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

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- Eli Fenichel, MS Thesis
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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]

I ASK ALL PROSPECTIVE EMPLOYEES THIS QUESTION TO TEST THEIR REASONING.

YOU HAVE ONE FOX AND TWO CHICKENS THAT YOU NEED TO GET ACROSS A RIVER. YOU CAN ONLY TAKE ONE AT A TIME IN THE ROW-BOAT. THE FOX WILL EAT THE CHICKENS IF LEFT ALONE.

I'D BUY LIVESTOCK INSURANCE, THEN BARBECUE THE CHICKENS AND BLAME THE FOX.

CAN YOU START TODAY?
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
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+Wilén+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, $\theta$, is a random variable
  - Realization of $\theta$ 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, $\tau$, if disclose $\theta$

- 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 $\geq$ 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.

$\Rightarrow$ 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 \( \tau^{IC} \) 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)
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 $\alpha_0 > 0$

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

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

$\Rightarrow$ Impose more risk on farmer to get desired behavior
Regulator’s objective function:
\[ E\{V(w)\} + E\{\text{gov’t cost}\} \text{ s.t. farmer (IC)} \]

\[
\begin{align*}
\text{Max}_{\tau, b} & \quad \int_{0}^{1} V\left(w_0 + \tau - \lambda(\theta) - \rho^R(\theta) - rb\right) f(\theta, b) d\theta + \kappa \int_{0}^{1} (-\tau - m) f(\theta, b) d\theta \\
\text{s.t.} & \quad b \in \arg\max_{\hat{b} \in B} \int_{0}^{1} V\left(w_0 + \tau - \lambda(\theta) - \rho^R(\theta) - w\hat{b}\right) f(\theta, \hat{b}) d\theta
\end{align*}
\]

\[ \kappa = \text{weight regulator applies to budgetary outlays} \]
\[ m = \text{monitoring cost of infected herds} \]
LaGrangian and FOCs

\[ L = \int_{0}^{1} V(\pi_0 + I(\theta) - C(\theta) - wb) f(\theta, b) d\theta + \kappa \int_{0}^{1} (-I(\theta) - m) f(\theta, b) d\theta \]

\[ + \mu \int_{0}^{1} \left[ -V'(\pi) w + V(\pi) \frac{f_b(\theta, b)}{f(\theta, b)} \right] f(\theta, b) d\theta \]

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

\[ \frac{\partial L}{\partial b} : \int_{0}^{1} \left[ -V'(\pi) w + V(\pi) \frac{f_b(\theta, b)}{f(\theta, b)} \right] f(\theta, b) d\theta + \kappa \int_{0}^{1} (-I(\theta) - m) f_b(\theta, b) d\theta \]

\[ + \mu \int_{0}^{1} \left[ V''(\pi) w^2 f(\theta, b) - 2V'(\pi) w f_b(\theta, b) + V(\pi) f_{bb}(\theta, b) \right] d\theta = 0 \]

\[ \Rightarrow \mu > 0 \]
Comparison w/ First-Best

Regulator’s FOC in a FB (unconstrained) world:
\[ V'(w) - \kappa = 0 \Rightarrow \tau^{FB}(\theta) \]

Deviations from FB are characterized by:
\[ \tau^{SB}(\theta) < \tau^{FB}(\theta) \iff \frac{f_b(\theta, b)}{f(\theta, b)} + \frac{-V''(w)}{V'(w)} r < 0 \]
\[ \tau^{SB}(\theta) > \tau^{FB}(\theta) \iff \frac{f_b(\theta, b)}{f(\theta, b)} + \frac{-V''(w)}{V'(w)} r > 0 \]

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)

τ^{SB}(θ) 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 $\theta$ (disease specific)
Bovine TB in Michigan

- 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
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

<table>
<thead>
<tr>
<th></th>
<th>Milk Production&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Milk Production&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Feeder Steer&lt;sup&gt;2&lt;/sup&gt;</th>
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<tbody>
<tr>
<td></td>
<td>$/cwt</td>
<td>$/cow</td>
<td>$/cow</td>
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<tr>
<td><strong>Revenue</strong></td>
<td>14.89</td>
<td>2,990</td>
<td>833</td>
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<tr>
<td><strong>“Variable” costs</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
<td>9.11</td>
<td>1,829</td>
<td>705</td>
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<tr>
<td><strong>“Fixed” costs</strong>&lt;sup&gt;4&lt;/sup&gt;</td>
<td>4.67</td>
<td>917</td>
<td>79</td>
</tr>
<tr>
<td><strong>Business Interruption Loss</strong>&lt;sup&gt;5&lt;/sup&gt;</td>
<td>5.78</td>
<td>1,160</td>
<td>127</td>
</tr>
</tbody>
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<sup>1</sup> Source: Wittenberg and Wolf.
<sup>2</sup> Source: Wittenberg and Black.
<sup>3</sup> Include costs that are not incurred without the cattle enterprise including feed, veterinary, and marketing.
<sup>4</sup> 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.
<sup>5</sup> 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