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Journal of Agricultural and Resource Economics 32(1):169–180
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Economic Benefits of Animal Tracing in the Cattle Production Sector

Levan Elbakidze

One of the options to prepare for a potential outbreak of an infectious livestock disease is to initiate an animal tracking system, which would provide information on animal movements and facilitate disease management. This study examines the benefits of implementing an animal tracking system in the context of a simulated cattle disease outbreak with and without animal tracking. Estimates are provided for some of the losses that would be avoided with an animal tracking system if an infectious animal disease were introduced. The results show that the economic efficiency of an animal tracking system depends on such factors as inter-herd contact rates, effectiveness of animal disease response actions, and the extent to which an animal tracking system decreases the time of tracing animal movements. In the event of a highly infectious animal disease outbreak, substantial economic losses could be avoided if an effective animal tracking system is implemented.

Key words: animal tracing, cost minimization, infectious disease spread mitigation

Introduction

The economic implications of foreign animal diseases and their mitigation options have become a more pertinent issue as fears of intentional and/or unintentional introduction of animal diseases have grown. Devastating economic consequences of foot-and-mouth disease (FMD) and bovine spongiform encephalopathy (BSE) outbreaks in the UK (Atkinson, 1999; Thompson et al., 2003; Henson and Mazzocchi, 2002; Burton and Young, 1996), as well as impacts of the 2003 BSE occurrence in Canada and the U.S. with subsequent closure of the U.S./Canada border and loss of export markets, have heightened the urgency of developing effective mechanisms for animal disease management.

The key to effective management of an infectious animal disease outbreak is timely detection, isolation, and destruction of infected and high-risk herds and animals (Bates, Thurmond, and Carpenter, 2003; Bates, Carpenter, and Thurmond, 2003; Garner and Lack, 1995; Schoenbaum and Disney, 2003). Currently, outbreak response strategy mainly relies on quarantine and depopulation of infected herds, identified based on "sound epidemiological evidence" [U.S. Department of Agriculture/Animal and Plant Health Inspection Service (USDA/APHIS), 2003]. Existing U.S. programs to detect and mitigate diseases such as FMD rely on the recognition and reporting of clinical signs by a producer, an animal caretaker, a meat inspector, or a veterinarian (Bates et al., 2003,

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Levan Elbakidze is assistant research professor, Department of Agricultural Economics, Texas A&M University, College Station. This research was supported in part through the Department of Homeland Security National Center for Foreign Animal and Zoonotic Disease Defense. The conclusions are those of the author and not necessarily the sponsor.

Review coordinated by DeeVon Bailey.

p. 609). Reliance on such an approach has two major problems. First, since detection is based on visual observation of clinical signs, the disease could have been present and possibly spreading before the visual confirmation of its presence. Second, the clinical signs of FMD are indistinguishable from the signs of some other diseases (Bates et al., 2003). Therefore, more reliable methods for detection and identification of infected herds may be appropriate.

One of the methods for enhancing the identification of possibly infected herds, once an outbreak has been confirmed, is an animal tracking system such as the National Animal Identification System (NAIS). Such a system would keep track of and store information on cattle movement across cattle production facilities over time. In the case of an infectious animal disease outbreak, the availability of such data could drastically speed up the identification and the accompanying isolation of potentially infected and high-risk herds by providing timely traceback information about contact herds. More prompt response in turn is likely to reduce the economic and sociological damage caused by a disease outbreak.

Implementation and operating costs are key deterrents against establishing a national animal tracking system. However, recent actions by the Food and Drug Administration (FDA) and USDA suggest that private entities will be required to closely track and report animal shipments, thereby requiring producers to shoulder part of the cost of tracing the disease outbreaks (Pritchett, Thilmany, and Johnson, 2005). The USDA has initiated the program on a voluntary basis, although it may become mandatory over time when and if the system becomes fully functional (Bailey, 2004; Collins, 2004; USDA/APHIS, 2005a, b).

Operationally, NAIS consists of two parts (USDA/APHIS, 2005a). The first is the premise identification number (PIN), a seven-digit identifier assigned to each premise, defined as "locations that hold or manage animals." The second part is the animal identification number (AIN) or the group/lot identification number (GIN), depending on whether an individual animal or a group of animals moved through the production chain. The AIN or GIN, the PIN of the receiving location, and the date of the animal(s)' arrival will be reported to the National Animal Records Repository as animals change ownership to accommodate the 48-hour traceback objective. Clearly, effectiveness of the tracing system is influenced by the percentage of animal movements that are recordable (USDA/APHIS, 2005a). Full participation of producers is therefore essential for the successful implementation and effective functioning of this program.

Functionality of a voluntary animal tracking system, as well as its prospects of becoming mandatory, largely depend on cattle producers' willingness to participate and comply. While examination of the individual producer's incentives is left for another study, it is important to provide some background on private incentives. Livestock producers have four primary motives for establishing an animal identification and tracking system:

- First, traceability of animals could be used to prevent theft or loss of animals. This factor is especially relevant in cattle ranching operations where cattle owned by several parties are often commingled.
- Second, enhanced record keeping would facilitate the identification of animals with superior genetics in terms of their productivity. For example, a feedlot operator could increase productivity by acquiring animals with genetically superior ability to gain weight based on past records.

- Third, certain traceability systems could make it possible for credence attributes to become observable. For example, farmers who can prove through a traceability system that their animals possess otherwise unobservable attributes—such as current vaccinations, proper medical care, animal welfare provisions, and appropriate feeding procedures—would potentially be able to sell their animals for higher prices (Golan et al., 2004).
- Fourth, traceability would allow for tracking and identifying potentially unhealthy animals, thereby enhancing efficiency of control and eradication of livestock diseases. Such information would be essential in implementing animal disease response strategies such as contiguous slaughter, vaccination, and setting up quarantine zones.

There are two main drawbacks associated with an animal tracking system from the producer's perspective.

- First, producers are reluctant to incur additional costs associated with implementing and operating an animal tracking system. These could include equipment costs as well as record keeping and maintenance costs.
- Second, producers are concerned about potential liability that could arise due to the information available through the NAIS (Golan et al., 2004). Producers worry that the NAIS information could be used to assign liability to them for unhealthy or low quality animals. In addition, some producers may be uncomfortable with the possibility of NAIS data becoming available to the Internal Revenue Service.

Advantages and disadvantages of an animal tracking system from the individual producer's standpoint need to be further investigated to formulate incentive-compatible policy.

The purpose of this study is to demonstrate the benefits of an animal tracking system to cattle producers under the possible outbreak of an infectious animal disease. Some of the factors that influence the economic efficiency of such a system are examined. The Reed-Frost functional form for infectious animal disease spread is adopted from the epidemiology literature and incorporated within the economic framework to arrive at some of the economic losses that would be avoided by having an animal tracking system in the event of an infectious animal disease outbreak.

Model Development

From the standpoint of the cattle production sector, the decision to invest in an animal disease mitigation program, such as the NAIS, depends on an array of factors, such as: (*a*) the likelihood of disease introduction, (*b*) disease spread rate, (*c*) effectiveness of such a program, and (*d*) costs and effectiveness of any alternative mitigation options. The merit of the NAIS is that such a system would allow for timely tracking of the diagnosed and exposed animals to their origins. Ideally, all cattle movement data would be available to the appropriate authorities in the event of an infectious animal disease outbreak, thereby facilitating the identification and eradication of the source of an outbreak. Under full participation, the NAIS would instantaneously identify all herds

that have been in contact with the diagnosed animals. This essentially implies that response actions could be implemented on high-risk properties sooner under the NAIS system than under the current documentation procedures.

The benefits of investing in a program such as the NAIS could be examined from the standpoint of minimizing expected losses to cattle producers from a potential animal disease outbreak. The total costs associated with an animal disease outbreak include lost production, suppressed demand in the cattle industry, lost export markets, indirect losses in related industries, and the costs of preventing and responding to an outbreak. Conceptually, the problem could be addressed by comparing the benefits of a mitigation program, such as the NAIS, to the costs associated with its implementation. Accordingly, the first step is to evaluate some of the benefits of establishing the program. The benefits of the animal tracking system are in part represented by the losses avoided under the presence of an infectious animal disease. In the cattle production sector, the value of lost cattle and the value of lost income are the major components of financial losses to the sector.

Equation (1) represents expected losses (EL) in the cattle production sector associated with an outbreak of a highly infectious disease, such as FMD:

$$\text{(1)} \qquad \underset{R}{\text{Min:}}\ EL_{\mu} = P \times \left[V \times H(R) \times D_{\mu} + CR \times R\right],$$

where P is the probability of disease introduction; V represents the value of monetary losses associated with each infected herd; R denotes the level of response to the disease outbreak; $H(R)$, which denotes response effectiveness, is the proportion of herds lost to the outbreak as a function of response actions; D_{μ} is the number of infected herds under various scenarios of days (μ) between infection and depopulation of infected herds; and CR is the cost of response actions.

The representation for disease spread, D_{μ}, needs to reflect the fact that in the early stages of an outbreak the disease will be spreading at an increasing rate. However, as the number of infected herds increases, the number of susceptible herds will decrease. Hence, at some point of the disease outbreak progression, the number of infected herds will start to increase at a decreasing rate. In addition, the representation of disease spread must be based on inter-herd contact rates in order to incorporate the effect of animal traceability. Therefore, D_{μ} is assumed to be based on a Reed-Frost equation form. This functional form has previously been used in modeling intra- and inter-herd spread of infectious animal diseases (Carpenter, 1984; Carpenter, Thurmond, and Bates, 2004; Elbakidze, 2004; Nyamusika et al., 1994).

In the context of this paper, the Reed-Frost formulation is well suited because it reflects the mechanics of an infectious disease spread in a finite population of susceptible subjects. Specifically, Reed-Frost formulation accommodates the fact that in the early stages of an outbreak, the number of infected herds increases at an increasing rate, while in the later stages of an outbreak the number of infected herds increases at a decreasing rate. In addition, the inter-herd contact rate could be explicitly incorporated.

The Reed-Frost formulation for infectious disease spread is based on projecting daily infections given the total population number and contact rates between subjects:

$$\text{(2)} \qquad D_t = \left[TN - \sum_{t=0}^{t^*=t-1} D_t\right]\left[1 - q^{CI_t}\right],$$

where D_t represents the number of herds infected on day t, TN is the total number of herds in the area, and therefore

$$\left[TN - \sum_{t=0}^{t^*=t-1} D_t \right]$$

is the number of susceptible herds at time period t^*; and q denotes the probability of avoiding adequate contact to transmit the disease. Therefore, $1 - q$ is the probability of making adequate contact to contract the disease and is equal to $k/(TN - 1)$ (Carpenter, Thurmond, and Bates, 2004; Nyamusika et al., 1994; Maia, 1952; Abbey, 1952), where k is the average number of daily "effective contacts" a herd makes with other herds. "Effective contact" refers to contact between two herds which results in disease transmission. Based on the contact rates used in previous investigations (Schoenbaum and Disney, 2003; Garner and Lack, 1995; Bates, Thurmond, and Carpenter, 2001), k was initially assumed to be 0.4. Sensitivity analyses were later performed to evaluate the effect of this parameter. CI_t is the cumulative number of infectious herds in any time period during the outbreak. The number of infectious herds is calculated using

$$CI_t = \sum_{\mu}^{7} D_{t-\mu}$$

to take into account that FMD spreads for at least seven days before showing clinical signs of infection, at which point the diseased herds are assumed to be diagnosed and destroyed. Since D_t is the number of newly infected herds in each time period during the outbreak, the total number of infected herds is given by

$$D_{\mu} = \sum_{t=0}^{t=t^*} D_t .$$

$H(R)$ represents the proportion of herds which are lost under response level R relative to no response ($R = 0$). $H(R)$ is assumed to have a convex functional form, implying that as more response actions—such as slaughtering—are employed, the damages from an FMD outbreak decrease:

$$H(R) = \left(a_1 + a_2 R + a_3 R^2 \right). \tag{3}$$

However, excessive use of response actions could increase the costs. For example, slaughtering infected and exposed herds could slow down the spread of the disease and thus decrease the damages. But unnecessarily slaughtering herds (slaughter of herds not exposed to the disease) may result in inflated overall damages of the disease outbreak and its mitigation. Therefore, quadratic formulation was adopted for $H(R)$ as the simplest form of a convex function to simplify the numeric computations (Elbakidze and McCarl, 2006).

For empirical specification, effectiveness and type of response actions to a potential outbreak of an infectious animal disease were adopted from Schoenbaum and Disney (2003). Specifically, $H(R)$ was normalized according to previous estimations where slaughtering herds with clinical signs and herds in direct contact with the diagnosed

herds resulted in a 17% reduction in the number of slaughtered animals as compared to the strategy of slaughtering only the diagnosed herds (Schoenbaum and Disney, 2003, p. 49). So at $R = 0$, the proportion of lost animals is 1, corresponding to the losses under slaughter of diagnosed herds only, while at $R = 1$, the proportion of losses is 0.83, corresponding to the slaughter of 37 herds with an observed direct contact with diagnosed herds; the latter is found to be the optimal level of response by Schoenbaum and Disney. Consequently, the response effectiveness function used in this analysis was $H(R) = 1 - 0.34R + 0.17R^2$. The absence of actual data or additional estimates of response effectiveness precludes consideration of alternative response scenarios. Therefore, sensitivity analysis was performed to examine the impact of a more effective response action on the losses under various animal tracking systems.

The value of monetary losses associated with each infected herd (V) was assumed to be \$58,000, which corresponds to the cattle's monetary value plus the annual gross income for a herd of 50 animals (Elbakidze, 2004; Elbakidze and McCarl, 2006). No consideration was given to the effects of lost consumer demand and lost trade. However, inclusion of demand and trade effects will probably increase the possible losses which would be avoided by an effective animal tracking system. Thus, the results of this work may be viewed as a lower bound of the benefits of an animal tracking system.

Cost of response (CR) associated with slaughter of direct contact herds was calculated based on Schoenbaum and Disney (2003, p. 36), estimates of appraisal (\$300 per herd), euthanasia (\$5.5 per head), and carcass disposal (\$12 per head), which for a 50-head herd equaled \$1,175. Therefore, the cost of the response strategy corresponding to $R = 1$ (37 herds) is assumed to be \$43,475.

Because FMD-infected cattle remain in a latent period for about one to two weeks (Garner and Lack, 1995), we can estimate the effects of an infectious disease outbreak with no animal tracking by assuming that infected animals spread the disease until the infection shows observable signs and the disease is confirmed, at which point appropriate response actions are immediately taken to isolate and destroy the infected herds. Clearly, the effectiveness of response actions is greatly affected by the ability of the authorities to identify the infected and exposed animals in a timely manner. The NAIS is expected to enable the 48-hour tracking of the movements of any infected or exposed animal. In terms of disease spread, having the NAIS in place essentially implies that potentially infected herds could be identified and quarantined much sooner. The benefits associated with such intervention, or the losses avoided by having such a program in place, could be estimated by comparing the expected losses under various scenarios for μ. For example, to estimate the losses due to a contagious animal disease outbreak under the scenario with a functioning NAIS, EL [equation (1)] was calculated with $\mu = 2$, assuming the NAIS enables a two-day trace of infected and exposed animals. Several other scenarios were considered to account for the length of trace with current cattle record-keeping methods. Specifically, EL was estimated under $\mu = \{3, 4, \ldots, 8\}$.

Although estimating the costs of implementing and operating an animal ID system is not the objective of this paper, the benefits derived from the above formulation could be compared to crude cost estimates. The costs of the NAIS for Texas producers were calculated using Blasi et al. (2003) who estimated per head annual costs of implementing the animal ID system at the producer level for cow/calf operators and feedlots. Their calculations included the costs of transponder tags, electronic readers, computer hardware, computer software, internet access, required upgrades, and labor. These estimates

were used in combination with Texas cattle inventory numbers from *Texas Agricultural Statistics* [USDA/National Agricultural Statistics Service (NASS), 2003] to derive an approximation of the NAIS costs based on Texas cattle herd composition according to size and operation type. Annual costs of the NAIS for the Texas cattle industry were estimated to be about $112 million. Note that this estimate is inflated due to the assumptions used by Blasi et al. Specifically, the costs to small producers are overstated because the possibility of pooling some of these costs by small producers was not considered. Nevertheless, this estimate provides a good conservative benchmark for evaluating the net benefits of the animal ID system in light of a possible infectious animal disease outbreak. Consideration of the possible pooling of costs by small producers will reinforce the benefits of animal tracing found in this analysis.

Results

The model was used to conduct sensitivity analyses of the benefits of investing in an animal tracking system; it considered the effects of inter-herd contact rates, effectiveness of animal tracking and response actions, and the likelihood of a disease outbreak. Two levels of herd contact rates, four levels of animal tracking effectiveness, and two levels of response effectiveness were considered, along with a range of disease introduction probabilities.

Figure 1 shows the losses caused by disease introduction as a percentage of the total cattle values and associated gross income in Texas. The figure displays the comparison of loss percentages among scenarios with various tracking capability, response effectiveness, and disease spread levels. For example, scenario 1 (sc1) corresponds to less effective response actions, leading to a 17% decrease in lost animals, and a high contact rate of 0.4. In this scenario, if it currently takes eight days to track infected and exposed animals, approximately 45% of the value of the Texas cattle production sector would be lost. Speeding up the tracking process to four days will reduce the losses to about 15%. The losses under a two-day traceability scenario represent a negligible percentage of the Texas cattle production sector. Under scenario 2 (sc2), the losses decrease relative to scenario 1 (sc1) at all traceability levels due to more effective response, with a 30% decrease in the number of lost cattle. Increasing the contact rates makes the tracking system less effective and increases the losses, while decreasing the contact rates decreases the losses. Under higher contact rates (sc1 and sc2), the tracking system, which would reduce tracing time from eight days to four days, leads to a decrease in losses from about 40% to about 15% of the Texas cattle production sector. Under lower contact rates of 0.2 (sc3 and sc4), an equivalent animal tracking system nearly eliminates the losses. Hence, the higher the contact rates or the faster the disease spreads, the less effective the tracking system is.

Figure 2 presents differences in expected losses expressed as a percentage of the value of the Texas cattle production sector, taking into account costs of implementing an animal tracking system such as the NAIS. For illustrative purposes, the results are presented across selected probabilities of infectious disease outbreak. Given an outbreak of infectious disease (probability = 1), with low herd contact rates, reducing the tracking time from eight to two days saves about 20% of the cattle production sector that would otherwise be lost. In the case of a high contact rate scenario, the benefits of a tracking system are more apparent. Figure 2 shows the effect of the likelihood of a

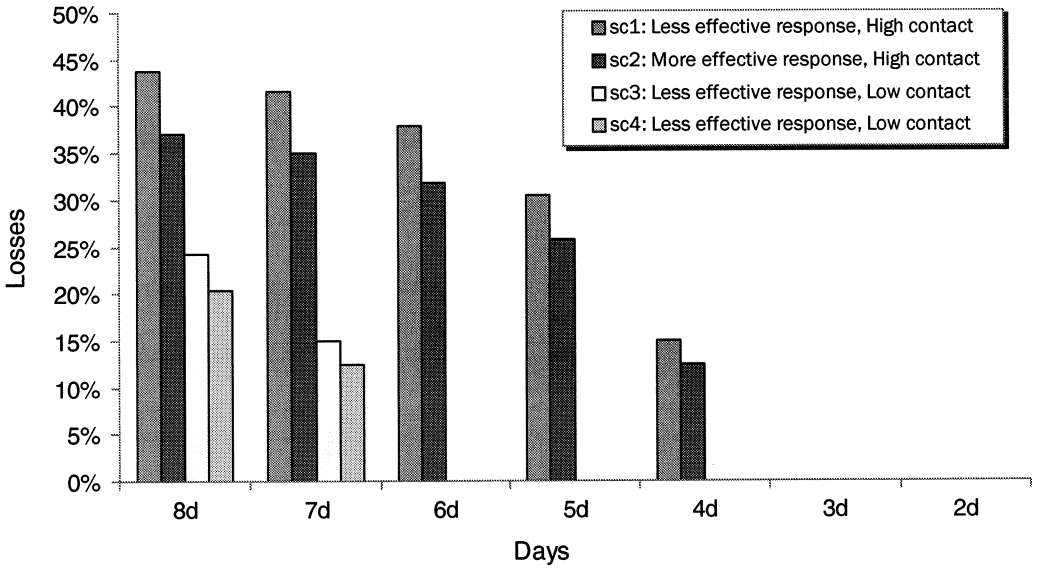

Figure 1. Losses as a percentage of value of the Texas cattle production sector

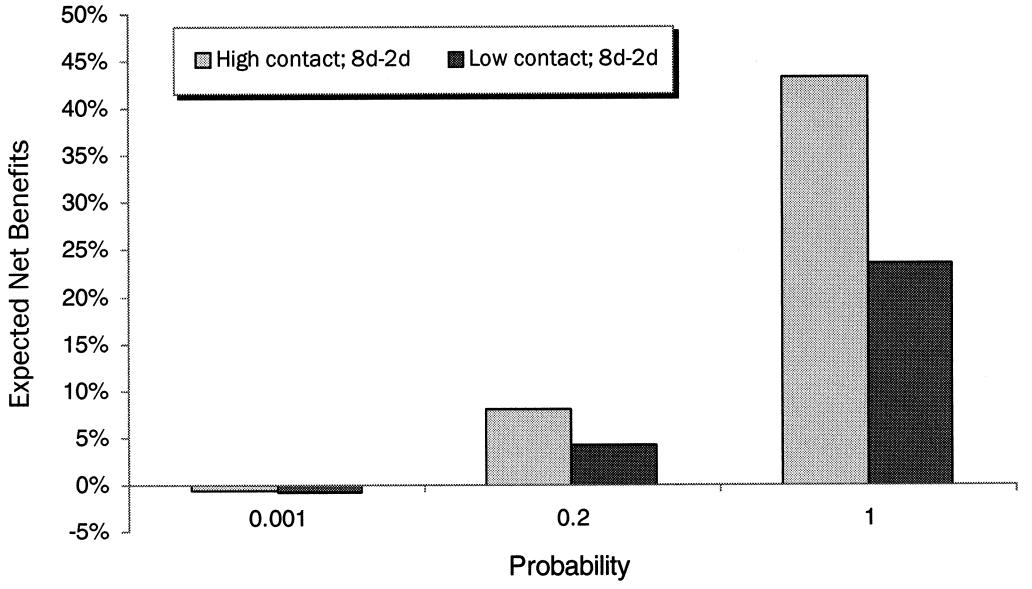

Figure 2. Expected net benefits of implementing a tracking system as a percentage of the value of the Texas cattle production sector

Table 1. Avoided Losses (in $1,000s) from Decreasing Tracking Time to Two Days Under Disease Outbreak: Scenarios 1–4

	Scenario			
Reduction in Tracking Time	#1 Response = 0.17 Contact Rate = 0.4	#2 Response = 0.3 Contact Rate = 0.4	#3 Response = 0.17 Contact Rate = 0.2	#4 Response = 0.3 Contact Rate = 0.2
8 days to 2 days	7,202,698	6,074,568	3,979,318	3,356,059
7 days to 2 days	6,841,557	5,769,991	2,442,926	2,060,307
4 days to 2 days	2,442,971	2,060,341	78	78
3 days to 2 days	207	198	26	26

disease introduction. As expected, the more likely the disease outbreak, the more economically advantageous it is to implement the NAIS. Notice that at the lowest considered levels of probability, costs of implementing and operating an animal tracking system may exceed considered benefits.

Table 1 reports the results in dollar amounts for various application scenarios of an animal tracking system. These estimates provide a lower bound of loss reductions because demand and trade implications as well as losses in other industries were not taken into account in this model. Nevertheless, comparing these estimates to the estimated costs of an animal tracking system provides preliminary empirical estimates of animal tracking benefits. As shown by table 1, significant benefits could result from an animal tracking system relative to its implementation costs if an infectious animal disease is introduced. For example, in scenario 1 (17% decrease in lost herds and 0.4 inter-herd contacts per day) and scenario 2 (30% decrease in lost herds and 0.4 inter-herd contacts per day), reducing tracking time from even four to two days will generate benefits that exceed the costs in the case of an infectious animal disease outbreak. Under scenario 3, with low contact rates, reducing tracking time to two days is beneficial if it currently takes seven or eight days to track animal movements, but not if it currently takes three or four days.

Conclusions

The objective of this study was to evaluate the regional benefits of an animal tracking system to cattle producers under the scenario of the possible introduction of an infectious animal disease. Sensitivity of those benefits was examined in association with animal contact rates, likelihood of disease introduction, and effectiveness of response actions that would mitigate the epidemic.

The benefits of an animal movement tracking system were measured in terms of the monetary value of cattle inventory and the associated gross income that would be lost due to an outbreak of an infectious disease. The estimates do not include the losses from lost consumer demand, trade, and losses that might take place in other industries, such as tourism (Mangen and Burrell, 2003). Inclusion of these losses would likely amplify the benefits of establishing an animal tracking system. However, lack of data related to the implication of a large-scale animal disease outbreak on demand for livestock products and on other industries precludes the inclusion of associated potential losses

into benefit-cost analysis. Therefore, it is important that empirical investigations be performed on the effects of a potential infectious animal disease outbreak on consumer demand and industries other than agriculture.

The results of the empirical analyses in this study show that the speed of animal tracking will have a great effect on the impact of the outbreak. The sooner the information on animal movement is available to be accessed, the sooner appropriate response actions will be implemented to halt the disease spread. Decreasing the time necessary to trace animal movement substantially decreases the losses that could be suffered due to the outbreak of a highly contagious animal disease such as FMD. However, the magnitude of the losses avoided due to implementation of an animal tracking system depends on contact rates and effectiveness of response actions, among other factors.

The results of the empirical analysis need to be interpreted with care and are meant to serve an illustrative purpose rather than as predictions of actual events. The spread of an infectious animal disease was modeled based on two key assumptions. First, the animal population, represented by cattle herds, was assumed to be homogeneous in terms of geographic location, composition, size, and operation type. These four factors could play significant roles in herd susceptibility and spread of a disease. Unfortunately, no data could be found to allow for spatial disease spread across heterogeneous herds. Second, the contact rate was based on similar studies (Schoenbaum and Disney, 2003; Bates, Carpenter, and Thurmond, 2003; Bates, Thurmond, and Carpenter, 2003) without considering actual contact rates appropriate for the region and alternative modes of disease spread, such as through air or wildlife. Sensitivity analysis was conducted to investigate the effect of different contact rates.

Despite the apparent benefits of an animal tracking system at a cattle production sector level, achieving full participation of individual producers may require extra effort. Currently the NAIS is expected to be operational on a voluntary basis until 2009, at which point the NAIS may become mandatory. Since functionality of an animal tracking system depends on the proportion of traceable livestock, and hence on the level of individual producers' participation and cooperation, it is important to investigate the incentives of individual producers and formulate policy in a manner which is incentive compatible.

[*Received November 2005; final revision received September 2006.*]

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