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# Producer Livestock Disease Management Incentives and Decisions

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## Abstract

This paper examines the economics of farm decisions to prevent and control infectious livestock disease. In the case of diseases with costly control tolerating some level of disease is often rational to the producer. Public policy intervention is based on future value and public good aspects of disease control which can lead to a discrepancy between private and public action thresholds. Producer incentives for disease management can be changed through new technologies that lower the cost of prevention or control, subsidies or cost sharing of control measures, or on the consumer side, a change in public desire for disease risk-free products that changes relative prices. Economists can incorporate appropriate epidemiology of a given disease in economic models to inform policy-makers on optimal value or method of subsidies that would prove most effective to make private incentives compatible with public policy goals.

Keywords: disease, epidemiology, producer incentives, public policy

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## Introduction

Livestock disease management is an issue of increasing importance in a world with large amounts of agricultural product trade, human travel, and the realization that many diseases pose threats for livestock, wildlife and human populations. Livestock disease control policy in the US is a combination of border controls, farm and processor inspections and tests, and indemnity and slaughter programs. In addition, publicly funded research and education programs assist in minimizing treatment and control costs.

On the farm, managers take precautions against diseases that are not present and mitigate the effects of diseases that exist. In doing so, managers weigh the costs of illness, prevention, and control. Left to their private incentives, producers are unlikely to voluntarily consider the entire social costs of disease effects on the livestock, wildlife and human populations. Private farm disease management behavior may therefore lead to externalities and a rationale for government intervention. We investigate the implications of rational choice by individual farmers about their response to infectious diseases.

Previous work by McInerney, Howe and Schepers brought the economic decision-making behind livestock disease management on the farm into focus. They noted that farmers make both preventive and control measure decisions with respect to disease. They also asserted that only avoidable disease losses were relevant to farm decision making. This latter assertion is especially important when one considers the much larger scope guiding public policy priorities and budget decisions. The standard reaction to an existing or potential disease outbreak is to estimate the disease “impacts.” The impact includes direct costs in the form of testing, slaughter, and production losses. A livestock disease outbreak has repercussions up and down the livestock supply chain to supporting industries. Consumers and human health may also be affected and often trade losses are of prime importance, starkly evidenced by the trade restrictions on the US and Canadian beef industries from recent single-cow outbreaks of BSE in each country.

Private response to disease depends on the prevalence level (the potential for hazard into illness) and the resulting expected losses (Geoffard and Philipson). Rational producer response to livestock disease includes tolerating positive levels of livestock disease when the required response cannot pay for itself. Another important implication of producer response to disease prevalence is that there may exist an economic threshold with respect to disease prevalence after which private management and control will be exercised. This private response, in turn, has implications with respect to disease management policies and disease impacts.

The objectives of this paper are to understand farm decision-making with respect to livestock disease prevention and control and to relate farm incentives for prevention and control to existing public policies and industry priorities. In the case of an already existing disease, farm action occurs after an economic threshold is surpassed making response economically rational. This action threshold is similar to the concept utilized in the economics of crop pest management except the livestock disease decision differs in that the farmer is managing a capital stock (i.e., livestock herd) through continuous production cycles rather than a single crop in a discrete season. The existence of the action threshold and discrete nature of response can result in farmers rationally tolerating some level of disease. Finally, government or industry policies can change the response by changing price incentives or the cost of treatment.

## Farm Livestock Disease Management

Livestock producers continually face decisions regarding disease. These management decisions are either ex ante to disease occurrence and include prevention (biosecurity) measures in susceptible herds or they are ex post regarding control measures when infection occurs (Chi,et al.). The probability of infection from a given disease depends on farm practices (prevention) as well as the prevalence rate in host populations (livestock, wildlife, humans) in the relevant area. As the prevalence in the area increases, probability of infection increases.

The private benefits of livestock disease prevention and control include higher production as morbidity is lowered, lower mortality or early culling, and avoided future control costs. Disease management costs include testing and screening, veterinary services, vaccines when relevant, and perhaps changes to practices and facilities to reflect movement restrictions and quarantines when animals are added to the herd.

The farm manager trades off expected losses of a disease with the control costs undertaken. The assumption is that increased control costs lower the expected losses by diminishing the expected scale of an infection. McInerney, Howe, and Schepers present the problem graphically as a cost minimization problem

$$\min C = L + E$$

where C is total annual disease cost, L is the value of output losses, and E are control expenditures (which themselves are a function of inputs purchased for control). The model is illustrated in Figure 1. LL' is a loss-expenditure frontier that shows the relationship between control and avoided losses. LL' represents the isocost for the current level of disease control technology. Cost is minimized at the point where the 45° line is tangent to the frontier such that the marginal cost of an additional unit of control is equated to the marginal benefit in terms of reduced loss. As drawn, the frontier runs parallel to the vertical axis indicating in this example that some positive level of disease loss is unavoidable. This assumption is justified

 

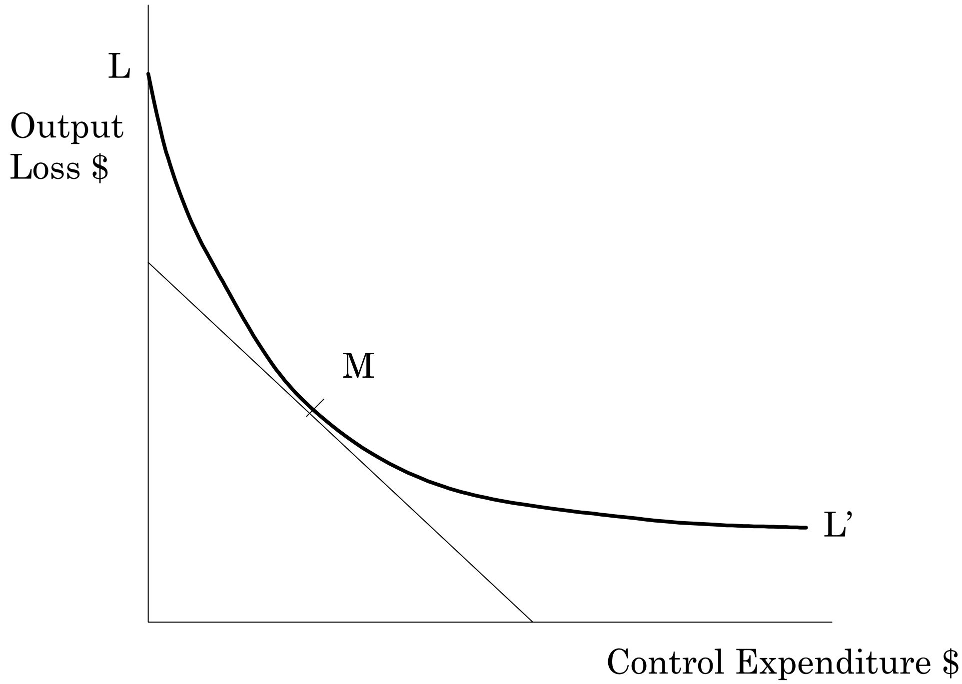


**Figure 1**: Farm Trade-off between Disease Loss and Control Expenditures (Adapted from McInerney, Howe and Schepers).

when diseases are unavoidably present in reservoirs on or adjacent to the livestock operations. A new technology that lowers the control cost, public management programs that lower the density of pests/disease, or government programs offsetting the losses with indemnity payments would shift the frontier down and result in a solution with less disease. Factors influencing the shape and level of this isocost curve--including disease epidemiology and potential treatment and control technologies--are the focus of the next sections.

Other studies have furthered the modeling of livestock disease management. Chi,et al. took these ideas and put them in a more formal economic framework of damage control inputs. They posited the farm decision as maximizing profits by choosing preventive and control measures as inputs in addition to standard production enhancing inputs. They found the standard marginal benefit equals marginal cost for standard inputs, prevention inputs and control inputs. Bicknell, Wilen and Howitt modeled a farm livestock disease control model with a wildlife disease vector. Utilizing a dynamic optimal control framework, they found that in many cases it was not rational for a farmer to eradicate the disease.

These models confirm the standard economic adage that profit-maximizing producers will only voluntarily control disease when the benefits outweigh the costs. They also illustrate why producers cannot necessarily be depended upon to

 

**Exhibit 1:** Quantifying Farm Losses from Livestock Disease

The true cost of disease can be difficult for producers to identify. Production losses, reproduction inefficiency, and even sources of mortality can be difficult to attach to any single cause. Veterinarians, animal scientists, and economists are increasingly working together to understand and quantify disease losses. The US Department of Agriculture's Animal and Plant Health Inspection Service performs a National Animal Health Monitoring Survey (NAHMS) periodically which generates baseline data on the incidence and control of disease. This data is also used to generate disease cost estimates (for example Ott, Wells and Wagner use the dairy NAHMS data to estimate costs associated with Johne's disease). Research over time is also useful in summary form to quantify production losses where herd and study factors are controlled for (for example, Fourichon et al.).

Just as the cost of disease can be difficult to calculate at the herd level, so can the benefits from disease control. Many of the practices that help to control or prevent a given disease will also prevent other diseases (for example, quarantine of new animals). These "spillovers" make it easy to underestimate the benefits of biosecurity investments and practices. In addition, herd practices benefit neighbors, industry and public health. These externalities and spill-overs are one compelling reason for public policy intervention in livestock disease control.

privately eradicate a disease. As the prevalence rate (percent of infected animals) declines, the marginal benefit of further lowering the prevalence declines while the marginal cost of finding and eliminating the disease climbs making it uneconomic in many cases to continue pursuing eradication.

In order for producers to make decisions regarding disease management, they must understand the options that they have relative to the disease in question. These options depend on disease biology, prevention techniques, tests for infection and their costs, treatments available, market reactions, as well as industry and government programs and policies. Disease biology includes transmission modes and rates, disease evolution (e.g., length of time to infectious period), production losses associated with the disease, and mortality rate (where applicable). Prevention of livestock disease often involves movement restrictions and quarantines. Treatments may include vaccines and other medicines to assist recovery. Market reaction involves the change in price for infected livestock and livestock products (which may result in a price of zero). Industry and government programs may include indemnity payments, quarantines, test and cull programs, or required depopulation and resulting business interruption losses (Wolf, Harsh, and Lloyd).

 

Individual producers may have many objectives when they make decisions that affect the health of their livestock. Producers are concerned about the direct cost of the disease. They will minimize the costs of prevention and curative activities insofar as they pay those costs (i.e., costs are not off-set by government indemnity or disaster payments). These considerations are irrelevant if the producer choice is limited because government programs mandate a response. This is true in the case of several livestock borne diseases that pose a direct human health threat or cause large economic damages to the livestock sector or related industries.

The producer makes decisions relative to individual animals when disease control is not mandated by public policy. We can examine the farm decision for an individual infected animal over time. Many diseases that are not treatable with vaccines or antibiotics, and cannot be recovered from, have disease losses that get progressively worse over time. For diseases that have no practical treatment, the disease control strategy is to cull infected animals. Because most infected animals still have a positive expected value (that is the cull value is less than the replacement value and net revenues from production are positive)—at least for a period after infection occurs—the farmer will wait to cull that animal.

These concepts are illustrated in Figure 2 with disease losses and control costs on the vertical axis and time on the horizontal axis. The origin represents the time of infection. For diseases that are not treatable, losses will increase over time

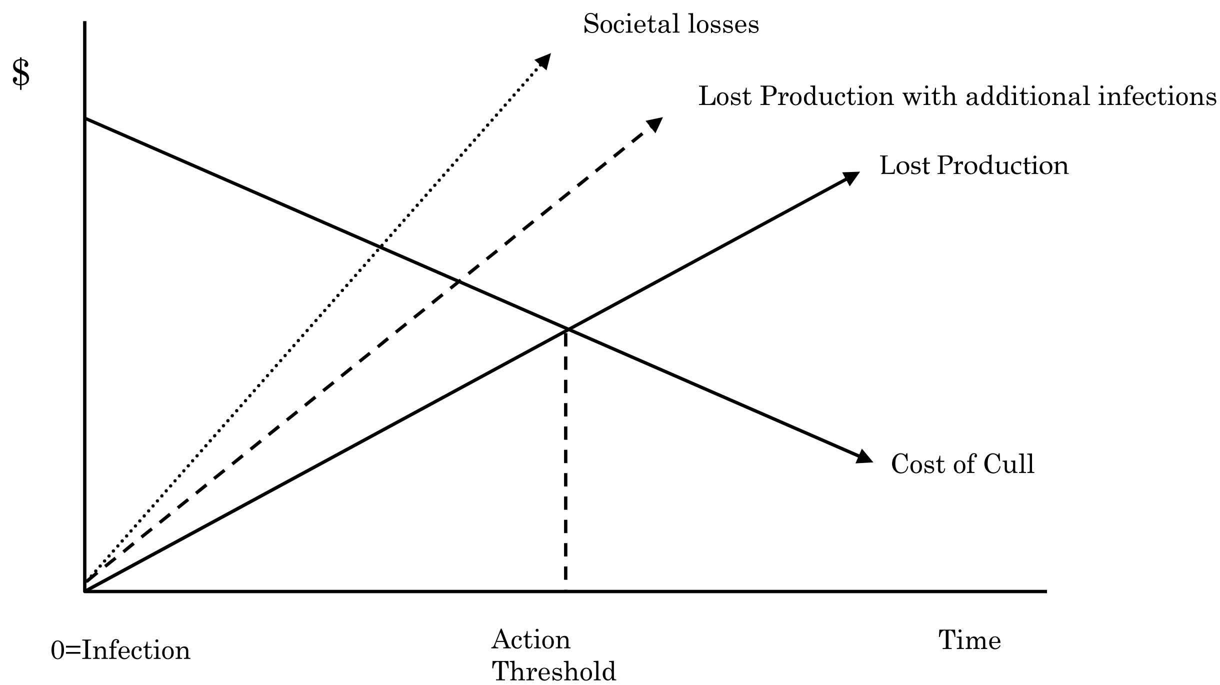


**Figure 2**: Individual Animal Disease Control when Culling is Required

 

eventually leading to a death (in an untimely manner). The cost of a cull declines over the life of the animal in question, regardless of the progression of the disease, as the expected death approaches and productivity declines with natural animal life-cycle and health issues. The classic capital replacement problem solution is to replace the asset when the expected value of the replacement animal is greater than the expected value of the current animal. In cases where a replacement is available, the decision is whether the replacement's net present value of production is greater than the existing animal's net present value plus the potential income from selling the replacement to another producer. If no replacement animal is currently available, the producer decision is keep the current animal as long as production is profitable. In this case, we might think of a break-even level where a cull occurs when production falls below this threshold.

Even in cases where culling is not required it is often the case that control costs could outweigh low levels of disease loss. Some diseases require whole-sale farm changes. If the disease management requires large capital investments, then these changes are a long-term response that depends on asset fixity due to adjustment costs as well as many other farm financial factors. This hurdle must be overcome to make treatment economical. These start-up costs could include purchasing veterinary services (calls are sold in discrete increments) or it could be whole-sale changes in facilities and production practices. The farm reaction still may occur immediately when losses are especially severe or response is mandated by law.

With respect to benefits of disease prevention and control, spillovers to other diseases could be important. That is, the same management practices that prevent or eliminate one disease may also control other diseases. However, these spillovers are difficult to assess and the result is a known investment for an unknown probabilistic benefit with respect to other diseases. Herd and farm level considerations are also important to the decisions and are examined next.

## Disease Epidemiology and Farm Decisions

Economics is based on rational decision making to allocate scarce resources. Incorporating producer decision-making changes the predicted prevalence time path of a disease. Mathematical epidemiological models are based on the simple period-to-period change in infection rate (x) equation:

$$\dot{x} = \alpha s x - \beta x$$

where x is the proportion of infected animals, s is the proportion of susceptible animals, $\alpha$ is the probability of infection from a meeting between infected and sick animals, and $\beta$ is either the probability of recovery or mortality (Gersovitz). In this epidemiological model, $\alpha$ incorporates both the contact rate and the infectiousness of the disease.  Without recognizing the incentive and role of producers (or government) to manage livestock disease, a standard assumption in epidemiological models is that $\alpha$ and $\beta$ are constants. The result is that the proportion of susceptible animals that become infected each period rises as x rises.

Incorporating producer economic behavior in the epidemiology includes making $\alpha$ a function of preventive measures and $\beta$ a function of curative or life-prolonging measures. The chosen level of preventive measures is likely to depend on the risk of becoming infected, which is a function of x. Thus, disease transmission models that allow for endogenous behavior produce a reduced form that has $\alpha$ as a function of prevalence, x, rather than a constant (Geoffard and Philipson; and Gersovitz). When transmission is an increasing function of x, then susceptible animals who become infected may or may not rise depending on how much the producer works to lower $\alpha$ as x rises.

This type of producer reaction to disease can be considered in a simple pest management framework. Crop integrated pest management programs have long utilized the concept of economic injury level and an economic threshold. Stern,et al. defined the economic threshold for pest mitigation as the level of infestation at which the application of pesticide is economically justified. The economic injury level is the "lowest population density that will cause economic damage" (Stern,et al.). The calculation of an economic threshold depends on control costs (price), output price, yields, and damages.

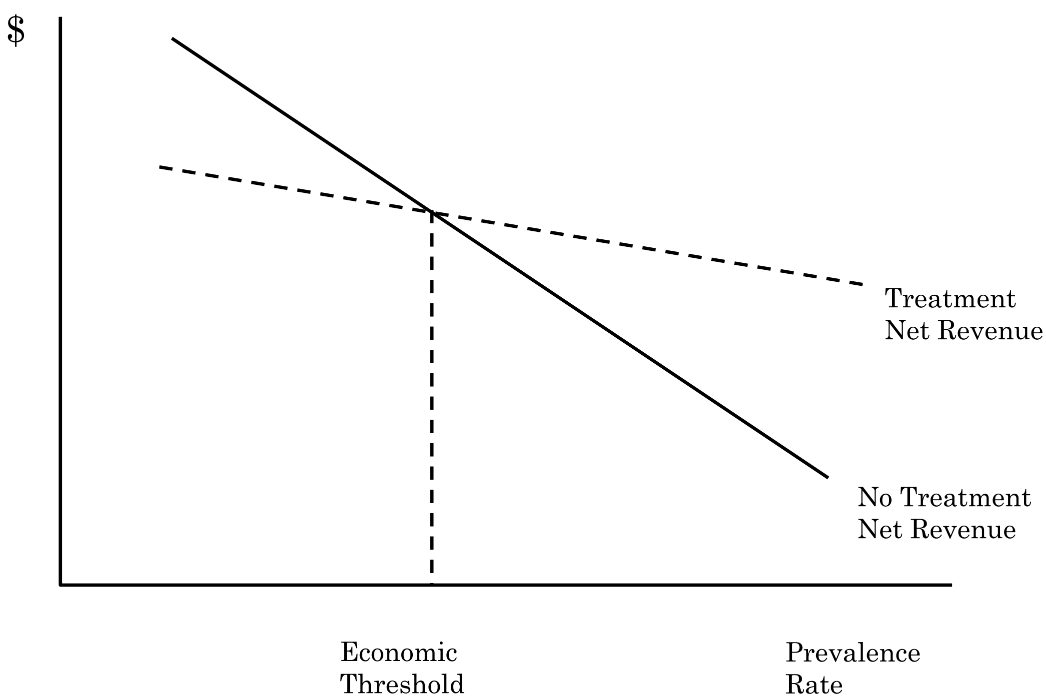


**Figure 3:** Disease Management Economic Threshold

 

The application of the economic threshold for action in livestock disease management is straightforward. Figure 3 demonstrates the economic threshold level that occurs when the net revenue including treatment costs crosses the net revenue with no treatment curve. It seems reasonable that most diseases would be expected to have more losses when the pest density—here the prevalence rate of infected animals—increases. The farm manager decision horizon is longer when managing a capital asset as embodied in livestock herds. While there is a “crop” annually in the form of meat, eggs or milk, the foregone production or losses avoided relative to disease control accrue over many years. If government, industry or market forces change the treatment costs or losses through subsidies or penalties, the threshold prevalence can be shifted out or back to reflect public preferences.

## Externalities and Policy Response to Livestock Disease

Public policy intervention in livestock disease management can directly impact producer decisions. Following Morris, we can categorize livestock diseases as endemic, sporadic, or epidemic. Endemic diseases are those that occur in most or all livestock herds in a country and cause some economic impact but are generally not viewed as public health concerns (or having significant public economic impacts). Supply and demand and market incentives are viewed as suitably allocating resources towards the prevention and control of endemic diseases. An example in livestock is mastitis.

A second category is sporadic diseases which affect only some herds in a given year and have an uncertain pattern of occurrence. An example of a sporadic disease is Newcastle disease. Finally, epidemics are generally not present or present at a very low level due to controls (e.g., foot and mouth, tuberculosis). However, when epidemics occur they have the potential to spread rapidly to a large number of animals and herds resulting in large mortality, morbidity or economic losses.

This disease typology is useful in both assessing which economic analysis and decision tools are relevant to their study (see Morris or Dijkhuizen, Huirne, and Jalvingh for more) as well as in setting policy standards for prevention and control. Diseases where human health is at risk or which have associated with them large potential economic effects are in the domain of public control. Public policies range from bounties/indemnities for infected livestock to required herd depopulation and farm decontamination. Economic justifications for public intervention in disease control include externalities, public good aspects, coordination failures, information failures, and income distribution considerations (Ramsay, Philip, and Riethmuller). In these situations, it is to be expected that individual farmers under-invest in prevention and control as the market does not reflect all costs or return all benefits for farm-level disease management.

 

Exhibit 2: Farm Impacts of Government Eradication Programs

The primary government objective relative to livestock disease is welfare maximization considering public health, cost to consumers, cost to producers (including longer-run investment and structural adjustment behavior), and cost to taxpayers. To accomplish eradication, the disease reservoir and vectors must be eliminated. Movement restrictions/quarantines, testing, slaughtering (usually with indemnity payments to the owners), vaccinations, and education programs are often involved. Bovine tuberculosis (TB) is an example of a US government eradication program (many other countries, for example New Zealand, also have TB eradication programs).

Bovine tuberculosis (TB) is a contagious, infectious, bacterial disease so named because it apparently originated in cattle. However, the disease can infect livestock (cattle, bison, goats), wildlife (e.g, deer and elk) and humans. Beginning in 1917, a US eradication program consisted of test-and-slaughter as well as movement restrictions and was effective in drastically reducing the prevalence rate. Michigan has been a traditional hot spot of TB. However, by 1979, Michigan had achieved TB accredited-free status. Accredited free status, bestowed by the US Department of Agriculture, is desirable as it prevents other states from placing testing, movement and quarantine restrictions on interstate animal exports.

The preferred policy reaction to an infected herds is depopulation which refers to removing all cattle from the farm. A mandatory period without cattle follows depopulation while the farm is cleaned and testing protocols are tailored to the individual farm situation. Public costs of the disease include those involved with testing, costs to purchase equipment, pay veterinarians and other workers involved in testing, and all laboratory expenses. Any indemnified animals are reimbursed using state and federal funds and must be disposed of properly. In addition, the state changed research and monitoring programs for both cattle and deer and incurred costs in managing the wild deer herd.

While the state covers the direct testing costs (e.g., lab tests and veterinary visits), farmers incur the incidental testing costs (e.g., labor and lost performance) as well as increased transportation and trade requirements. Farmers are largely reimbursed for animal value through indemnity payments. Current Michigan law mandates that farmers be compensated for 90 percent of the fair market value up to $3,000 per animal. However, depopulated farms must deal with business interruption costs until the farm can be repopulated (Wolf, Harsh and Lloyd). Business interruption losses from stamping out or eradication programs were also significant in the case of swine fever in the Netherlands (Meuwissen et al.) and Foot and Mouth outbreaks around the globe.

Because of the financial strain caused to farms by depopulating infected herds, business interruption reimbursement and insurance is often discussed. Often business interruption insurance would require public subsidy to make it affordable (Meuwissen et al.). It is critical that these policies not minimize farm incentives to adequately invest in biosecurity and disease avoidance. Understanding the farm-level financial consequences enables efficient and responsible policy response.

 

Public intervention in livestock disease management in the US includes prevention strategies at the borders, indemnification of infected animals, and in some cases eradication programs that include livestock depopulation and decontamination of operations. The indemnification payments have the potential to influence farm behavior.

Many diseases directly or indirectly affect the well-being of consumers, other producers, taxpayers, wildlife, and human health. For this reason, infectious disease seems to fit the classic externality model. There are two types of externalities that arise in the context of infectious disease, the infection externality and the prevention externality (Gersovitz). The infection externality arises if individual producers do not take into account the fact that their herd becoming infected affected the risks of others' becoming infected. The prevention externality exists whether the herd becomes infected or not. When a farmer mitigates disease it lowers others' risks of becoming infected, whether the manager's herd becomes infected or not. Government or industry intervention either rewards or requires the prevention aspect or it shifts a larger degree of the public infection cost onto the producer.

When farmers mitigate disease through prevention or control, they benefit not just themselves but any others at risk of adverse outcomes from the presence of disease on that operation. At-risk populations include residents, visitors and consumers. The beneficiaries might also include at-risk wildlife populations surrounding the farm that may have direct or indirect contact with livestock or livestock related material. Finally, livestock operations in the area of the infected farm benefit from disease management on their neighbor's farms. The standard dynamic considerations of benefits accruing over time also apply to these populations. For these reasons, it is justifiable to think about the social or public disease loss curve, being higher than the private curve, resulting in a socially optimal earlier movement to disease control.

## Application to Johne's Disease Control

Many studies have examined disease on livestock farms and found large damages. In some cases, the damages are so large as to off-set virtually all potential enterprise profits (albeit most losses are non-cash). There are at least three potential explanations for disease damages in cases where farmers do not move to eradicate the disease. The first amounts to an information problem as the losses are foregone production from sub-clinical infection. In this case, the farmer simply does not know what he is missing and thus does not allocate the appropriate resources. We reject this explanation for widespread diseases that are public knowledge. A second potential explanation is that the relevant costs of diseases are the avoidable costs. That is, some environmental factors are simply unavoidable and the correct farm decision utilizes a marginal benefit that includes avoidable disease occurrence.

 

Similarly, damages may only accrue when the disease is a full-blown clinical case and current management practices may limit the expected life-span of livestock to a time period smaller than the incubation period of the disease. A third explanation is that response to some diseases requires whole-sale farm changes. If the disease management requires large capital investments, then these changes are a long-term response that depends on many other farm financial factors.

Johne's disease, mycobacterium paratuberculosis, is a widespread bacterial disease found in US cattle operations. It has been estimated to be present in 22 percent of dairy operations and 8 percent of beef operations (Wells). Following infection in calves, the disease progresses slowly, causing diarrhea and weight loss usually starting around three to six years of age. Eventually the disease is fatal. Losses from the disease include lost productivity (milk or weight gain), costs of early and involuntary culling (or subsequent mortality), and increased veterinary and medical expenses. Transmission occurs through milk or fecal matter.

Johne's disease impact has been estimated to be over $100 per cow in inventory annually with costs in excess of $200 per cow annually in herds that have 10 percent or greater clinical infections (Ott,et al.). Estimates consistently show that higher prevalence rates are associated with higher farm-level disease losses. Aggregating losses has led analysts to conclude that the industry loses $200 million annually. Losses also occur in the beef industry although they are smaller than the dairy losses. Another reason for concern is that the disease has been informally linked to Crohn's disease in people. This link, if confirmed, would make Johne's a significant human health concern and substantially change industry and farm incentives for disease eradication.

Recommended control measures include 1) identification and removal of infected cattle, 2) prevention of calf ingestion from adult cow manure, milk, or water, 3) decrease of environmental contamination, and 4) screening of purchased cattle (Wells). The inability of current Johne's tests to accurately identify true positive young cattle has been reported to make test and cull control programs economically infeasible (Van Groenendaal and Galligan). Nonetheless, Van Groenendaal and Galligan did estimate that the disease was economically controllable over a period of several years.

In response to the disease, industry and government officials have organized a set of voluntary programs. These programs are jointly run by state and federal officials with industry and academic advisory members. Because the disease is not currently considered a human health problem or a potential large public economic impact, the justification for a government program does not exist. In general, voluntary programs are preferred by industries as they allow latitude in implementation and interpretation at the producer level that is not possible in a formal program that must necessarily define compliance and enforcement. Thus, the existence of the voluntary program is rational and improves industry welfare.

At the same time, the programs have not resulted in widespread participation. There are several reasons why this might be occurring. First, positive cows are more valuable producing milk than as a cull animal. This is the asset fixity problem as described in Figure 2. A positive cow may have an expected loss of $200 per lactation. In addition, the cow will be a hazard to spread the disease as long as she is in the herd and is shedding the disease bacteria. In contrast, a cull costs the difference between the replacement value and the salvage value (cull cow price). This is the case even if the farm operation already possesses its own replacements as these heifers could be sold rather than brought into the herd. Typically in the US, replacement dairy heifers are worth $1,200 to $1,800 each. Cull cow prices are $400 to $600. This price discrepancy might explain why cows are kept for a period of time even when they are known to have the disease.

Second, and directly related to the previous reason, clinical cases—which correlate to rapid decline in productivity and condition—may occur after expected cull. The average number of lactations is about 2.5 (Hadley). The incubation period of Johne's can be several months to a couple of years (Ott, Wells, and Wagner). Thus, positive cows may be kept because the farmer expects them to be culled prior to the time when the disease will be clinical and significantly influence production losses.

Third, tests are relatively expensive and have a high false positive rate. False positives can result in unnecessary culling. The expense of the testing results in a less frequent than desired testing interval. Fourth, closed herds are costly to maintain during expansion. In order to remain competitive, many farms build new, large-scale milking and housing facilities. These large capital facilities investments must produce large amounts of revenue to be economically viable. When facilities are not a herd size constraint—at least in the short to medium term—every cow that is producing above break-even price is kept. Large expansions have occurred in every region in recent years. If and when these expansions slow down, we might expect producers to concentrate more on issues such as Johne's disease.

Fifth, there currently exists no price premium for milk from Johne's certified-free herds. As milk produces the vast majority of revenues on dairy farms, the milk price is of primary importance. Because pasteurization is thought to control Johne's, no price premium (or price penalty) is currently tied to herd status. Finally, no trade restrictions exist for Johne's positive cattle or cattle products. Thus, there is no over-whelming public economic damage to control as there is in the case of a disease like foot-and-mouth.

 

## Implications and Conclusions

Given the economic incentives to eradicate disease, or lack thereof, we might think about what can be done to encourage farmers to actively manage disease. Several areas of public expenditure might be justified—especially for diseases that have relatively larger social costs. These include adding information so that farmers understand spillovers and can effectively assess the total benefits from potential biosecurity and disease control decisions. In addition, public expenditures to improve the price and efficacy of disease tests might be in order.

Industry or government programs can facilitate disease management by subsidizing farm testing costs. Bounties or indemnity payments may assist in locating and removing diseased animals. These payments must be large enough to encourage compliance without being so large as to encourage "manufacturing" newly diseased animals. In the case of mandatory government programs that require depopulation and facility decontamination, the business interruption losses that are not subsidized serve to off-set the moral hazard associated with indemnity payments. Industry can benefit from removing breeding animals and shifting the supply curve back. Although not disease related, this was the case with the Cooperatives Working Together voluntary supply control program in the US dairy industry in 2003-04 which purchased about 33,000 cows to lower supply. One could imagine an industry-funded program such as this that paid a premium for Johne's positive cows (or herds with high prevalence rates), thereby lowering the industry disease prevalence and simultaneously shifting supply back.

Finally, some states are currently running finance programs that provide low interest loans to producers to purchase cows for dairy expansions. Other programs encourage dairy production provide tax credits. One could imagine a requirement that all cows be certified Johne's free in order to qualify for these programs.

Economists continue to have an important role in understanding livestock disease control. Economists can utilize bioeconomic models that incorporate appropriate epidemiology of a given disease to inform policy-makers on optimal value or method of subsidies that would prove most effective/efficient to get private incentives to public levels. These models can also estimate the degree to which indemnity payments change incentives. Any simulation of disease impacts over time should also recognize that disease response is a function of prevention price elasticity and prevalence elasticity due to losses. Understanding where the private response may occur can facilitate more accurate disease prevalence paths and therefore more accurate cost and benefit estimates. Collaboration between economists and epidemiologists is essential for effective and efficient livestock disease control.

 

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