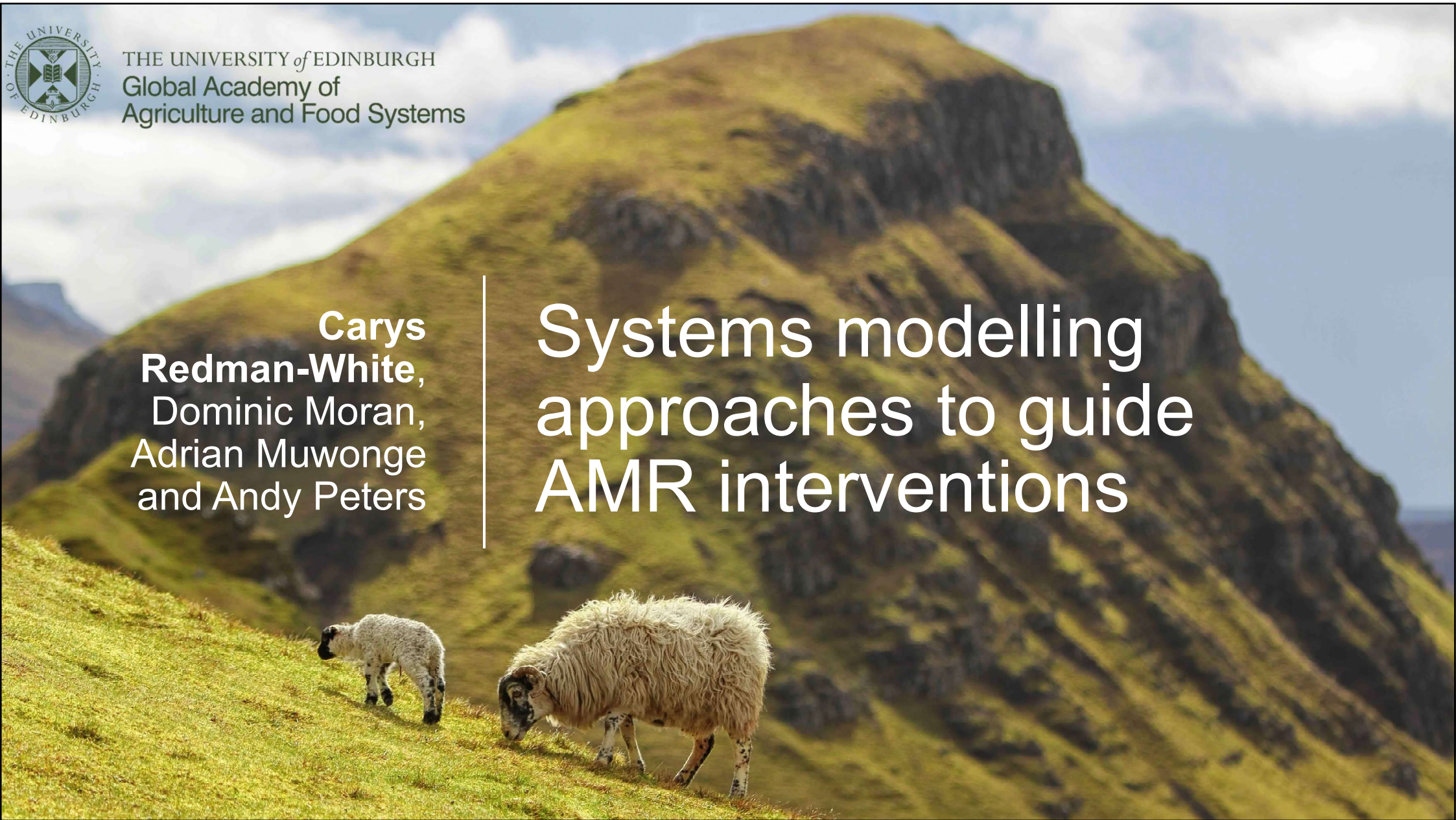




THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

**Carys  
Redman-White,**  
Dominic Moran,  
Adrian Muwonge  
and Andy Peters

# Systems modelling approaches to guide AMR interventions





THE UNIVERSITY *of* EDINBURGH  
Global Academy of  
Agriculture and Food Systems

# Outline

- Background and methods: AMU, AMR and System Dynamics
- Predictors of AMU and AMR on livestock farms
- Mapping the system and subsystems
- Using causal loop diagrams for policy development
- Discussion and next steps



# Background: AMU & AMR influences and consequences



THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

**Interlinkages, delayed effects,  
feedback loops...  
A good candidate for a  
systems approach!**

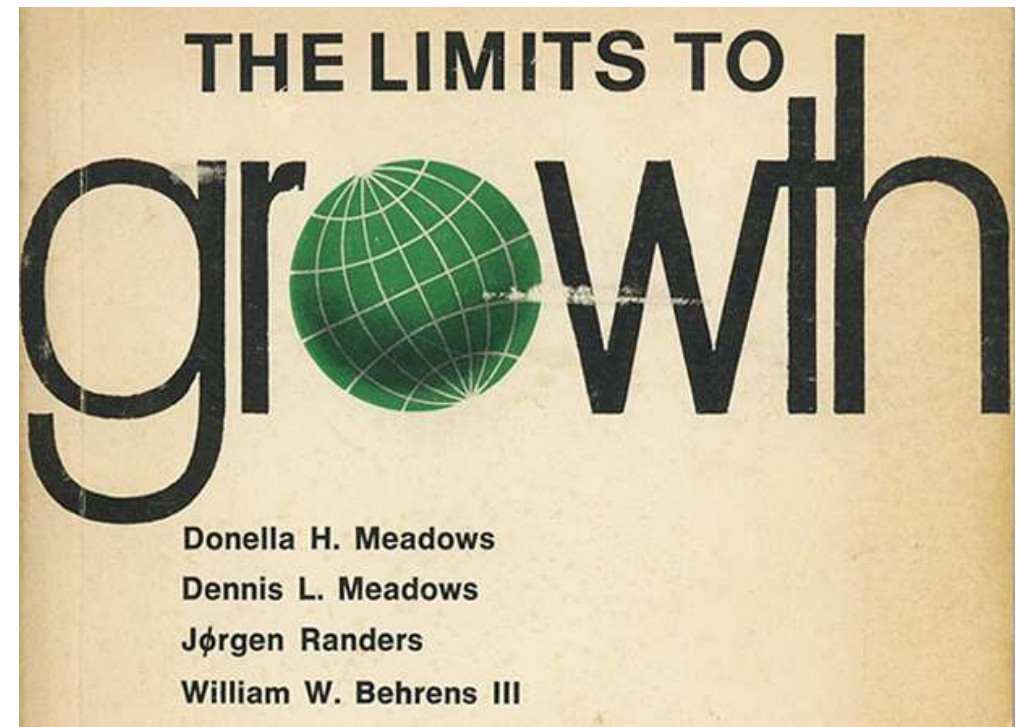


# System dynamics: what and why?

- Part of the broader Systems Thinking approach to complex problems
- System Dynamics (SD): a mathematical modelling approach using “stocks” and “flows”
  - Incorporates feedback loops and delays
  - Models changes in systems over time, including (frequently!) oscillations
- SD models often build on causal loop diagrams (CLDs), used to map the system and pick out feedback loops



THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems



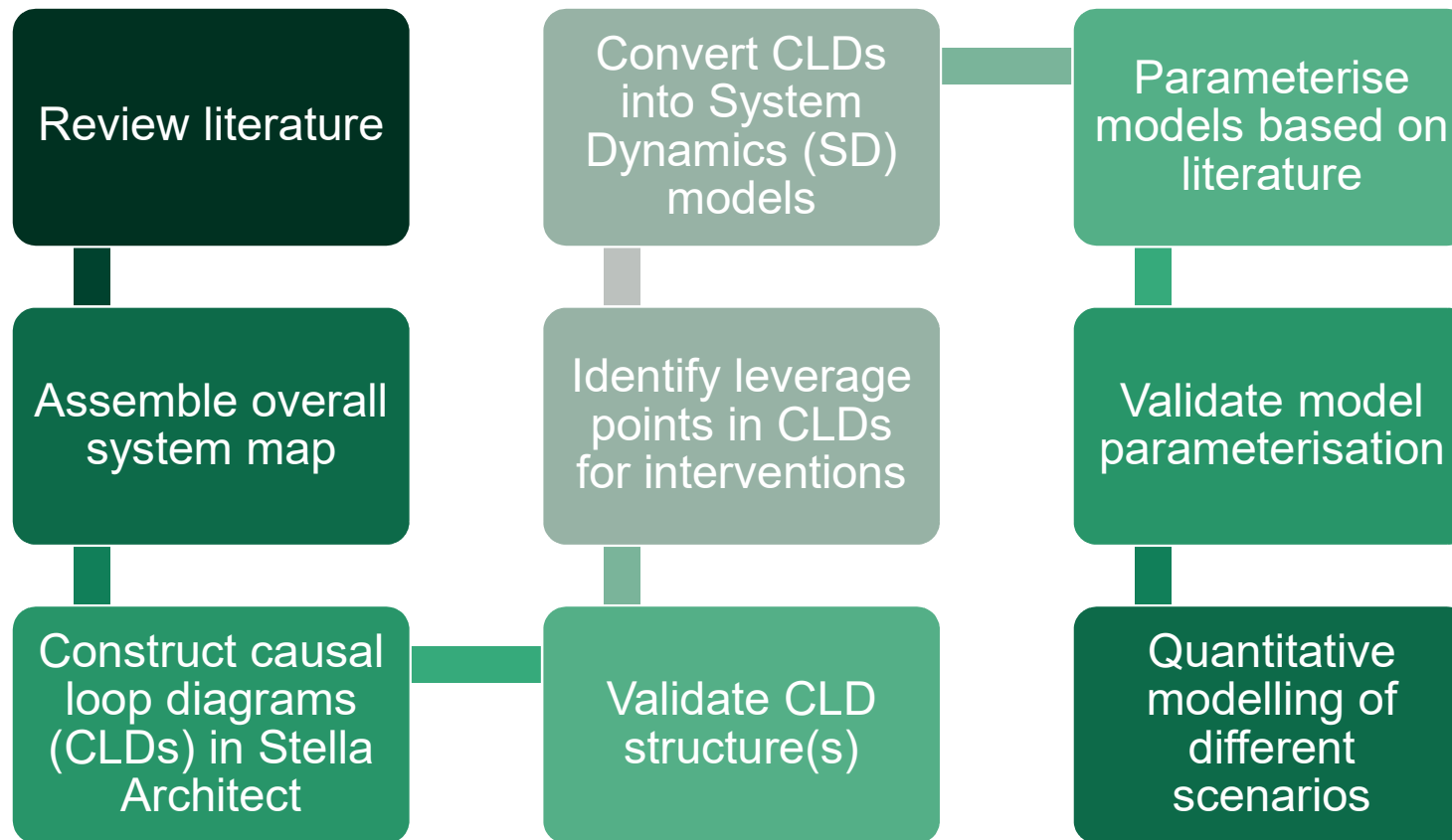
*Universe Books, 1972*



# Methods



THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems



# Literature: farm-level predictors of low AMU and AMR

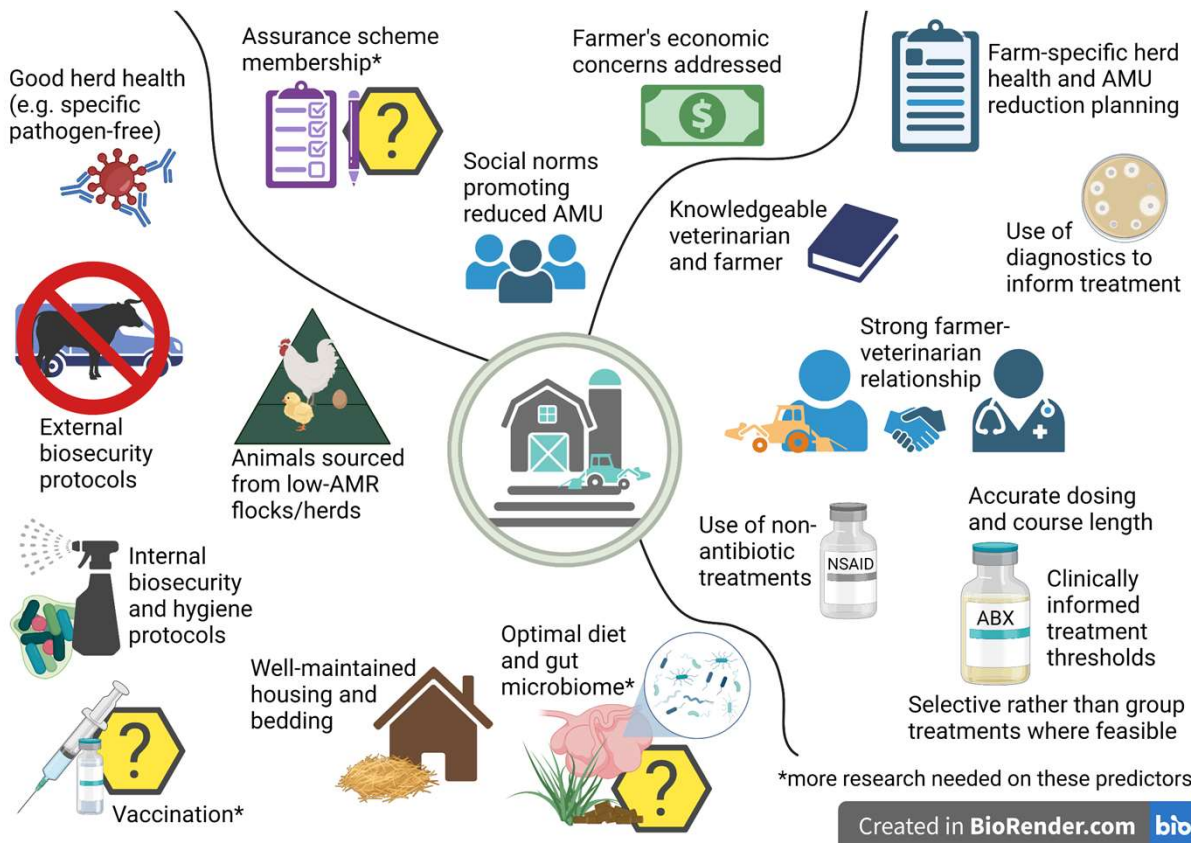


THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

## Broader societal factors

Animal husbandry and herd health

**Pictured predictors focus on farms in the UK and Europe: some globally important factors missing**



Created in [BioRender.com](https://www.biorender.com)

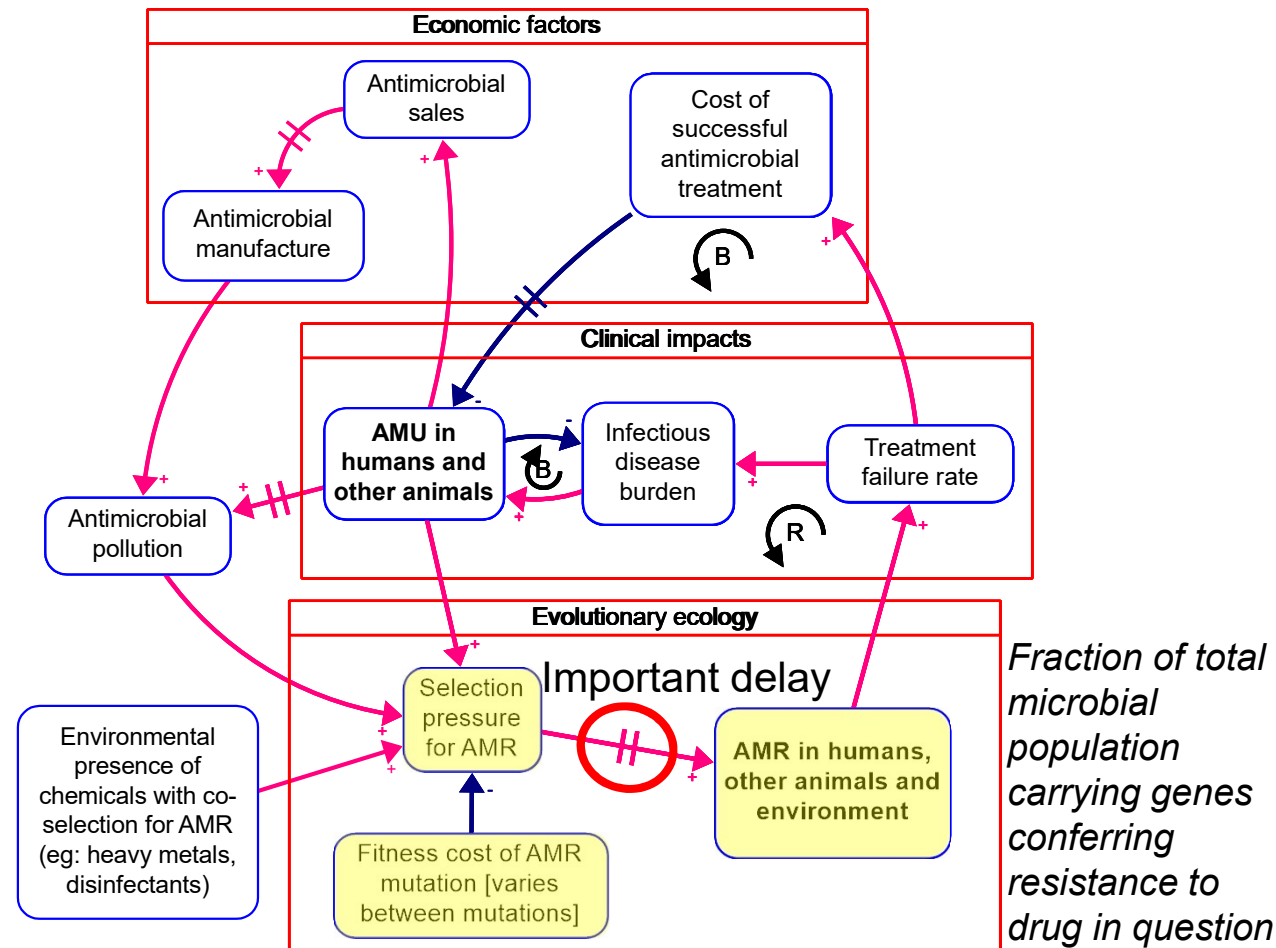


# Mapping the system: ecology and economy



Key:

- Positive
- Negative
- Unknown/complex
- Hypothesised
- Time-delayed
- Reinforcing (positive feedback) loop
- Balancing (negative feedback) loop

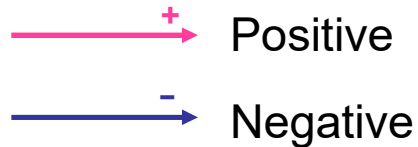




# Mapping the system: water for sanitation and health



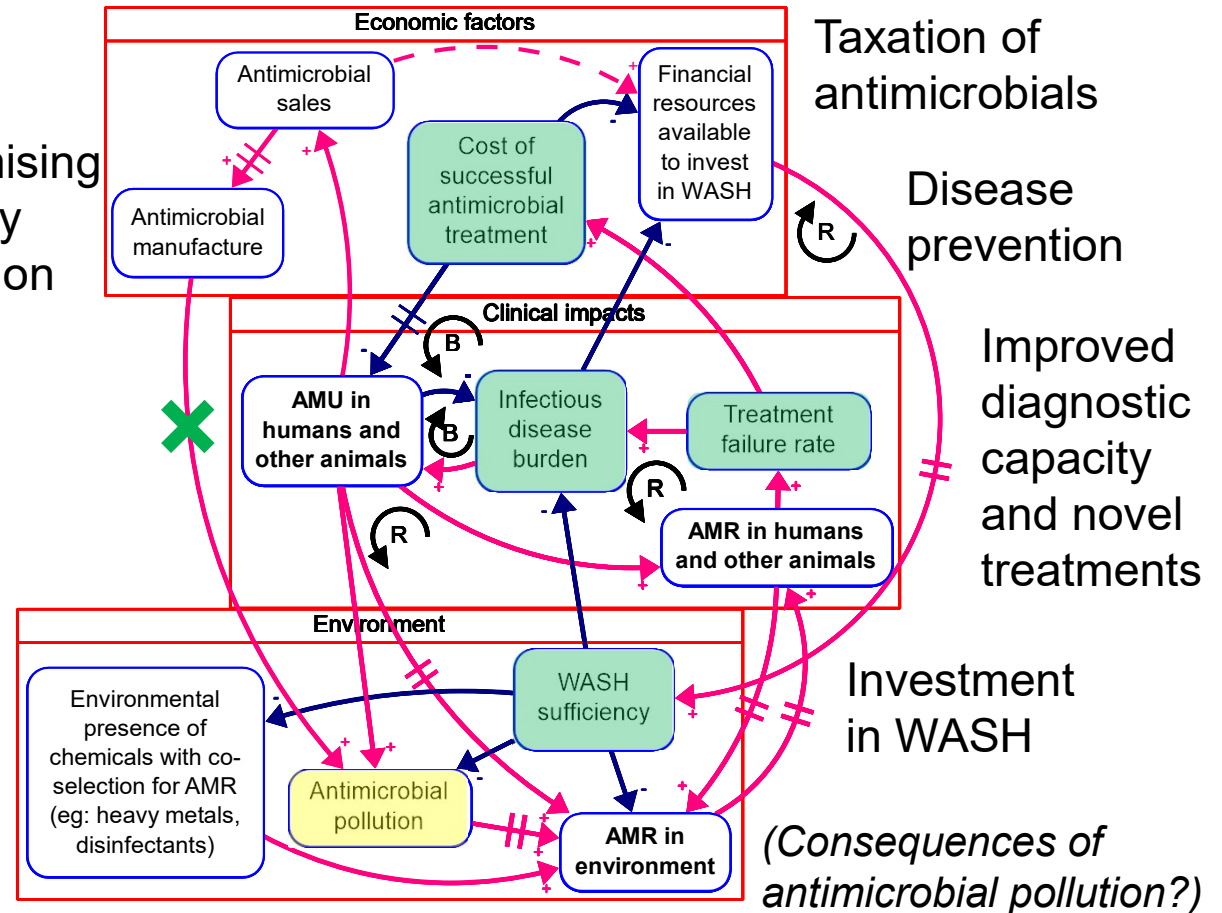
Key:



## Example policy levers:

- Non-intervention
- Regulation
- Incentivisation
- Direct public service provision
- Education and knowledge exchange

Minimising  
factory  
pollution





# Literature to inform structure and parameterisation



THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

- National-level **predictors** of AMR
  - Multivariate analyses of national-level data (e.g. Allel et al., 2023; Collignon et al., 2018)
  - Predictors of AMR include population health, socioeconomic factors, climate, governance
- Economic **costs** of AMR
  - World Bank estimates for 2050 (Jonas et al., 2017): AMR could ↑ human healthcare expenditure by 25% in LICs, 15% in MICs and 6% in HICs
  - Same report: LMICs could see a 5-10% reduction in livestock production by 2050
- AMR as a **One Health** problem
  - Antimicrobial residues, resistant organisms and AMR gene transfer between compartments?
  - Herrero et al. (2023): ↓ livestock productivity assoc. with ↓ outcomes for farmers and environment
- System **lags** and the AMU-AMR relationship
  - Rahman et al. (2023) on human clinical data in 26 countries: AMR prevalence ↑ immediately after AMU but continued rising ≥4 years after ceasing AMU
  - Some studies (Brealey et al., 2021; Dorado-García et al., 2015) observe AMR prevalence ↓ after curtailing AMU





THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

# Discussion & next steps

- AMR well-suited to systems approaches
  - CLDs help ID interventions and data gaps
  - SD for quantitative modelling including delays
  - Highlights AMR-sensitive interventions

## Ongoing work:

- Quantitative modelling with SD
  - ODEs to describe relationships
  - Parameterisation from literature
- Refining & combining submodels



@BioCarys



c.j.redman-white@sms.ed.ac.uk

# Acknowledgements

- CRW acknowledges support from the UKRI Biotechnology and Biological Sciences Research Council (BBSRC) and Zoetis
- DM acknowledges support of grant BB/T004452/1, which is [co] funded by the UK Department of Health and Social Care as part of the Global AMR Innovation Fund (GAMRIF)
- AM acknowledges the support of the University of Edinburgh Chancellor's Fellowship



THE UNIVERSITY of EDINBURGH  
Global Academy of  
Agriculture and Food Systems

