Outbreak risks, cases, and costs of different vaccination strategies against wild poliomyelitis

Short title: how we used simple models to inform economic decision-making

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Broader context of study & relevance for health policy

- We focus on the challenge of polio supplementary immunization activities (SIAs) in non-endemic countries, given a fixed (limited) budget
  - **Context**: wild poliovirus serotype 1 (WPV1) in AFRO
  - **Current status of pSIAs**: average number of preventative SIAs (pSIAs) have declined in recent years and some countries have not conducted a pSIA in over a decade…

  - Explore corresponding costs and trade-offs
    - Global Polio Eradication Initiative (GPEI) perspective (future funding and programmatic needs)
    - Non-GPEI perspective (including health system perspective)
    - Global perspective (eradication goals)

Model assumptions and parameters

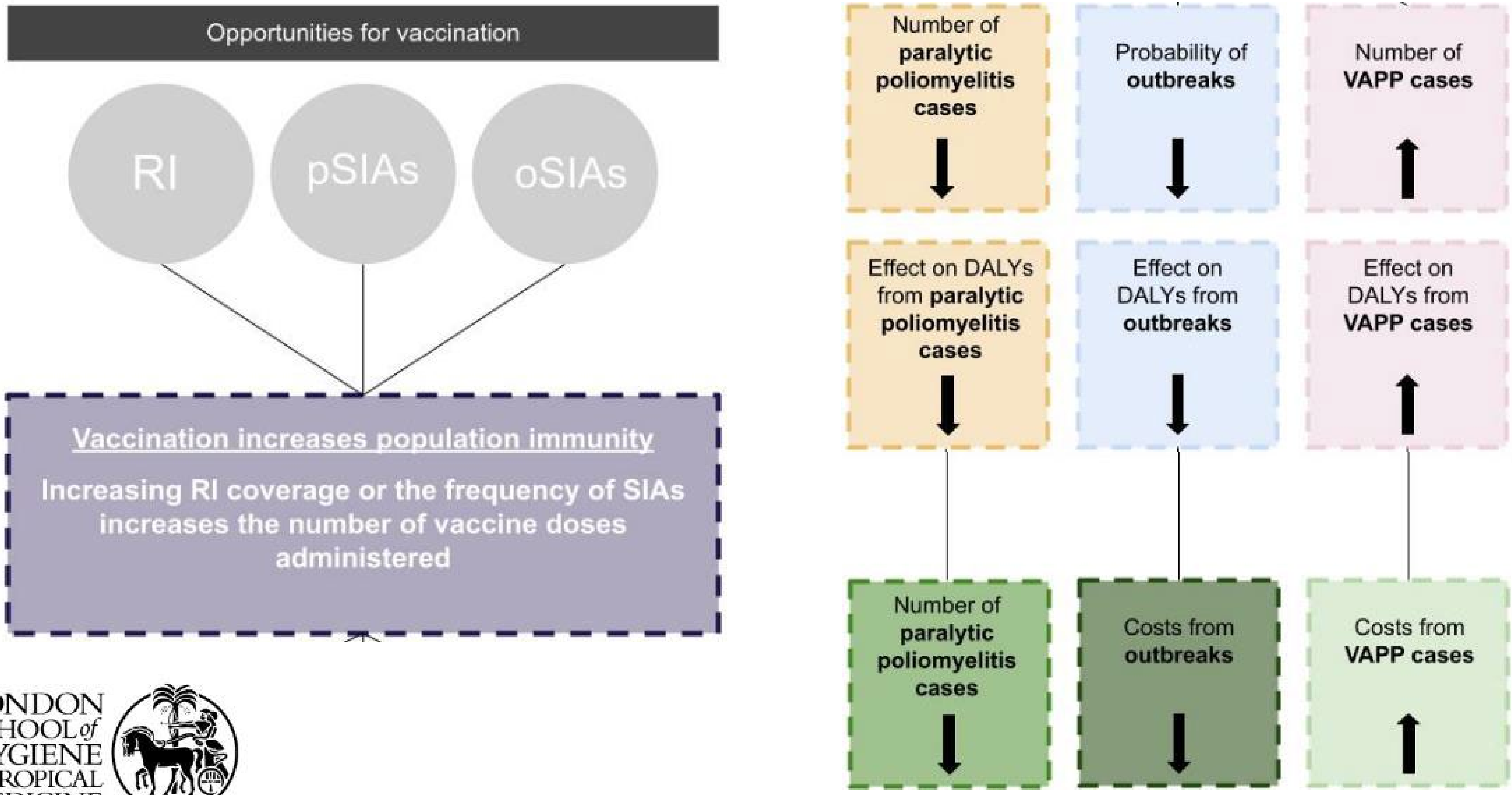
- Extended SIR model, stochastic simulations to allow for variability
  - Account for differential immunity with dose exposure (i.e. not all or nothing for vaccination)
  - RI includes both bOPV and IPV
  - Allow for importations of infection
  - Case to infection ratio (WPV 1:200)
  - $R_0 = 3$, so, herd immunity threshold is ~ 67%

- 5-year time horizon to align with GPEI strategic plan
- Model a "hypothetical" population for an LMIC country in Africa (~8 Million children <5 years of age)
- Model outputs for each vaccination strategy:
  - Expected cases of paralytic polio
  - Disability adjusted life-years (DALYs)
  - Number of outbreaks
  - Probability no outbreaks occur
  - Adverse events of vaccination (vaccine associated paralytic polio, VAPP)

Comparator vaccination strategies

3 Vaccination strategies –outbreak is defined as ≥1 case of paralytic polio

1. RI + oSIAs: vaccination via RI, no preventative SIAs, only outbreak response in simulations with ≥1 case ** baseline comparator **
2. Annual pSIAs: RI + annual preventative campaigns in all simulations
3. Biannual pSIAs: RI + biannual preventative campaigns in all simulations



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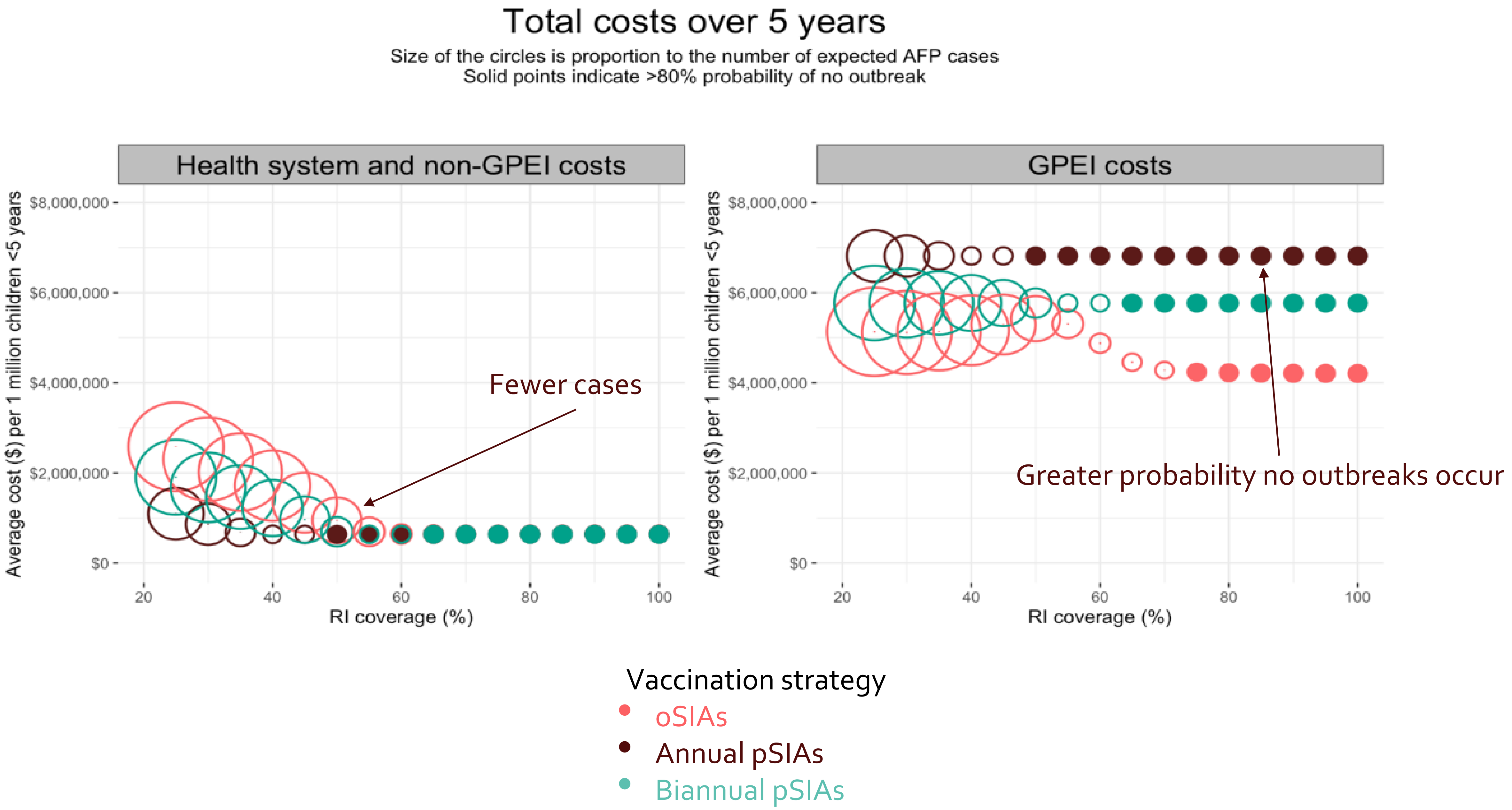
Cost data and assumptions

Economic assumptions:

- SIA cost data from GPEI (operational, procurement, social mobilization)
- oSIAs are more expensive than pSIAs
- Cost and DALYs per paralytic poliomyelitis case = VAPP case
- Who pays for what?
  - **Health system (non-GPEI) costs =**
    - bOPV via RI + cases + VAPP
  - **GPEI costs =**
    - SIAs + IPV via RI


Total costs over 5 years
Size of the circles is proportion to the number of expected AFP cases
Solid points indicate >80% probability of no outbreak
Health system and non-GPEI costs
GPEI costs
Average cost ($) per 1 million children <5 years
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
20
40
60
80
100
RI coverage (%)
Fewer cases
Greater probability no outbreaks occur
Vaccination strategy
oSIAs
Annual pSIAs
Biannual pSIAs

From GPEI perspective, in comparison to oSIAs alone (baseline comparator)…

Low RI

DALYs averted

Annual pSIAs >> Biannual pSIAs

Cost per DALY averted

Annual pSIAs cost-effective

High RI

DALYs averted

Annual pSIAs = Biannual pSIAs

Cost per DALY averted

Annual pSIAs >>> Biannual pSIAs

Biannual pSIAs cost-effective

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Implications for decision-making

RI coverage	Implications for decision making
<50%	pSIA removal would have high risks and consequences
50-70%	Removal of pSIAs altogether could lead to a high risk of outbreaks in subsequent years
80-90%	Reducing the frequency of pSIAs could still maintain a low risk of large outbreaks
100%	Even if pSIAs are removed, there is low to no risk of outbreaks

Pros and cons of using a simple model

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- Assumptions made:
  - Homogenous mixing
  - SIAs reach 25% of children missed by RI
  - Use a simple single value for R_0 alongside other parameters
- We do not consider the costs of further delaying the eradication timeline
- By limiting our analysis to a 5-year time horizon, we underestimate the benefits of pSIAs as they will increase the likelihood of eradication

- Model is implemented using R package SimInf
  - Easy to code
  - Easy to manipulate parameters
  - Can be used across wide range of settings
- Simple model with clear cost inputs and outputs is easy to communicate
- Model clearly shows risks and benefits of different vaccination strategies and can be used to inform imminent policy and funding decisions

THANK YOU

Questions, comments & feedback: Megan.Auzenbergs@lshtm.ac.uk

1. What experiences do you have using models to answer economic or financial needs?

2. What experiences do you have using models in interdisciplinary research?

Additional slides with results

Not included in main talk- these figures are additional outputs from the model described in this presentation (cut from presentation for time sake, left here hidden at the end in case of questions)

Routine immunisation (RI) coverage & historical preventative SIAs (pSIAs)

RI coverage <60% >60% RI <80% >80% RI <90% >90%

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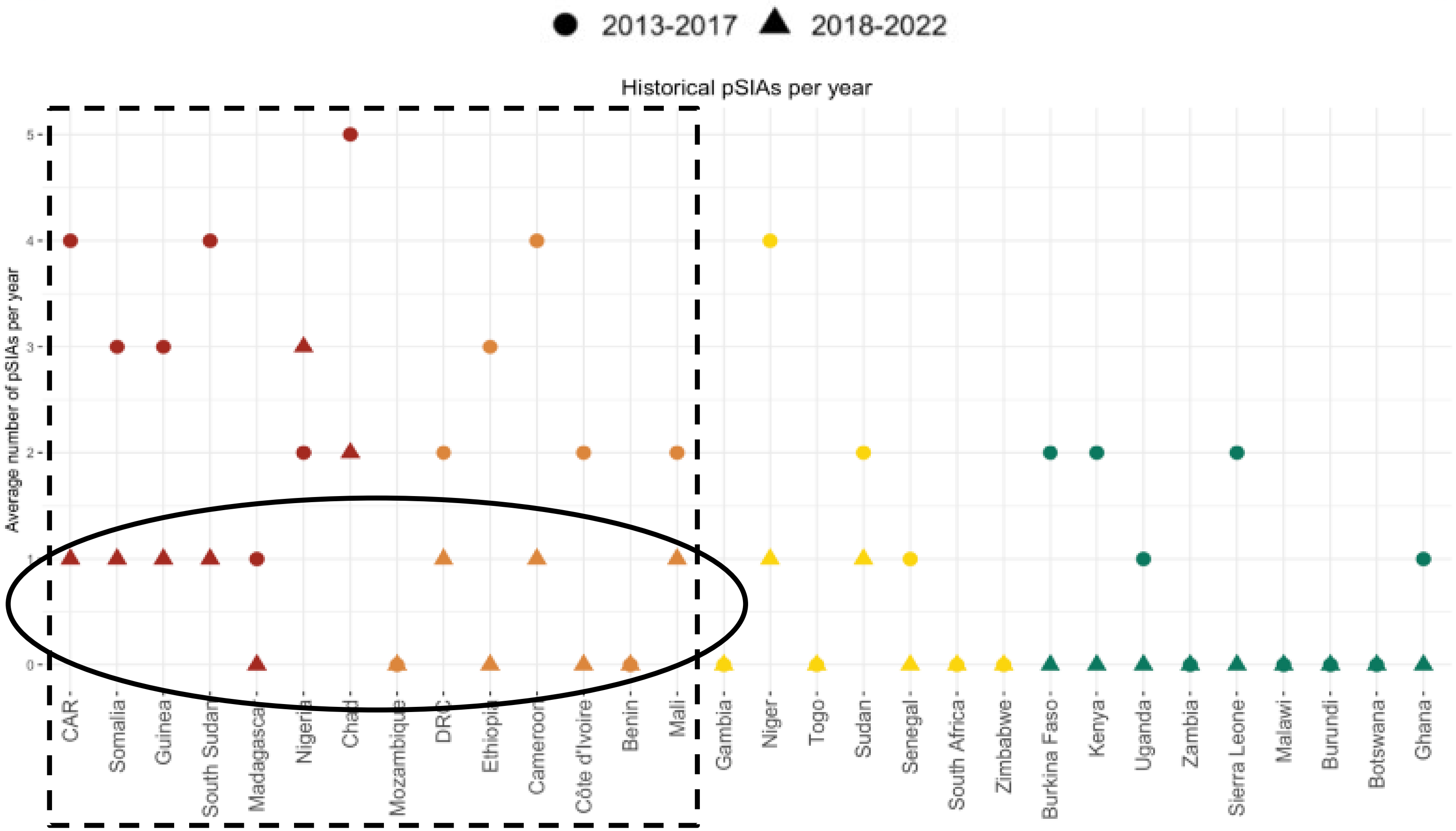

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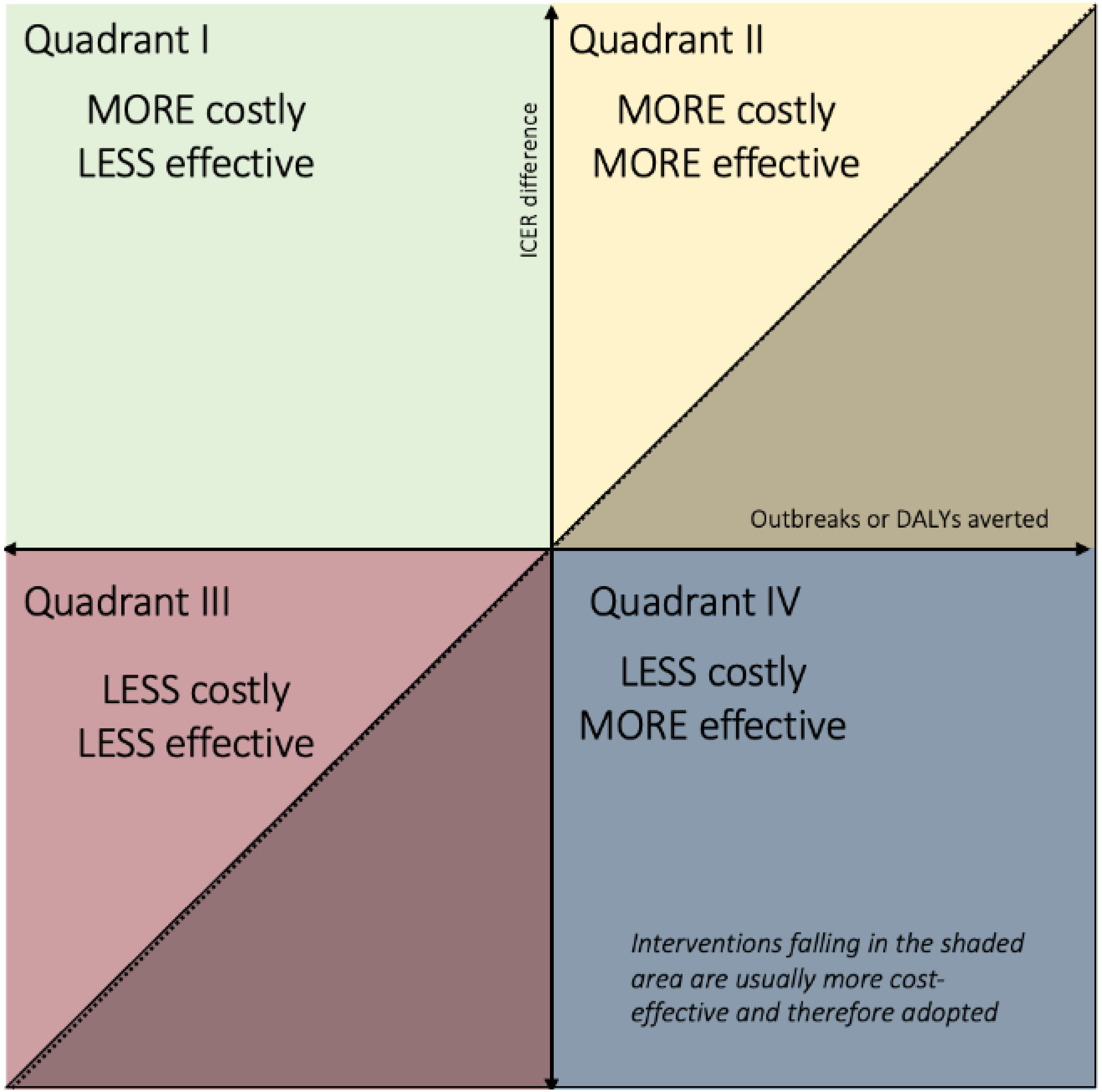
Country	DTP3 coverage 2021	Year of last pSIA
RI coverage <60%		
CAR	42%	2021
Somalia	42%	2021
Guinea	47%	2021
South Sudan	49%	2021
Madagascar	55%	2019
Nigeria	56%	2021
Chad	58%	2021
>60% RI coverage <80%		
Mozambique	61%	2011
DRC	65%	2021
Ethiopia	65%	2021
Cameroon	69%	2021
Côte d'Ivoire	76%	2018
Benin	76%	2018
Mali	77%	2019
>80% RI coverage <90%		
Gambia	82%	2014
Niger	82%	2019
Togo	83%	2014
Sudan	84%	2019
Senegal	85%	2016
South Africa	86%	2010
Zimbabwe	86%	2007
>90% RI coverage		
Burkina Faso	91%	2016
Kenya	91%	2019
Uganda	91%	2019
Zambia	91%	2009
Sierra Leone	92%	2019
Malawi	93%	2010
Burundi	94%	2011
Botswana	95%	2004
Ghana	98%	2015



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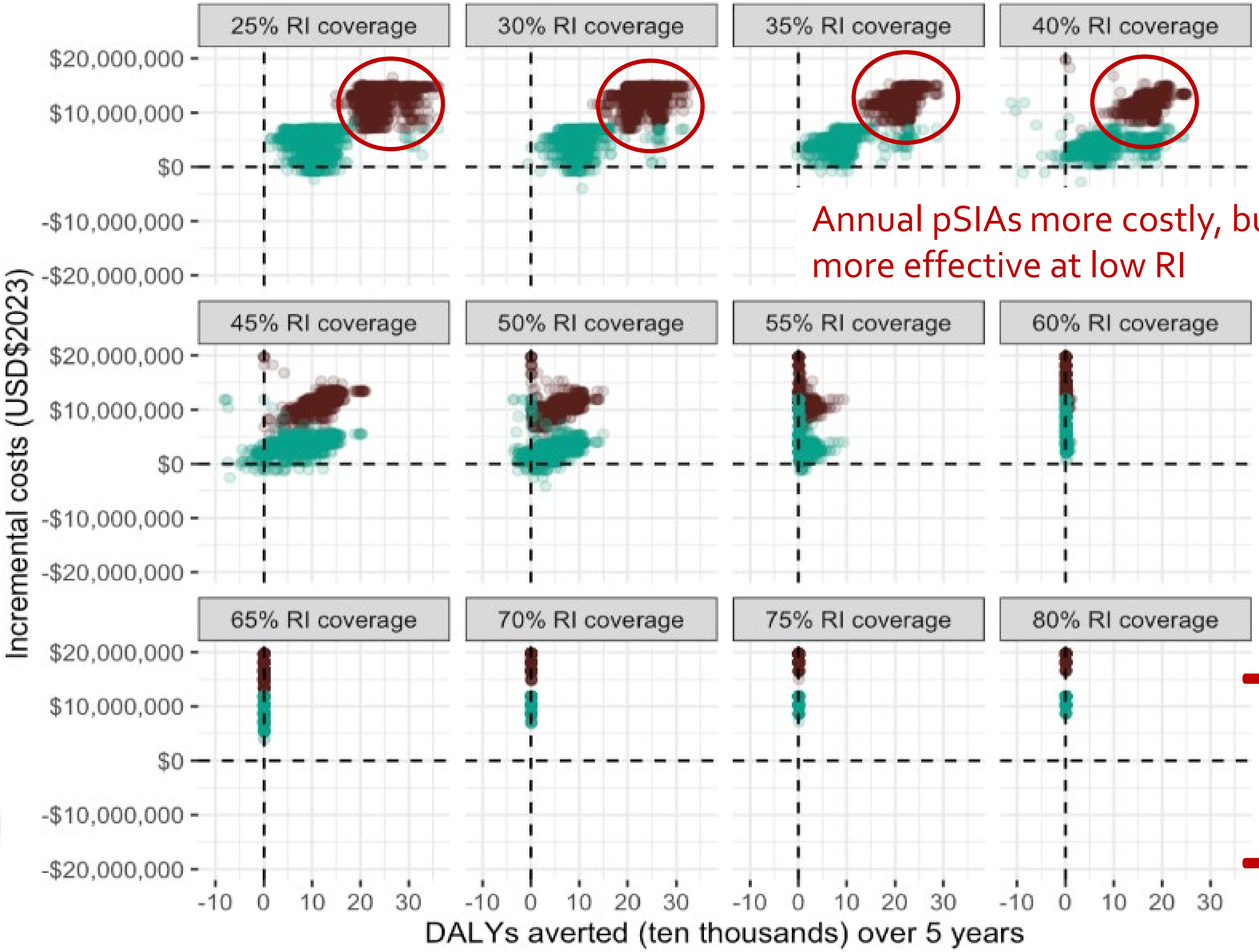
DALYs AVERTED
(across 1,000 model simulations)

GPEI perspective

Includes cost of SIAs and IPV RI, but not costs of paralytic poliomyelitis cases or VAPP

Vaccination strategy
- Annual pSIAs
- Biannual pSIAs

*Baseline comparator: oSIAs



Annual pSIAs more costly, but more effective at low RI

When RI coverage exceeds 67%, the point when herd immunity is achieved in this simple homogenously mixed model, the annual pSIA strategy becomes less efficient in averting DALYS

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