

ANIMAL TRACING: BENEFITS IN CATTLE INDUSTRY  
AND PRIVATE INCENTIVES

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## **Abstract**

A large scale outbreak of an infectious animal disease is likely to cause major economic damages in the cattle industry. One of the strategies to mitigate potential outbreak of an infectious cattle disease is to initiate animal tracking system, which would provide animal movement information in time to prevent the disease spread. This article provides a) a theoretical examination of private participation issues and b) empirical estimates of some of the losses that would be avoided with animal tracking system if infectious animal disease were introduced. The results show that herd contact rates, effectiveness of animal disease response actions, and the extent to which animal tracking system decreases the time of tracing animal movements, influence economic efficiency of animal tracking system. Substantial economic losses could be avoided in case of a highly infectious animal disease outbreak if animal tracking system, which would allow 48 hour movement tracking, is implemented.

Key Words: Animal Tracing, Infectious Disease Spread, Cost Minimization, Incentives

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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 effects of FMD and BSE outbreaks in the UK (Thompson *et al.* 2001; Henson and Mazzocchi 2002; Burton and Young 1996), as well as impacts of the 2003 BSE occurrence in Canada and the US with consequent closure of the US Canada border and loss of export markets, have heightened the urgency of developing effective mechanisms for animal disease management.

The key to effective internal management of infectious animal disease outbreak is timely detection, isolation, and destruction of infected and high risk herds and animals (Bates *et al.* July and February 2003; Garner and Lack 1995; Schoenbaum and Disney 2003). Currently, outbreak response strategy mainly relies on quarantine and depopulation of infected herds and contact premises, identified based on “sound epidemiological evidence” (USDA 2003). Current US programs to detect and mitigate diseases such as Foot and Mouth Disease (FMD) rely on the recognition and reporting of clinical signs by a producer, animal care taker, meat inspector or veterinarian (Bates *et al.* September 2003 p. 609). Reliance on such an approach has two major problems. First, detection based on visual observation of clinical signs implies that the disease could have been present and possibly spreading before the visual realization of its presence. Second, clinical signs of FMD are indistinguishable from the signs of some of the other diseases

(Bates *et al.* September, 2003 p. 609). Therefore, more reliable methods for detection and identification of infected herds may be appropriate. Present methods for identification of possibly infected premises, the promptness of which influences the length of disease presence, may be enhanced by the availability of animal tracking system such as National Animal Identification System (NAIS). This system would store information on cattle movement across premises which would be made available to the authorities in case of an infectious cattle disease outbreak. Such a system could drastically speedup identification and accompanying isolation of potentially infected and high risk herds by providing timely trace back information about contact herds, which in turn would likely reduce the economic and sociologic damages caused by a disease outbreak.

The concerns about the costs of implementing and operating the identification system are a key factor against establishing national animal tracking system. However, recent actions by the Food and Drug Administration and US Department of Agriculture suggest that private entities will be required to closely track and report animal product shipments, thereby requiring producers to shoulder part of the cost of tracing the disease outbreaks (Pritchett, Thilmany and Johnson 2005). The USDA is initiating the program on a voluntary basis, although it may become mandatory over time as and if the system becomes fully functioning (Bailey 2004; Collins 2004).

The primary benefit of animal tracking system, discussed in this article, is its significant role as an animal disease mitigation tool in case of an infectious animal disease outbreak. Operationally, NAIS consists of two parts (SUDA 2005). First is the premise identification number (PIN), a seven digit identifier assigned to each premise.

Second is animal identification number (AIN) or group/lot identification number (GIN), depending on whether individual animal or a group of animals moved through production chain. The AIN or GIN, the PIN of the receiving location, and the date of the animal or animals' arrival will be reported to National Animal Records Repository as animals move between premises to allow 48 trace back objective, which is directly affected by percentage of animal movements that are recordable (USDA 2005). Therefore, full participation of producers is essential for successful implementation and effective functioning of this program. The purpose of this article is two fold. First goal is to examine the producers' standpoint and conceptualize the pros and cons of NAIS from individual producers' point of view. Possible incentives for full producer participation and cooperation are examined. Second goal is to demonstrate the industry wide benefits of animal tracking system under possible outbreak of an infectious animal disease and examine some of the factors that influence economic efficiency of such system. A Reed-Frost functional form for infectious animal disease spread was adopted from epidemiology literature and incorporated in the economic framework to arrive at some of the economic losses that would be avoided by having animal tracking system if infectious animal disease were to strike.

### **Producers' Perspective**

Livestock producers have four main motives for establishing animal identification and tracking. 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 commingled. Second, traceability would allow for identification and

tracking of healthy and unhealthy animals, which would enhance efficiency of control and eradication of livestock diseases. Such information would be essential in implementing animal disease response strategies such as ring culling and vaccination, and setting up quarantine zones. 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 such otherwise unobservable animal attributes as proper vaccinations, proper medical care, animal welfare provisions, and appropriate feeding procedures, might be able to sell their animals for higher prices (Golan *et al.* 2004). Fourth, enhanced record keeping would facilitate identification of animals with superior genetics in terms of their productivity. For example, a cow/calf or a feedlot operator could increase the productivity by acquiring animals from a family tree with superior ability to gain weight as revealed by past records.

There are two main drawbacks associated with animal tracking system from producers' perspective. One is that the producers are reluctant to incurring additional costs that might be associated with implementing and operating animal tracking. These costs could include equipment costs as well as record keeping and maintenance costs. The second major concern of the producers is potential liability that could arise due to the information available through NAIS (Golan *et al.* 2004). Producers worry that NAIS information could be used to place liability on them for unhealthy or low quality animals. In addition, producers could be uncomfortable with the possibility that NAIS data could be available to the IRS.

Taking into account advantages and disadvantages of NAIS one could formulate a decision process from a producer's perspective. For a typical risk neutral decision maker

we assume the goal is to maximize net returns minus expected losses associated with animal disease introduction and mitigation costs.

$$(1) \quad NR_i = P[W_i - \pi_i Q_i - (1 - \pi_i)(L_i + \varphi \cdot LL_i) - \text{cost}_i] + (1 - P)[W_i - \varphi \cdot LL_i - \text{cost}_i]$$

Where,  $P$  is the probability of foreign animal disease introduction,  $i$  is a subscript indicating cooperation ( $c$ ) or no cooperation ( $n$ ) in NAIS,  $W_i$  is the net value of a cattle operation including all expenses other than those associated with animal tracking system and possible disease introduction.  $Q_i$  is losses if the premise is infected under cooperation and no cooperation. Hereafter it is assumed that  $Q_c = \alpha Q_n$  ( $0 < \alpha < 1$ ) and  $Q_n = W_n$ , which means that producers who don't cooperate in NAIS lose all net value of the operation while those who do cooperate lose only a fraction of their net value possibly due to compensation programs.  $\pi_i$  represents probability of individual producer being infected with the disease under cooperation and no cooperation in animal tracking program. Clearly  $\pi_i$  is a conditional probability. That is  $\pi_i \geq 0 | P > 0$ .  $L_i$  is losses suffered by producers who are not directly infected by the disease but have to face market consequences of disease outbreak. This value could be either positive or negative depending on the relative size of demand and supply effects of an outbreak.  $\varphi$  is the probability that the producer will suffer liability losses if he/she decides to participate in NAIS.  $LL_i$  is liability losses that could be incurred by the farmer if he/she participates in NAIS and is 0 if  $i = n$ . Liability losses, as perceived by the producers, reflect possible losses that could be incurred due to identification system above direct implementation costs. For example, the possibility that traceability could be used to place liability for unhealthy or low quality animals on farmers makes many in the livestock sector uncomfortable because there is always the possibility that even the most careful producer

could experience a safety problem (Golan *et al.* 2004).  $Cost_c$  is direct implementation costs of participating in NAIS.

Under cooperation and no cooperation, equation (1) takes the forms of equations (2) and (3) respectively.

$$(2) \quad NR_c = W_c - P\pi_c Q_c - P(1 - \pi_c)L_c - \varphi \cdot LL_c(1 - P\pi_c) - cost_c$$

$$(3) \quad NR_n = W_n - P\pi_n Q_n - P(1 - \pi_n)L_n$$

Subtracting equation (3) from equation (2) will give us the benefits of investing in NAIS. it can be shown that the difference could be expressed as:

$$(4) \quad \Delta NR = \Delta W + P[\Delta(\pi Q) + \Delta L - \Delta(\pi L)] - cost_c - \varphi LL_c(1 - P\pi_c)$$

This equation could be examined to differentiate the factors with positive effect on this difference from those with negative effects. Table 1 summarizes the results. With the assumptions of  $0 \leq L_c \leq L_n \leq W_n \leq W_c$ ,  $Q_n = W_n$ , and  $0 \leq \pi_c \leq \pi_n \leq 1$ , it can be shown that  $[\Delta(\pi Q) + \Delta L - \Delta(\pi L)] \geq 0^1$ , therefore  $(\partial \Delta NR / \partial P) \geq 0$ . This simply implies that the benefits of cooperating in animal tracking system increase as the probability of infectious animal disease outbreak increases. The effects of  $Q$ ,  $\pi_n$ ,  $L_n$ ,  $L_c$ ,  $cost$ ,  $\varphi$ , and  $LL_c$  are straightforward and could easily be seen from equation (4). The increase in  $Q_n$ ,  $\pi_n$ , and  $L_n$ , and decrease in  $Q_c$  will have a positive effect on the difference between net returns under cooperating and not cooperating in NAIS. Hence, increase in  $P$ ,  $Q_n$ ,  $\pi_n$ , and  $L_n$  will increase the benefits of participating in NAIS. On the other hand increase in  $L_c$ ,  $cost$ ,  $\varphi$ ,  $Q_c$  and  $LL_c$  will decrease the benefits of participating in NAIS. The effect of  $\pi_c$  on benefits of cooperating in NAIS is determined by the sign of  $P(L_c + \varphi LL_c - Q_c)$ , which could be assumed to be negative since the losses under direct infection are probably



greater than losses under disease outbreak but no direct infection plus expected losses from possible liability issues<sup>2</sup>. In such case the higher the  $\pi_c$  the less the expected benefits of cooperating in NAIS. However, if losses under no infection with disease outbreak plus expected losses from liability issues are greater than losses under infection, then increase in  $\pi_c$  increases the benefits of cooperating in NAIS.

The policy implication of table 1 is that the factors listed in the table could be used to sway the participation decision of cattle producers. Agent behavior becomes important when considering animal disease mitigation strategies. Public institutions influence the behavior of private parties through various programs, regulations, mandates, and other incentive mechanisms (Pritchett *et al.* 2005). Increasing the levels of factors listed in the positive effects column or decreasing the effects of factors listed in the negative effects column will provide additional incentives for producers to participate and comply with animal tracking system. For example, decreasing  $Q_c$  through providing compensation for lost product to those producers who participate in the program will increase the expected net benefits of cooperating, and therefore will provide incentive for participation.

### **Industry perspective**

From industry's standpoint the decision to invest in an animal disease mitigation program such as NAIS depends on an array of factors such as likelihood of disease introduction, disease spread rate, effectiveness of such program and alternative mitigation options and corresponding costs. Actions that could affect any of those factors could potentially be considered as a disease mitigation tool. For example, animal testing could be used to speed up the recognition of disease presence and thus facilitate timely response and

eradication of the disease (Elbakidze 2004). The merit of NAIS is that such system would allow for timely tracking of the diagnosed and exposed animals to their origins. All cattle movement data would be available to the authorities in case of infectious animal disease outbreak. This would facilitate identification and eradication of the source of an outbreak. In addition, under full participation, NAIS would instantaneously identify all herds that have been in contact with diagnosed animals. This essentially implies that response actions could be implemented on high risk properties sooner under NAIS system than under current documentation procedures.

Figure 1 depicts a hypothetical example of animal movement across premises to help demonstrate the application of animal tracing system. Suppose that on day 1 an infectious animal disease was introduced in herd 3 ( $H_3$ ). Suppose that it takes about 8 days for the infected animals to show the sign of the disease, at which point the herd is isolated and destroyed to prevent further spread of the disease. According to the diagram, on day 3 the animals were moved from  $H_3$  to  $H_1$  and  $H_5$ . On day 5 animals were moved from  $H_5$  to  $H_4$ , on day 6 from  $H_1$  to  $H_2$ , on day 9 from  $H_2$  to  $H_6$ , from  $H_4$  to  $H_7$ , and from  $H_5$  to  $H_9$ , and so on. Let's compare two scenarios of tracing animal movements. Under the first scenario it takes two days for any animal movement to become completely traceable. So, for example on day 5 we will know that animals were moved from  $H_3$  to  $H_1$  and  $H_5$ , on day 7 we will know that animals were moved from  $H_5$  to  $H_4$ , and so on. Under such system the progression of infection and it's detection will be as follows. On day 8  $H_3$ ,  $H_5$ , and  $H_1$  will show the signs of infection and will be taken out of the system along with  $H_4$  and  $H_2$  because those herds will by than be known to have been contacted by herds  $H_5$  and  $H_1$  on days 5 and 6 respectively. Since on day 7  $H_5$  was not known to be

a high risk herd some animals were moved to H<sub>8</sub>. This becomes known on day 9 and H<sub>8</sub> is destroyed. On day 10 the outbreak of the disease is contained with H<sub>2</sub>, H<sub>3</sub>, H<sub>5</sub>, H<sub>1</sub>, H<sub>4</sub>, H<sub>8</sub>, destroyed and H<sub>6</sub>, H<sub>7</sub>, H<sub>9</sub>, H<sub>10</sub>, and H<sub>11</sub> unaffected.

Now suppose that it takes 6 days to trace any given animal movement. On day 8 after introduction of the disease the signs show up on herds H<sub>3</sub>, H<sub>5</sub>, and H<sub>1</sub>. On day 11 herds H<sub>2</sub>, H<sub>8</sub> and H<sub>4</sub> show signs because animals that were infected on day 3 are now in those herds. Notice that H<sub>4</sub> is also identified as having received infected animals on day 5 from H<sub>5</sub>. On days 13, 14, and 15 H<sub>7</sub>, H<sub>6</sub>, and H<sub>11</sub> respectively show signs of disease. On day 16 H<sub>9</sub> is identified as having received infected animals from H<sub>7</sub> on day 10, therefore movements to H<sub>10</sub> are prevented. In this scenario all herds except for H<sub>10</sub> are directly affected by the outbreak. By comparing the two tracing systems one can see how the system with faster traceability will result in fewer herds being destroyed. Hence, less agricultural product and associated producer income will be lost.

The benefits of investing in a program such as NAIS could be examined from the standpoint of minimizing potential losses to the cattle industry. Total costs associated with animal disease outbreak include direct financial losses due to lost production and suppressed demand in cattle industry, including lost export markets, indirect losses in related industries, and costs of preventing and responding to an outbreak. Conceptually, the problem could be addressed by comparing the benefits of a mitigation program such as NAIS to the costs associated with its implementation. Therefore, the first step is to evaluate some of the benefits of establishing the program. The benefits of NAIS could in part be represented by the losses that could be avoided due to the tracking system if a contagious animal disease was introduced. In the livestock industry, the value of lost

cattle and the value of lost income are major components of financial losses to the producers.

Equation (5) represents expected losses ( $EL$ ) in the livestock industry associated with an outbreak of a highly infectious disease, such as Foot and Mouth Disease (FMD).  $P$  is the probability of disease introduction;  $V$  is a value of monetary losses associated with each infected herd,  $R$  is level of response to a disease outbreak,  $H(R)$  is proportion of herds lost to the outbreak as a function of response actions,  $D_\mu$  is the number of infected herds under various scenarios of days ( $\mu$ ) between infection and removal of infected animals,  $CR$  is cost of response actions.

$$(5) \quad \underset{R}{MIN} : EL = P \times [V \times H(R) \times D_\mu + CR \times R]$$

$$(6) \quad D_\mu = \left[ TN - \sum_{t=0}^{t=t^*-1} \hat{D}_t \right] [1 - q^{CI}]$$

$$(7) \quad H(R) = (a_1 + a_2 R + a_3 R^2)$$

The representation for disease spread,  $D_\mu$ , needs to reflect the fact that in the early stages of 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 disease outbreak progression, number of infected herds will increase at a decreasing rate. Therefore,  $D_\mu$  (equation 6) is assumed to have a Reed-Frost equation form (Carpenter, 1984; Carpenter, Thurmond and Bates 2004; Elbakidze 2004)

where,  $TN$  is total number of herds in the area and  $\hat{D}_t$  is number of infected animals on

day  $t^*$ , therefore  $\left[ TN - \sum_{t=0}^{t=t^*-1} \hat{D}_t \right]$  is number of susceptible herds at time period  $t^*$ .  $q$  is

the probability of avoiding the adequate contact, necessary to transmit the disease.

Therefore,  $1-q$  is the probability of making an adequate contact and is equal to  $k/TN - 1$ ,

where  $k$  is number of disease transmission adequate contacts a herd makes with other herds per day.  $k$  was initially assumed to be 0.4 based on contact rates used in previous investigations (Schoenbaum and Disney 2003; Garner and lack 1995; Bates, Thurmond and Carpenter 2001). Sensitivity analyses were later performed to evaluate the effect of this parameter.  $CI$  is cumulative number of infectious herds in any time period during

the outbreak. The number of infectious herds is calculated using  $CI = \sum_{\mu}^7 \hat{D}_{t-\mu}$  to reflect

the fact that FMD spreads for at least 7 days before showing clinical signs of infection at which point the diseased herds are assumed to be diagnosed and destroyed.  $\hat{D}_t$  is

number of infected herds in each of the time periods during the outbreak. Therefore, the

total number of infected herds will be given by  $D_t = \sum_{t=0}^{t=t^*} \hat{D}_t$ .

Proportion of hers lost during the outbreak,  $H(R)$ , is hypothesized to be convex implying that as more response actions, such as slaughtering, are employed the damages from FMD outbreak will decrease (equation 7). However, too much of response actions could increase the costs. Therefore, a convex quadratic form was assumed for this function.

For empirical evaluation  $H(R)$  was normalized according to previous estimations where slaughter of herds with clinical signs and herds in direct contact with the diagnosed herds leads to 17% reduction in number of slaughtered animals as compared to the strategy of slaughtering only the diagnosed herds (Schoenbaum and Disney, 2003, page

49). By normalizing response actions if at  $R=0$  the proportion of lost animals is 1, corresponding to losses under no response actions, than at  $R=1$  the proportion of losses is 0.83. Consequently, the response effectiveness function used in this analysis was  $H(R)=1-0.34R+0.17R^2$ .  $V$  was assumed to be \$58,876, which corresponds to cattle monetary value plus annual gross income for a herd of 50 animals (Elbakidze 2004).

The costs of NAIS for Texas producers were calculated using Blasi *et al.* (2003) who estimated per head annual costs of implementing 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 2003) to come up with an approximation of NAIS costs based on Texas cattle herd composition according to size and operation type. Annual costs of NAIS for Texas cattle industry were estimated to be about \$112 million.

Because FMD infected cattle stays in latent period for about one to two weeks (Garner and Lack 1995) we can estimate the effects of a contagious disease outbreak with no animal tracking by assuming that infected animals spread the disease until infection shows signs and the disease is confirmed, at which point appropriate response actions are immediately taken to isolate and destroy the infected herds. The effectiveness of response actions is greatly affected by the ability of the authorities to track the infected and exposed animals in a timely manner. NAIS is expected to enable 48-hour tracking of the movements of any diseased or exposed animal. In terms of disease spread, having NAIS in place essentially implies that potentially infected herds could be identified much

sooner. Therefore, potentially infected premises could be quarantined much sooner, which means there will be fewer herds spreading the infection in any given period. The benefits associated with such intervention, or losses avoided by having such program in place, could be estimated by comparing the expected losses under various scenarios for  $\mu$ . For example, to estimate losses due to a contagious animal disease outbreak under the scenario with a functioning NAIS system, EL (equation 5) was calculated with  $\mu=2$ , assuming that NAIS enables a two day trace back of infected and exposed animals. With no NAIS traceback could take longer than two days. Several scenarios were considered to account for length of trace back with current cattle record keeping. Specifically, EL was estimated under  $\mu=3, \dots 8$ .

## **Results**

The model was used to conduct sensitivity analyses in terms of the effects of herd contact rates, effectiveness of response actions, and likelihood of disease introduction on expected losses caused by disease introduction and on the benefits of investing in animal tracking system. Three levels of herd contact rate, four levels of animal tracking effectiveness, and two levels of response effectiveness were considered along with a range of disease introduction probabilities.

Figure 2 shows losses brought by disease introduction as a percentage of cattle industry value in terms of cattle values and 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, let's examine scenario 1 (sc1) with less effective response actions, which lead to 17 percent decrease in lost animals, and high contact rate of 0.4. If it currently takes 8 days to track infected and

exposed animals, we would lose about 45% of the value of Texas cattle industry. Speeding up the tracking process to 4 days will reduce the losses to about 15%. Losses under 2 day traceability scenario represent 0.0006% of cattle industry value. Under scenario 2 (sc2) losses decrease relative to scenario 1 (sc1) at all traceability levels due to more effective response with 30 percent decrease in lost cattle. Increasing the contact rates makes 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 8 days to 4 days, leads to about 25-30% reduction in losses. Under lower contact rates (sc3 and sc4), animal tracking system leads to around 22% decrease in losses reducing the losses to around 0.001 percent of industry's value. Hence, the higher the contact rates among cattle herds or the faster the disease spread, the less effective is the tracking system. Nevertheless, even with lower rates of daily herd contacts, the enhanced animal tracing system leads to a substantial reduction in losses relative to a slower system for identification of infected and exposed herds.

Figure 3 presents the expected losses taking into account costs of implementing an animal tracing system such as NAIS. In case of a high contact rate scenario, reducing tracking time from 8 days to 2 days would have a benefit equal to about 45 % of cattle industry value. If it currently takes five days to track animal movements, then reducing the time to two days will generate benefits worth of almost 30% of cattle industry value in Texas. However, for lower contact rates, the net benefits of animal tracking are lower. With low herd contacts rates, reducing the tracking time from 8 to 2 days saves about 20% of cattle industry that would otherwise be lost. Reducing tracking time from 5 to 2



days under low contact rates will cost more than the losses, included in this study, which the tracking system would help to avoid. The figure also shows the effect of the likelihood of disease introduction. The more likely the disease outbreak the more economically advantageous it is to implement NAIS.

Table 2 presents the results in dollar amounts for various application scenarios of animal tracking system. These estimates provide a lower bound of loss reductions because losses brought by demand and trade implications as well as losses in other industries were not taken into account. Nevertheless, these estimates could be compared to the estimated costs of animal tracking system to get preliminary empirical estimates of animal tracking benefits. The table shows that significant benefits could result from animal tracking system relative to its implementation costs if infectious animal disease is introduced. For example, in scenarios 1 and 2, reducing tracking time from even four to two days generate benefits that exceed the costs in case of an infectious animal disease outbreak (probability =1). In scenario 3, with low contact rates, reducing tracking time to two days is beneficial if it currently takes eight or seven days to track animal movements but not if it currently takes four or three days. Table 2 also shows that the expected benefits, in terms of avoided losses comprised of cattle values and associated gross income in cattle industry, are smaller at the lower probabilities of disease introduction and could be lower than animal tracking implementation costs.

### **Limitations**

The results of the empirical analysis need to be interpreted with care and are meant have more illustrative purpose rather than predictions of actual events. Spread of

an animal disease was modeled based on two key assumptions. First, the animal population, represented by herds, was assumed to be homogeneous in terms of animal geographic location, composition, size, and operation type. These four factors could play a significant role in herd susceptibility and spread of the disease. Unfortunately no data could be found to allow for spatial disease spread across heterogeneous herds. Reed-Frost formulation, adopted in this study, presents a rough approximation for the disease spread and does not require special data. Second, contact rate was based on similar studies (Schoenbaum and Disney 2003; Bates *et al.* 2003) without considering actual contact rates appropriate for the region and alternative models of disease transmission, such through air or wildlife. Sensitivity analysis was conducted to investigate the effect of having a different contact rate.

Effectiveness and type of response actions to a potential outbreak of infectious animal disease was also adopted from Schoenbaum and Disney (2003). 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 more effective response action on losses under various animal tracing systems.

The monetary losses associated with an animal disease outbreak under various animal tracing scenarios were calculated using cattle inventory that would be lost due to disease outbreak and associated lost gross income. 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 effective

animal tracing system. Therefore, results of this work may be viewed as a lower bound of the benefits of animal tracing system.

The costs of implementing animal tracing system were calculated by using estimates reported in related studies (Bailey 2004; Blasi *et al.* 2003). These cost estimates imply that substantial economies of size in implementing animal tracing exist at the producer level. However, the cost to small producers may be somewhat overstated because they did not account for the possibility of pooling some of these costs. For example, small producers might be able to share costs for computer hardware, electronic readers or even labor to work cooperatively on animal ID system. In calculating NAIS costs for feedlot operations, number of animals in each feedlot size group were approximated according to proportions of annual marketing (USDA 2003). This was the best available estimate of the distribution of animal numbers across feedlots of various sizes in the absence of actual distribution.

### **Conclusion**

The objective of this article was two fold. First was to theoretically formalize some of the factors that influence the incentive of individual cattle producer to participate and fully cooperate in animal tracing system. Second was to evaluate the regional industry-wide benefits of animal tracking system under the scenario of possible introduction of an infectious animal disease using epidemiologic disease spread formulation and examine the sensitivity of those benefits towards animal contact rates, likelihood of disease introduction, and effectiveness of response actions that would mitigate the epidemic.

Even though benefits of animal tracing system are apparent on an industry wide level, achieving full participation of individual producers may require extra effort.

Currently NAIS is expected to be operational on voluntary basis until 2009, at which point NAIS may become mandatory. In this article individual producer motives were examined to possibly encourage producer participation in a voluntary program and to encourage cooperation in a mandatory program. Among the factors that positively influence the intention of the producers to adopt NAIS are, likelihood of disease outbreaks, value of assets including capital and income, likelihood of being infected under no participation in the program, and magnitude of losses brought by possible disease outbreak. On the other hand some of the factors that negatively affect the decision are magnitude of losses brought by disease outbreak even under adoption of NAIS, costs of adopting NAIS, likelihood and magnitude of losses due to liability issues made possible by adoption of NAIS, and likelihood of being infected even under adoption of NAIS. These factors could be used as educational tools to convince producers in investing in NAIS. For example, producer's perspective of likelihood of disease introduction could be increased by stressing that some of the diseases are present in neighboring countries. It could be emphasized that magnitude of damages brought by an animal disease is determined by the ability of the industry to effectively respond to an outbreak. It could also be communicated that in case of highly infectious disease such as FMD, the likelihood of being infected even in remote regions from the epicenter of an outbreak is high unless the disease is contained in a timely manner by, in part, relying on a fully functioning animal tracking system. The empirical results of this work could be used to illustrate the difference between monetary values of losses suffered with and without animal tracking. In addition, confidentiality of data in NAIS could be assured to

reduce the risks perceptions of losses due to possible liability issues. NAIS data accessibility could be limited to infectious disease outbreak mitigation purposes only.

Benefits of animal movement tracing system were measured in terms of monetary value of cattle inventory and associated gross income that would be lost due to an outbreak of an infectious disease. The estimates do not include the losses that would be suffered due to lost consumer demand, trade, and losses that might be endured in other industries such as tourism (Mangen and Burrell 2003). Inclusion of these losses would probably amplify the benefits of establishing animal tracking system for the purposes of tracking animal movements. However, lack of data related to implication of a large scale animal disease outbreak on demand for livestock products and on other industries precludes inclusion of associated potential losses into benefit cost analysis. Therefore, it is important that empirical investigations be performed on the effects of potential infectious animal disease outbreak on consumer demand and industries other than agriculture.

The results of empirical analyses in this article show that 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 in case of an infectious animal disease outbreak. Decreasing the time of animal movement traceability substantially decreases the losses that could be suffered due to an outbreak of highly contagious animal disease such as FMD. However, the magnitude of losses avoided due to animal tracking system depends on contact rates and effectiveness of response actions, among other factors.

## Footnotes

<sup>1</sup> Let  $W=L_c+x$ , and  $Q_c=\alpha W$  (under cooperation producers get compensated for some of the losses,  $\alpha < 1$ ),

$$\begin{aligned} \text{then } [\Delta(\pi Q) + \Delta L - \Delta(\pi L)] &= L_c \pi_n + x \pi_n - \pi_c \alpha (L_c + x) + L_n - L_c - L_n \pi_n + L_c \pi_c = \\ &= x(\pi_n - \alpha \pi_c) + (1 - \pi_n)(L_n - L_c) + \pi_c L_c (1 - \alpha) \geq 0 \end{aligned}$$

<sup>2</sup>  $P(-\alpha L_c - \alpha x + L_c + \phi L L_c) = P(-\alpha(L_c + x) + L_c + \phi L L_c) = P(-\alpha W + L_c + \phi L L_c) = P(L_c + \phi L L_c - Q_c)$

**Table 1. Factors Influencing Private Decisions to Cooperate in NAIS**

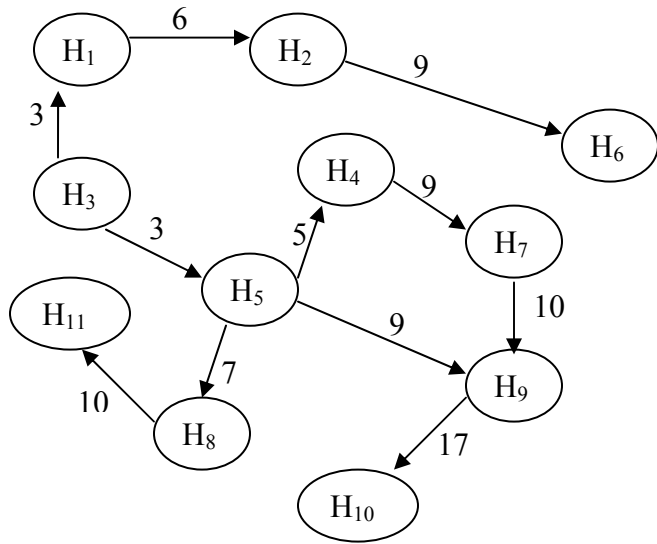
Positive Effects	Negative Effects
P	$L_c$
$Q_n$	$Q_c$
$\pi_n$	Cost <sub>c</sub>
$L_n$	$\varphi$
$\pi_c$ if $L_c + \varphi L L_c > Q_c$	$L L_c$
	$\pi_c$ if $L_c + \varphi L L_c < Q_c$

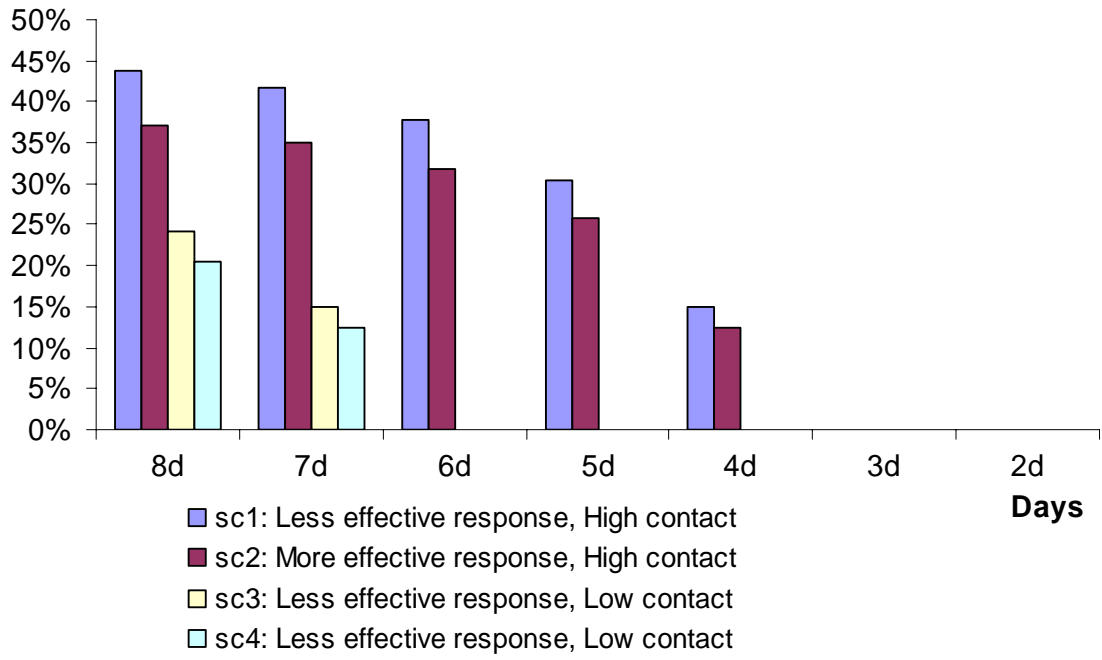
**Table 2. Avoided Losses by Decreasing Tracking Time to Two Days in  
\$1,000**

	Probability					
	0.001	0.03	0.1	0.2	0.4	1
Scenario 1: Response Effectiveness 0.17; contact rate 0.4						
8days-2days	7,202.7	216,080.9	720,269.8	1,440,540.0	2,881,079.0	7,202,698.0
7days-2days	6,841.6	205,246.7	684,155.7	1,368,311.0	2,736,623.0	6,841,557.0
4days-2days	2,443.0	73,289.1	244,297.1	488,594.2	977,188.4	2,442,971.0
3days-2days	0.2	6.2	20.7	41.4	82.8	207.1
Scenario 2: Response Effectiveness 0.3; contact rate 0.4						
8days-2days	6,074.6	182,237.0	607,456.8	1,214,914.0	2,429,827.0	6,074,568.0
7days-2days	5,770.0	173,099.7	576,999.1	1,153,998.0	2,307,996.0	5,769,991.0
4days-2days	2,060.3	61,810.2	206,034.1	412,068.1	824,136.3	2,060,341.0
3days-2days	0.2	5.9	19.8	39.6	79.1	197.8
Scenario 3: Response effectiveness 0.17; contact rate 0.2						
8days-2days	3,979.3	119,379.5	397,931.8	795,863.6	1,591,727.0	3,979,318.0
7days-2days	2,442.9	73,287.8	244,292.6	488,585.3	977,170.6	2,442,926.0
4days-2days	0.1	2.3	7.8	15.5	31.1	77.7
3days-2days	0.0	0.8	2.6	5.2	10.4	25.9
Scenario 4: Response effectiveness 0.3; contact rate 0.2						
8days-2days	3,356.1	100,681.8	335,605.9	671,211.9	1,342,424	3,356,059
7days-2days	2,060.3	61,809.2	206,030.7	412,061.5	824,122.9	2,060,307
4days-2days	0.1	2.3	7.8	15.5	31.0	77.7
3days-2days	0.03	0.8	2.6	5.2	10.4	25.9

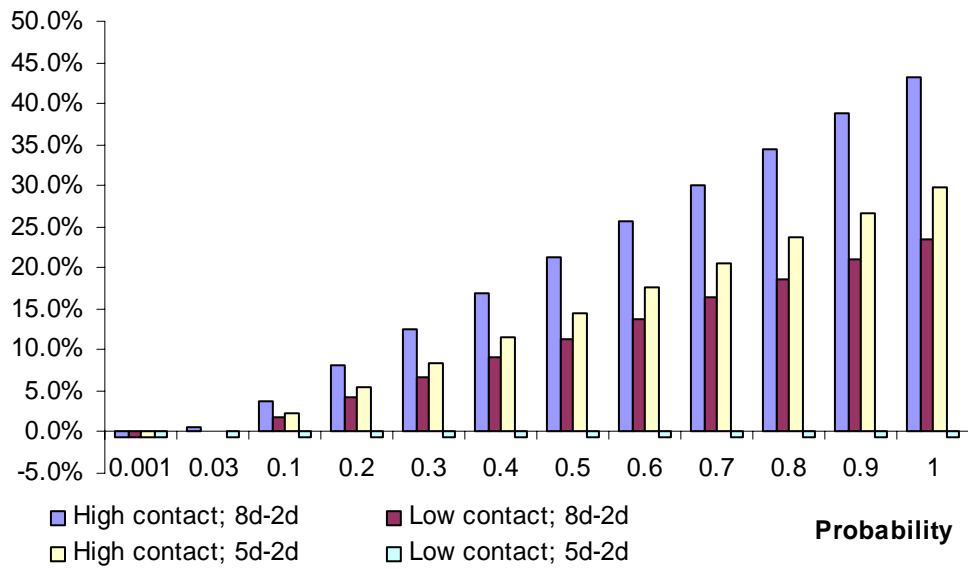


**Figure 1. Hypothetical Example of Animal Movement**





**Figure2. Losses as percentage of value of agricultural industry**



**Figure 3. Expected net benefits of tracking system as percentage of industry value**

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