Livestock Disease Indemnity Design When Biosecurity Externalities Exist

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Introduction

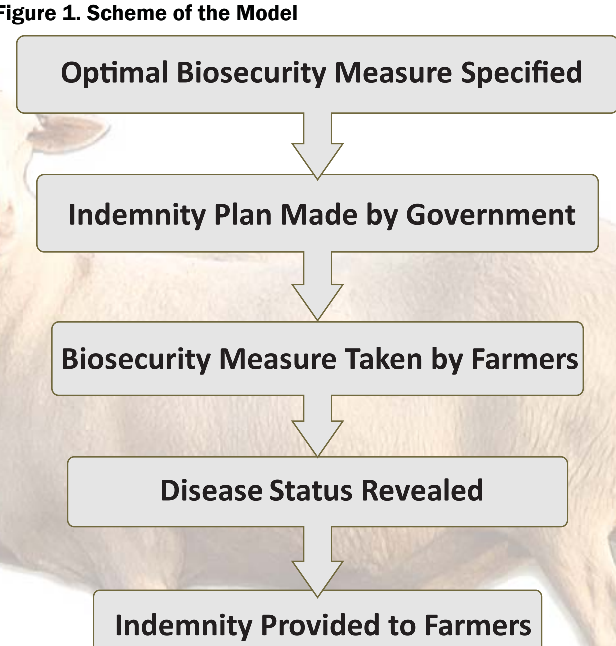
GOVERNMENT INDEMNITY PLAYS two conflicting roles in livestock disease control. The positive side is that it gives producers an incentive to report. In this regard, empirical studies have shown that the supply of scrapie-infected sheep changes with different levels of indemnity payment (Kuchler and Hamm, 2000). Early disclosure of disease is vital in disease control and eradication, as reflected by shorter disease duration and reduced total loss. On the other hand, government indemnity may induce producers to curtail their biosecurity input as a result of reduced loss from disease (Muhammad and Jones, 2008).

As a result, careful thought is required to properly design any government indemnity scheme seeking to control a livestock disease. Previous literature has generally assumed away the third party externality effects of livestock disease. However, considering contagious diseases such as Bovine TB, the output of one farm depends not only on its own biosecurity effort, but crucially on the measures taken by adjacent farmers as well. Poorly maintained fences and common use of water or other resources can lead to infection by neighboring herds. See Table 1 for examples of exotic and endemic animal diseases in the U.S., and relevant biosecurity measures to be taken. Even low contagion diseases (e.g., bovine spongiform encephalopathy) generate externality problems in that they may cause major losses for producers of non-infected livestock through price impacts when very few animals are affected. This is a major issue for those seeking to rid a region of a disease.

Table 1. Examples of exotic and endemic animal diseases in the United States

Rift Valley Fever	BSE	FMD	Johne's Disease
Mosquito-borne exotic disease	Non-contagious exotic disease	Highly contagious exotic disease	Contagious, chronic endemic disease
Endemic in sub-Saharan Africa, vaccines are used to protect animals in endemic regions	BSE can be prevented by not feeding ruminant tissues that may contain prions to susceptible species	Control over the importation from counties where FMD occurs; keep animal, people movement to minimum; clean thoroughly	Remove calves from pen ASAP to reduce the risk of ingestion of JD bacteria; determine the JD status of the herd for replacements

Figure 1. Scheme of the Model



Model

WE PRESENT A ONE-PRINCIPAL, two-agent model in the manner of Mookherjee (1984), where the principal stands for the government and the agents stand for two producers whose livestock face a probability of contracting a certain contagious disease.

A diagrammatic explanation of the model scheme can be found in Figure 1. Here the possible livestock output of each producer is jointly determined by the biosecurity inputs of both producers as well as the ambient disease prevalence rate. Let $q_i(b_i, b_{-i}, \theta)$ denote the output produced by producer i, where b_i and b_{-i} are respectively the biosecurity inputs for producer i and the rest of producers, and $\theta \in [0, 1]$ stands for an ambient disease prevalence rate. $I_i(q_i, q_{-i})$ is government's indemnity to agent i when the output pair is (q_i, q_{-i}) and w represents the unit cost of biosecurity input. The joint probability density that the output level (q_1, q_2) is realized given the biosecurity input level (b_1, b_2) is $f(q_1, q_2 \mid b_1, b_2)$. Producer i's utility function can be denoted as $U\{q_i, I_i(q_i, q_{-i}), b_i\} = V\{q_i, I_i(q_i, q_{-i})\} - b_i w$. Assume the producers' reservation profit is $\underline{U}$.

Here, the objective of the government is to choose a pair of indemnity payment functions $\{I_1(q_1, q_2), I_2(q_1, q_2)\}$to minimize its expected indemnity payment, subject to each agent choosing the optimal biosecurity input level $(\hat{b}_i, \hat{b}_{-i})$:

$$\min_{I_1, I_2} \iint [I_1(q_i, q_{-i}) + I_2(q_i, q_{-i})]\, f(q_i, q_{-i} \mid \hat{b}_i, \hat{b}_{-i}) dq_1 dq_2.$$

Under an optimal indemnity scheme, strategy pair $(\hat{b}_i, \hat{b}_{-i})$ satisfies participation constraint and nash incentive compatibility constraint:

$$\iint U(q_i\, I_i(q_i, q_{-i}), \hat{b}_i)\, f(q_i, q_{-i} \mid \hat{b}_i, \hat{b}_{-i})\, dq_i\, dq_{-i} \geq \underline{U}$$

$$\iint U(q_i\, I_i(q_i, q_{-i}), b_i)\, f(q_i, q_{-i} \mid \hat{b}_i, \hat{b}_{-i})\, dq_i\, dq_{-i}$$

$$\geq \iint U(q_i\, I_i(q_i, q_{-i}), b_i)\, f(q_i, q_{-i} \mid \hat{b}_i, \hat{b}_{-i})\, dq_i\, dq_{-i}, \forall b_i \neq \hat{b}_i.$$

Analysis

SUFFICIENT CONDITIONS UNDER which a separate indemnity contract between the government and a farmer will be optimal are identified. It requires that no externalities, as discussed, exist among producers. Figures 2a and 2b depict the cases in which a separate contract for farmer 1 or 2 is optimal, while Figure 2c shows the case in which separate contracts are optimal for both farmers. In other cases optimal indemnity contract that takes externality effects into account requires one producer's indemnity to be a decreasing function of the other producer's output. An indemnity scheme of this form will improve the welfare of the government and all farmers, compared with an indemnity contract that ignores these effects. Pareto improvement is achieved due to improved risk sharing (Hölmstrom, 1979).

Figure 2a. Separate contract for farmer 1 is optimal

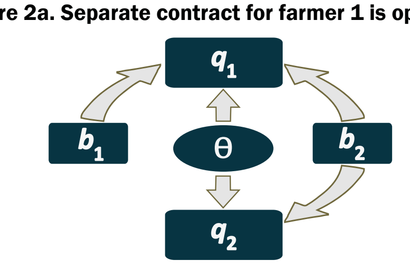


Figure 2b. Separate contract for farmer 2 is optimal

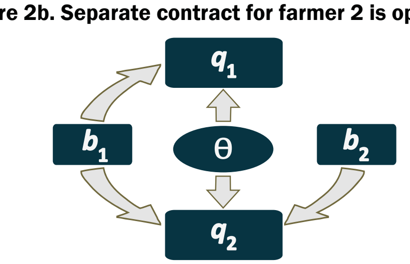
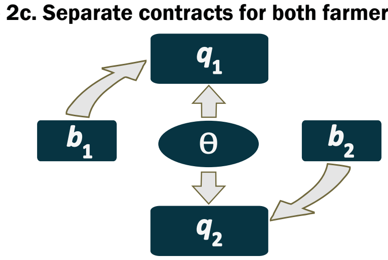


Figure 2c. Separate contracts for both farmers are optimal



We find that if the disease is exotic and all the farms are disease susceptible, then the current government indemnification practice is optimal, i.e., the indemnity level should be based on the fair market value. Suppose, on the other hand, that a disease is endemic, and it is known that producer A has the disease-harboring herd while producer B's herd is disease susceptible. Then, all else equal, optimal biosecurity inputs for producer A will be higher than is the case for producer B. To provide farm A with an incentive to biosecure optimally, its indemnity level should be less than the fair market value.

Conclusion

BIOSECURITY EFFORTS PLAY a fundamental role in livestock disease control. If managed improperly, there might be widespread economic losses. This study takes into account the individual producer's incentive to use the biosecurity inputs in an environment where third party externalities exist. We suggest that the indemnity level should not to be set uniformly as the fair market value but should be conditioned on the nature of the disease and the other herds' disease status as well.

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