MODELING OF AVIAN INFLUENZA MITIGATION POLICIES IN COMMERCIAL SECTOR

BACKYARD SEGMENT OF THE POULTRY SECTOR

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Purpose of the talk

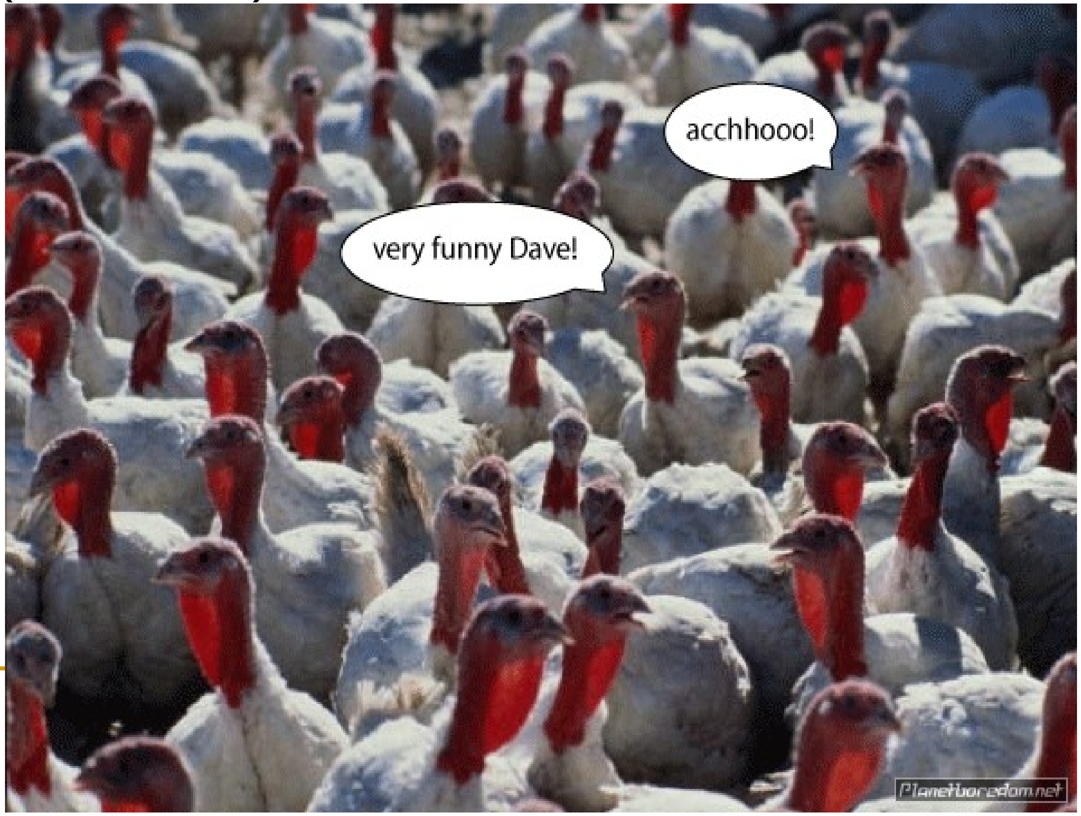
- PREISM AI project
  - Investigation of the economics of animal disease control measures in a stochastic setting
    - Commercial poultry flocks
    - Allocation of *resources* across *ex ante* vs. *ex post* actions
  - Paper on controlling AI in backyard level
    - Develop framework
    - Preliminary analysis of control option categories
    - Allocation of resources across control options

Avian Influenza – Bird flu

- Humans are susceptible to some strains
- Various combinations of H (16) and N (9) subtypes (Pelzel et al., 2006) : H5N1 and H5N2
- Mutation

- Latency 3:5 days - 21 days (OIE, 2006)
- Symptomatic period

- Transmission
- Direct contact
- Indirect contact



Previous AI in the US

- Most recent outbreak H5N2 in TX– February 2004 (Pelzel et al., 2006)
    - A broiler farm with 6,600 birds
    - Two live bird markets
    - Control costs
- Similar outbreaks in the Northeast in the 80s (Garnett, 1987)
- Exotic Newcastle Disease in CA in 2002 (Nolen, 2002, - JAVMA)
- Exotic New Castle Disease in CA in 2002/2003
- Recent HPAI in Asia heavily involved backyard flocks (Tiensen el al. 2006)

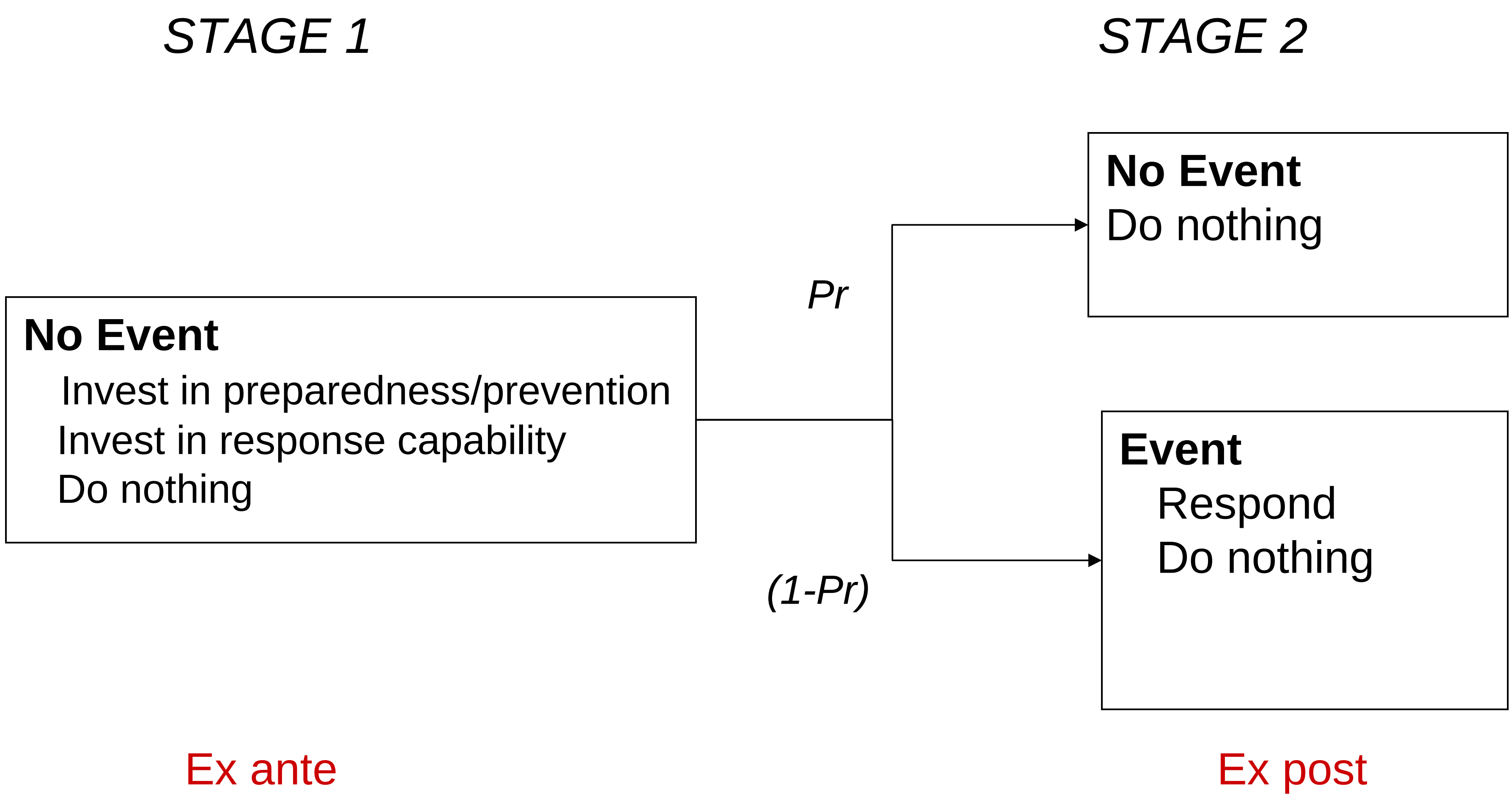
Backyard Flocks

- Need a comprehensive understanding of mitigation at Backyard flocks level
  - Very limited data
    - Garber et al. 2007
      - 1.9 residences within 1 mile of commercial flocks have poultry
      - 0.3% of commercial flocks have 20 or more backyard flocks within 1 mile
- Less compliant with bio-security measures
- Difficult to impose and enforce control options, expensive

Previous studies on AI

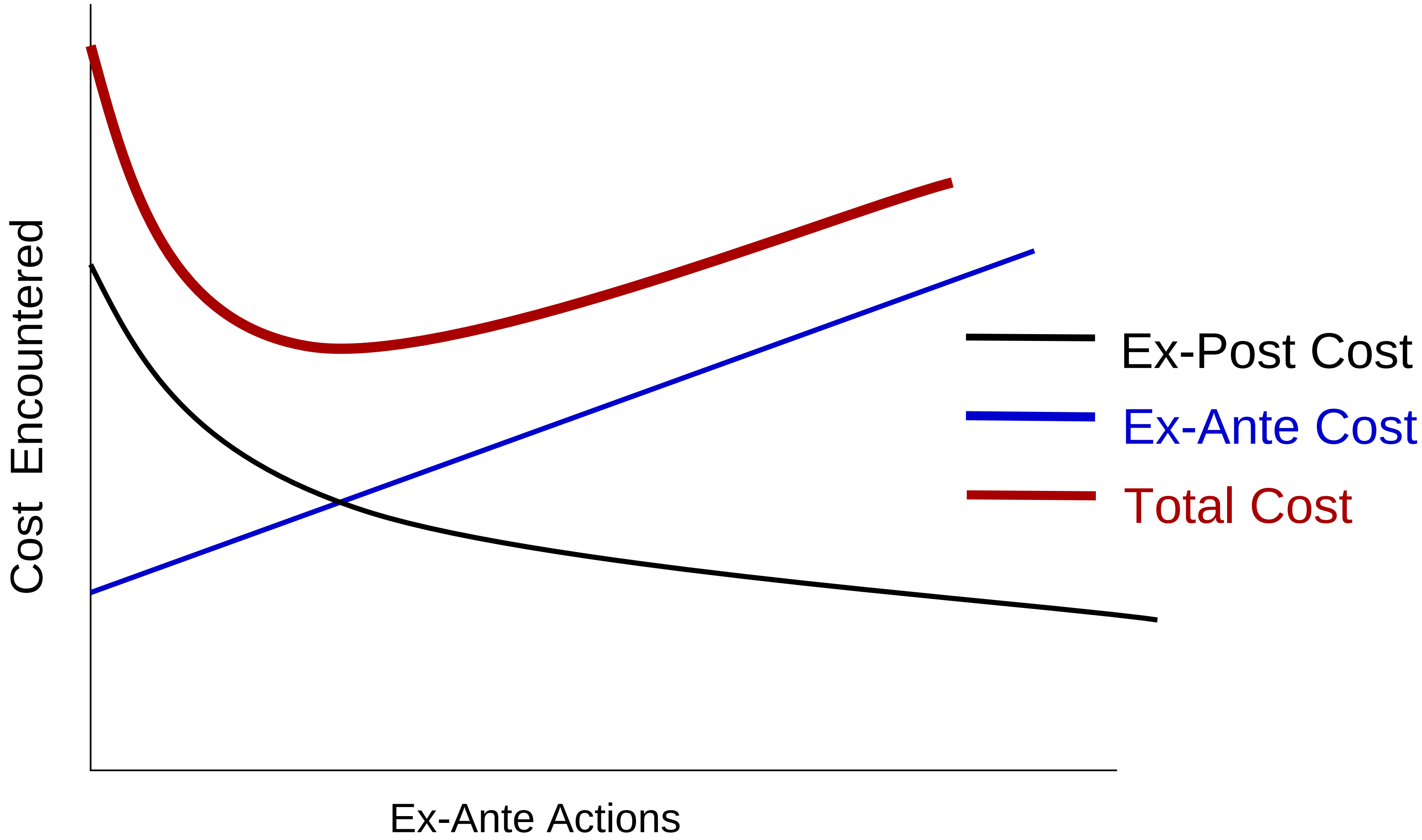
- Several dozen scientific articles in 2006 alone
- JAAE 2007
  - Paarlberg et al. – Regionalization (into disease free regions)
  - Djunaidi and Djunaidi – Trade effects of simultaneous outbreaks in Asia, US, Brazil, and EU
  - Beach et al. – Producer behavior under livestock disease risk
  - Brown et al. – Potential effects of AI outbreak on US agriculture
- Study needs
  - systematic operational effectiveness of mitigation strategies and control mechanisms
  - small scale poultry farms level
- **This work proposes a framework where an economic model is integrated with epidemiologic simulation methods to study the effectiveness of AI mitigation strategies.**

Analytic Conceptualization
Simple Model -Two Stages



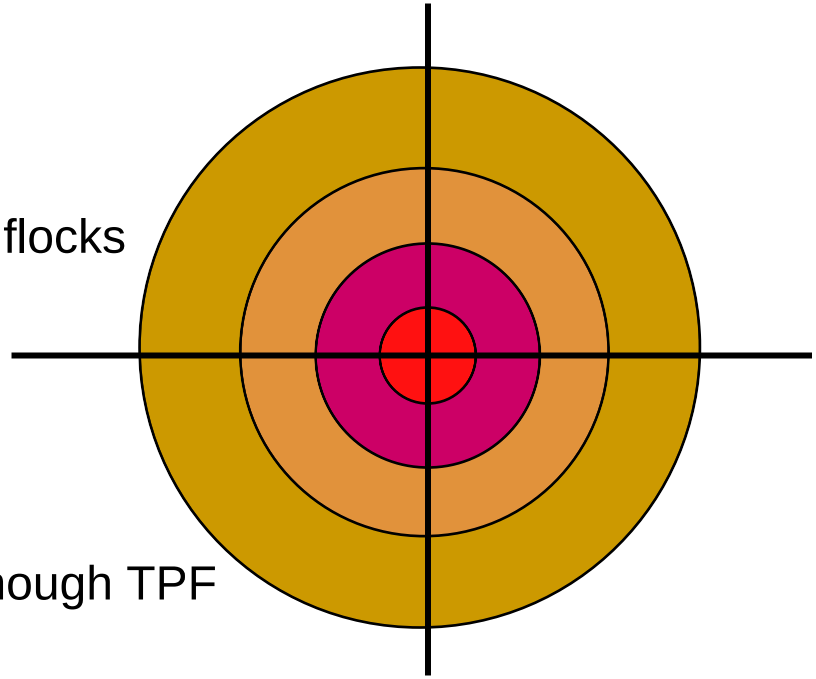
Source: Elbakidze and Mccarl (2006)

Analytic Conceptualization of the Project (EOQ)



Mitigation options

- Current mitigation plans in TX (TAHC)
  - depopulation of the infected flocks
  - movement restrictions and surveillance all flocks with direct contacts with the infected flock
  - movement restrictions 5 miles
  - surveillance testing 10 miles
  - cleaning and disinfection
  - Voluntary surveillance an response fund though TPF

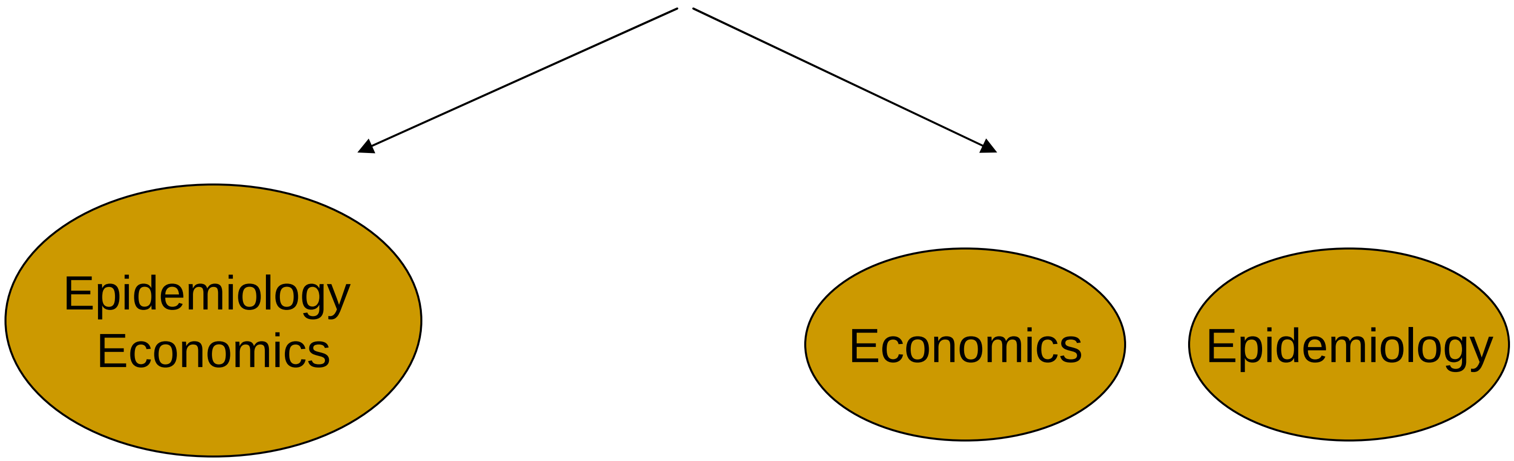


- Control Option Categories

	Latent	Symptomatic
Reduce Length	Speed up discovery	Encourage reporting
Reduce contact rate	Movement restrictions	Quarantine, Depopulation

Modeling

- Two approaches

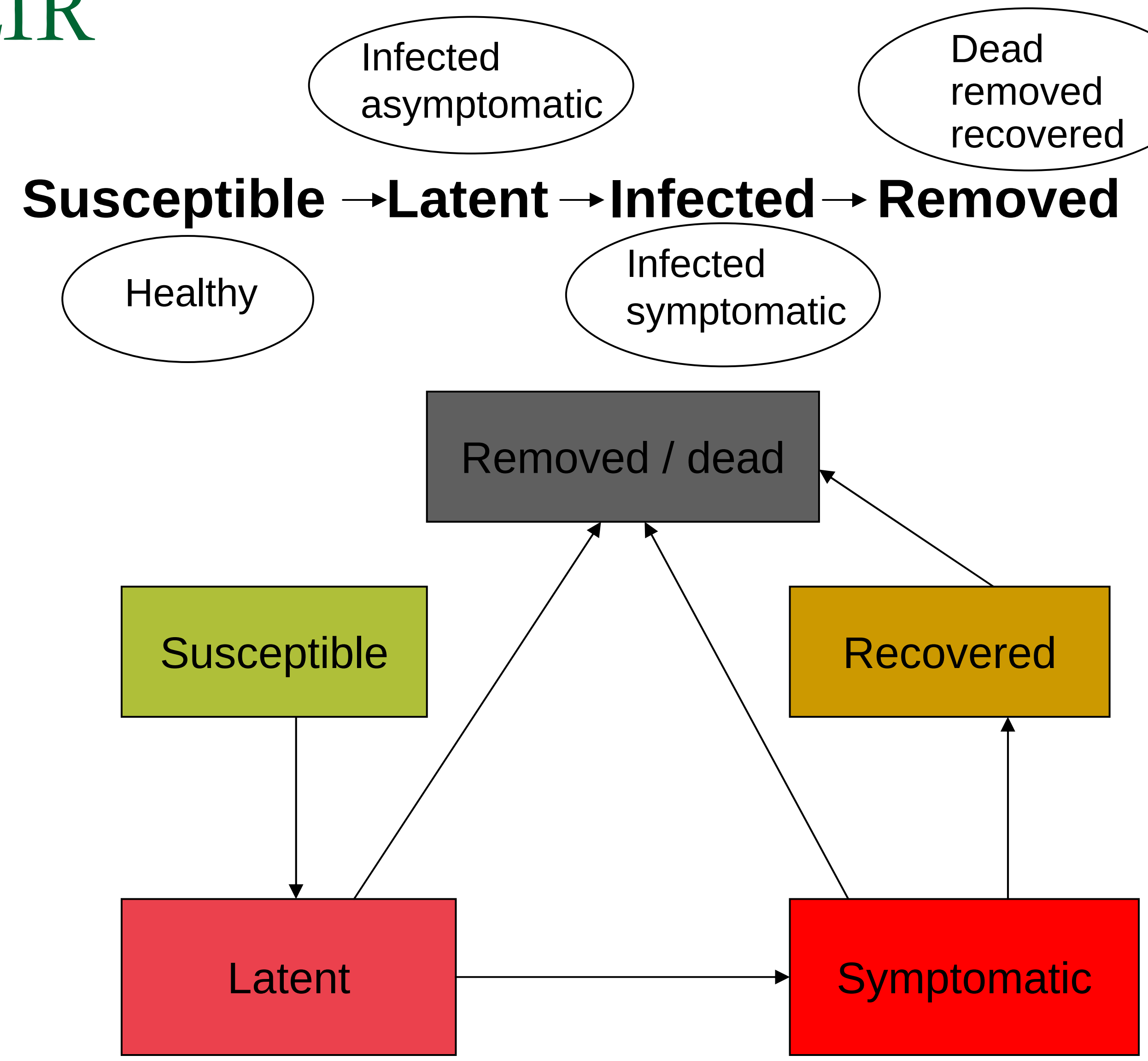


- Integrated modeling
  - Fast and less complex
  - Mostly done by veterinary modelers
- Linked modeling
  - New, complicated, time consuming, expensive
  - Collaborative
  - Could also include other areas like environmental models

Applications of SIR Economics

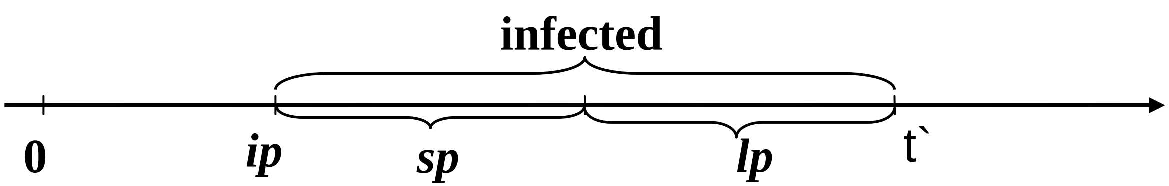
- Horan and Wolfe (2005)
  - SI framework
  - Bovine tuberculosis among Michingan white tailed deer.
- Bicknell et al. (1999)
  - SI framework
  - Incentives of profit maximizing producers to control bovine tuberculosis in New Zealand
- Rich and Winter-Nelson (2007)
  - SIR framework
  - FMD in the Southern Cone of South America
  - Assess economic effectiveness of spatially sensitive control options.
- Hufnagel et al. (2004), Garner and Lack (1995), Schoenbaum and Disney (2003), Berentsen et al. (1992)

SLIR


Infected asymptomatic
Dead removed recovered
Susceptible → Latent → Infected → Removed
Healthy
Infected symptomatic
Removed / dead
Susceptible
Recovered
Latent
Symptomatic

Empirical approach

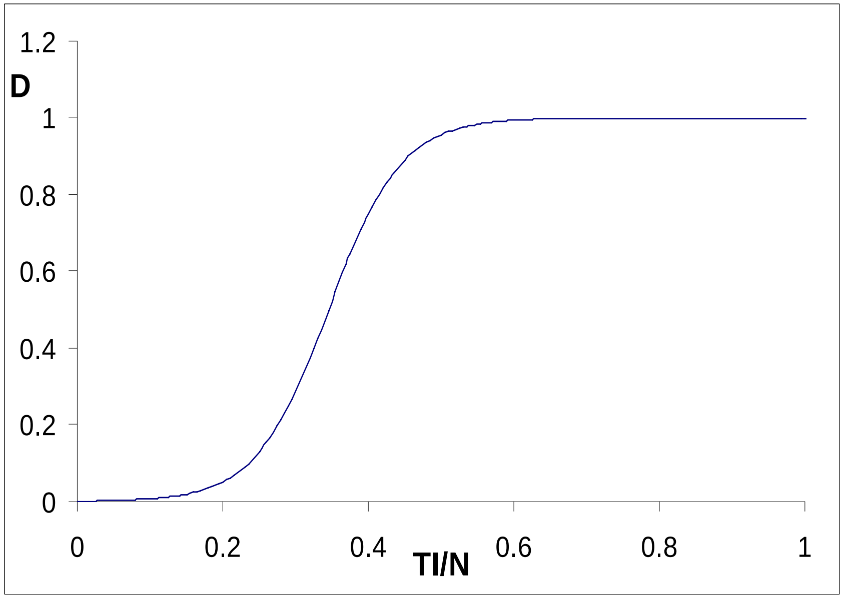
- Theoretical formulation
  - Differential equations
  - Analytically intractable given the dimensions
- Numerically investigate the relationship between
  - Efforts for earlier diagnosis of asymptomatic flocks
  - Efforts to reduce length of symptomatic period
  - Efforts to reduce contact rates of latent flocks
  - Efforts to reduce contact rates of symptomatic flocks



Empirical formulation

MIN:
w.r.t.
be,de,ipe,lpe

$$TCI = \frac{1}{1+\beta_1 e^{\beta_2 \frac{TI}{N}}} + c(be+de+spe+lpe) \qquad (6)$$



be – Efforts to reduce latent contacts [0:1]

de – Efforts to reduce symptomatic contacts [0:1]

spe – Efforts to reduce length of symptomatic period [0:1]

lpe – Efforts to diagnose latent flocks [0:1]

TI – total number of infected/removed flocks

c – rate of mitigation strategy costs relative to maximum possible losses

TCI – Total normalized costs where maximum costs from disease spread are 1 plus normalized costs control actions

Empirical formulation

- Contact rate for latent flocks as a function of efforts to decrease latent contact rate

  *b=brate-brate*be* (7a)

- Contact rate for symptomatic flocks as a function of efforts to decrease symptomatic contact rate

  *d=drate-drate*de* (7b)

- Length of asymptomatic period as a function of efforts for earlier diagnosis of latent flocks

  *lp=lperiod-lperiod*lpe,* (7c)

- Length of symptomatic period as a function of efforts to reduce symptomatic period

  *sp=speriod-speriod*ipe.* (7d)

- Number of new infections on day t

$$x_t = b \cdot \frac{S_t}{N} \cdot \left[\sum_{\tau=0}^{t-1} x_\tau - \sum_{\tau=0}^{t-lp} x_\tau \right] + d \cdot \frac{S_t}{N} \cdot \left[\sum_{\tau=0}^{t-lp} x_\tau - \sum_{\tau=0}^{t-lp-sp} x_\tau \right] \qquad (8)$$

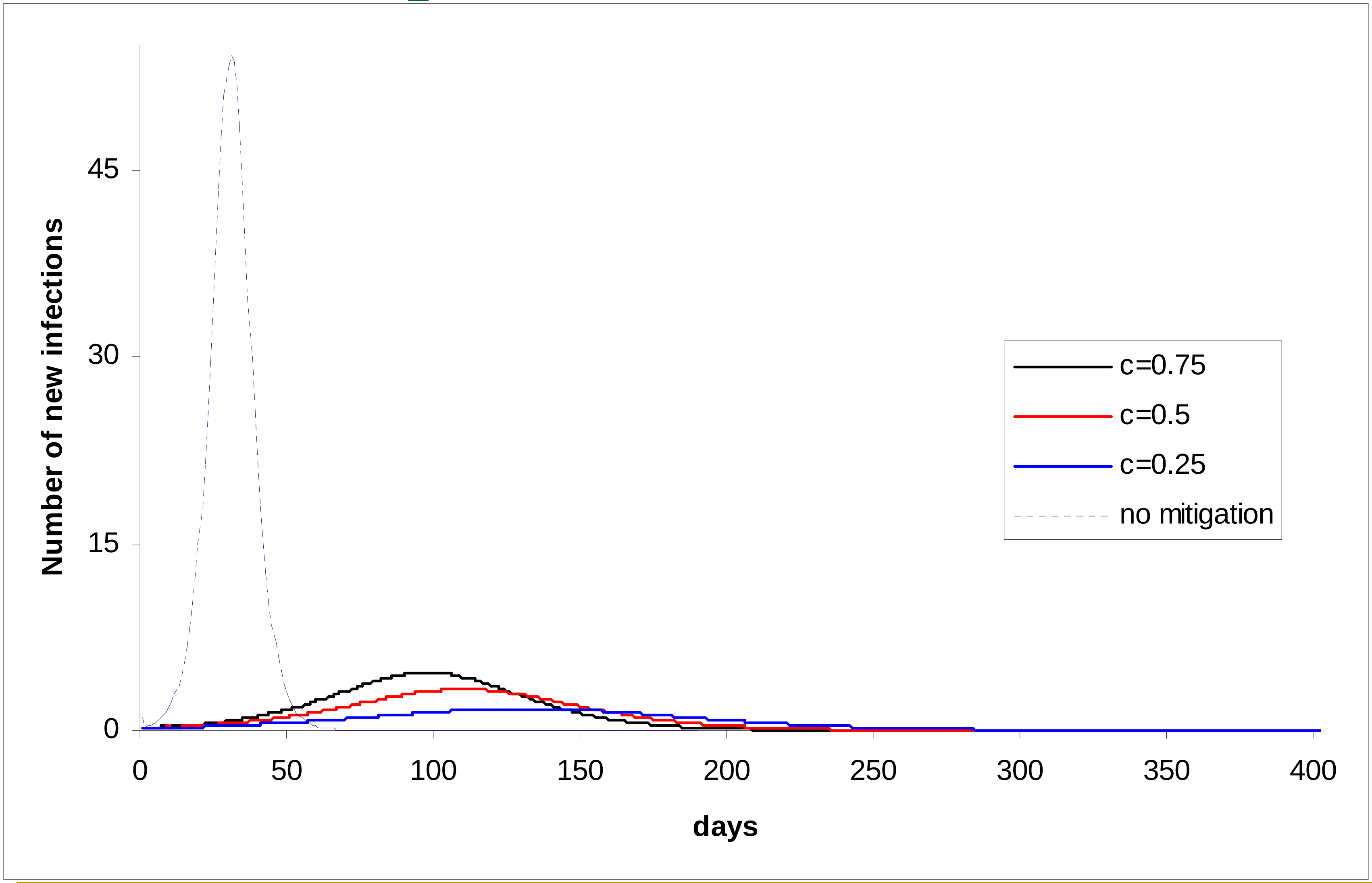
- Number of susceptible flocks on day t

$$S_t = N - \sum_{\tau=0}^{t} x_\tau \qquad (9)$$

- Number of removed flocks

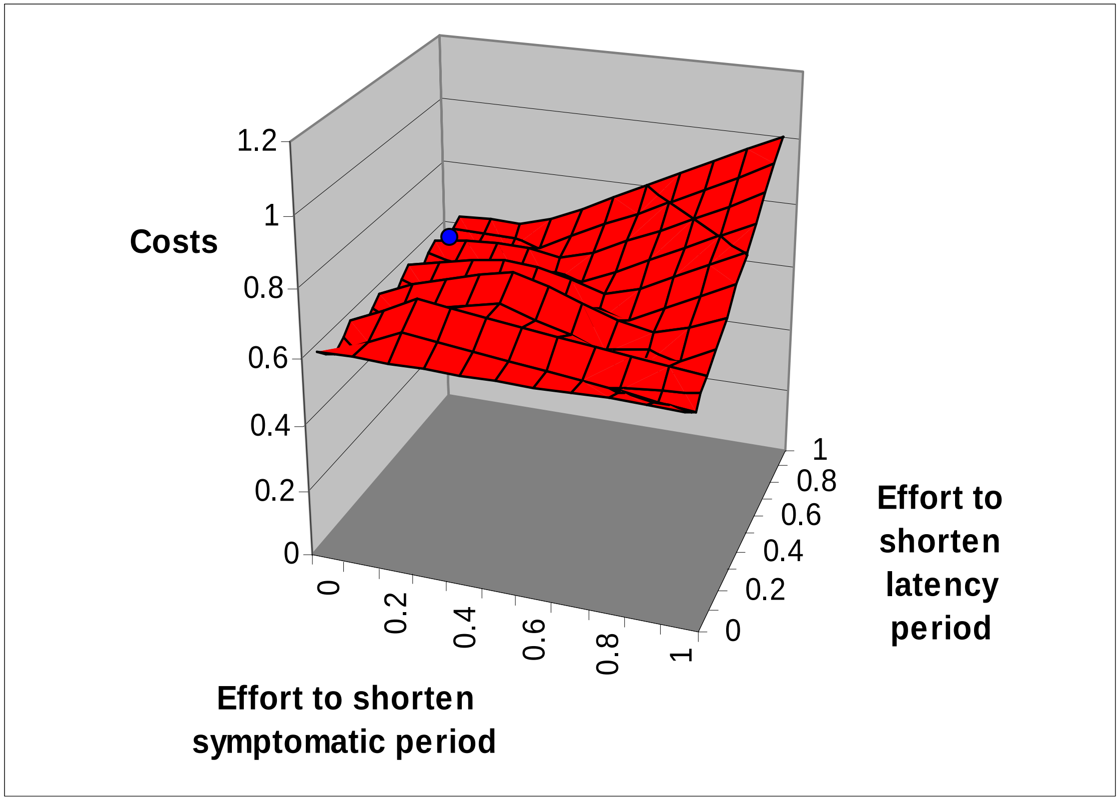
$$TI = \sum x_t \qquad (10)$$

Results – spread



Results - costs

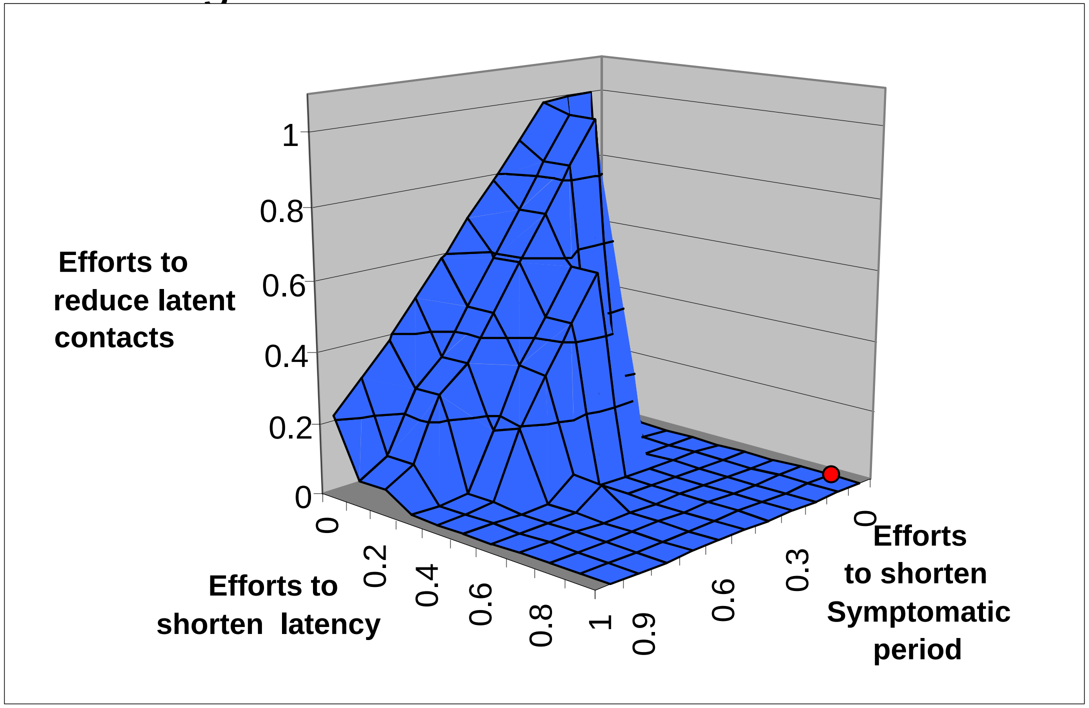
- The costs are minimized with respect to efforts to decrease inter flock contact rates of latent and symptomatic flocks
- Cost minimizing combination of efforts to decrease the length of latent and symptomatic periods
  - Asymptomatic=0.9 from 5 to 0.5 days
  - Symptomatic =0 leave at 10 days



Results – latent contacts

- The optimal level of effort to decrease inter flock contact rates for latent flocks, corresponding to the cost minimizing point from previous figure is zero.

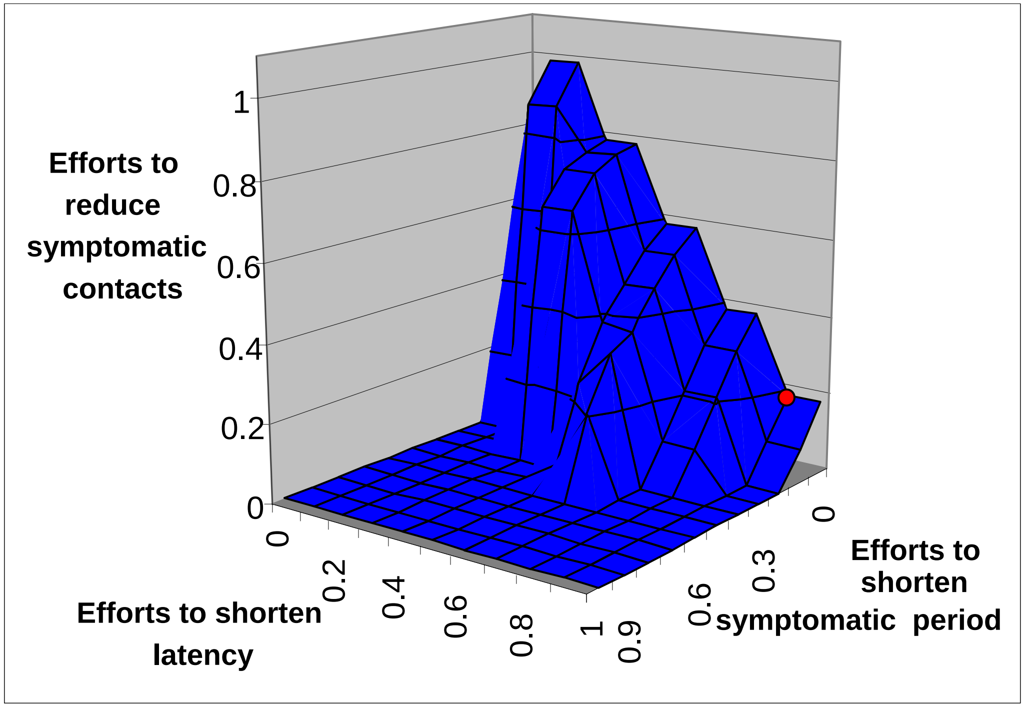
- Efforts to decrease inter flock contact rates for latent flocks function as substitutes to reduction of the lengths of
  - asymptomatic period
  - symptomatic period



Results - symptomatic contacts

- The optimal level of efforts to reduce symptomatic flock contact rates corresponding to cost-minimizing point is 0.19, (from 0.15 to 0.12 per day)

- Reduction of symptomatic contact rates functions as a substitute to reduction of the lengths of
  - latent period
  - symptomatic period



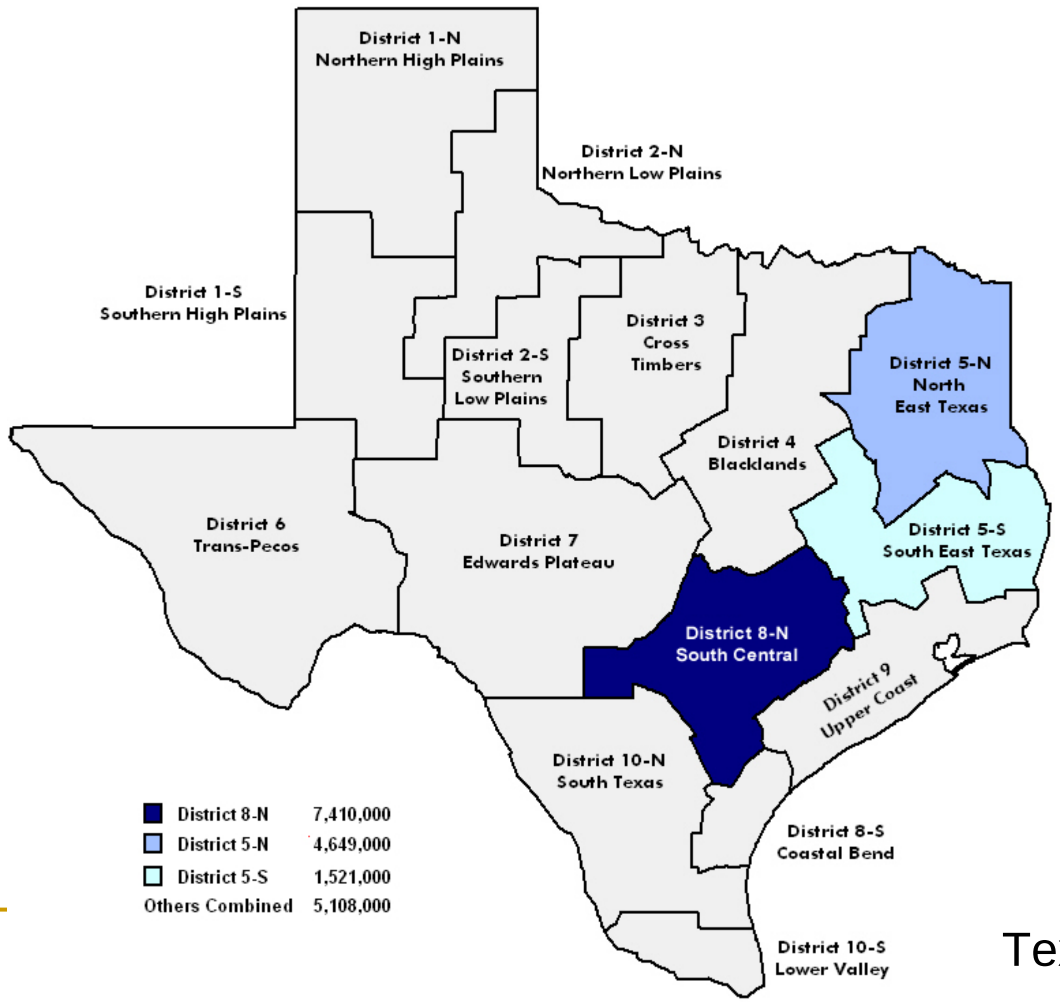
Implications

- Control of Contact rates is difficult at backyard level
- Given the substitutability of the contact rate control and reduction in the lengths of infectiousness periods
  - Decrease length of symptomatic period
    - E.g. compensation scheme to disclose the presence of disease.
      - False reporting
  - Speed up diagnosis of latent flocks
    - Encourage development of technology for earlier diagnosis of latent flocks
      - Similar to TPF response fund

↓

- Less reliance on controlling inter flock contact rates

Texas Hens & Pullets of Laying Age: December 1, 2005 Inventory



Texas Ag. Statistics

Data: Layers, >100,000 birds

- **Direct contacts**
  - Chicks from hatchery.............................every 6 weeks
  - Eggs received from other farms...............every 4 weeks
- **Indirect contacts**
  - Feed trucks.....................................6 - 9 / week
  - Propane tanks fill up.......................2 / month
  - Utility services...............................1 /month
  - Electricity and plumbing................1 /month
  - Broken eggs pick up.......................every 6 weeks
  - Disabled animals pick up..................every 6 weeks
  - Local volume retailer......................2 /week
  - Food distribution............................1 /month
  - Eggs transport................................9 /week
  - Veterinarian....................................4 - 6/ year
- **Cost elements**
  - Production cycle cleaning.............$4000 /year
  - Vaccination.................................$60000/year
  - Tests...$450/year

Data: Turkey

- **Direct contacts**
  - Between turkey farms 5 times/year
- **Indirect contacts**
  - Feed trucks...............................1 / week
  - Propane tanks fill up.................4 / week
  - Veterinarian..............................every 3 months
  - Nutritionist ....1 / year (go to all the farms)
  - Loading crews..........................4 / week
- **Cost elements**
  - Plastic cloths and gloves...............5,000 / year
  - Detergents for cleaning................40,000 / year
  - Production cycle cleaning.............1000,000 / year
  - Vaccination.................................4800 / year
  - Tests...300 / month

- Thank you

SLIR

$$\dot{S} = -b \cdot I(t) \cdot \frac{S(t)}{N} - d \cdot L(t) \cdot \frac{S(t)}{N} \tag{1}$$

$$\dot{L} = b \cdot I(t) \cdot \frac{S(t)}{N} + d \cdot L(t) \cdot \frac{S(t)}{N} - b \cdot I(t - lp) \cdot \frac{S(t - lp)}{N} - d \cdot L(t - lp) \cdot \frac{S(t - lp)}{N} \tag{2}$$

$$\dot{I} = b \cdot I(t - lp) \cdot \frac{S(t - lp)}{N} + d \cdot L(t - lp) \cdot \frac{S(t - lp)}{N} - b \cdot I(t - lp - sp) \cdot \frac{S(t - sp - lp)}{N} - d \cdot L(t - sp - lp) \cdot \frac{S(t - sp - lp)}{N} \tag{3}$$

$$\dot{R} = b \cdot I(t - sp - lp) \cdot \frac{S(t - sp - lp)}{N} + d \cdot L(t - sp - lp) \cdot \frac{S(t - sp - lp)}{N} \tag{4}$$

$$TC = \int_0^T \left[D\left(\dot{R}\right)\right] dt + C(b, d, lp, sp) \tag{5}$$

Parameters

Notation	Definition	Base value
N	Total number of flocks in the area	1000
β_1	Parameter for logistic damage function	1000
β_2	Parameter for logistic damage function	-10
c	Cost coefficient for mitigation efforts	0.25, 0.5, 0.75
brate	Contact rate of latent flocks	0.3 contacts/day
drate	Contact rate of symptomatic flocks	0.15 contacts/day
lperiod	Latency period	5 days
speriod	Symptomatic period	10 days