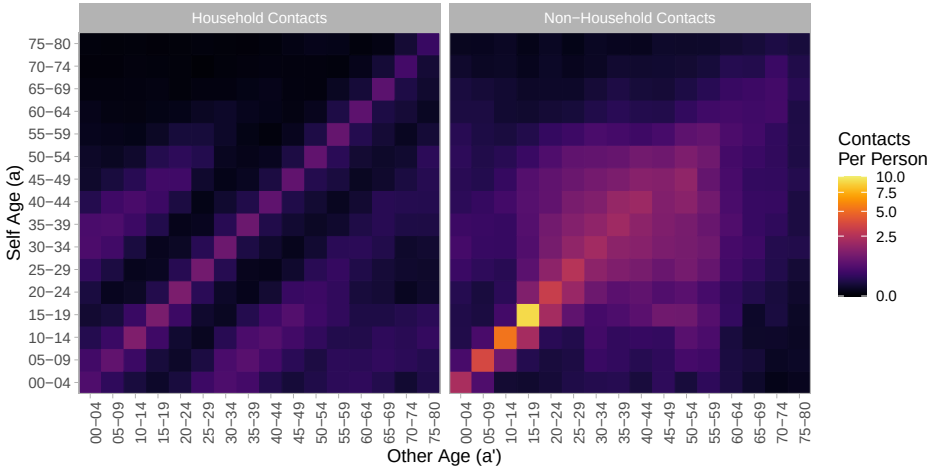
Age Mixing 2: Decile Age Distributions



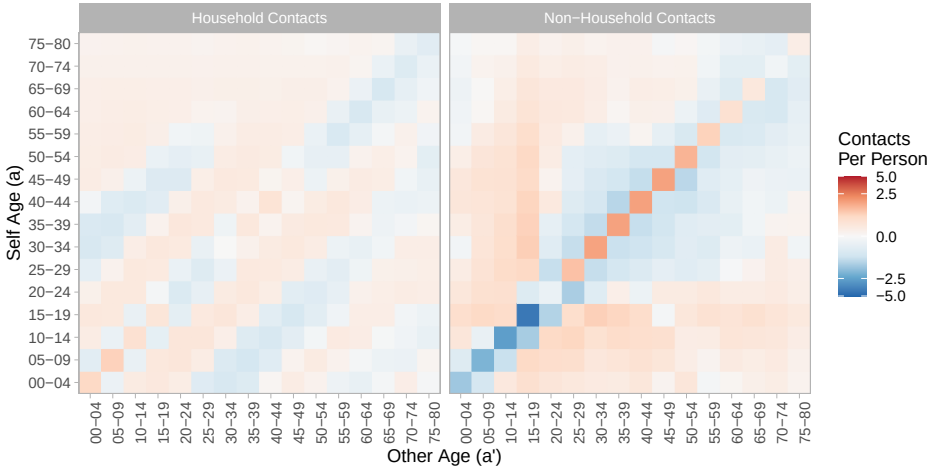
Age Mixing 2: Polymod ϵ Approximation



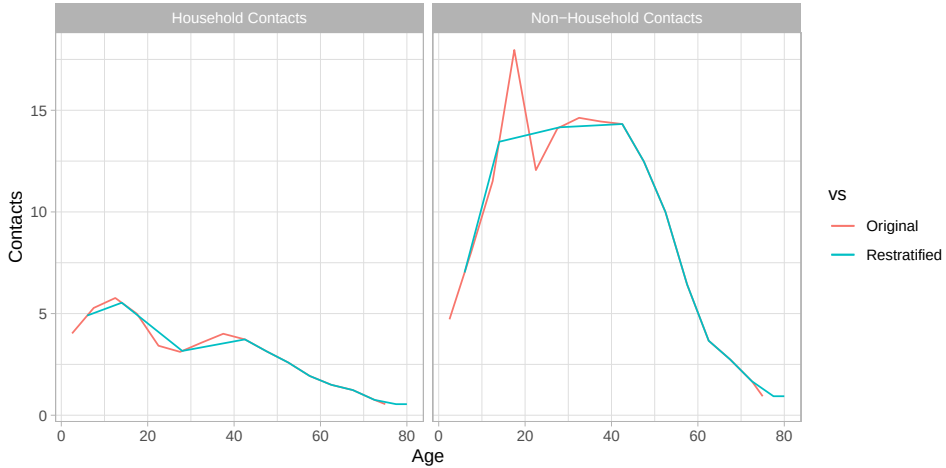
Age Mixing 2: Polymod Original



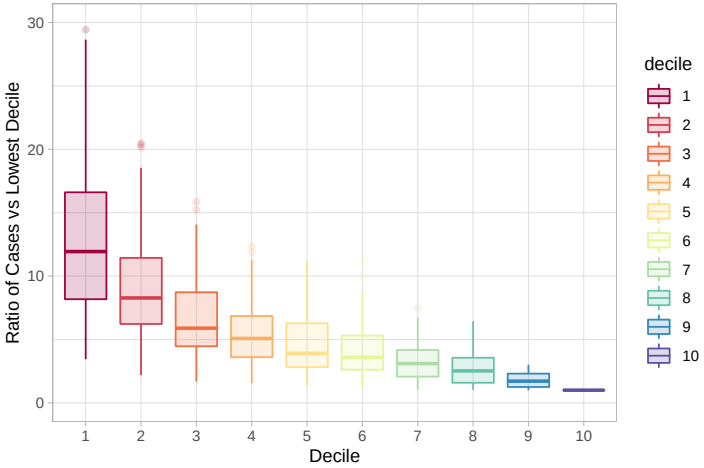
Age Mixing 2: Polymod ϵ Approx — Original



Age Mixing 3: Re-stratified Age by Interpolation



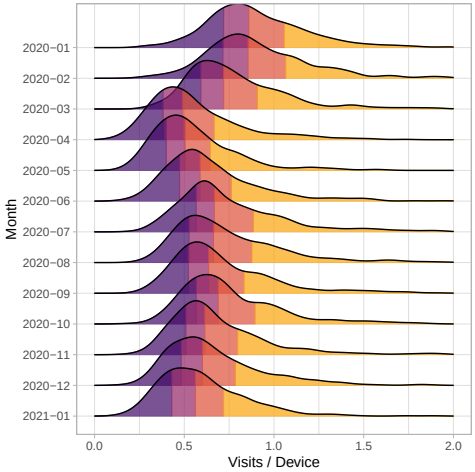
Contact Rates: Forced Scaling by Decile



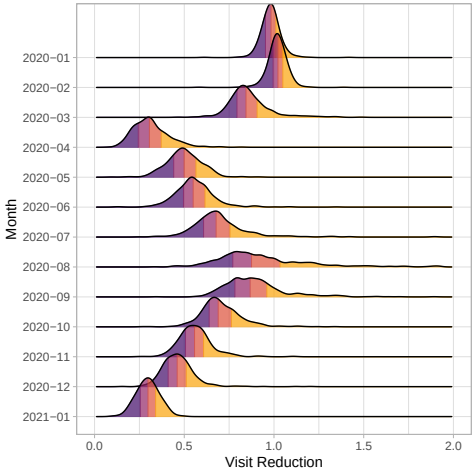
Mobility Data

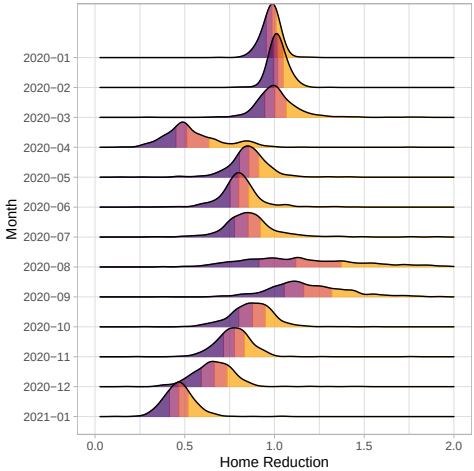
- ~2 % devices in each FSA
- For each device:
  - Define **Home** FSA
  - Count **Visits** to other FSA per day (2h+)
- Average # devices per FSA per day:
  - at Home, H_g
  - Visited other FSA, $V_{gg'}$
- Repeat by calendar month, t

Mobility Data: Unbiased Sample?



Mobility Data: Unbiased Sample?





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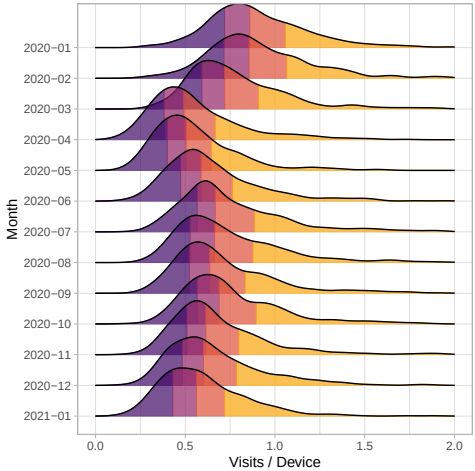
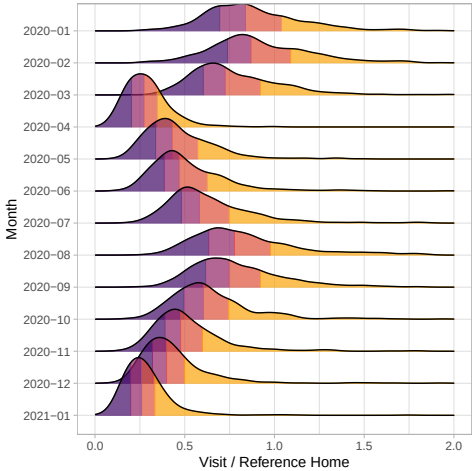




Mobility Data: Assumptions

Problem 1: Visits ($V_{gg'}$) per device (H_g) does not reflect mobility reduction

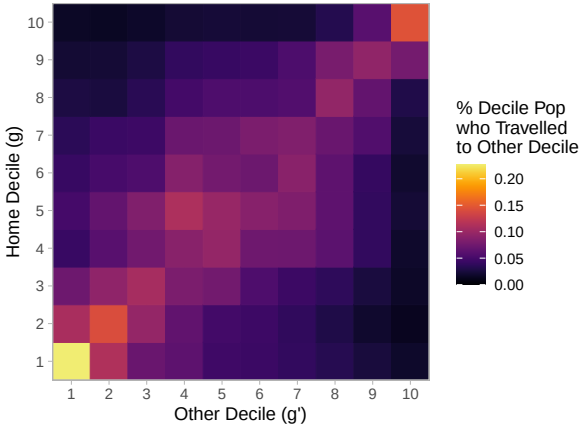
Solution 1: Use denominator ($H_{g'}$) from REF period (t_0: Jan–Feb 2020)

Problem 2: Unobserved devices (98%) less mobile

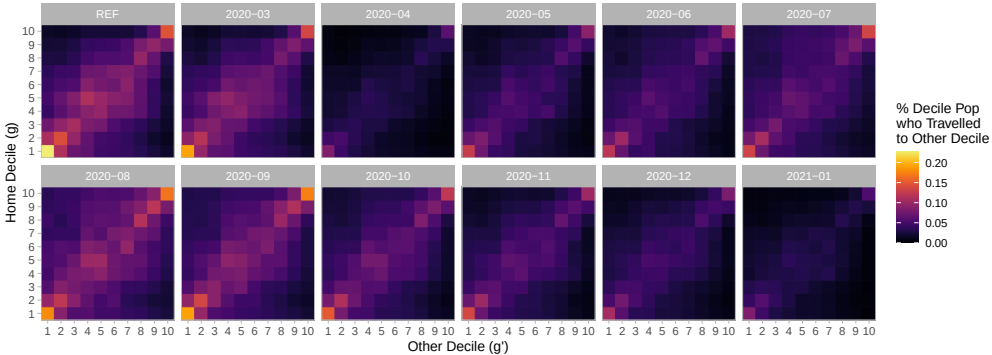
Solution 2: Assume $\phi = 0.9$ as mobile

Define: $B_{gg't} = V_{gg't}/H_{gt_0}\left[1 + \phi\left(P_g - H_{gt_0}\right)\right]$

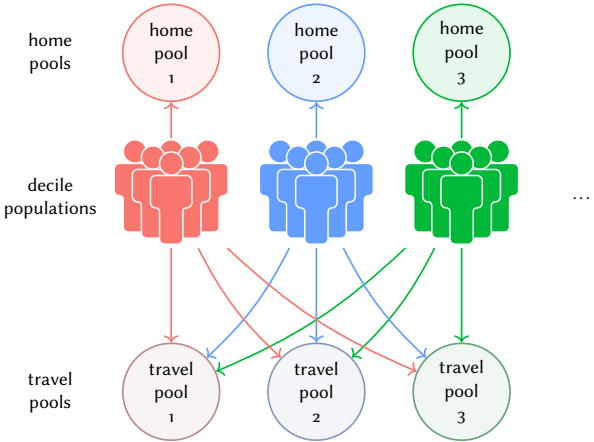
Mobility Matrix, $B_{gg'}$ (REF)



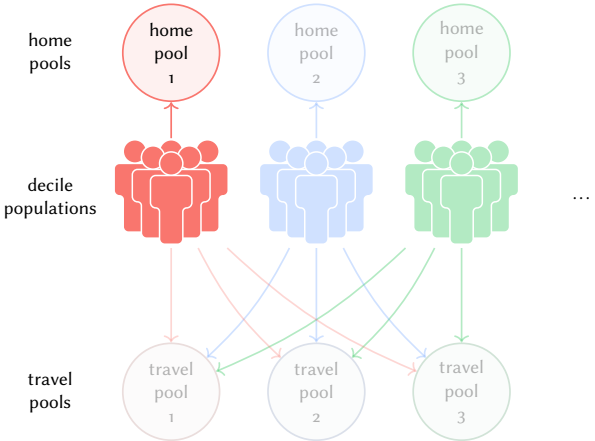
Mobility Matrix, $B_{gg'}(t)$



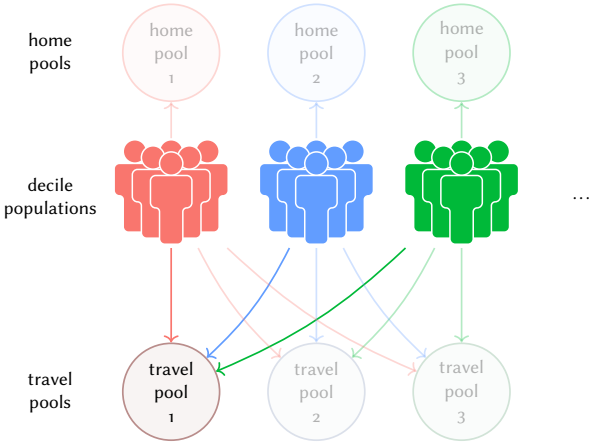
Mixing Pools Model:



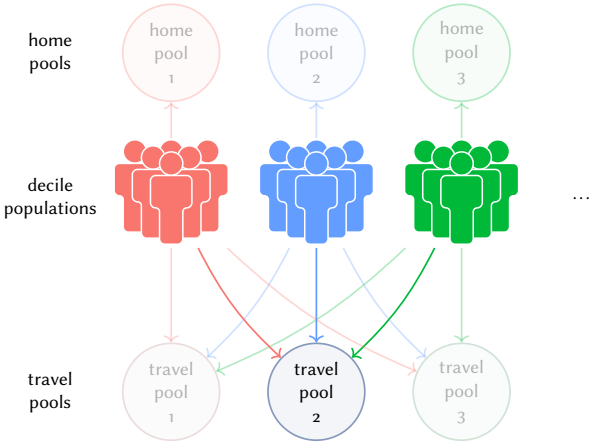
Mixing Pools Model: home contacts



Mixing Pools Model: others visiting my decile



Mixing Pools Model: others visiting same decile as me



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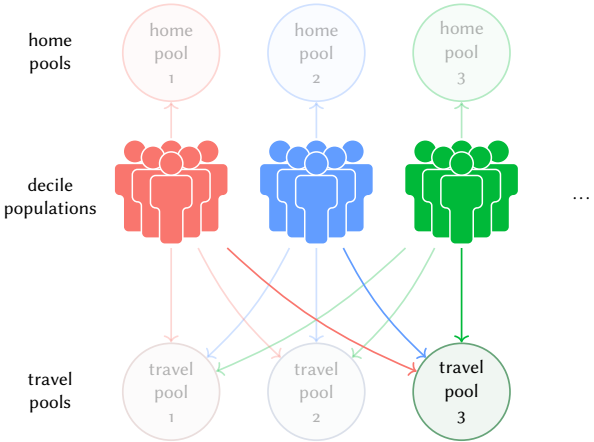


Mixing Pools: Math

Total type y contacts made available by age group a in decile g: $Q_{gay} = P_{ga} \times C_{gay}$

Home Contacts:

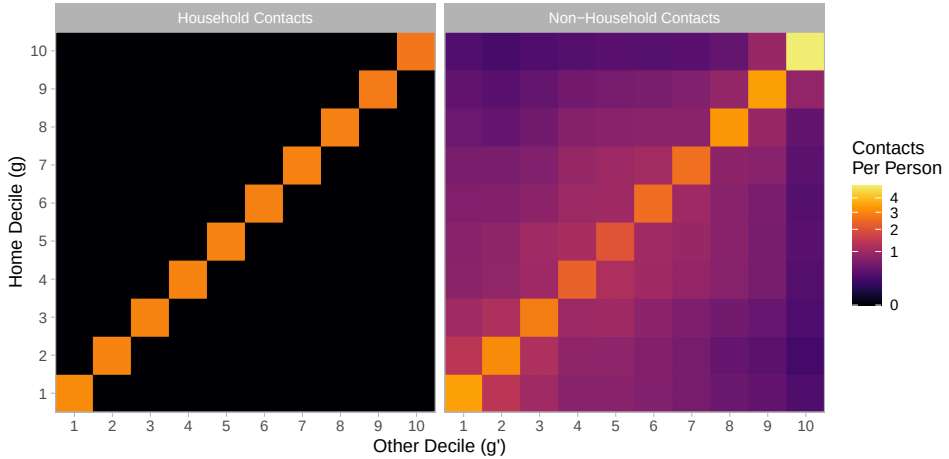
- 100% Q_{gay} with same decile
- $X_{gg'}$ mixing by decile g: identity matrix
- $X_{aa'}$ mixing by age a: from ϵ-POLYMOD "home"

Mixing Pools: Math

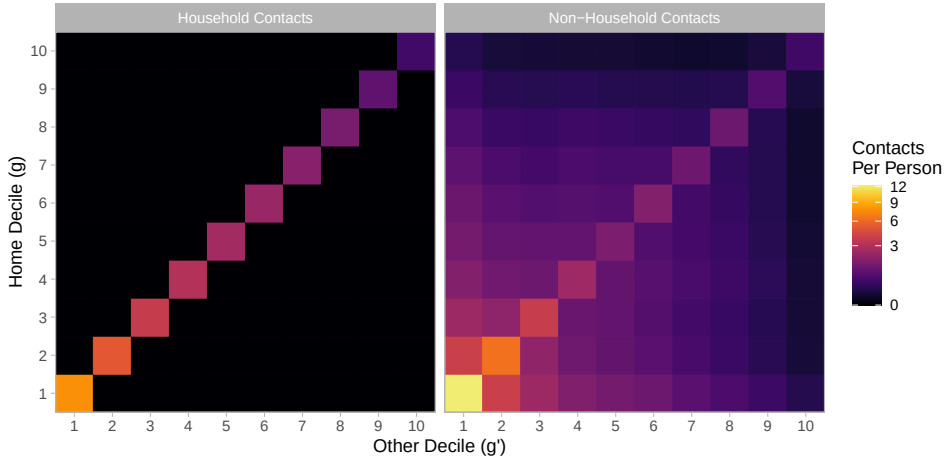
Other Contacts:

- $B_{gg'}$ % of Q_{gay} formed in (not with) g'
- Within g^* travel pool:
  - Total contacts available (denominator): $T_{g^*} = \sum_g B_{gg^*} Q_{gay}$
  - $X^{g^*}_{gg'}$ mixing by decile g: proportionate
  - $X^{g^*}_{aa'}$ mixing by age a: from ϵ-POLYMOD "travel"
- Total mixing across all travel pools: $\sum_{g^*} X^{g^*}_{gag'a'y}$
- Assume remaining contacts $(1 - \sum_{g'} B_{gg'})$ formed with local travel pool

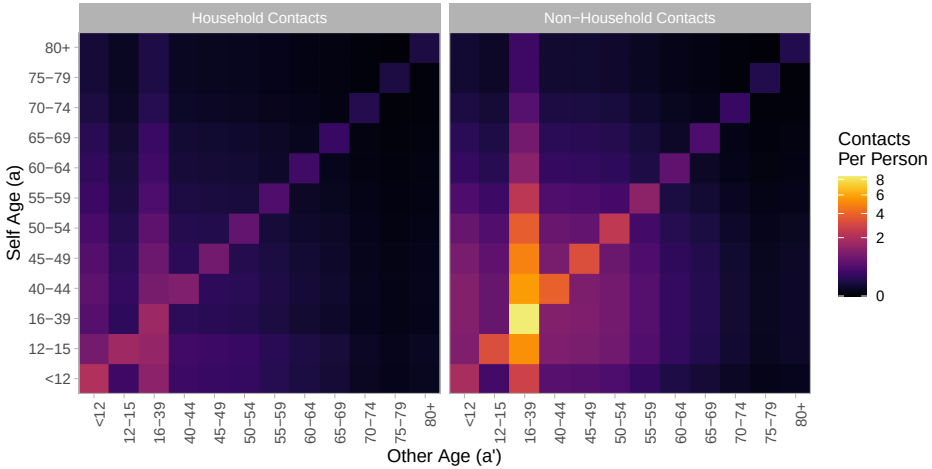
Decile Mixing: No Contact Scaling



Decile Mixing: With Contact Scaling



Age Mixing


Household Contacts
Non−Household Contacts
Self Age (a)
80+
75−79
70−74
65−69
60−64
55−59
50−54
45−49
40−44
16−39
12−15
<12
Other Age (a')
Contacts
Per Person
8
6
4
2
0