Economic Incentives in the Management of Infectious Animal Diseases

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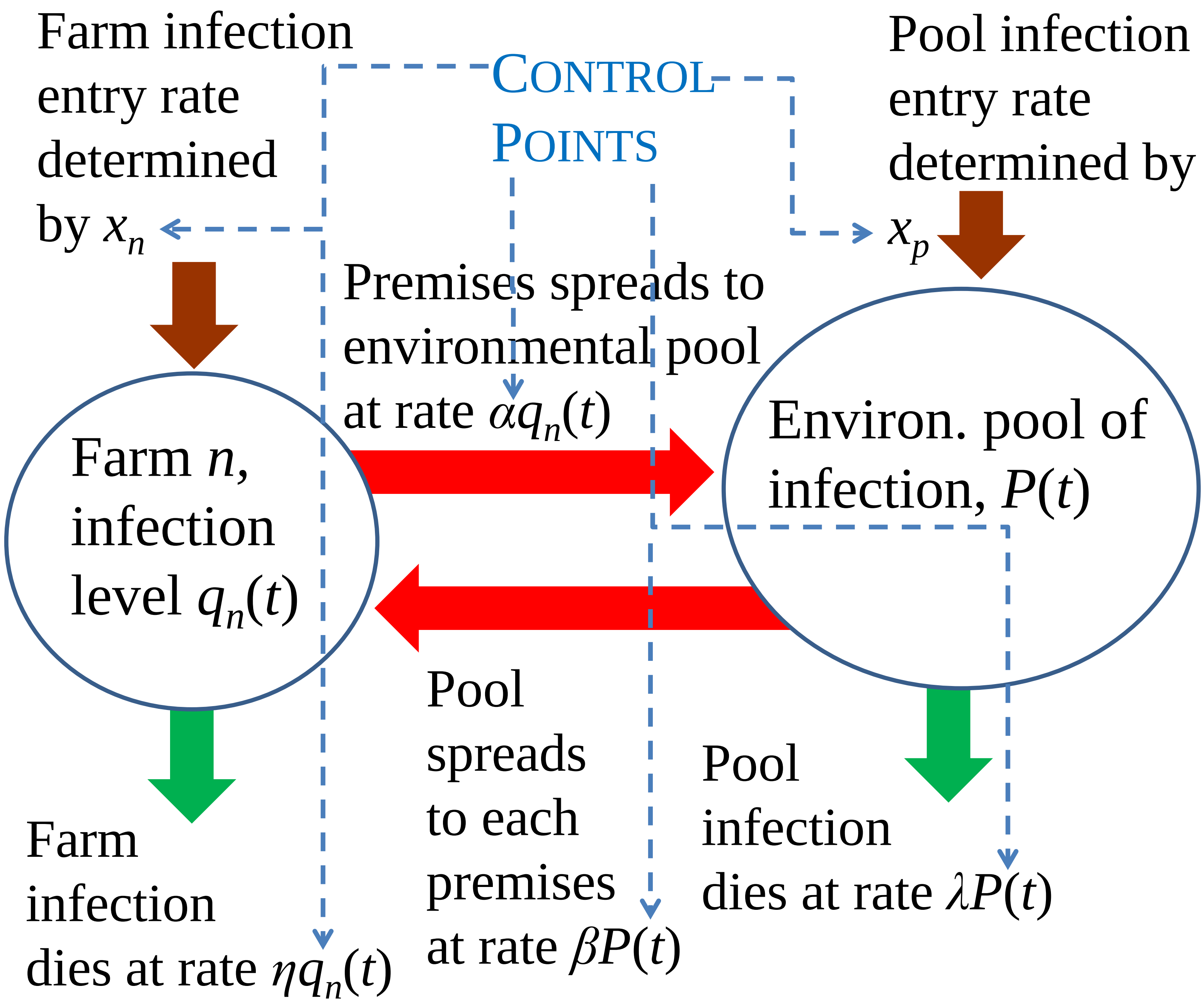
Economic Models and Viewpoints on Infectious Animal Diseases

- Substitutes and Complements
- Games farmers may play
- A voluntary program, and how tipping may occur
- Some talking points on policy issues on distributed knowledge, veterinarian markets and professionalization, animal protein industry structure, etc
- Questions for you

Substitutes: Common Pool, Endemic

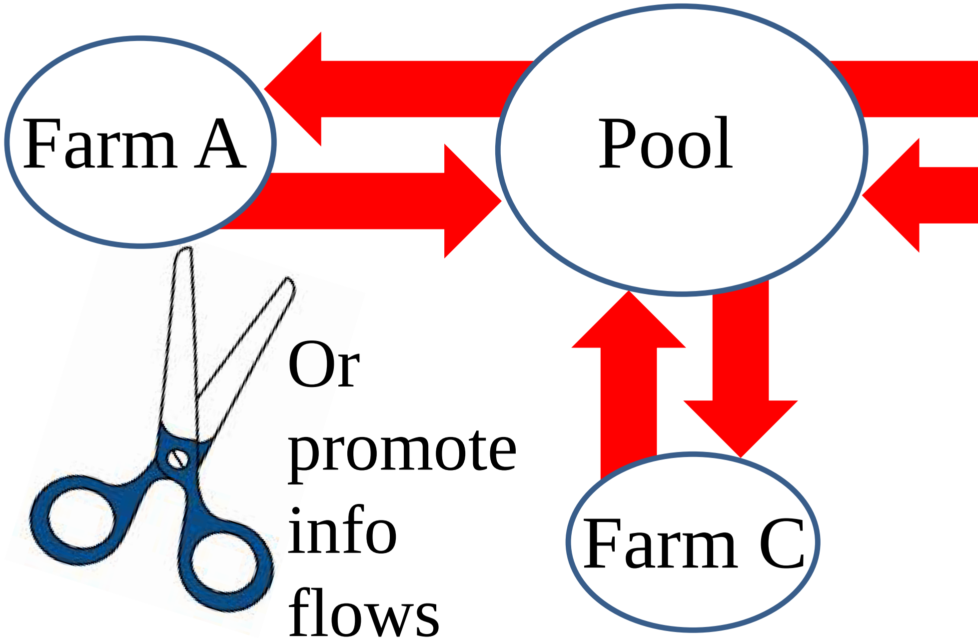
- What is the setting? For endemic infectious diseases, the notion of a 'common pool' is often invoked
- Quantitative epidemiologists often work with variants of differential equation system to study disease dynamics and equilibrium. With exception of vaccination, missing typically are biosecurity inputs
- Suppose that there is an environmental pool of infection that can be targeted with public effort x_p and N farms each of which can target disease on their farm with effort x_n
- Can readily show that when things settle down more public effort means less private effort



Farm infection entry rate determined by x_n
CONTROL POINTS
Pool infection entry rate determined by x_p
Premises spreads to environmental pool at rate $\alpha q_n(t)$
Farm n, infection level $q_n(t)$
Environ. pool of infection, $P(t)$
Pool spreads to each premises at rate $\beta P(t)$
Farm infection dies at rate $\eta q_n(t)$
Pool infection dies at rate $\lambda P(t)$

Equilibrium for 'common pool'

- Key point 1: private efforts to control (i.e., x_n) substitute. Others' actions reduces my need to act
- Each farm may
  - happily lean on good actions by other farms & gov't,
  - happily incur costs for own-farm to stay upright, but
  - be reluctant to incur cost of being leaned on
- Leaning on others leads to sub-optimal outcomes
- Key point 2: public effort to control an endemic disease (i.e., x_p) substitutes for private effort to control (i.e., x_n)



*Much of gains from mkts can be had from contracts, with less risk. For ruminants, grass is a fly in ointment

*Larger enterprises are easier to engage in government & private programs, and have biosecurity input scale economies

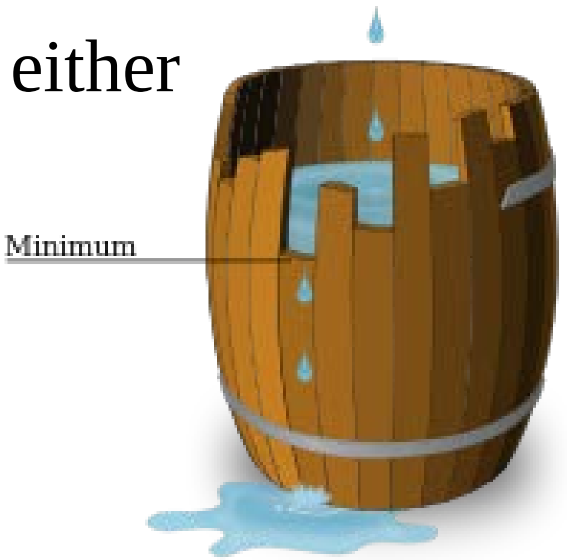
*Do we want to go there? Organics, an. welfare, demand for pastoral env’t. Better understanding the plumbing may be the best solution. That involves integrated interdisciplinary work

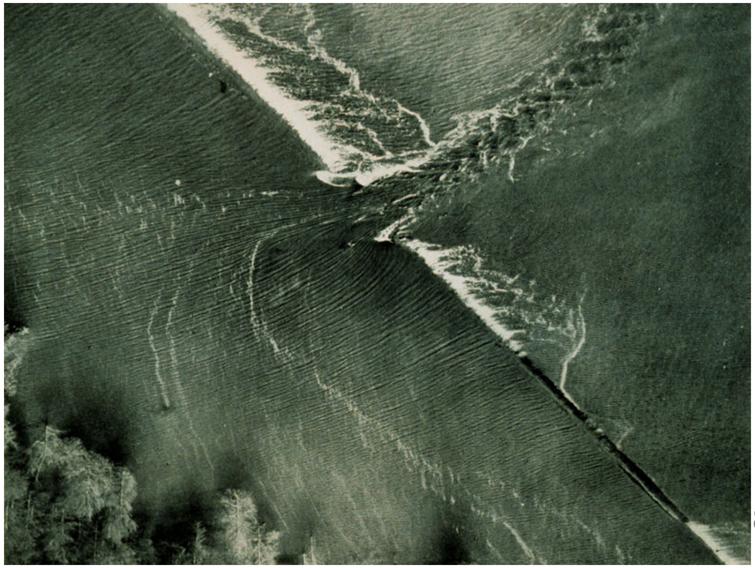
Complements: Weakest Link and Keeping a Disease out (Exotic)

- Suppose you and I try to keep a disease out of a region
- I gain a $100 if it is out, and so do you
- If I let it in then it spreads to you for sure, and likewise with you
- It costs $20 to take some effort to be sure that I don’t let it in
- If I don’t take effort then it enters my farm with probability 0.25, and likewise with you

Weakest Link

- Rough numbers: If I know you take the effort then I compare expected loss of 100*0.25 =25 with cost of 20. I take the action
- If I know you don't take the effort then my baseline is 100*(1-0.25) = 75 and I compare expected loss of 75*0.25 = 18.75 with cost of 20. I don't take the action either





Coordination for stronger weakest link

- Point is that if I believe others have done their part then I have a very strong private incentive not to be the weakest link
- But if I think that you have slacked then my private incentive to act is weak
- A disease manager's task is to coordinate and cajole to get everyone on the best same page, namely likely all taking the action
- Share information, foster communication, understanding and trust

Prevention & Communication

- Each producer facing costly biosecurity action to keep a disease/pest out of a region can think
  - Why bother, entry is likely anyway, or
  - Better do it as others are, I'm a weak link
- Which thought wins depends on what one thinks others do. Either *most act* <u>or</u> *few act*
- Communication about what others are doing is key to ensuring most see their action as critical

Preventing and Stamping Out an Highly Infectious Disease

- Public and private sector actions are involved in preventing and stamping out PRRS, FMD, etc.
- How do public prevention and stamp-out efforts affect private prevention and stamp out efforts?
- Turns out theory would suggest that public effort to prevent entry encourages private sector parties to try harder to prevent, and to stamp-out in the event of an outbreak
- Securing property rights and reducing property transfer costs should also better engage private sector efforts

Complements: Another Way to Look at Keeping Disease Out

- Standard loss benefit analysis for disease asserts that if a farmer faces loss at level L with probability p and can take an action at cost c to eliminate the risk of direct entry onto a farm;
- then the action should be taken if and only if

$$pL \geq c$$

- This makes sense to a farmer because expected loss to be avoided is pL and cost is c so profit change is $pL - c$. Rule improves the bottom line
- But infectious diseases create externalities

What is the issue?

- Suppose now that there are two farms, A and B, in a region. Either farm can introduce a disease with probability p and pass it on to the other farm with (independent) probability q
- Now a given farm has two ways to get disease; directly with prob. p and indirectly with prob. q
- Expected loss is
  - $pL + pqL$ to each if neither act. Why?
  - c to each if both act? Why?
  - $pqL + c$ to a farm that acts when the other doesn't
  - pL to a farm that doesn't act when the other does

Games

For both farms, (Act,Act) is best box to be whenever $c < pL+pqL$

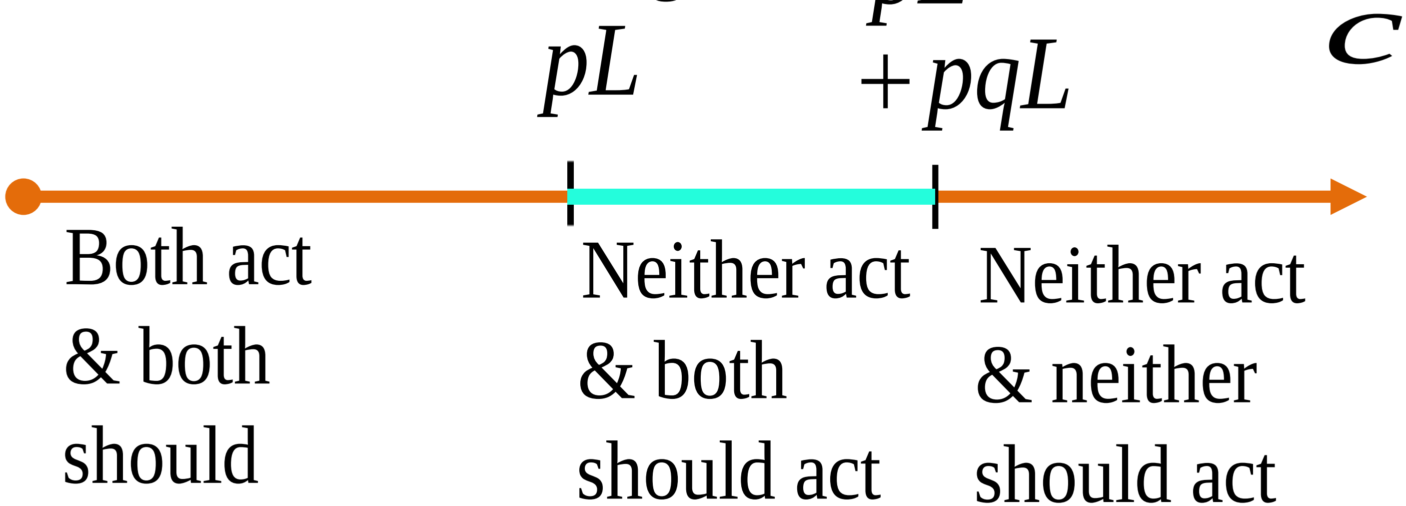
- This can be put in a game theory payoff matrix as follows. All entries are losses, so high is bad.

Farm	B acts	B doesn't act
A acts	(c, c)	$(pqL+c, pL)$
A doesn't act	$(pL, pqL+c)$	$(pL+pqL, pL+pqL)$

- Left entry is payoff to farm A, right to farm B
- When farm B does not act then farm A acts if and only if $pqL+c \leq pL+pqL$, i.e., $c \leq pL$
- When farm B acts then farm A acts if and only if $c \leq pL$
- So neither acts whenever $c > pL$

Outcome

- If neither farm acts then loss to each is $pL + pqL$
- We have the following



- As infectiousness q increases, the problematic gap increases

Voluntary Control Program: Participation Incentive

- The success of a voluntary program hinges on producer participation
- Most voluntary programs span multiple years, with evolving participation rates
- It is important to consider dynamic interactions among participant choices
- Below are 4 examples, all from US

Interesting Dynamics of Disease Control & Related Programs

- Texas Tick Fever
- National Animal Identification System
- NPIP (Nat. Poul. Imp. Prog.)
- Voluntary Johne's Disease Herd Status Program

- Good (Texas Tick Fever, NPIP) worked. Bad (USNAIS for bovines) failed. Ugly (Johnes) a grind

Texas Tick Fever

- Texas tick fever was a major threat to the U.S. cattle industry from the Civil War until end of World War I
- Efforts to eradicate tick carriers started as early as 1898
  - Active resistance to the programs emerged after participation became mandatory in 1906
  - larger ranchers began to see the benefit as sources for re-infection diminished and returns on treated animals increased
  - a virtuous cycle of events led to a better equilibrium for those who could bear eradication costs
- By 1933 Texas fever was no longer a major problem for the cattle industry

National Animal Identification System (NAIS)

- Estimated benefit from NAIS implementation increases as participation levels increase
  – in event of F&M disease outbreak producer losses for a program with a 90% participation rate would be $4.5 billion less than a program with a 30% participation rate (NAIS Benefit-Cost Research Team 2009)
- Participation rates in the premises registration step has reached only 18% for cattle (Schnepf 2009), and stalled in mid 2000s
- For bovines this program was largely unsuccessful, due partly to failure by the USDA to communicate program benefits to producers (Anderson 2010)

NPIP

- Voluntary and set up in 1930's as a cooperative program between industry, state, and US federal government, initially to eliminate Pullorum Disease, widespread and could cause devastating losses
- Program later extended to testing/monitoring for other diseases, incl. AI
- Covers commercial hens and broilers, turkeys, waterfowl, show and backyard poultry, and birds for shooting
- Participation requires Annual P-T Testing, AI Testing, Annual Premises Inspection and Records Audit
- Widespread participation and has been very successful in cleaning up disease

Application (with Tong Wang)

- Johne's Disease (paratuberculosis) is a bovine disease that U.S. government seeks to control through a voluntary reporting scheme
- Infectious and eventually causes decreased productivity in beef and dairy cattle. Some concern about zoonotic implications
- Scheme involves voluntary testing by herd owner and test-based herd classification. Owner selling, e.g., dairy replacement heifers, can use this information to boost price or remain silent
- Silent herds: either *i*) don't test or *ii*) do & don't tell

Voluntary Johne's Disease Herd Status Program

- Larger herds were more likely to participate than smaller herds (Wells, Hartmann and Anderson 2008)

  During 2005-'06

  - 52.9% of Minnesota dairy herds with ≥ 500 cows participated, but
  - 9.9% of herds with < 50 cows
- Dairy herds were more likely to participate than beef herds
  - Starting from less than 0.9% in 1999, U.S. wide dairy herd participation had increased to 30.8% by the end of 2006
  - Meanwhile beef herd participation rate had increased from less than 0.1% to 2.1%

Model

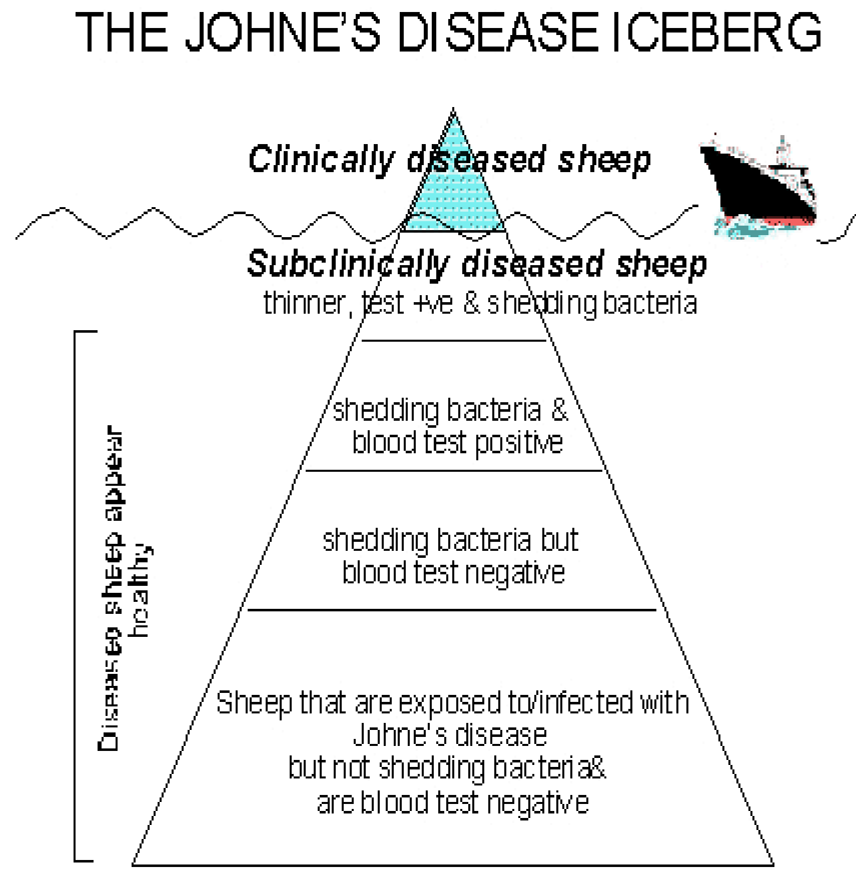
- Our model is closely connected with the quality disclosure literature
- We extend Shavell's 1994 RAND J. Econ. paper to study dynamics. Argument essentially reverses Akerlof's famous study of unraveling in car markets
- Producers make two choices: whether
  - to participate in a program to obtain quality information
  - and, if participating, to disclose such information
- In the version to be presented, both participation and disclosure are voluntary

Plumbing issue: Why test quality can matter for economic outcome

- Consider Johne's disease test (poor quality) and buying cows for production. Suppose there are two test outcomes; high H, or likely not diseased, and low L
  - Buyer would like to know that they are getting H, & would pay more
  - But seller may be ignorant too, have to pay test cost and may not want to report outcome
  - So there may be two cow types in the market; a) tested and known to be H, and b) the rest, i.e., a pool of *i*) untested and *ii*) tested but found by seller to be L
  - Incentive to test will be given by gap between price for known H cows and average price for the rest

Application

- Johne’s Disease is infectious and eventually causes decreased productivity
- Three key components of U.S. bovine program: *a*) education, *b*) management, and *c*) herd testing and classification
- Silent herds: either *i*) don’t test or *ii*) do & don’t disclose



Source: Ontario Ministry of Ag. Food.

Model Outline

V : value of disease-free animal

αV: value of diseased animal

r : true disease-free rate in a herd

$[r + (1 - r)\alpha]V$: mean unit value of animal from herd

$F(r)$: distribution of disease-free rates r

r_t^S: time t average disease-free rate in silent herds

c: participation cost, distribution $G(c) : [\underline{c}, \overline{c}] \rightarrow [0,1]$

c and r assumed statist. indepen. (Pillars et al. 2009)

Expected Premium in Period *t*

Unit value of animal outside program: $[r_t^S + (1 - r_t^S)\alpha]V$

Unit value of animal inside program:

$$\begin{cases} [r_t^S + (1 - r_t^S)\alpha]V, & \text{if } r \le r_t^S \\ & \text{(choose not to reveal; take pooled price)} \\ [r + (1 - r)\alpha]V, & \text{if } r > r_t^S \\ & \text{(choose to reveal; take market prices)} \end{cases}$$

Expected premium: expected price in less price outside

$$I_t(r_t^S; \alpha, V) = (1 - \alpha)V \int_{r_t^S}^{1} (r - r_t^S)\, dF(r)$$

Producer Participation decision

If $c \le$ market premium (or cost $\le$ expected premium)

then it makes sense to participate in this period.

So as $G(c) =$ distribution of costs,

in period $t+1$, fraction $G\left(I_t(r_t^S)\right)$ of producers join

Presumably these participating farms would be larger farms with scale economies in participation costs

Expected Premium $I_t(r_t^S;\alpha,V)$

- Expected premium from participation will increase if:

i) Society becomes more aware of the disease $\alpha\downarrow$

ii) value of an animal increases $V\uparrow$

iii) average disease-free rate among silent producers decreases $r_t^S\downarrow$

As the perceived mean quality in the unknown pool declines, then buyers become willing to pay a larger premium to obtain livestock with a confirmed high disease-free rate

Period t+1

r_t^S and I_t are pre-determined in period t

Participation decision based on premium I_t :

a share $\eta_{t+1} \equiv G\left(I_t(r_t^S)\right)$ of producers join

Test results revealed, disclosure decision made based on r_t^S

r_{t+1}^S and so I_{t+1} are determined

Move on to period $t+2$

Momentum Result

Under plausible conditions outlined in paper, over time

i) mean disease-free rate of silent producers falls;

ii) premium from program participation rises;

iii) participation rate rises;

Or

$$r_0^S \equiv E[r] \geq r_1^S \geq r_2^S \geq \; \dots \; \geq r_\infty^S$$

$$I_0 \leq I_1 \leq I_2 \leq \; \dots \; \leq I_\infty$$

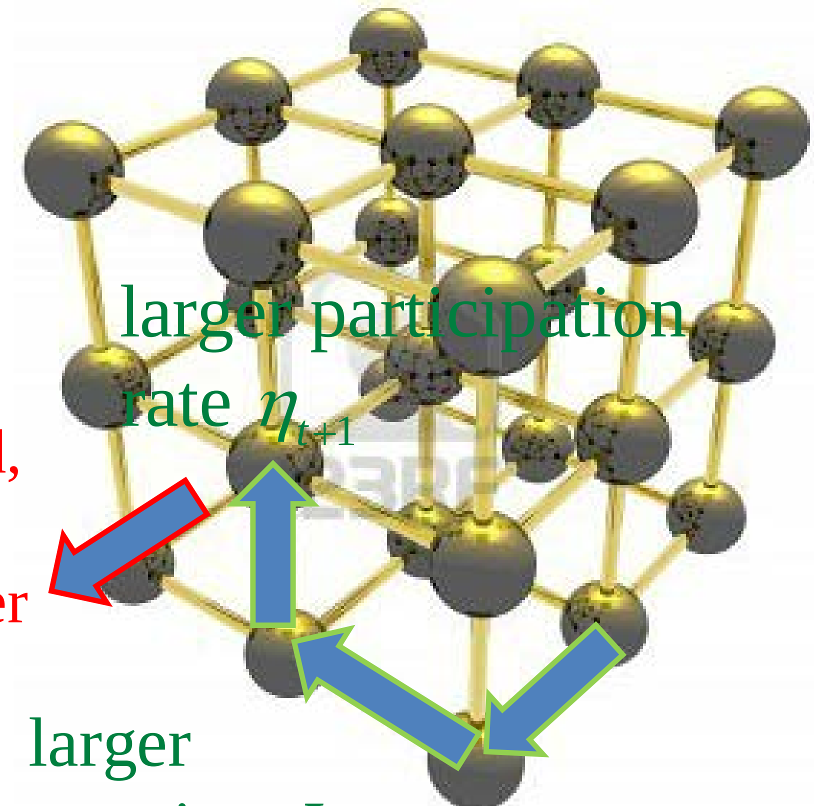
$$\eta_0 \equiv 0 \leq \eta_1 \leq \eta_2 \leq \; \dots \; \leq \eta_\infty$$

Momentum on a Lattice

Hope it attains escape velocity

Think of a point lattice
that extends indefinitely in 3D

next period, even smaller r_{t+1}^S



Draining the Swamp?

All producers are silent to begin with.
Growers see premium I_0
and make program choice η_1.
As growers enter program, mean
disease-free rate for silents r_1^S falls.
This raises I_1 so more enter program
(or η_2 rises) and so r_2^S falls.
And so on to possible convergence

But better test quality or knowledge on disease transmission, etc., likely to have the same effect. More herds test. Those that don't are most likely problematic; will get low prices; will improve or close down

Comment

- It is assumed here that producers actually know several related pieces of information.

  In particular the market premium, the premium reflects participation rate and some sense of the distribution of disease-free rates

- These information are public goods (like weather information) and it is reasonable to presume a role for government in bringing such information together and making these public

Simulation

- Model parameter values are based on the current literature on Johne's disease

- We assume that both average disease-free rate and the participation cost are uniformly distributed

$$r \sim U[\underline{r}, 1]; \quad c \sim U[\underline{c}, \overline{c}]$$

- Intent is to predict participation rates under different scenarios

Parameters

$V:$ value of a healthy dairy cow \$1,696

the simple average of prices over 2006-2010

α: $0-30\%$ (Groenendaal and Galligan 2003)

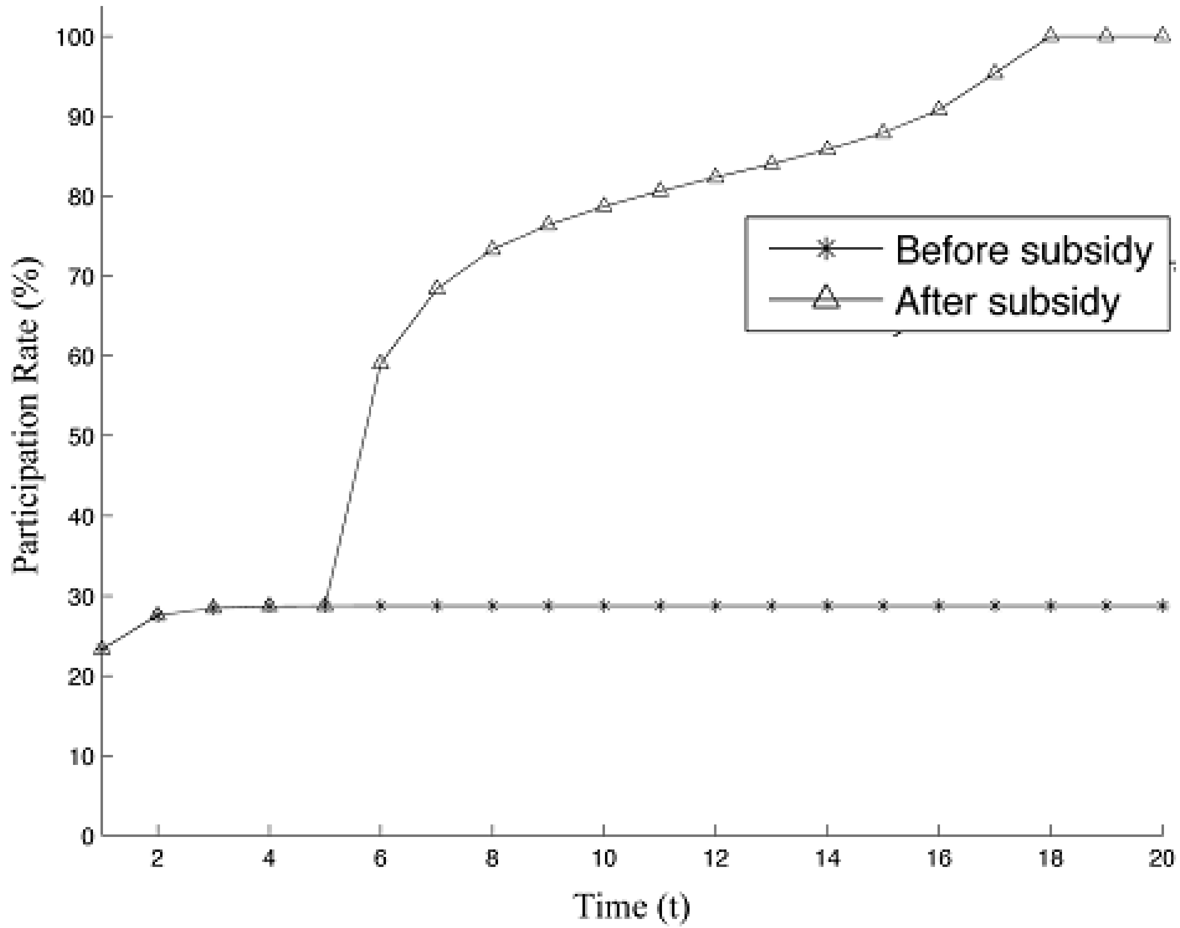
$r:$ $r \sim U[0.89,1]$

average within-herd prevalence is 5.5% (USDA 2005)

$c:$ $c \sim U[5.79,81.07]$ (Pillars et al. 2009)

Application: Tipping

- $\alpha = 0$ Momentum can stall. A temporary cost subsidy to some high-cost growers could tip equilibrium, as in theory of Heal & Kunreuther (2006)



Tipping

- Definition of Tipping: Moving from non-participation or partial participation to full participation equilibrium, perhaps because of some market event or economic engineering.

Other instances: network economies & incompatibilities that caused writers to move from Wordperfect to Word, or English to dominate international business

Tipping in Simulation just provided

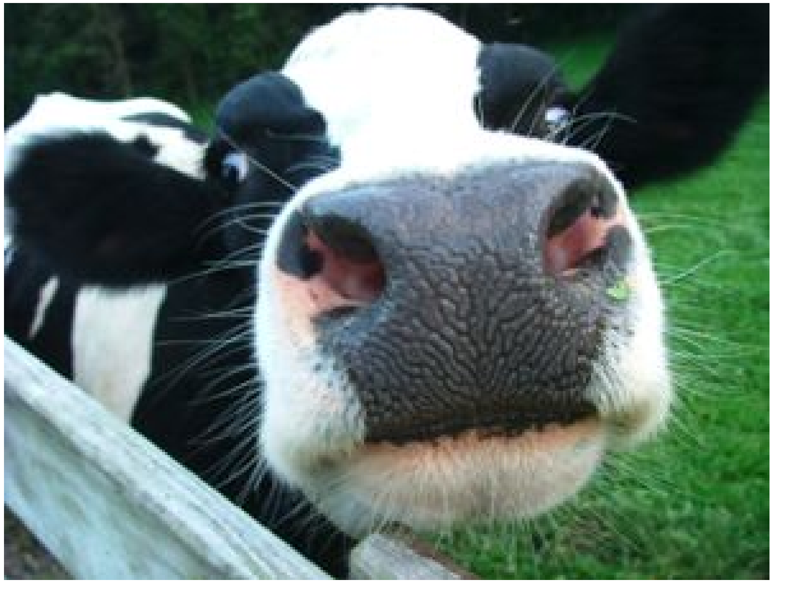
- Equilibrium without subsidy will be reached at around the 5th period, where 29% of producers participate and the price premium is $27
- In 6th period, suppose the government provides a uniform subsidy of $55 to producers in the upper 30 percentile of the cost distribution
- Then the participation rate will climb again and the new full participation equilibrium will be reached after another 13 periods. No producer has the incentive to deviate from it even when government subsidy is withdrawn

Caveat

- So far we've assumed that participation doesn't affect disease-free rate
- So momentum has nothing to do with that
- But voluntary programs usually include education + management components
- Effective program below accommodates these aspects of programs
- These would only strengthen the case that participation would grow over time

Further Caveat

- Nor has our model addressed issue of disease infection externalities
- Channel through which participation changes was through:
  - rational expectation on premium
  - has nothing to do with any cross-farm disease effects



Policy

- Similar to cost subsidy, government may also boost price premium and motivate program participation through:

➢ Educating producers

➢ Providing producers with opportunities to credibly communicate a quality trait

Policy

- Program coordination
- Information collection and distribution
- Improving test quality?
- Temporary subsidies

Talking Point: Animal Id.

- Recurrent events in US show need for animal id. USDA Nat. Animal Id. System seeks
  - Premises registration (give contact info, no cost)
  - Animal identification (tag animal or lot number)
  - Animal tracing (choose private sector tracking database and report relevant movements)
- Voluntary, resistance from some smaller producers. Cost ($1-$3/head), privacy, paperwork issues. Growers may resent inference they aren't doing enough

TP: Strength of China Policy on Vert. & Horiz. Integration?

- Large, integrated feedlots tend to be
  - ❖- exposed to large losses, centralized feed etc. systems, and productive but perhaps vulnerable stock
  - ❖+ easy to process in prevention/crisis and don’t use marts
  - ❖+ scale efficient when biosecuring. Illustration: 1 pig needs 4 units of fencing, 100 need 40 or 0.4 per animal

TP: Biosecurity in China's Farmed Animal Sector

- I was on NRC assessment of NBAF (Nat. Bio. & Agro-defense Fac.), 2012, involving much discussion about sharing lab capacity internationally
- Veterinarians a group of heavy hitting globe trotters. Discussions saw little role for China in this dimension of global animal health management
- This led me to identify gap in international audience's understanding of China's pertinent infrastructure and legislation
- Why I sought to work with Xinjie and Wanlong in developing an overview available to int'l audience

TP: Distributed Knowledge & Professionalized Animal Health Jobs

- Animal disease incidence is dispersed, as are problems with animal health administration
- Strong state action can be great for getting defined tasks done
- Effect on eliciting investment in self-improvement, supporting growth of local leadership in animal health, new ideas, etc., is less clear
- One interesting issue I was made aware of was China's efforts to professionalize animal health jobs, almost from scratch. Impressive and encouraging to see

TP: Distributed Knowledge & Professionalized Animal Health Jobs

- How to do it right is an intriguing question
- I've spent 23 years in US academics where
  - asserted culture is of independent thought,
  - institutions are there to protect that,
  - jobs are not on line, and yet
  - people are afraid to say what they think on many matters
- Result: investments in dubious projects abound
- Independent wealth, independent thought and governments that listen matter, in animal health as elsewhere
- Question: strategies to develop animal health careers?

Other Questions for You

- Out of ignorance and cursory curiosity
- What are CAHEC's missions?
- Dominant view of animal health; cheap protein? concerns about adverse spillovers to general economy? One Health dimension?
- How is China seeking to grow its international footprint, connect with diaspora on animal health professionals?
- Journals in English?
- Place for me to read up on these matters?
- I'm interested in working with you guys if you see a role for me & you think it worth your effort to set me in a mutually agreeable direction

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