The Economics of Managing Infectious Wildlife Disease When Livestock are at Risk

Richard Horan

and

Christopher Wolf

Michigan State University

Project People

- Ken Mathews, ERS
- Eli Fenichel, MS Thesis
- Ben Gramig, on-going PhD

Objectives

1. Build bioeconomic models for infectious wildlife disease that affects wildlife and livestock populations
2. Apply these models to bovine tuberculosis in deer and cattle in Michigan
3. Assess the efficacy of existing policies of disease control and eradication

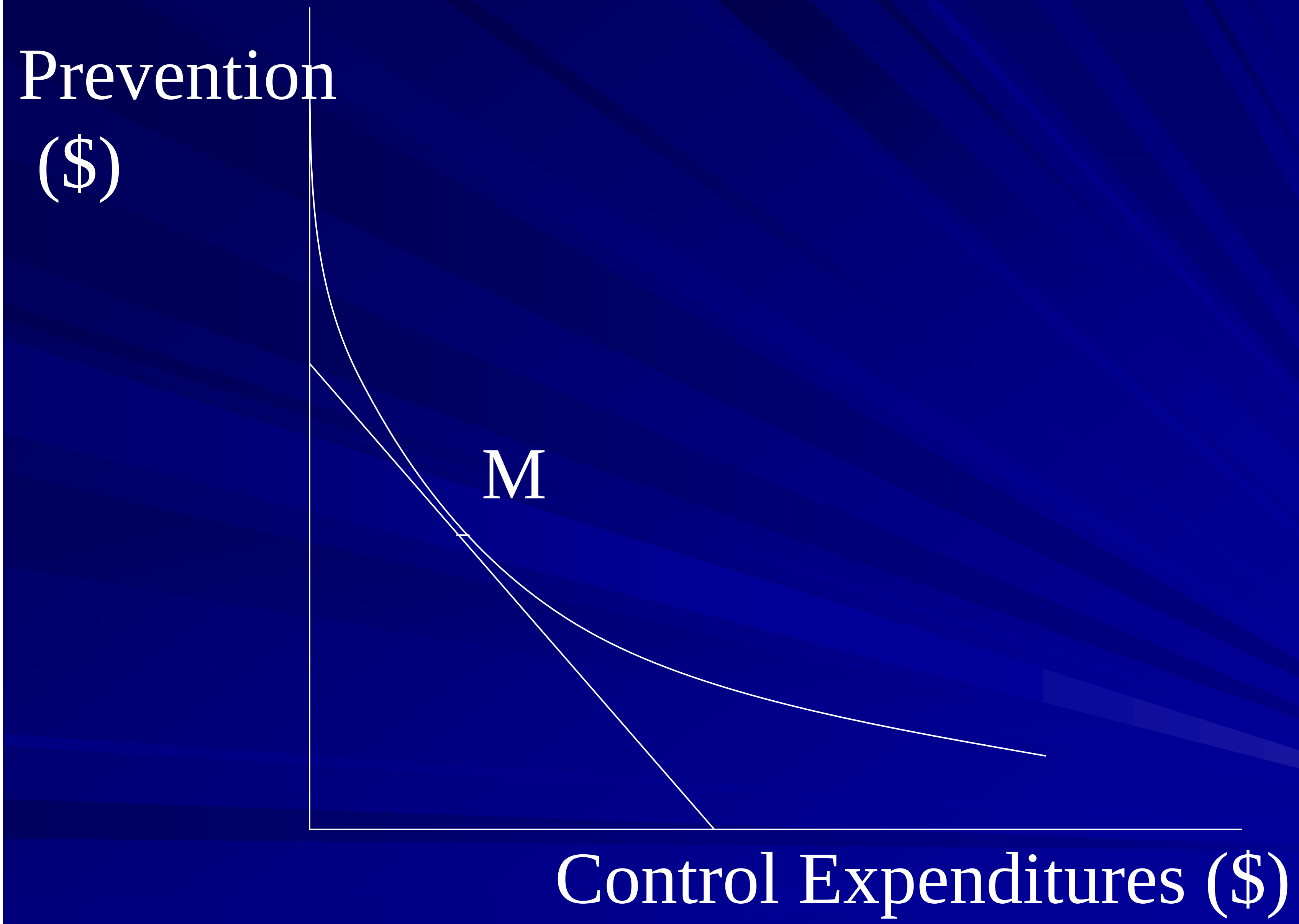
The past couple of year's presentations have focused on objectives 1 and 2—this year I will focus on 3

Dilbert on moral hazard and livestock insurance [27 November 2003]

Incentive Compatibility in Livestock Disease Indemnity Programs

- US policy to address livestock disease outbreak:
  - Border control to prevent incursion
  - Response to intra-border outbreak
  - Indemnities for animals culled

- Goal today is to assess the compatibility of policy and private incentives to prevent and control disease


Prevention ($)
M
Control Expenditures ($)

Prior Work on Disease Prevention and Control Incentives

- Disease
  - Gov't eradication programs (Kuchler+Hamm)
  - Optimal actions to contain FMD outbreak in Brittany (Mahul+Gohin)
  - Effect of gov't eradication programs in NZ (Bicknell+Wilen+Howitt)
  - Optimal control of transmitted btw wildlife, livestock (Horan+Wolf)
- Insurance & Moral Hazard
  - Constrained Pareto optimal insurance contracts (Chambers)
  - Optimal crop insurance contract form (Hyde+Vercammen)
- Moral Hazard & Livestock Disease Risk Management
  - Incentive compatibility under moral hazard in livestock disease risk mgt policy (Gramig+Barnett+Skees+Black)
  - Current model incorporates information asymmetry into a P-A model to investigate incentives

Nature of Hidden Action

- Disease prevalence, θ, is a random variable
  - Realization of θ corresponds to outbreak
- *Ex Ante:* Individuals have private information about preventive biosecurity measures prior to outbreak
- *Ex Post:* Individuals possess private information about the disease status (prevalence or rate of infection) following outbreak

Basics of Model

- Farmer with susceptible livestock
  - Indirect utility a function of wealth: $V(w)$ where $V'>0$, $V''<0$
- $w = w_o$ when the herd is not infected
- Farmer knows true disease prevalence in herd: $\theta \in [0,1]$
- Gov't program specifies a removal (cull) rate $\hat{\theta} \geq \theta$
- If outbreak occurs, farmer is subject to:
  - Asset value losses, $\lambda(\theta)$ and $\lambda(\hat{\theta})$
  - Consequential losses, $\rho^{NR}(\theta)$ and $\rho^{R}(\hat{\theta})$
- Eligible for gov't provided indemnities, τ, if disclose θ
- No externalities from disease in the model

Ex Post Moral Hazard

- Gov't wants farmers to disclose (suspected) prevalence and uses indemnities as policy instrument
- Incentive compatibility condition (IC): Reporting state ≥ Non-reporting state

$$w_0 - \lambda(\hat{\theta}) - \rho^R(\hat{\theta}) + \tau \geq w_0 - \lambda(\theta) - \rho^{NR}(\theta) + S(\theta)$$

$$\Rightarrow \tau^{IC} \geq [\lambda(\hat{\theta}) - \lambda(\theta)] + [\rho^R(\hat{\theta}) - \rho^{NR}(\theta)] + S(\theta)$$

- Under disclosure the farmer is fully indemnified against the alternative state

⇒ IC indemnity is only market value of culled animals when there are no differences in terms of asset or consequential losses from reporting

Status quo Indemnity

$$\tau^{SQ} = \lambda(\hat{\theta})$$

- Status quo indemnity incentive compatible only if it is at least as large as τ^{IC} implying:

$$\rho^{R}(\hat{\theta}) \leq \lambda(\theta) + \rho^{NR}(\theta) - S(\theta)$$

- Consequential losses under the reporting state must be smaller than all the losses under the non-reporting state

Origin of *Ex Ante* Moral Hazard

- Consider ex ante farmer incentives
  - Private investment in bio-security, *b*
  - Per unit cost r
- Bio-security investments made to affect the conditional pdf of disease, $f(\theta,b)$, and $F_b(\theta,b) \geq 0$
- Incentive: Reduce risk of non-indemnified losses
- Policy maker seeks higher investment than would otherwise be privately chosen
- *b* has both observable and unobservable dimensions

Indemnity to deal with *Ex Ante* biosecurity investment

- Principal must worry about participation and incentive compatibility
- If biosecurity is observable, then can either subsidize it or make indemnities contingent on it
  - With verifiable effort the agent obtains full insurance from a risk-neutral principal and the indemnity is the same regardless of the state of nature
- Concrete investments are observable (e.g., fences) while management practices are not
- Increasing indemnity lowers incentive to invest in biosecurity (but would increase incentive to report)

Policy Instruments for *Ex Ante* + *Ex Post* Moral Hazard

- Two distinct sources of MH imply need for two policy instruments
  - Indemnities address ex ante MH
  - Penalties or insurance, $P(\theta)$, address ex post MH
- Probability of detection, $\alpha(\theta)$, with $\alpha_\theta > 0$

$$IC: V(w_0 + \tau - \lambda(\hat{\theta}) - \rho^R(\hat{\theta}) - rb) \geq \alpha(\theta) V(w_0 - \lambda(\theta) - \rho^{NR}(\theta) + S(\theta) - P(\theta) - rb)$$
$$+ (1 - \alpha(\theta)) V(w_0 - \lambda(\hat{\theta}) - \rho^R(\hat{\theta}) - rb)$$

- Optimal penalties with indemnities achieve IC whenever $\theta > 0$

$\Rightarrow$ Impose more risk on farmer to get desired behavior

Ex Ante & Ex Post MH Model

- Regulator's objective function: E{V(w)} + E{gov't cost} s.t. farmer (IC)

$$\underset{\tau,b}{Max} \int_0^1 V(w_0 + \tau - \lambda(\theta) - \rho^R(\theta) - rb)\, f(\theta, b)\, d\theta + \kappa \int_0^1 (-\tau - m)\, f(\theta, b)\, d\theta$$

$$s.t. \quad \mathrm{b} \in \underset{\hat{b} \in B}{\mathrm{argmax}} \int_0^1 V(w_0 + \tau - \lambda(\theta) - \rho^R(\theta) - w\hat{b})\, f(\theta, \hat{b})\, d\theta$$

κ = weight regulator applies to budgetary outlays

m = monitoring cost of infected herds

LaGrangian and FOCs

$$\text{L} = \int_0^1 V(\pi_0 + I(\theta) - C(\theta) - wb)\, f(\theta,b)\, d\theta + \kappa \int_0^1 (-I(\theta) - m)\, f(\theta,b)\, d\theta$$

$$+\, \mu \int_0^1 [-V'(\pi)w + V(\pi)\frac{f_b(\theta,b)}{f(\theta,b)}]\, f(\theta,b)\, d\theta$$

$$\frac{\partial \text{L}}{\partial I(\theta)} : V'(\pi) - \kappa = \mu[V''(\pi)w - V'(\pi)\frac{f_b(\theta,b)}{f(\theta,b)}] \quad \Rightarrow \tau^{SB}(\theta)$$

$$\frac{\partial \mathcal{L}}{\partial b} : \int_0^1 [-V'(\pi)w + V(\pi)\frac{f_b(\theta,b)}{f(\theta,b)}]\, f(\theta,b)\, d\theta + \kappa \int_0^1 (-I(\theta) - m)\, f_b(\theta,b)\, d\theta$$

$$\Rightarrow \mu > 0$$

$$+\, \mu \int_0^1 [V''(\pi)w^2 f(\theta,b) - 2V'(\pi)wf_b(\theta,b) + V(\pi)\, f_{bb}(\theta,b)]\, d\theta = 0$$

Comparison w/ First-Best

- Regulator's FOC in a FB (unconstrained) world:

$$V'(w) - \kappa = 0 \Rightarrow \tau^{\text{FB}}(\theta)$$

- Deviations from FB are characterized by:

$$\tau^{SB}(\theta) < \tau^{FB}(\theta) \quad \Leftrightarrow \quad \frac{f_b(\theta,b)}{f(\theta,b)} + \frac{-V''(w)}{V'(w)} r < 0$$

$$\tau^{SB}(\theta) > \tau^{FB}(\theta) \quad \Leftrightarrow \quad \frac{f_b(\theta,b)}{f(\theta,b)} + \frac{-V''(w)}{V'(w)} r > 0$$

SB > FB when farmer MR from biosecurity is positive and SB < FB when biosecurity MR is negative

Implications

- Current policy:
  - Few ex ante compensation rules
  - No explicit consideration of consequential losses
  - Indemnities are often sole mechanism
- Our model suggests:
  - Farm biosecurity choices are endogenous to the indemnity
  - Indemnity alone not sufficient to provide incentives for biosecurity and disclosure
  - Gov't shouldn't fully insure farmers (Arrow, Raviv; Laffont and Martimort)
  - $\tau^{SB}(\theta)$ should account for consequential losses in excess of direct losses when reporting

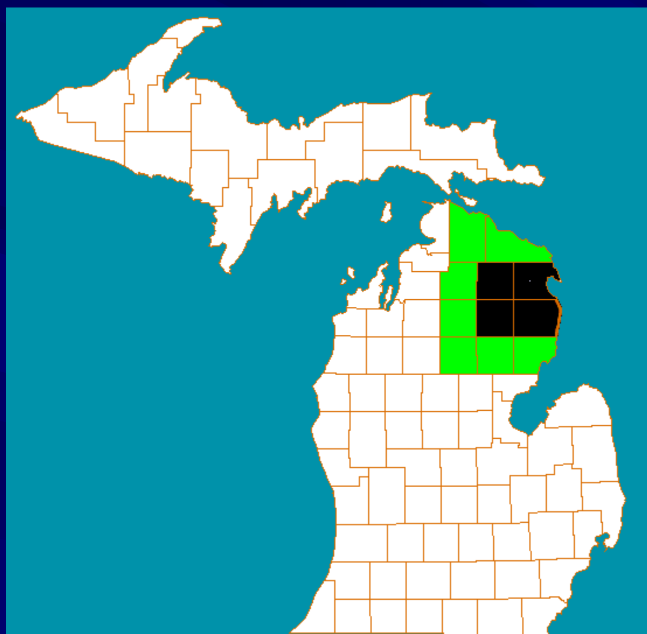
Implications & Limitations

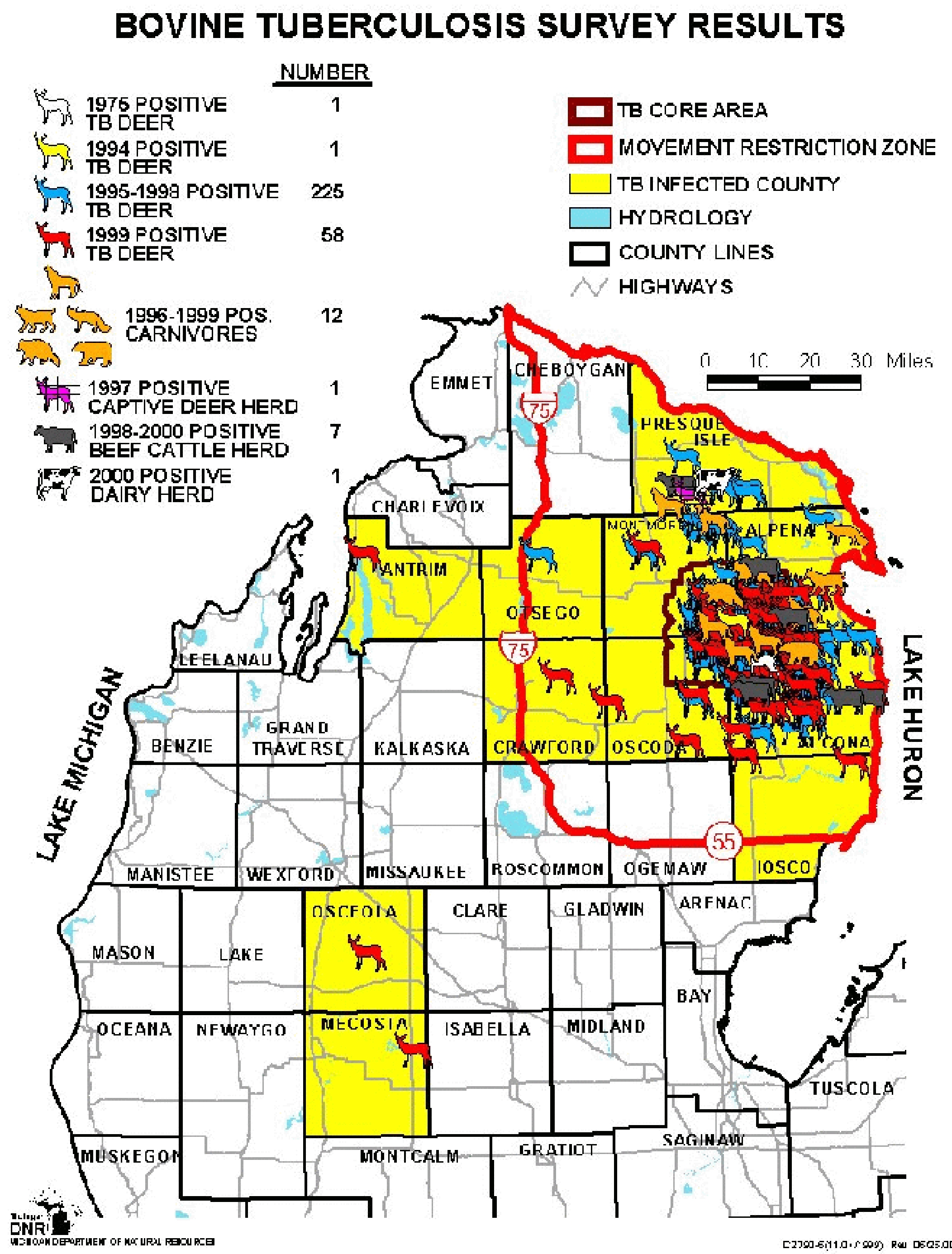
- Possible alternatives that move toward IC:
  1. Business interruption insurance
  2. Declining marginal (per head) indemnity
  3. Indemnities contingent on self-reporting
  4. Disease specific indemnity schedules to achieve SB

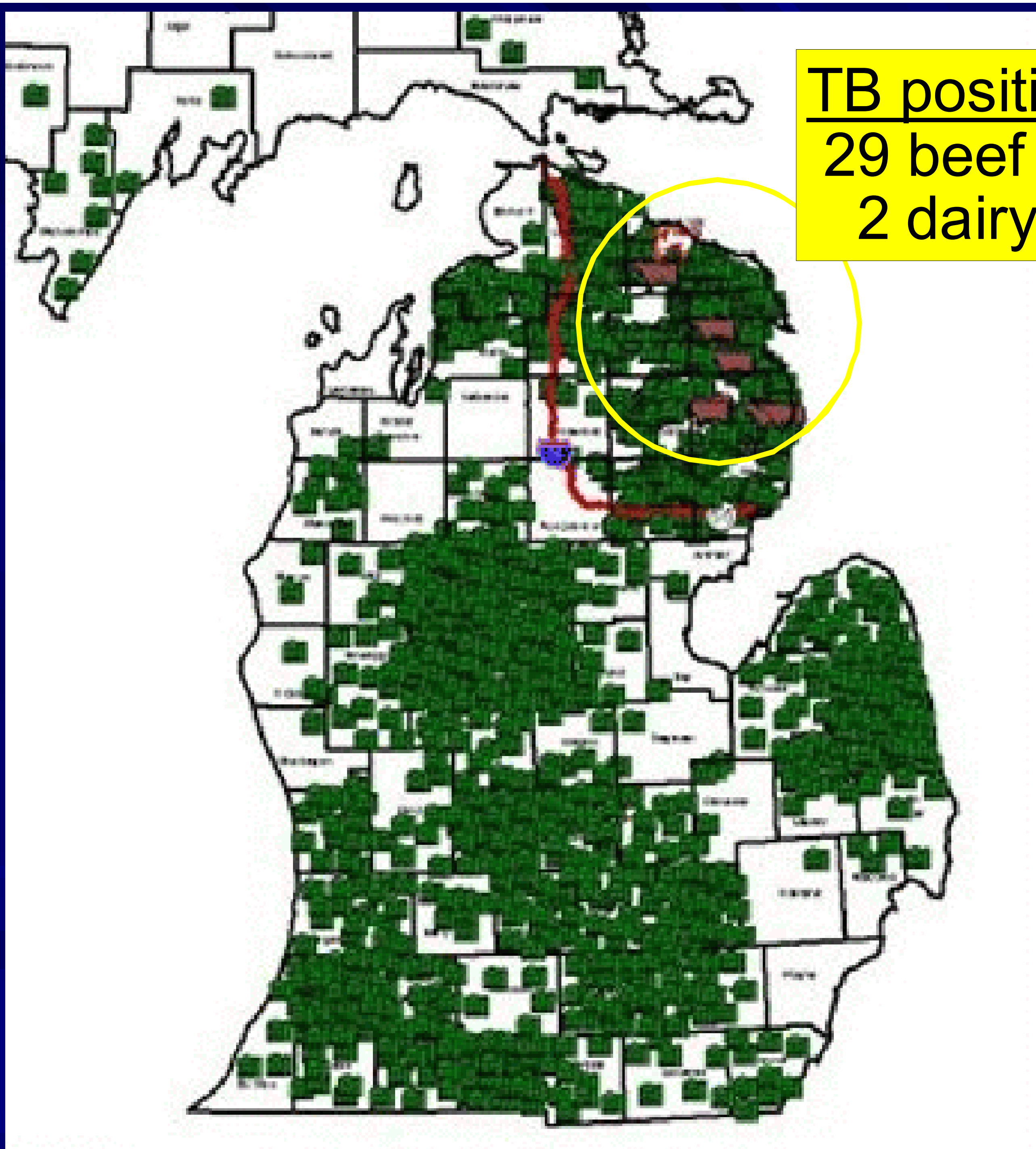
- Limitations
  - Feasibility of fines for non-disclosure
  - Imperfect farmer knowledge of θ (disease specific)

Bovine TB in Michigan

- Michigan TB accredited free from 1979 – 1998
- Positive deer found in 1995
- Sustaining in deer population
  - 4.4% prevalence rate in 1998; ~2% in 2005
- Management and control involves farmers, hunters, MDA and DNR
- Split-state status as of 2005
- 7 new infected herds so far in 2006




BOVINE TUBERCULOSIS SURVEY RESULTS
NUMBER
1975 POSITIVE TB DEER 1
1994 POSITIVE TB DEER 1
1995-1998 POSITIVE TB DEER 225
1999 POSITIVE TB DEER 58
1996-1999 POS. CARNIVORES 12
1997 POSITIVE CAPTIVE DEER HERD 1
1998-2000 POSITIVE BEEF CATTLE HERD 7
2000 POSITIVE DAIRY HERD 1
TB CORE AREA
MOVEMENT RESTRICTION ZONE
TB INFECTED COUNTY
HYDROLOGY
COUNTY LINES
HIGHWAYS
0 10 20 30 Miles
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
MONTMORENCY
ALPENA
ANTRIM
OTSEGO
LEELANAU
GRAND TRAVERSE
BENZIE
KALKASKA
CRAWFORD
OSCODA
ALCONA
LAKE MICHIGAN
LAKE HURON
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
BAY
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
75
55
DNR
MICHIGAN DEPARTMENT OF NATURAL RESOURCES



TB positive herds

29 beef herds

2 dairy herds

Farm Decisions

- Reporting not currently an issue in core area
- Farm biosecurity decisions still an issue

- Farms have been given the option of Test and Slaughter or Depopulation protocols

- All beef farms have depopulated while all dairy farms have chosen test and slaughter

Business interruption losses under depopulation

- Farms lose revenue and must cover fixed costs
- But do not have variable costs

- Therefore, business interruption losses are revenue less variable costs

- Categorization of fixed and variable depend on farm and length of depopulation

Size of Business Interruption Losses

	Milk Production[1]	Milk Production[1]	Feeder Steer[2]
	$/cwt	$/cow	$/cow
Revenue	14.89	2,990	833
“Variable” costs[3]	9.11	1,829	705
“Fixed” costs[4]	4.67	917	79
Business Interruption Loss[5]	5.78	1,160	127

[1] Source: Wittenberg and Wolf.
[2] Source: Wittenberg and Black.
[3] Include costs that are not incurred without the cattle enterprise including feed, veterinary, and marketing.
[4] Fixed costs include costs of empty facilities (taxes, insurance, depreciation) as well as hired labor. Hired labor was $2.42/cwt for dairy and $39/head for beef.
[5] Business interruption annual losses calculated as revenue less variable costs.

Conclusions

- Indemnity policy affects farm decisions
- More instruments and/or more refined instruments may be necessary to align public and private incentives
- Farm types and characteristics affect incentives