Prevention by vaccination: the economics of vaccination programmes

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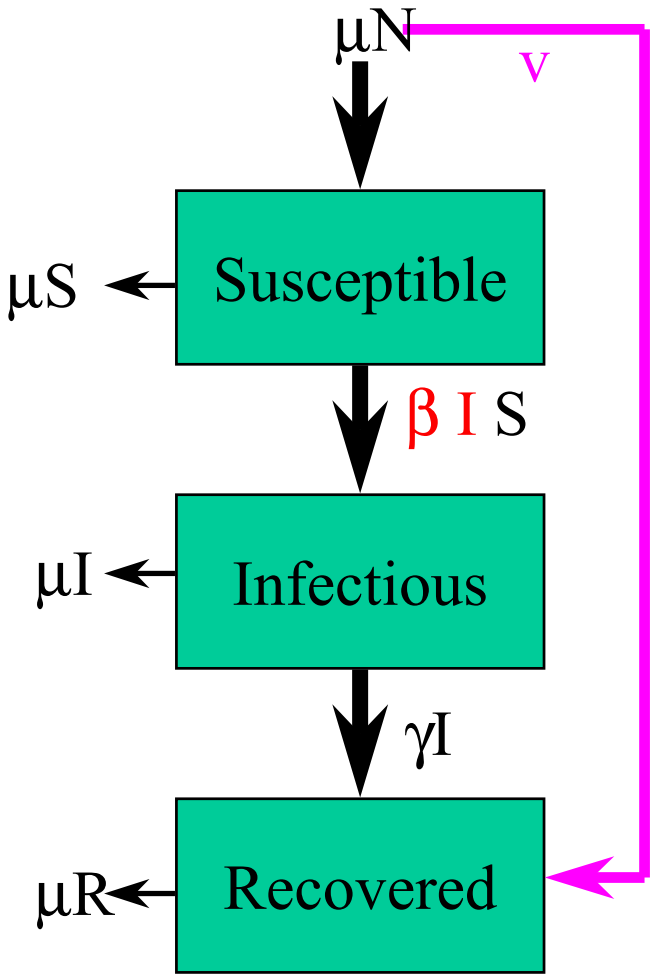
Introduction

- Infectious diseases are different
  - They are infectious
- Interventions aimed at preventing or treating disease in one individual has knock-on effects on others in the population
  - Externalities (both positive and negative)
  - Free-loader problem as all vaccine carry some risk
  - Equity: affect distribution of disease

Structure of talk

- Simple relationship between infection & disease
  - Epidemic theory
  - Demand for vaccines
    - As a function of prevalence, and/or risk of adverse events
  - Observational data
    - Response to vaccine scares
  - Empirical studies
- Complex relationship between infection & disease
  - Equity considerations

A simple epidemic (SIR) model



$N_t = S_t + I_t + R_t$

$dS/dt = \mu N(1-\nu) - \beta I S - \mu S$

$dI/dt = \beta I S - \mu I - \gamma I$

$dR/dt = \gamma I - \mu R + \mu N \nu$

Geoffard & Philipson: $V_t(\underline{I}^t, \underline{p}^t)$

Threshold for persistence

$dI/dt = 0$ = endemic equilibrium (for $I > 0$)

$S^* \beta/(\gamma + \mu) = 1$

- If maintain $S_t < S^*$ (by vaccination) then infection cannot persist in the population
- I.e. threshold for elimination, $Pc >= 1\text{-}S^*$

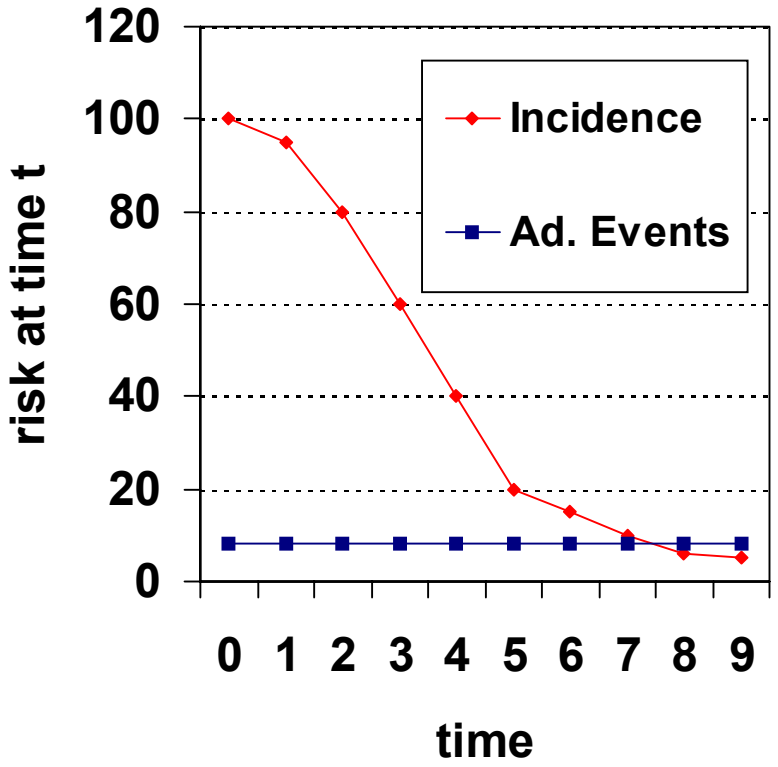
Geoffard & Philipson

- Central assumption is that demand for prevention is prevalence dependent $V_t(I^t,p^t)$
- As prevalence of disease falls, then demand for vaccine falls
- Result: increase in disease
- Very difficult (impossible) to eradicate
  - regardless of market structure (demand problem)
  - Pigovian price subsidies may not be sufficient
  - Mandatory vaccination decreases incentive for others (outside) programme to vaccinate

Modification:

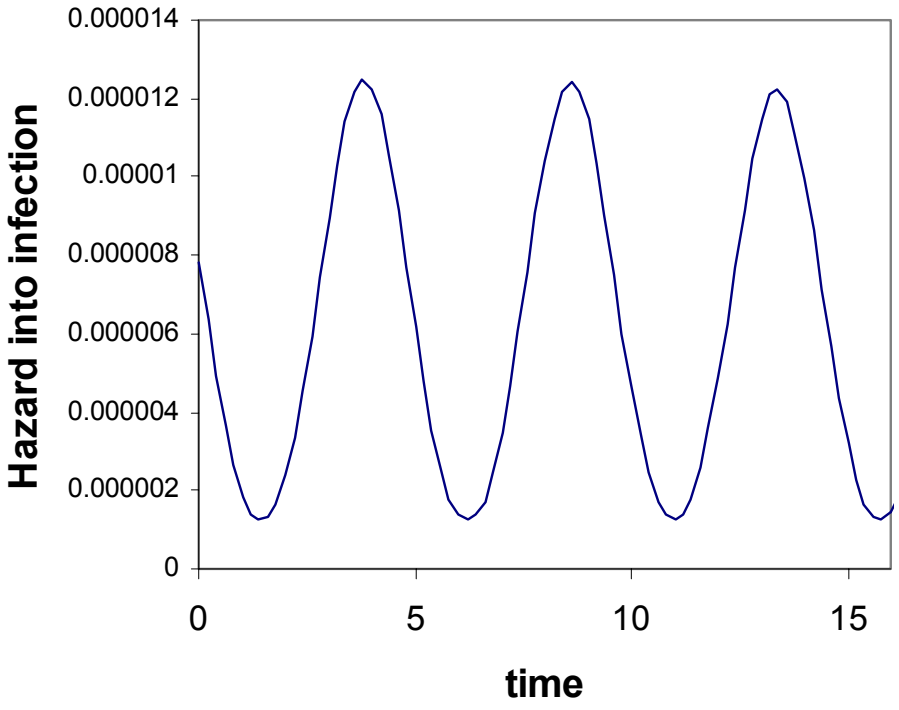
demand a function of perceived risk of vaccine

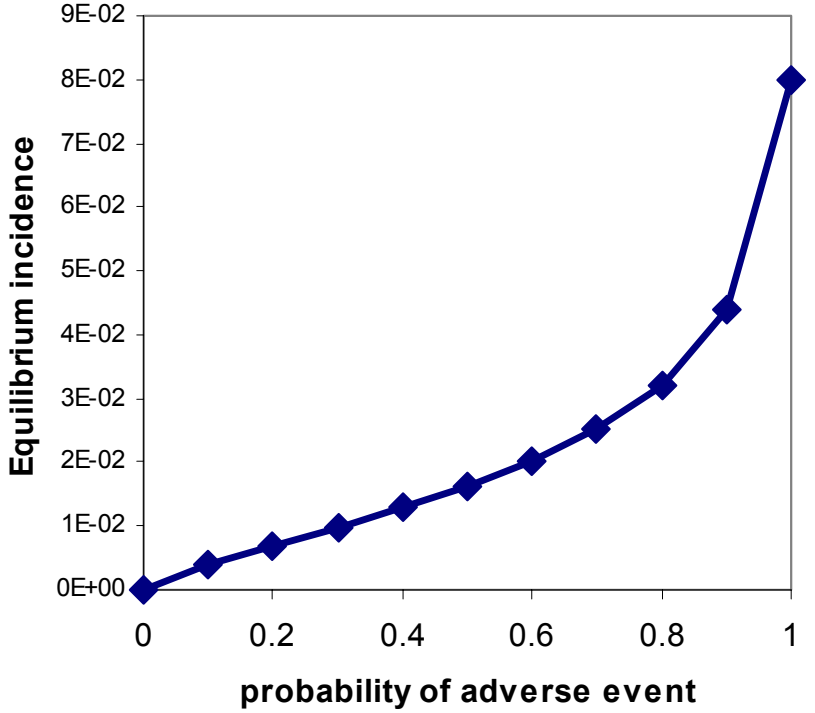
- Risk from vaccine remains unchanged
- Risk from natural infection declines
- Therefore benefit:risk ratio (to individuals) decreases
- Difficult to eliminate
- Qualitatively similar to Geoffard & Philipson



Demand as a function of risk

Example: lifetime risk based on current risk

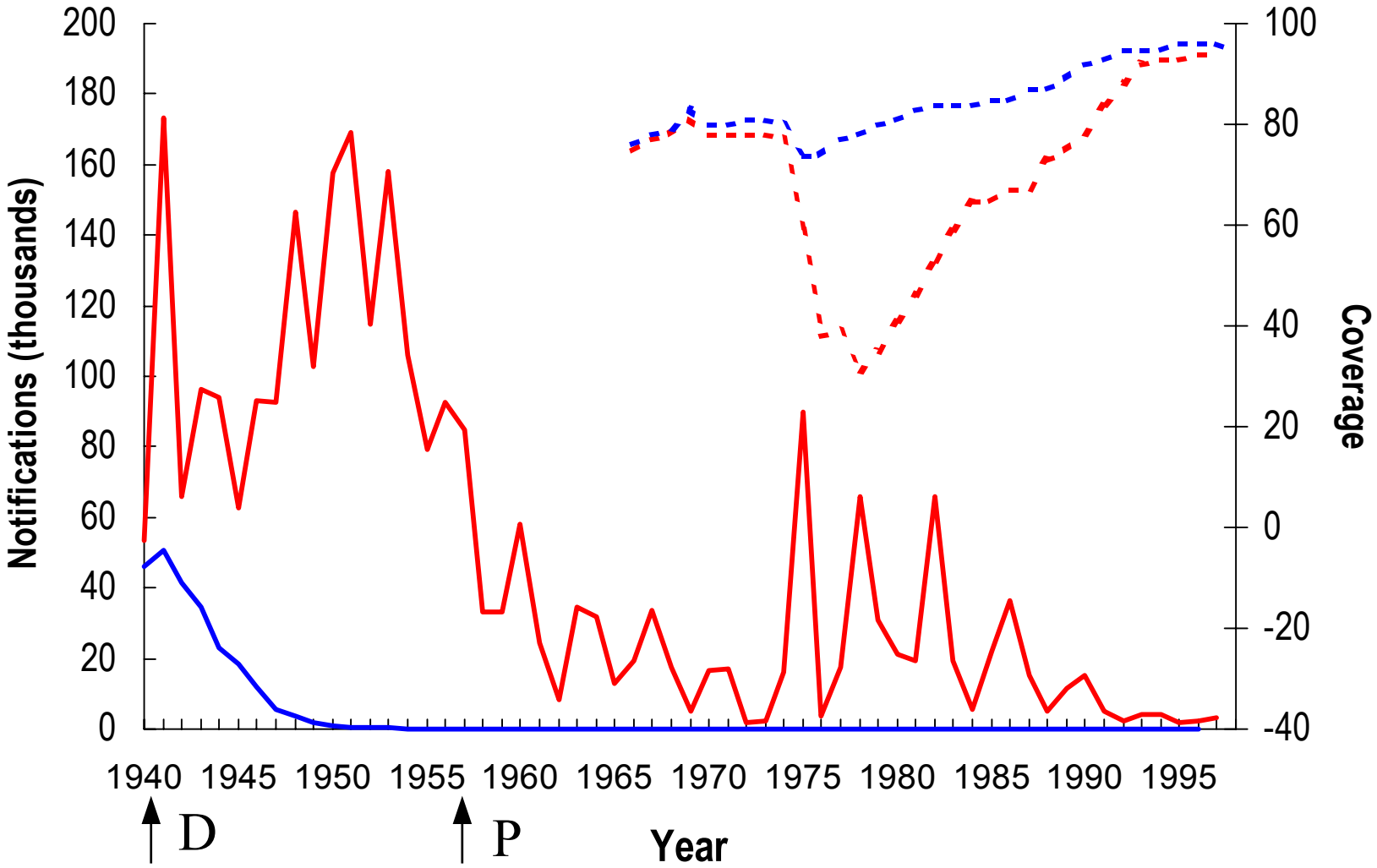




Is demand prevalence / risk dependent?

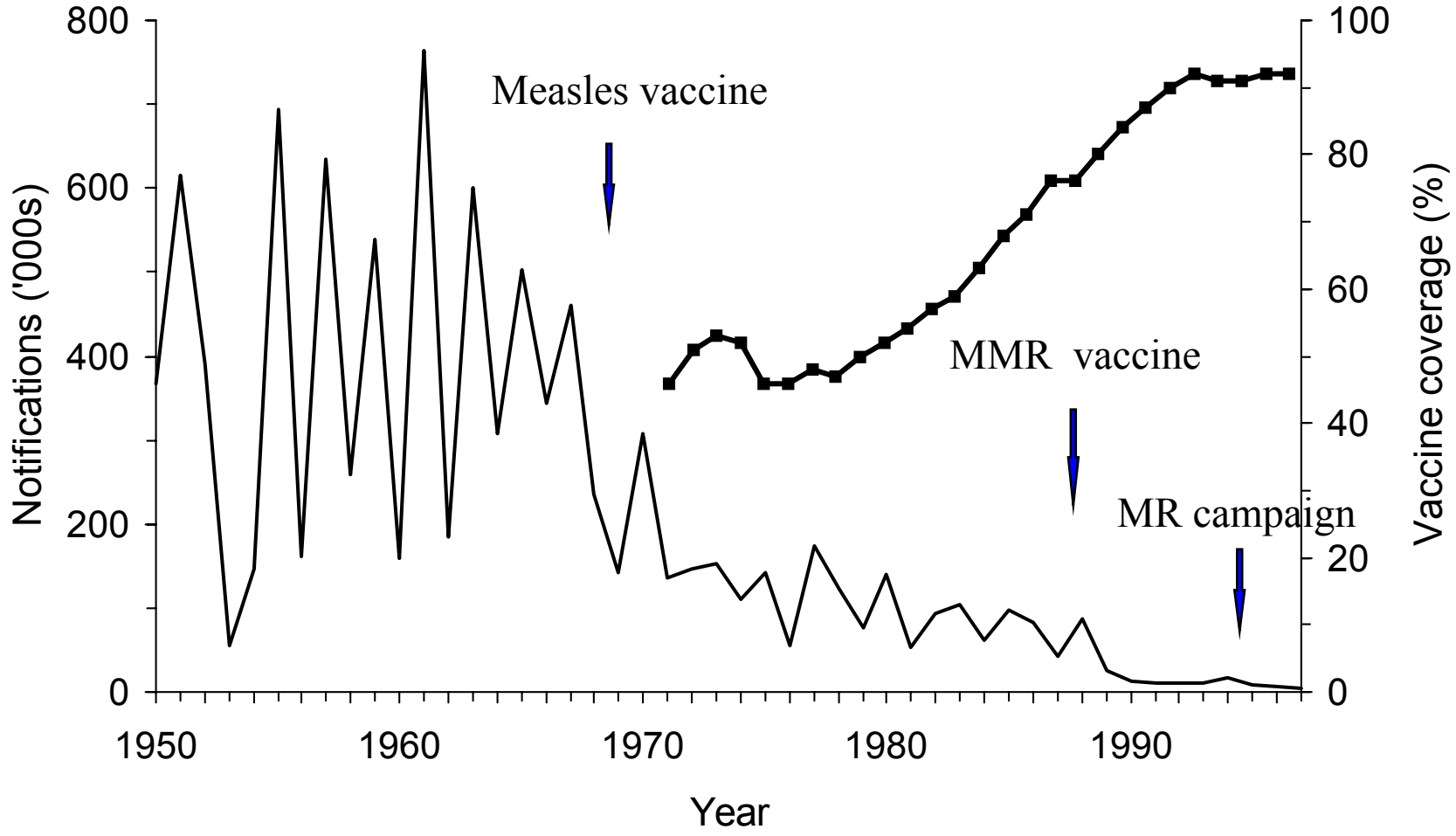
- Observational studies
  - Geoffard & Philipson MMR vaccination in the US 1984-1991: regional caseload has large positive impact on hazard rate into vaccination (most influential explanatory variable)
  - Diphtheria – Tetanus – Pertussis vaccine in UK
  - MMR in the UK
- Empirical studies

Whooping cough & diphtheria notifications & vaccine coverage England and Wales, 1940-97



Annual measles notifications & vaccine coverage

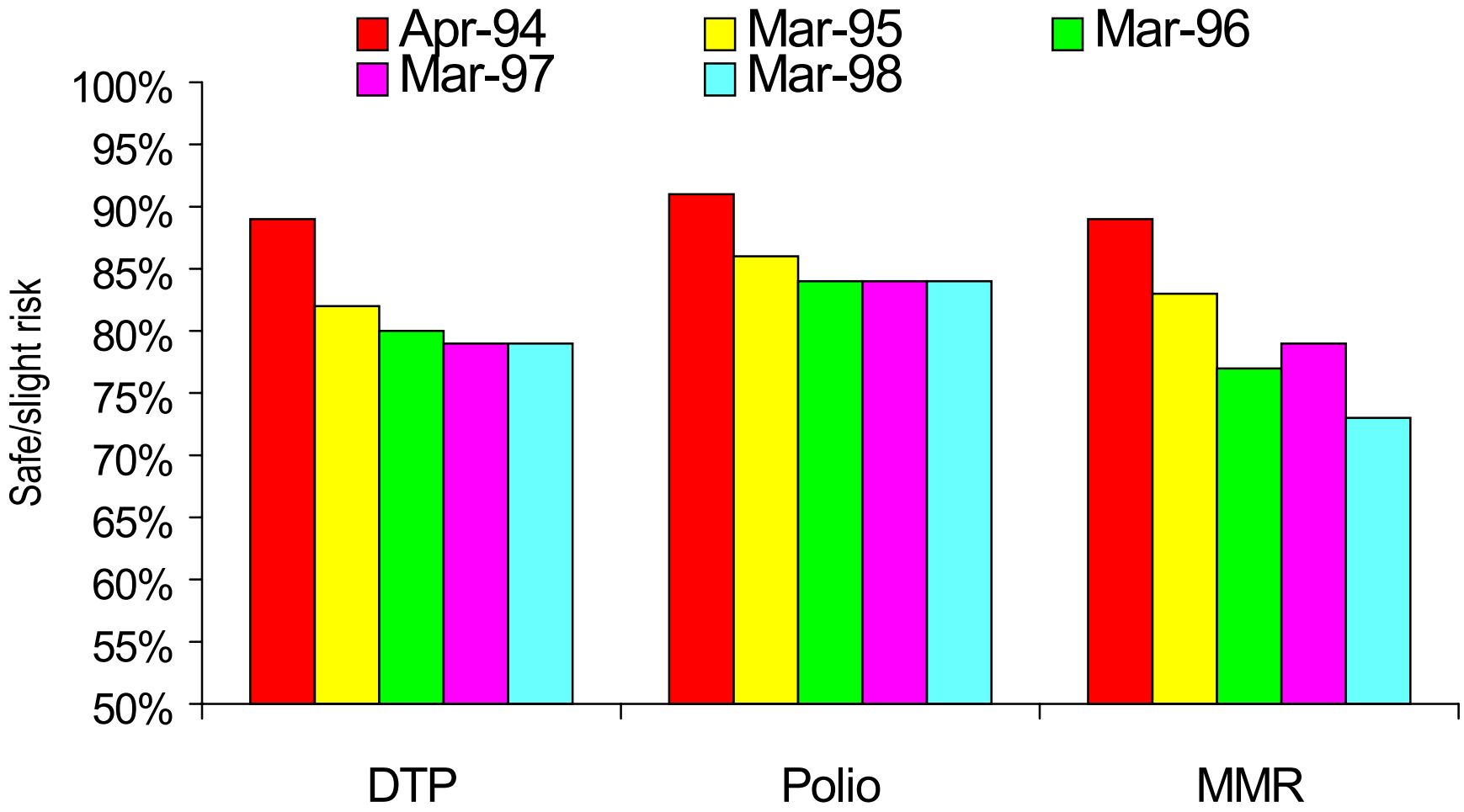
England and Wales 1950-1997



Source: Office for National Statistics and Department of Health

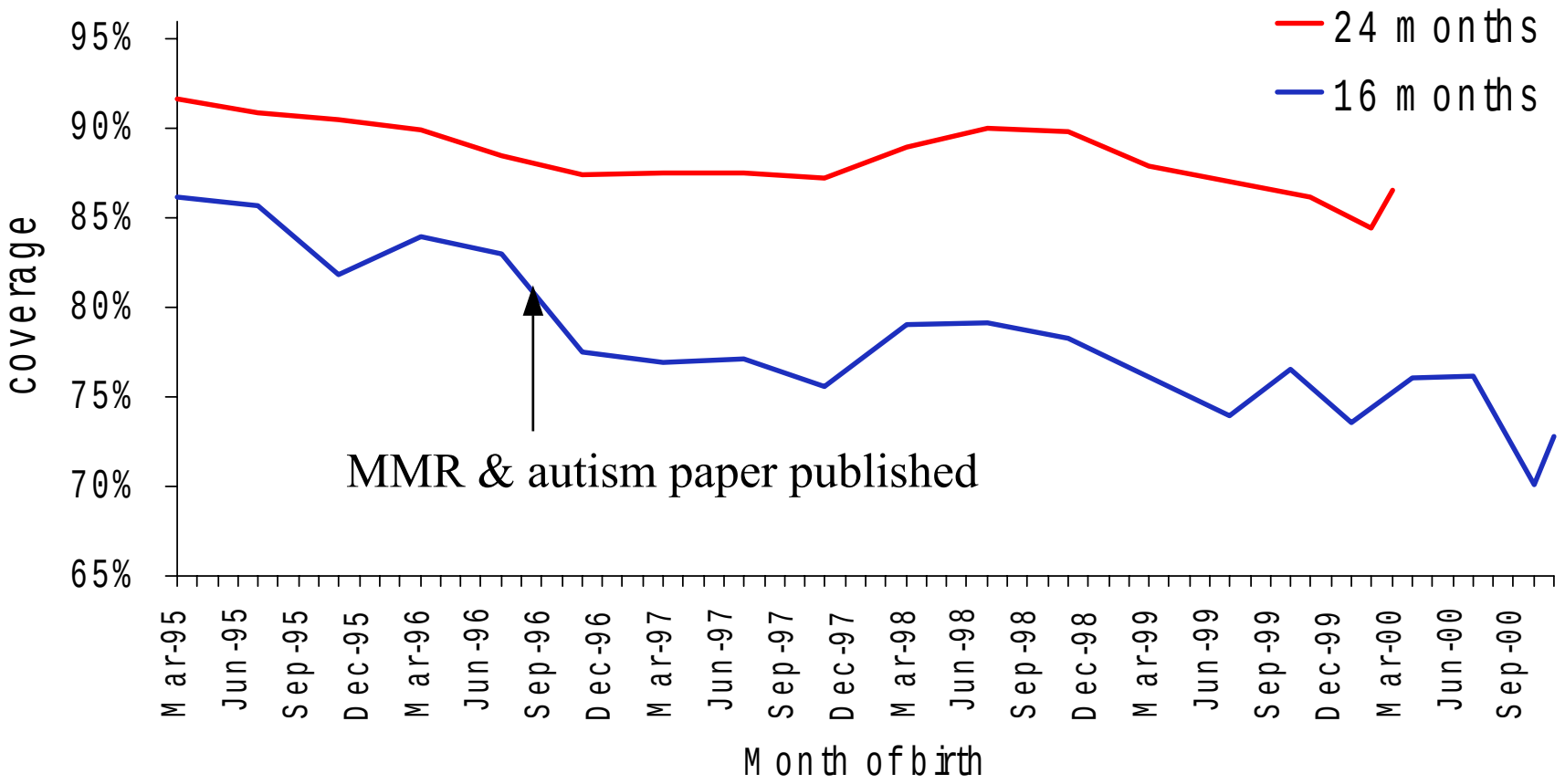
Mothers beliefs of vaccine safety

HEA survey 1994-8



MMR vaccine coverage at 16 and 24 months

(English districts/trusts using the NCHS)



Demand as a function of risk?

WTP (£) for varicella vaccination: pilot survey

	100% risk	50% risk	25% risk
Median wtp	88	88	88
Mean wtp	109	97	102
St Dev	61	79	79
n	16	16	16

Demand for vaccines: summary

- Demand for vaccines is probably a function of expected future incidence of disease & perceived risk of the vaccine (& other factors)
  - Either renders elimination difficult (though achieved)
- Possibly more sensitive to perceived risk of vaccine than (future) prevalence of disease
  - Possible imbalance in demand relationship due to memory
- Demand fairly inelastic regarding risk (assuming no substitute goods)
- Implications:
  - Coverage remains high when incidence low
  - Vaccine scares can affect coverage
  - Education regarding true risk of vaccines critical

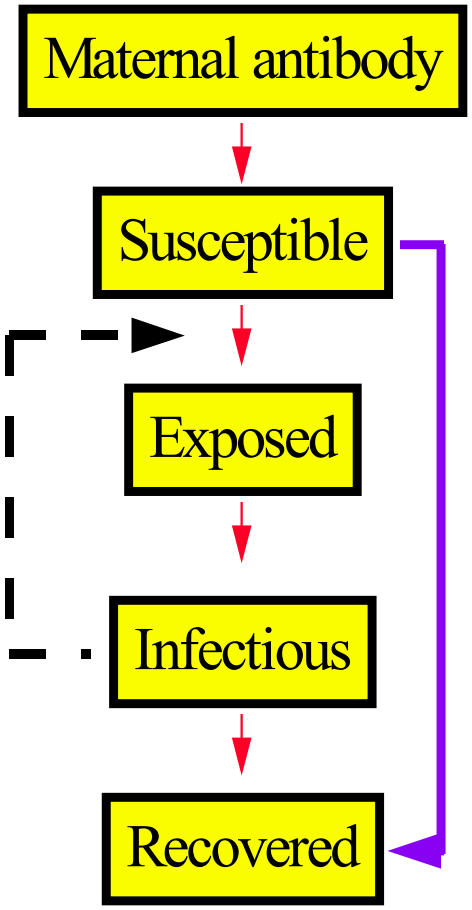
Risk of vaccination *programmes*

- Often the probability of disease given infection is related to factors such as age
- Many viral infections are more severe if contacted during adulthood:
  - Chickenpox, polio, mumps, HAV, rubella

Effects of mass (childhood) immunisation

- Direct protection
  - Individual vaccinees are protected
- Increased susceptibles in older age groups
- Increased average age at infection
  - Temporal (vaccinees are in the younger age-groups)
  - Long-term (due to reduced probability of infection)

An age-structured epidemic model



$$\frac{\partial M}{\partial a}+\frac{\partial M}{\partial t} = -[\alpha+\mu(a)]M,$$

$$\frac{\partial S}{\partial a}+\frac{\partial S}{\partial t} = -[\lambda(a,t)+p(a,t)+\mu(a)]S+\alpha M,$$

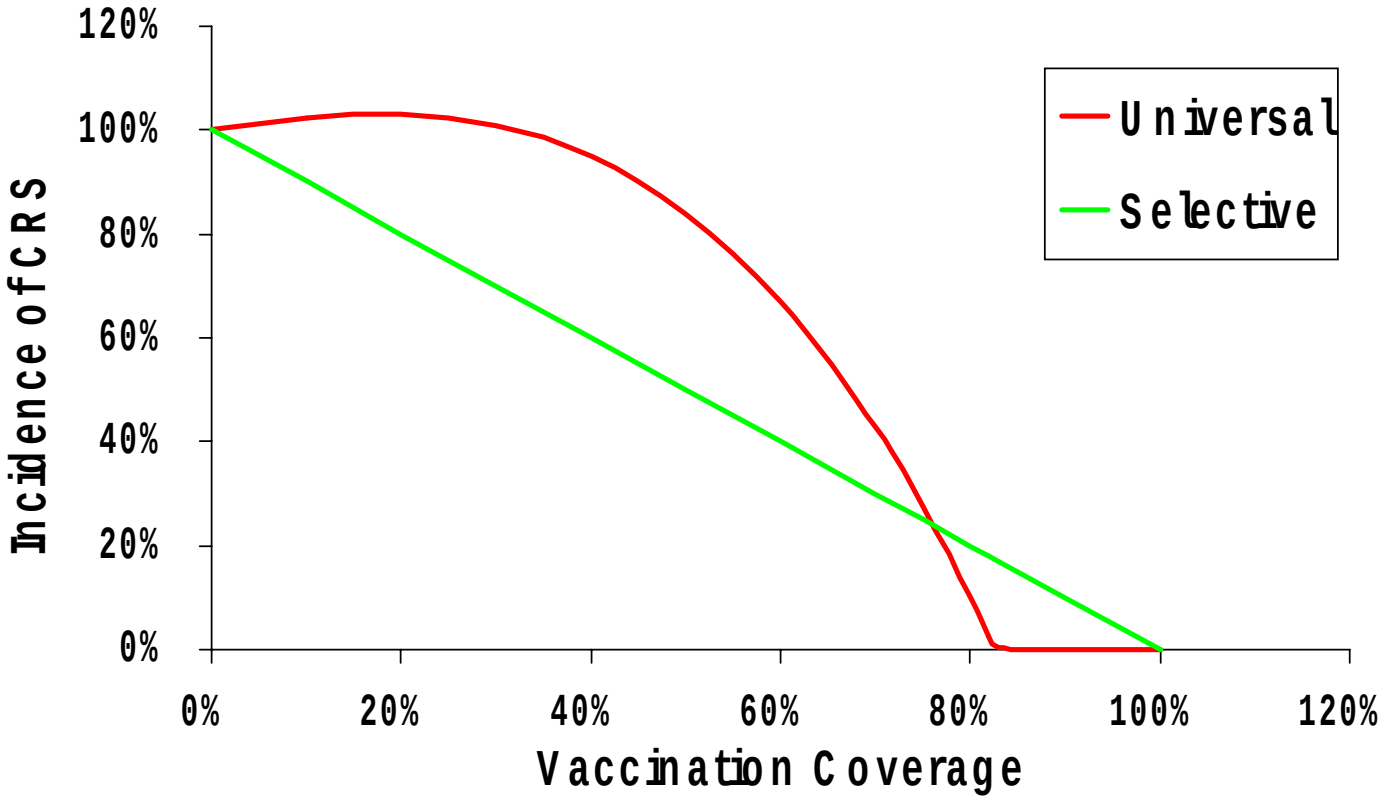
$$\frac{\partial E}{\partial a}+\frac{\partial E}{\partial t} = -[\sigma+\mu(a)]E+\lambda(a,t)S,$$

$$\frac{\partial I}{\partial a}+\frac{\partial I}{\partial t} = -[\nu+\mu(a)]I+\sigma E,$$

$$\frac{\partial R}{\partial a}+\frac{\partial R}{\partial t} = -\mu(a)R+\nu I+p(a,t)S.$$

$$\lambda_i(t) = \Sigma\,\beta_{ij}\,I_j(t)$$

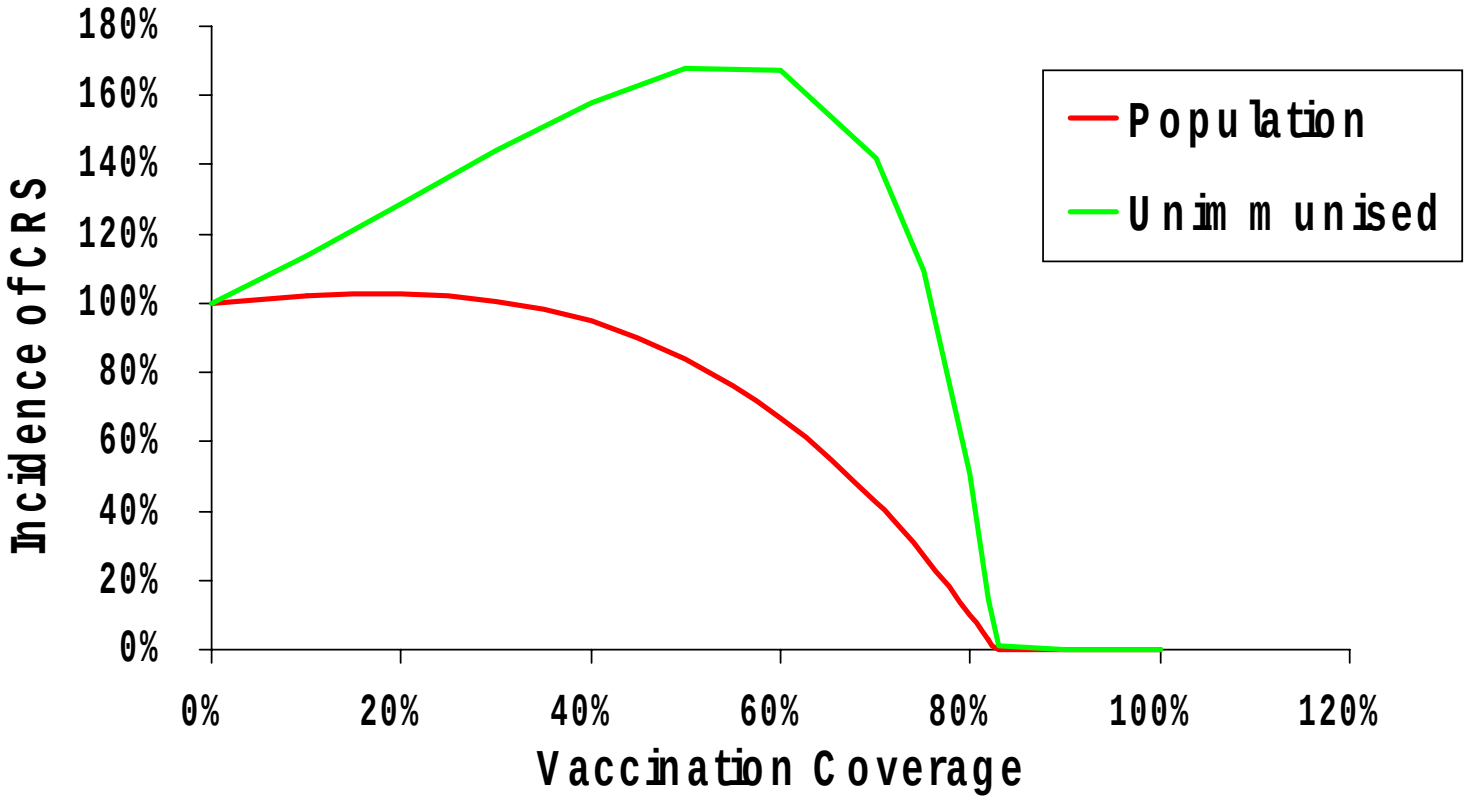
Predicted long term incidence of CRS in the UK
Selective and universal vaccination programmes



following Anderson & Grenfell, 1986

Predicted long term incidence of CRS in the UK

Universal vaccination programmes



Risks of vaccination programmes

- Risk to individual may increase with increasing uptake of the vaccine, then fall
- Low / intermediate coverage often results from "free market" supply of vaccines
- Can reduce health of the population (short and long-run)
- Can lead to dramatic increase in inequalities
- Such risks can be difficult to portray to decision makers