An economic Exploration of Prevention versus Response in Animal Related Bioterrorism Decision Making

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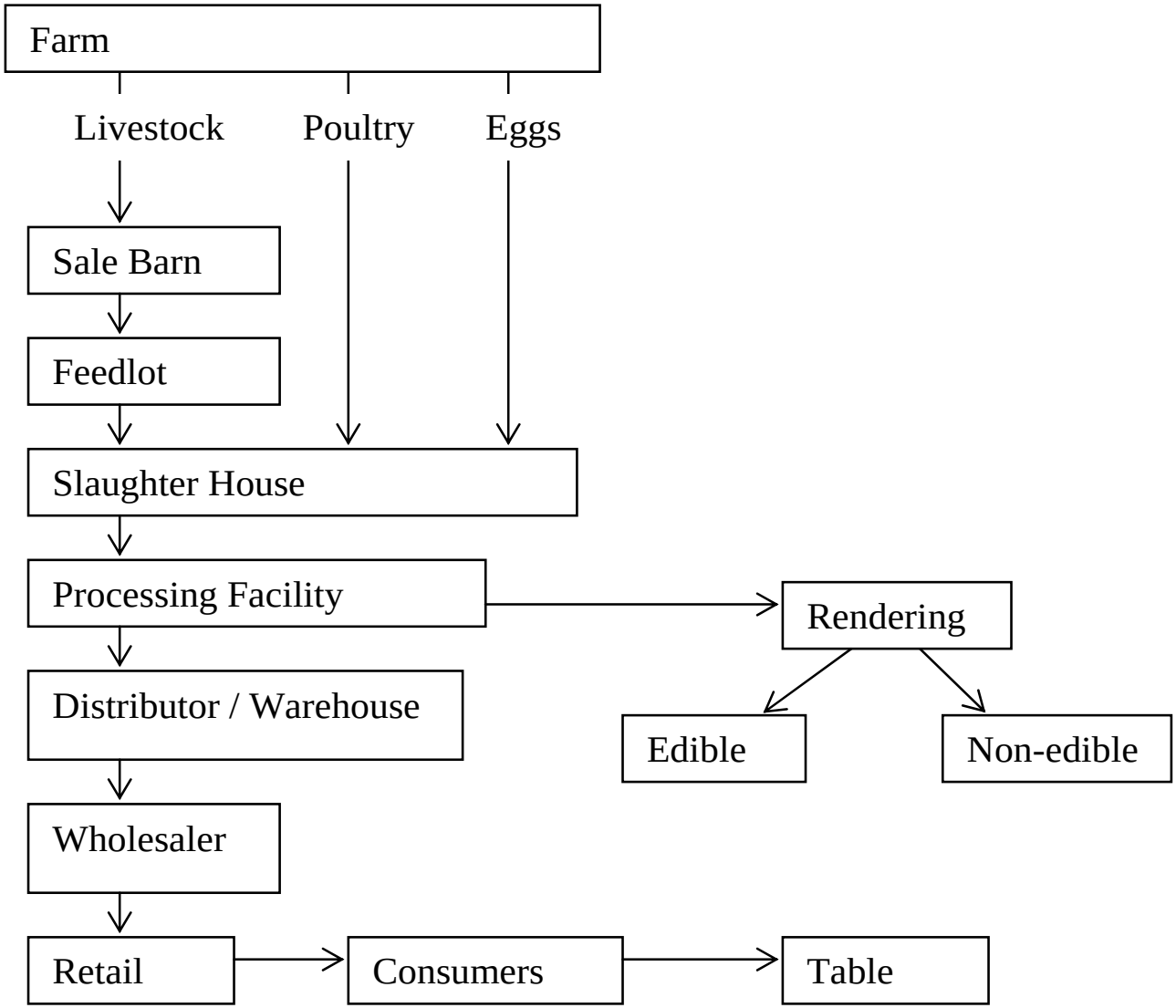
Agricultural Terrorism

- *food terrorism* - “an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and/or disrupting social, economic or political stability”(WHO, 2002)

Vulnerability

- Implementation difficulty and magnitude of damages.
- Food borne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5000 deaths annually in the United States (Mead et. al. 1999)
  - Lost consumer/producer surplus
- Food and water contamination remains the easiest way to distribute harmful chemical and biological agents (Khan et. al 2001)
- Two General Categories of Agricultural Sabotage
  - Direct Food contamination (Torok, et. al. 1997, Mermin et al. 1999)
  - Introduction of non-indigenous species (Pinmentel et al 2000, Shogren, 2000)

The Food Process: Farm-to-Table



Source: FSIS 2003

Foot and Mouth Disease (FMD)

- 2001 UK Outbreak: 2026 cases, £7.6-8.5 billion,
  - Effects:, Tourism £4.5-5.3, farmers and related industries (Mangen, and Barrell 2003)
- Exports
- Found in 34 Countries during 18 month prior to Apr 2001
- Unchecked epidemic in first 15 month could cost 30$ billion

Foot and Mouth Disease (FMD)

- Spread: air, transportation, artificial insemination, milk related transmission, direct contact, and wildlife
- Don’t show signs of disease for one or two weeks but are contagious. (Garner and Lack, 1995, Economist 2001)
- Virus can survive even in processed meat and dairy products (Economist 2001)

- Not harmful to humans

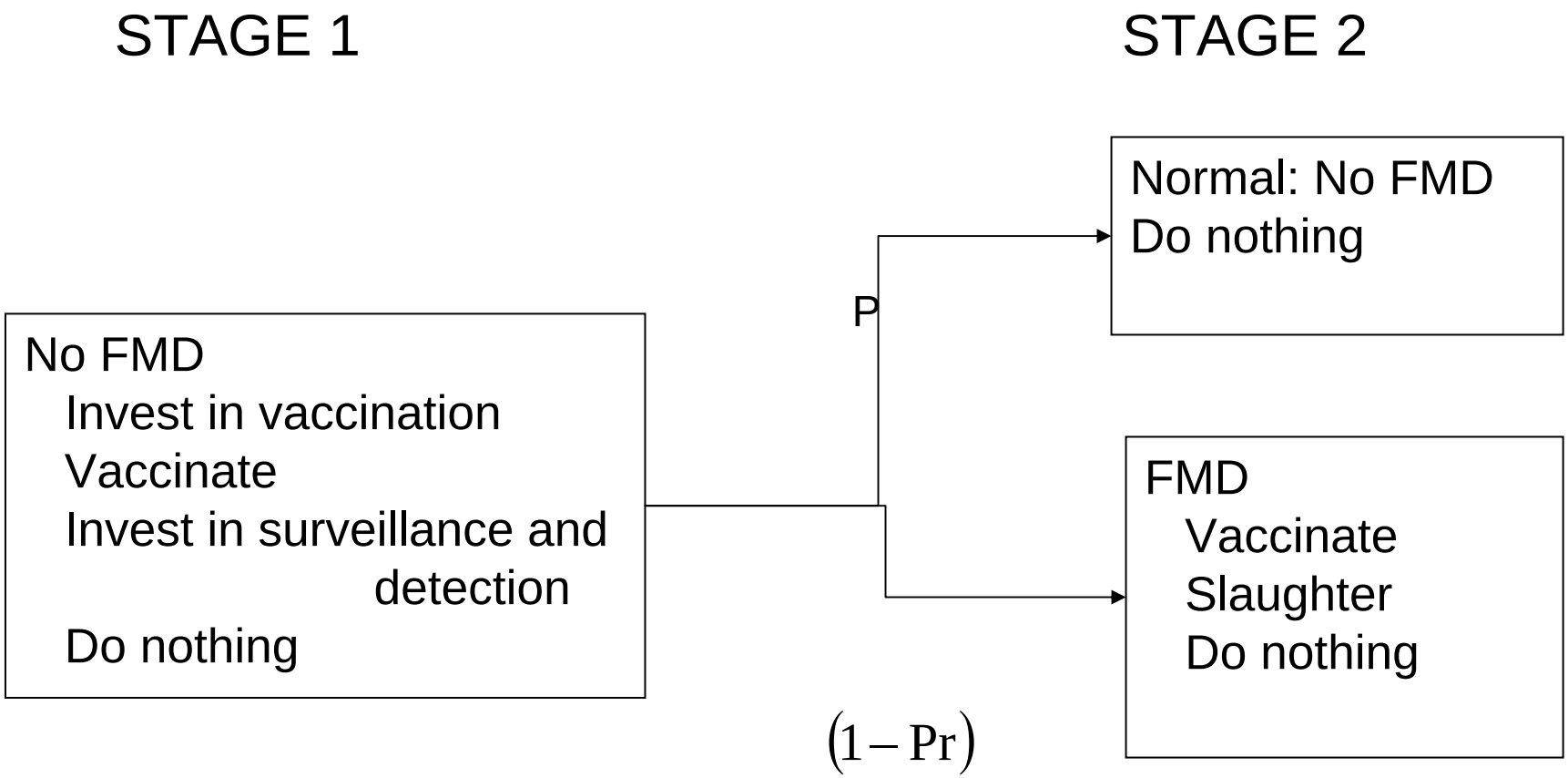
FMD mitigation options

- Vaccination (Schoenbaum and Disney 2003, Carpenter and/or Bates, Ferguson 2001,Berentsen 1992, etc.)
- Slaughter (Schoenbaum and Disney 2003, Carpenter and/or Bates, Ferguson 2001,Berentsen 1992, etc.)
- Movement Ban (Ferguson 2001)
- Surveillance and Detection (McCauley et al. 1979)
- Monitoring imports (McCauley et al. 1979)
- Monitoring travel
- Tracing
- Recovery/information (Ryan et al. 1987)

Formation of Animal Disease Management System

- Prevention -- systems where there are actions undertaken to try to intercept disease vectors before they are introduced
  - Preinvestment in response and detection
- Detection -- systems designed to screen animals to detect disease early to allow more rapid treatment and much lower spread than would otherwise be the case
  - pre and post event
- Response – systems which involve actions to stop the spread and ultimately eradicate the disease and to avoid further economic losses.
- Recovery -- systems put in place to restore lost assets or demand shifts due to introduction of animal disease

Two Stages


STAGE 1
STAGE 2
No FMD
Invest in vaccination
Vaccinate
Invest in surveillance and detection
Do nothing
P
$(1-\Pr)$
Normal: No FMD
Do nothing
FMD
Vaccinate
Slaughter
Do nothing

Case study

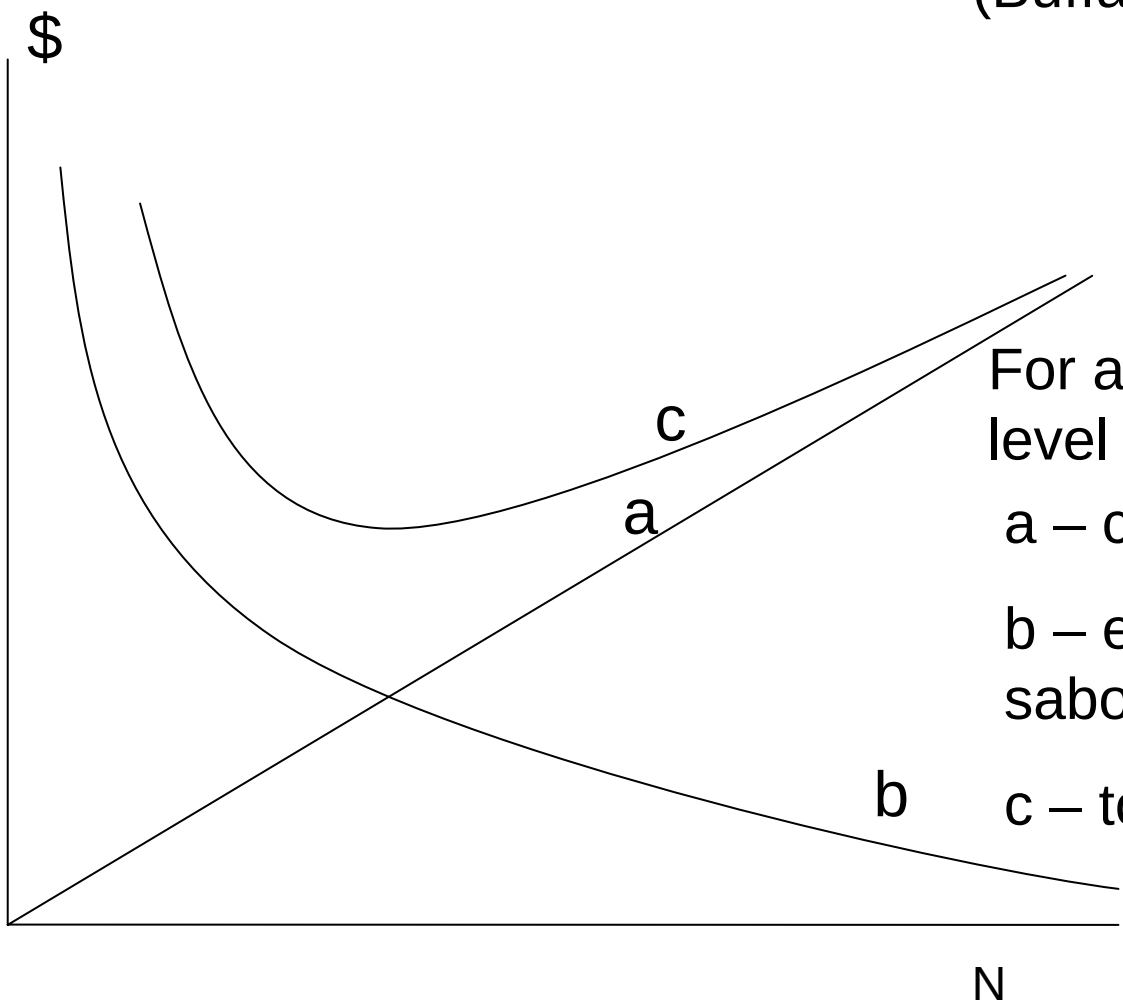
- Impact of, and mitigation strategies against FMD
- Region Texas
- Unknown probability
- Investigate adoption of surveillance/detection, as a form of prevention, and slaughter, as a response strategy
  - Probability level
  - Spread rate
  - Costs of implementation
  - Effectiveness of response
  - Recovery programs

The Model

- Cost minimization of expected costs plus costs of prevention, response, and recovery.
- Response effectiveness
  - Slaughter (Schoenbaum and Disney, 2003)
  - Convexity
- Disease spread
  - Exponential (Anderson and May, 1991)and Reed-Frost (Carpenter et al. 2004)
  - Fast (0.4) and slow (0.15) contact rates (Schoenbaum and Disney, 2003)
- A priori investment
- Unknown Probabilities

Optimal Number of Tests

(Buffa 1973)



For a given Probability level

a – costs of detection

b – expected costs of sabotage

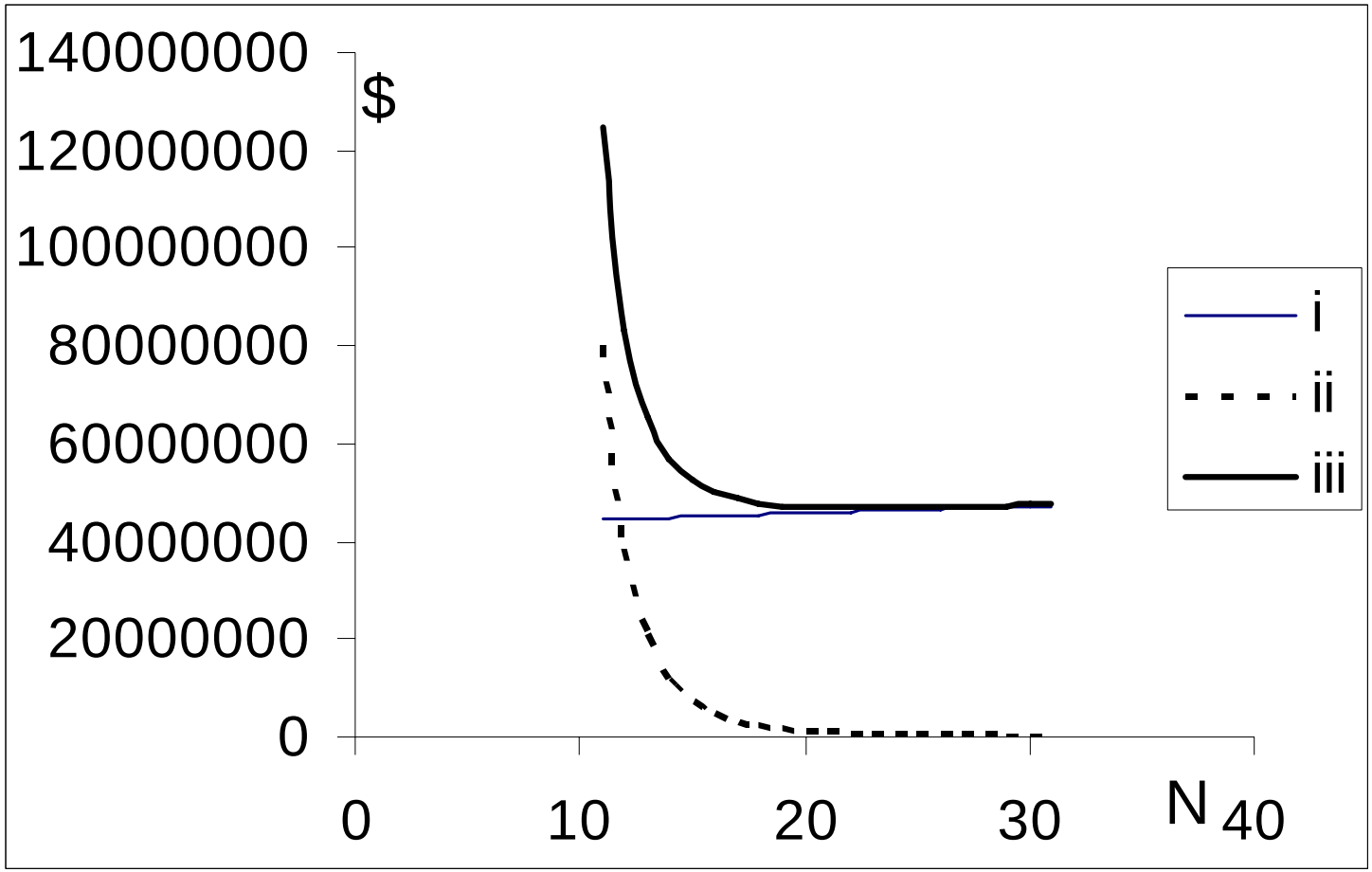
c – total costs

Model Experimentation

- Event levels: Probability 0.001 – 0.9
- Severity or spread rate: slow vs. fast
- Response effectiveness: 17% - 30%
- Variable costs of detection 0.1TVC, 0.01VTC
- Average herd size: 50 to 400.
- Ancillary benefits: FTC-$50 per herd
- Recovery actions: decrease loss of GI per animal by 30%

Results

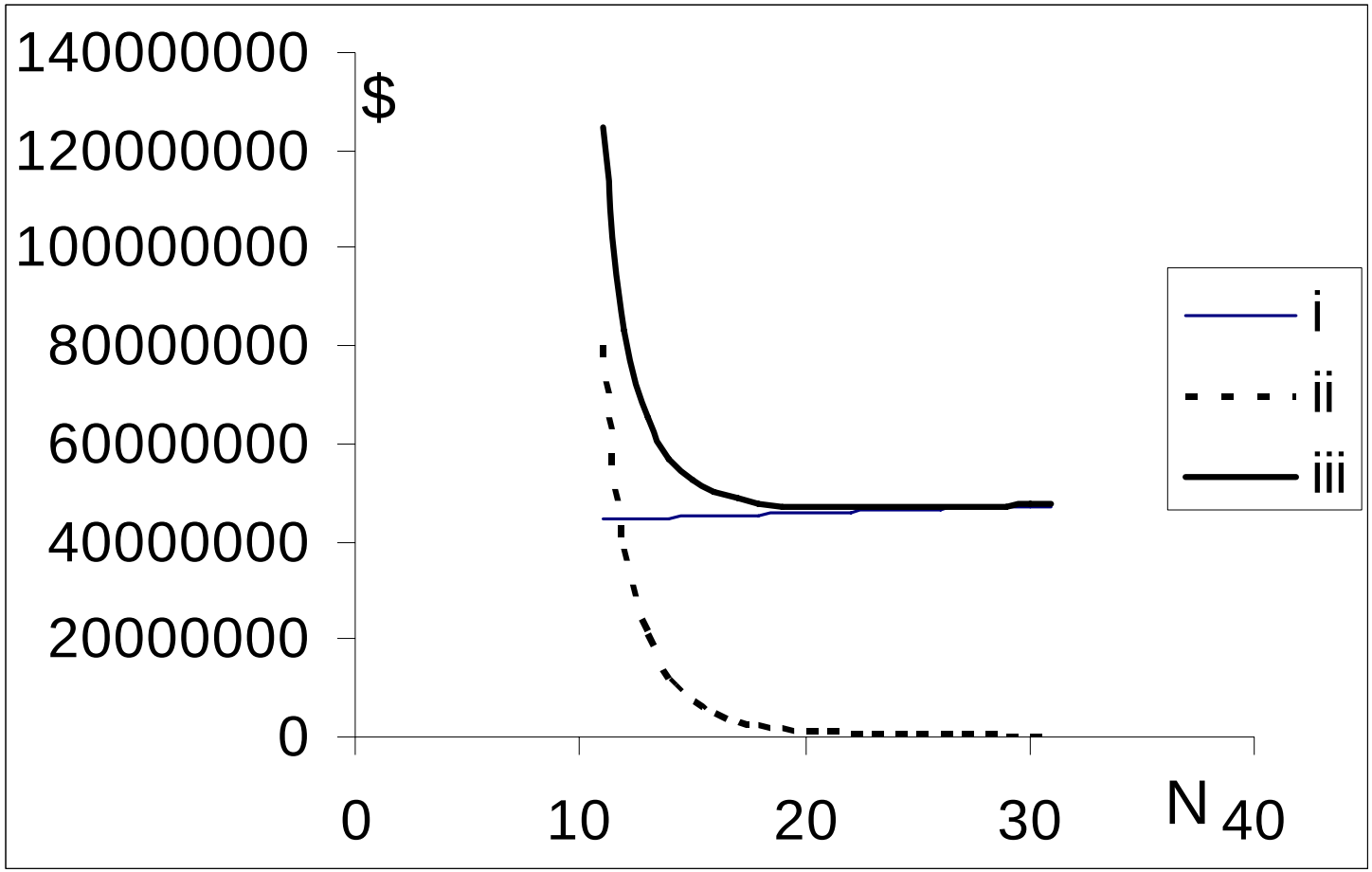
Example of total cost minimization under fast RF spread, p=0.2



i – Surveillance and detection costs ii – Expected costs of outbreak
iii – Total costs to be minimized.

Results

Example of total cost minimization under fast RF spread, p=0.2



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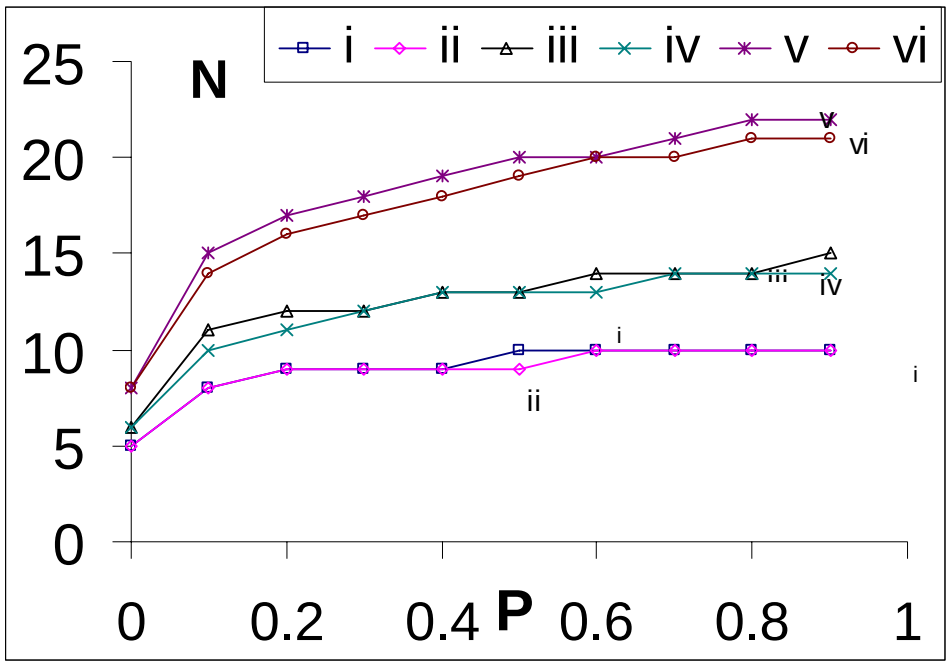
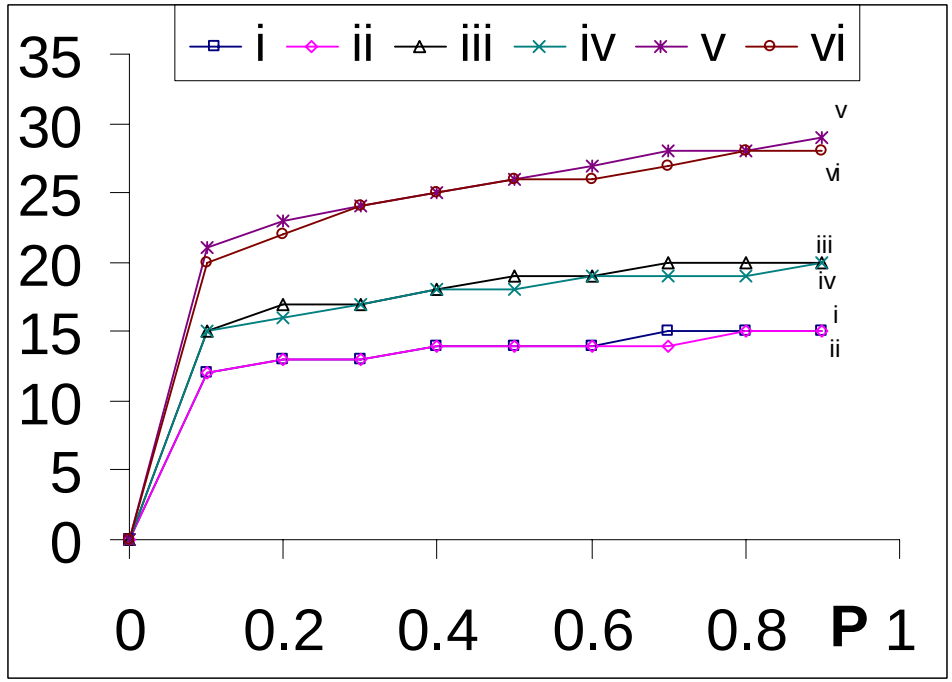
Event Probability, Response Effectiveness, VTC costs

Exponential



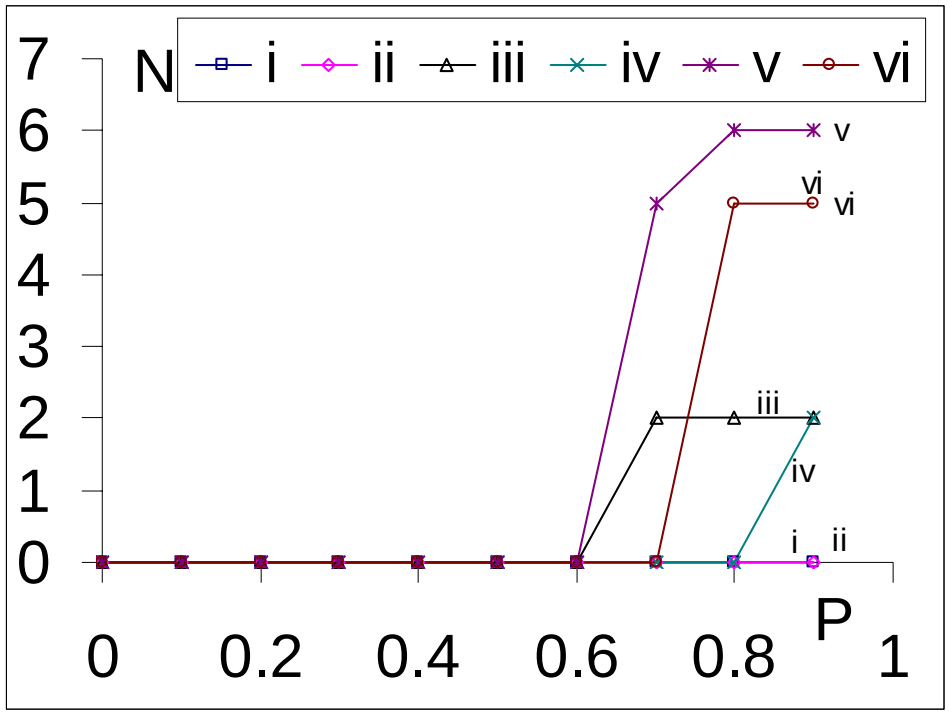
RF



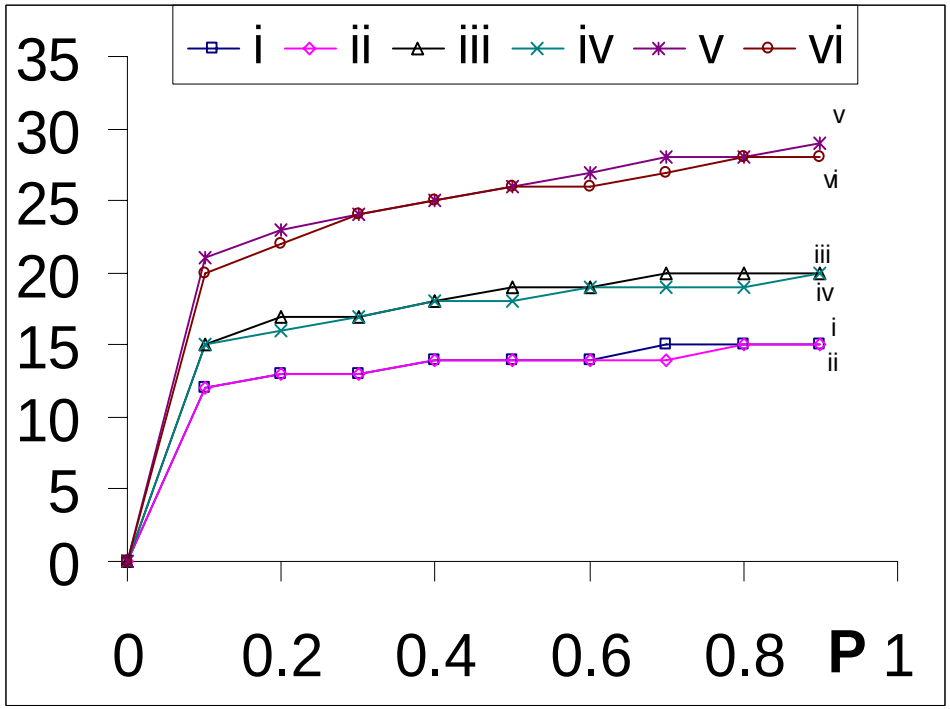
i – Full variable Costs (VC), Response Effectiveness (RE)=0.17
ii – VC, RE =0.3
iii – 0.1VC, RE=0.17
iv – 0.1VC, RE=0.3
v – 0.01VC, RE=0.17
vi – 0.01VC, RE=0.3

Spread Rate

Slow RF



Fast RF



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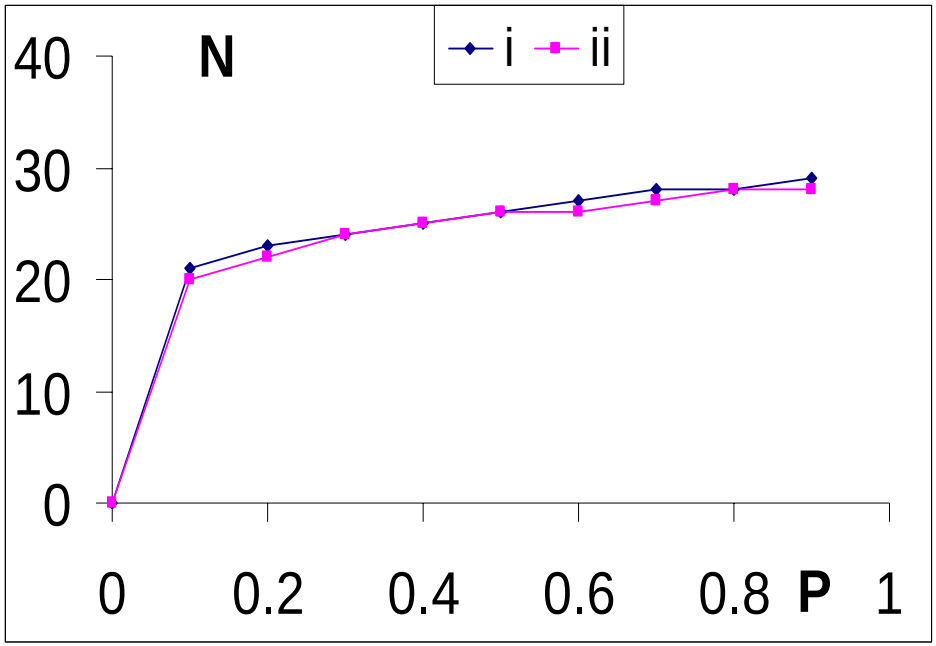
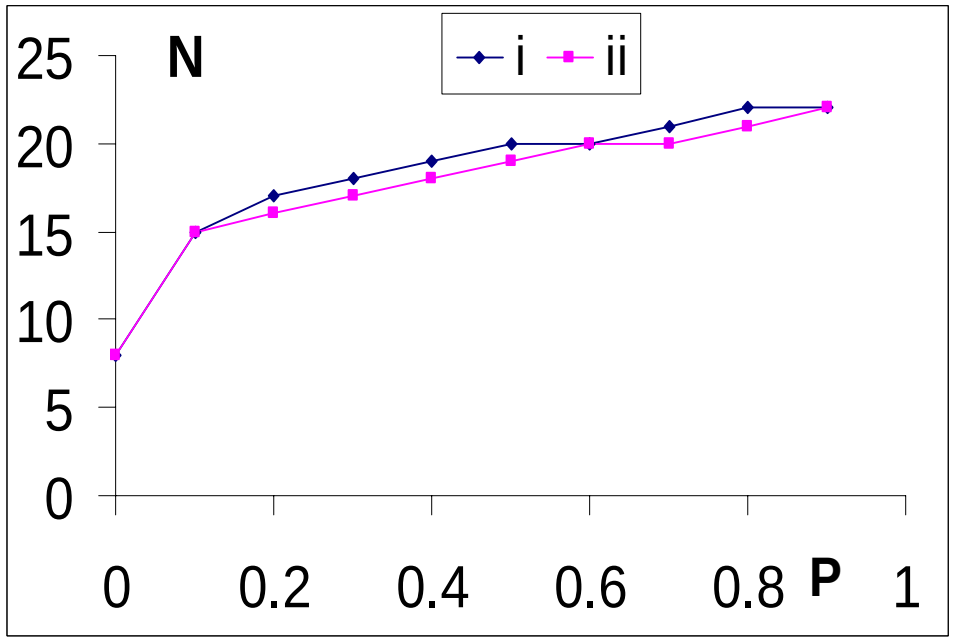
Recovery Actions

RF



Exponential



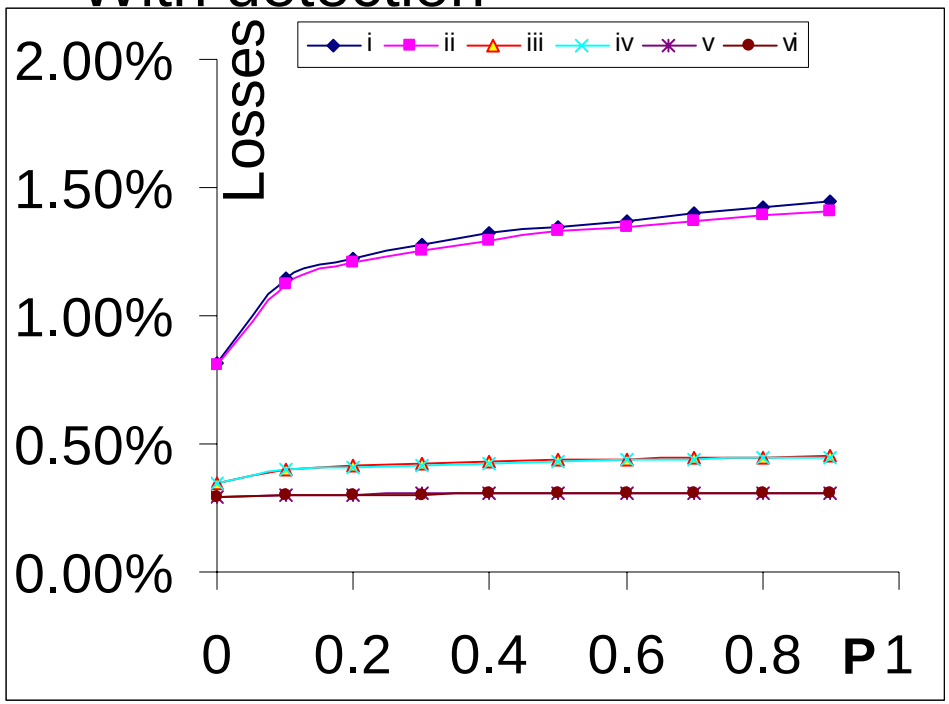
i – Without recovery program

ii – With recovery program

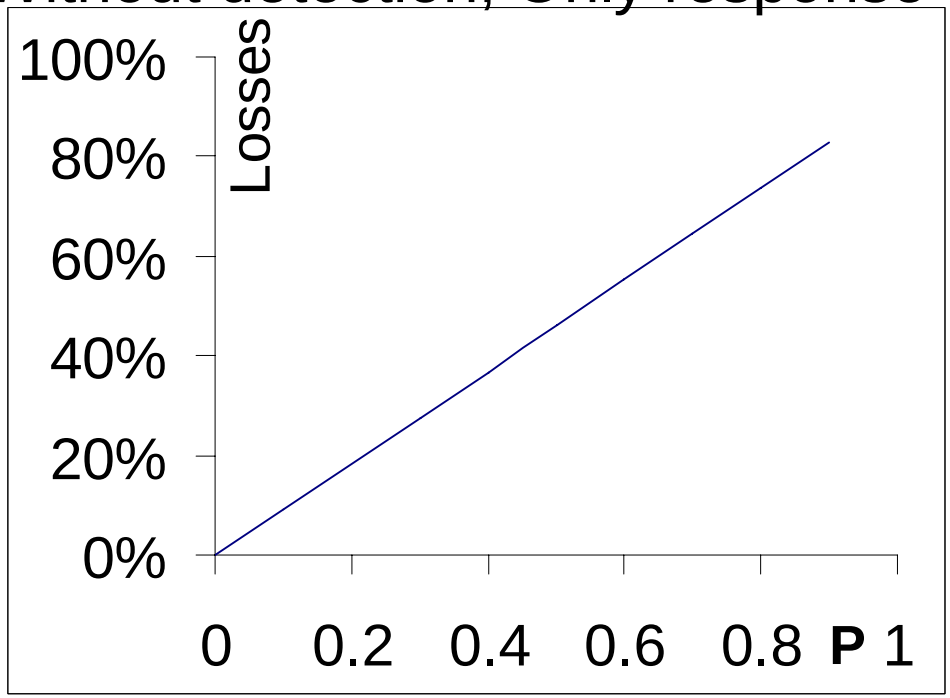
Economic Consequences

Fast spread under exponential

With detection



Without detection, Only response



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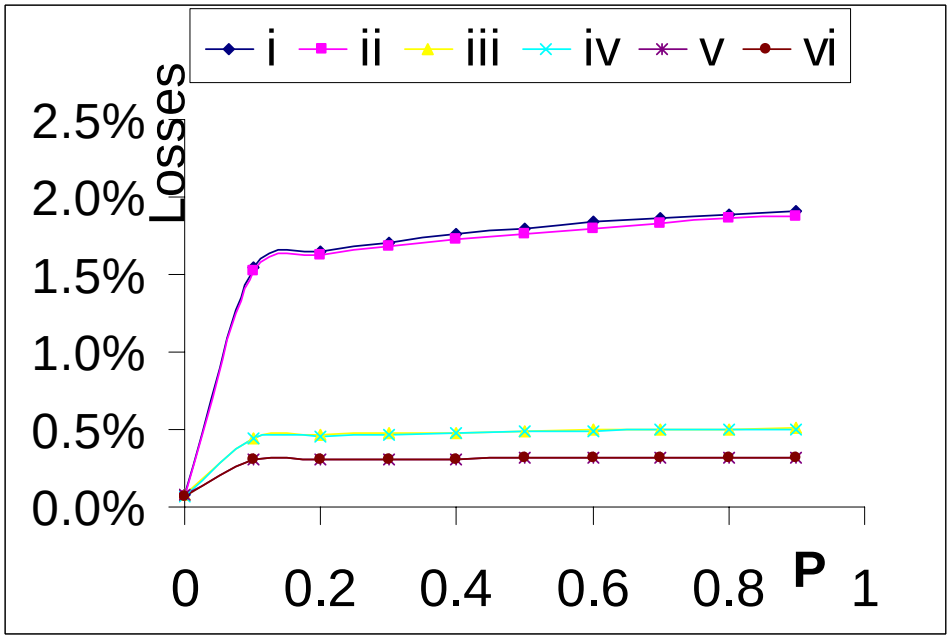
Economic Consequences

Fast spread under RF

With detection



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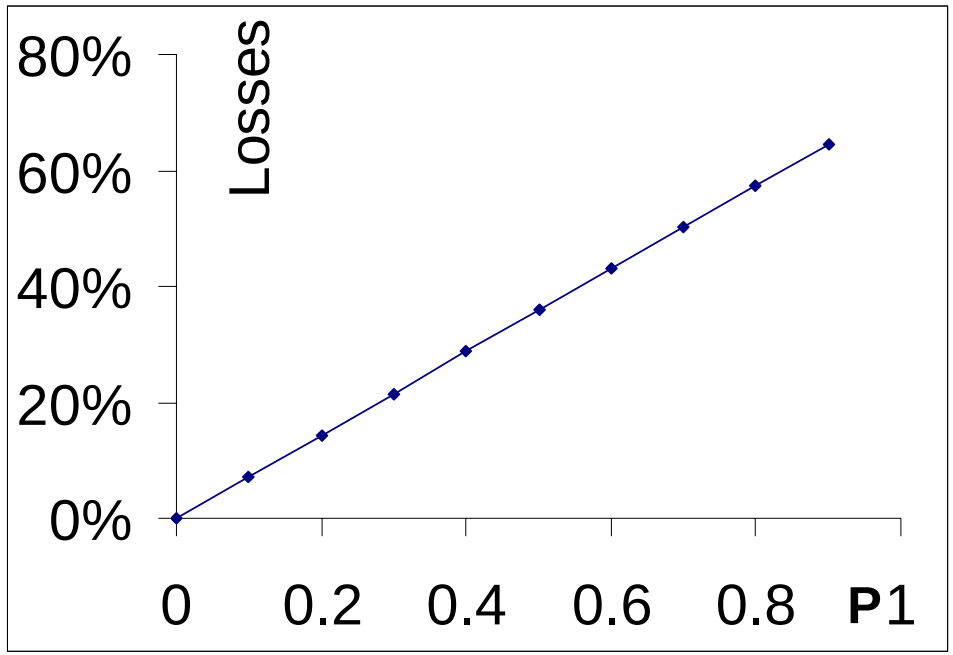

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Conclusions

- Investigated relationship between detection (prevention) and slaughter (response) strategy.
  - effort in a priori surveillance increases with threat level, cost reductions in surveillance, with disease spread rate, lower degree of effectiveness in response, and average herd size
- Estimates of lower bounds of losses due to FMD outbreak. Trade, consumer scare, other industries.

Conclusions

- Caution: functional forms, parameters, cost estimates.

- Future:
  - Explicitly include vaccination, recovery,
  - Disaggregate to localized strategies
  - Include Risk Aversion
  - Link to epidemiology model

Future work

- An economic model linked to epidemiologic model
  - Multiple state of nature
  - Broader mix of strategies
  - Multiple vs. single purpose strategies
  - Risk aversion
    - Effects on optimal mix of strategies
  - Possibly three stage formulation
    - Localized decision making