A MODEL OF THE ECONOMIC IMPACT OF AFRICAN HORSE SICKNESS TO THE EQUINE BREEDING INDUSTRY IN SOUTH AFRICA

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Abstract

A deterministic model for the economic impact of African Horse Sickness (AHS) on the equine breeding industry was developed for South Africa. It was applied to the case of the 2007/2008 outbreak of AHS in the Eastern Cape as a pilot application of the model, using data from breeders in the province. It was concluded that the deterministic model's extension to include other areas of equine livelihoods could be effective in exposing the need for further research into the control and treatment of AHS in South Africa.

1. INTRODUCTION

UNLIKE THE SPHERE OF HUMAN HEALTH, in which the objective is to eliminate loss and suffering, the objective of animal health is in fact to eliminate economic loss (Perry *et al.,* 2001: 236). Viral diseases pose a significant threat to the equine industry all over the world due to the large scale and high rate of movement of horses for breeding and competition purposes both within and between countries (MacLachlan *et al.*, 2007: 5578). African horse sickness (AHS) is no exception. AHS is a non-contagious, infectious disease caused by the African Horse Sickness Virus which is transmitted by the biting midge, *Culicoides imicola,* and has a mortality rate of over 90% for AHS naive horses (MacLachlan and Guthrie, 2010: 40; Mellor and Hamblin, 2004: 446). It affects equids in most of sub-Saharan Africa, which is considered its endemic area, but epizootics have also occurred in North Africa (spread via the movement of nomads with their animals) Europe and the Middle and Near East (MacLachlan and Guthrie, 2010: 41; Niven, 2005; Mellor and Hamblin, 2004: 450). In 1959, there was an outbreak of the disease in Iran, spreading from there to the Persian Gulf, India, Pakistan, Turkey and Afghanistan in the following two years, and killing in the region of 300 000 horses over the period of the outbreak (Niven, 2005). Between 1987 and 1990, AHS spread to Spain via zebra that were imported from Namibia (MacLachlan and Guthrie, 2010: 41). In 1997, in recognition of its devastating socio-economic effects and significance in the international trade of equids, the World Organisation for Animal Health (OIE) classified AHS as a List A notifiable disease (von Teichman and Smit, 2008: 5014). MacLachlan and Guthrie (2010: 41) warn that the spread of AHS to North Africa could quickly lead to its dispersal across the Mediterranean basin and into Europe or the Middle East, as was seen with the Bluetongue virus which is transmitted by the same vector. Were this to happen with the

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AHS virus, the economic effects would be catastrophic as these regions are highly involved in the international trade and movement of horses (MacLachlan and Smit, 2010: 41).

Since the 19th century, AHS has established itself as endemic almost completely across South Africa and cases have been observed virtually countrywide with seasonal outbreaks disrupting the equine industry on a regular basis (Niven, 2005; Mellor and Hamblin, 2004: 450). Furthermore, South Africa is the only country in which all nine serotypes of the virus have been isolated (von Teichman and Smit, 2008: 5014). Because the reproduction of *Culicoides* is reliant on wet, humid conditions, the occurrence of dry summers does result in the reduced prevalence of AHS in South Africa in some years. Given favourable conditions, the disease will begin to emerge in the summer rainfall areas in February and through to April, subsiding at the first signs of frost, but some cases have been observed in May and June in the Lowveld areas (Niven, 2005).

The Onderstepoort Veterinary Institute in Pretoria has developed a vaccine to cover seven of the nine serotypes, and it is compulsory that the two separate injections are administered to all horses in South Africa on a regular basis, except those within the free and surveillance zones in the Western Cape (von Teichman and Smit, 2008: 514-515). The vaccine, produced by Onderstepoort Biological Products Ltd., is an attenuated live virus vaccine which has been widely used throughout southern Africa since 1991 (von Teichman and Smit, 2008: 5014). The vaccine has been shown to build up a level of immunity in horses that are regularly vaccinated, however, they are never fully protected from the disease, and infection can still occur in regularly vaccinated horses (Niven, 2005). Furthermore, it has been suggested that vaccinating adult horses too often can reduce their immunity to the disease (Niven, 2005). But it is clear that the introduction and widespread use of the vaccine by horse owners in South Africa has been successful in significantly reducing the number of deaths caused by the disease. There is, unfortunately, no known cure for the disease, though there are several treatments that have been seen to have positive effects, but with mixed successes.

Some recent outbreaks of AHS were reported in KwaZulu Natal, the Eastern Cape and Gauteng in 2003 and in the Western Cape in 2004 (von Teichman and Smit, 2008). In 2007, 433 cases of AHS in the Eastern Cape were reported to the local State Veterinary Office (African Horse Sickness Trust, 2010). Because these outbreaks and other isolated cases of the disease continue to occur across South Africa, the disease "impacts significantly on the local economic and recreational horse industry" (von Teichman and Smit, 2008: 5014), and it is thus important to determine just how significant this economic impact is.

The primary objective of this study is to develop a model that is a suitable tool for calculating the economic impact of AHS on the sport horse breeding industry in the South African context. In order to test the comprehensiveness of the model, the case of the 2007/2008 outbreak of AHS in the Eastern Cape will be applied as a pilot study. In addition, the loss-expenditure frontier will be considered as a complementary tool for analysis of control strategies for AHS in South Africa.

2. THEORETICAL APPROACH

A deterministic economic model will be constructed using examples of models from case studies of livestock diseases from other countries and applying those methods to the case of African Horse Sickness in the equine breeding industry in South Africa (see Bennett *et al.,* 1999; Mahul and Durand, 2000; Mukhebi *et al.,* 1999). It will be modelled predominantly on the example of Velthuis *et al.* (2010), who conducted a comprehensive analysis of the financial losses incurred as a result of outbreaks of the Bluetongue virus in the Netherlands in 2006 and 2007 respectively using a deterministic economic model. The *Culicoides imicola* midge is also the vector of Bluetongue, which affects sheep, goats and cows (Niven, 2005, Velthuis *et al.,* 2010: 294). The model developed in this study and the authors' method of investigation provide a good benchmark for research into the economic impact of AHS in South Africa as the case involved very similar inputs and scenarios to those found for AHS in South Africa. Velthuis *et al.* (2010: 303) suggest that their model is suitable to assist authorities and stakeholders at the sector level in retrospectively assessing the effectiveness of control measures taken during an outbreak and in planning future controls or vaccination strategies. A similar model in the case of AHS in South Africa will seek to determine the economic impact of the disease in the equine breeding industry in the province.

The basic model produced by Velthuis *et al.* (2010: 295) is as follows:

$$L = \sum_i \sum_j P_{i,j} + T_{i,j} + D_i + M_{i,j}, \qquad (1)$$

where L represents the total change to the entire livestock population due to the epizootic, P the production losses of farm type i in the context of animal type j, T the corresponding treatment costs, D the diagnostic costs, and M the cost of control measures. Each of these is then broken down further into equations involving more specific inputs. Data was collected for each input from each farm type and for each animal type over the periods of the two epidemics of the Bluetongue virus in the Netherlands in 2006 and 2007 respectively, and entered into the model. This research method is a sound starting point for an investigation into the case of AHS in the breeding industry in South Africa, providing a good framework which will be adapted to create a model that can accommodate the inputs involved in the case in question.

The model will then be applied to the case of the 2007/2008 outbreak of AHS in the Eastern Cape, and data will be obtained from a small number of breeders in the province in order to assess the functionality of the model.

3. A MODEL FOR AFRICAN HORSE SICKNESS IN SOUTH AFRICA

Drawing from the model used by Velthuis *et al.* (2010) to quantify the financial costs of outbreaks of the Bluetongue virus, the following model was constructed for AHS in the equine breeding industry in South Africa:

$$L = P + T + D + M \qquad (3)$$

Where:
P = production losses
T = treatment costs
D = diagnostic cost
M = cost of control measures

Production losses are calculated as the value of horses that were lost to AHS over the period, provided by the owner, including an estimation of their keeping expenses over their lifetime and the cost to the owner of having the carcass removed from their premises. Production losses also include the value of any foals that are lost to still births or abortions due to the infection of a pregnant mare.

There is currently no cure for AHS, and treatment is limited to making the horse more comfortable and hoping for the best. There are several unconventional approaches to treatment; including homeopathic treatments and "home remedies" (see Niven, 2005). However, as these are not endorsed or recommended by most vets in South Africa, costs incurred administering them are considered negligible. The model does, however, account for the administration of antibiotics and anti-inflammatories (to reduce the oedema), as well as any additional labour required to attend to a sick horse. These make up the treatment costs.

Diagnostic costs are composed of veterinarian fees, the cost of samples and post mortems for the horse-owner's account. Once a horse owner has seen the symptoms of AHS, it is unlikely that he or she will call out a vet to diagnose subsequent cases, so this component of the costs will be likely to be small, or diminishing. Furthermore, if a horse-owner wishes to have blood samples taken, or a post mortem conducted, the expenses incurred can be claimed back from the state, should the owner go through the official channels.

Control measures accounted for by the model include the administration of the AHS vaccine, either by a veterinarian or other party; the application of insecticide to stables, vehicles and horses; the instalment of fans in stables; the erection of shade cloth on the premises; and the cost of quarantining a horse at the various quarantine facilities available for South African horses.

Details of the model specification are provided below:

(a) Production Losses

$$P = MT + ABSB \tag{3.1}$$

Where MT = mortality
ABSB = abortions and still births

Further: $$MT = \sum_i (v_i + 12.kc_i.yr_i + rc) \tag{3.1.1}$$

Where v_i = estimated value of the horse lost
kc_i = estimated average cost of keeping a horse/month
yr_i = age of horse lost
rc = cost incurred to have carcass removed
i = each horse lost to AHS

$$ABSB = \sum_j fv_j \tag{3.1.2}$$

Where: fv_j = estimated value of the foal at birth
j = each case of abortion or stillbirth due to infection

(b) Treatment Costs

$T = a_{AI} . c_{AI} + a_{AB}.c_{AB} + ot.p_{ot}$ (3.2)

Where a_{AI} = number of horses treated with anti-inflammatories.
c_{AI} = cost of the average course of treatment with anti-inflammatories
a_{AB} = number of horse treated with antibiotocs
c_{AB} = cost of the average course of treatment with antibiotics
ot = number of extra labour hours paid for
p_{ot} = price of extra labour hours

(c) Diagnostic Costs
$D = VET.p_{VET}$ + samples. (price of test) + $pm.p_{pm}$ (3.3)

Where VET = cost of veterinarian's labour
P_{VET} =cost of vet's labour for diagnosis
samples = number of samples taken
price of test = price of testing each sample
pm =number of post mortems performed at owner's expense
p_{pm} = cost of a post mortem

(d) Cost of Control Measures
$M = TI + VC + QC + sc.p_{sc} + f.p_f$ (3.4)

Where TI = cost of spraying with insecticide
VC = cost of vaccination
QC = cost of quarantine
sc = meters of shade cloth erected on premises
p_{sc} = average price of shade cloth per meter
f = number of fans installed on premises
p_f = average price per fan

And further:
TI = (ns_{IT} . fs_{IT} . price per stable + na_{IT} . fa_{IT} . price per animal + nv_{IT} . fv_{IT} . price per vehicle).duration of outbreak (months) (3.4.1)

Where: ns_{IT} = number of stables sprayed
fs_{IT} = frequency with which stables sprayed per month
na_{IT} = number of animals sprayed
fa_{IT} = frequency with which stables sprayed per month
nv_{IT} = number of vehicles sprayed
fv_{IT} = frequency with which stables sprayed per month

And: VC = na_{VC} . $price_{VC}$ (P_V . ac + P_{sa}).2 (3.4.2)

Where: na_{VC} = number of horses vaccinated over this period
$price_{VC}$ = price of vaccine
P_V = proportion of animals whose vaccination was administered by a veterinarian
ac = administration cost

P_{sa} = proportion of animals vaccinated by animal owner or caretaker

$$\text{And: } QC = na_{QK}.p_{QK} + na_{QM}.p_{QM} + na_{QN}.p_{QN} \quad (3.4.3)$$

Where: na_{Qk} = number of animals quarantined at Kenilworth
p_{QK} = price of 40 days of quarantine at Kenilworth
na_{QM} = number of horses quarantined in Mauritius
p_{QM} = price of 40 days of quarantine in Mauritius
na_{QN} = number of animals quarantined at Newburg
p_{QN} = price of 40 days quarantine at Newburg

4. LIMITATIONS AND ASSUMPTIONS OF THE MODEL

It must be acknowledged that the model is significantly limited in several ways.

It is difficult to objectively assign a monetary value to a horse. Firstly, it may be argued that it is unethical to assign a value to certain things that do not have market values (Ngategize *et al.,* 1986: 192). The market value of a horse may not reflect its true value to the owner, which is likely to depend on unobservable factors such as the horse's potential, its temperament, its genetic suitability for breeding, the level of sentimentality that the owner places on it or other such intangible attributes. Aside from this, the vast discrepancy in the values of horses based on these attributes makes it very difficult to objectively assign a value to any given horse, as the researcher always requires the guidance of the owner in discerning the horse's value. It may be possible to mathematically model the value of a horse based on more objective data which could be provided by the owner, displacing the owner's subjective power in providing a value, however, this is beyond the scope of this study. As a result, owners were asked to provide an estimate of the value of each horse they lost, and production losses had to be calculated separately for each horse. The mathematical modelling of horse values would reduce the repetition required in calculating production losses, and would make the model less subjective and hence more credible.

Similarly, owners were required to provide the potential value of each foal lost to stillbirth or abortion. This estimation is also subjective, and is further based on the breeders' perception of the foals' lineage.

The cost of removing a carcass from the breeder's premises was established using the average of costs reported by each breeder. This limits the accuracy of the model, as these costs may also vary greatly between premises and removal methods

The model assumes that the cost of keeping a horse is the same for any horse on any premises, where this cost can vary significantly according to, for example, how much training, food and veterinary attention it requires; and the availability of suitable feed in the area. Where brood mares may not require training, horses being groomed for sale may require expensive training; where young horses may live out, horses in training may be stabled, and so forth. The figure used in this study was based on an average of the estimates of a monthly cost of keep provided by each individual breeder.

The model does not account for veterinarian travel costs, which, as most studs are based outside of urban areas, may form a significant part of the routine cost of AHS to a breeder.

The model assumes that the cost of vaccine is R70 where some outlets may charge more than this. This figure is based on an average of several accounts of the amount paid for vaccine. The cost of spraying a horse, vehicle or stable were also estimated at R5 each, based on the most commonly purchased insecticide at a local veterinarian. The frequency of spraying was assumed to be once every two days over the period of analysis.

Similarly, the cost of antibiotics and anti-inflammatories were based on the price of administering them to the average full-grown horse for five days, obtained from one local veterinarian. Dosages, duration of treatment and outlet prices may vary for each case.

Lastly, limiting the treatments considered to antibiotics and anti-inflammatories may be oversimplifying this component of the total impact. Further research indicated that some veterinarians may recommend much more extensive treatments such as the administration of a bronchodilator; a diuretic; and possibly a course of vitamin C. Estimates obtained from one veterinary clinic, and based on a five day administration of these treatments could cost owners around R1 700 per grown horse.

5. APPLICATION OF THE MODEL TO THE EASTERN CAPE

Data for each variable specified in the model was collected from four stud farms in the province, detailing their costs and losses relating to AHS between October 2007 and May 2008, as these are the dates between which the AHS virus was present in the province (AHS Trust, 2010). The data were entered into the model, which revealed a total economic impact of R2 513 979 for four farms over this period.

It is notable that 83.9% of the total impact can be attributed to the losses incurred due to the mortality (*MT*) as specified by equation (3.1.1). More specifically, the actual values of the horses lost, as estimated by their owners and represented by v_i in equation (3.1.1), contributed 28% of the total impact. Thus the issue of allowing breeders to subjectively assign values to horses becomes significantly problematic and the need for an objective method of valuation is emphasised. However, it must also be acknowledged that sport horses do fetch high prices in reality, and thus this high figure is not completely unjustifiable. The average reported price of horses lost was in the region of R40 000.

The research process revealed that the questionnaire was effective in acquiring the relevant data and was seldom misinterpreted. Responses from the four breeders indicated that the research questions were reasonable and relevant, thus indirectly reaffirming the completeness of the model for its intended purpose.

6. PROSPECTS FOR EXTENDING THE MODEL

The model is designed specifically for the equine breeding industry in South Africa. An extensive study of the economic impact of AHS in South Africa would have to consider costs and losses incurred much more broadly. For example, the disease may significantly impact the horse racing industry; equine tourism industries such as game rides, trail rides and beach rides; the revenue of sport organising bodies for all equine disciplines such as endurance, saddler competitions, tripling, etc. Leisure riding is also adversely affected by AHS. Here, the valuation of the impact is a much more tricky business, as the value of goods such as leisure; emotional attachment and social status is particularly difficult to establish. AHS also impacts heavily on the informal sector and in rural areas, where horses and ponies are used, for example, as a mode of transport, as working horses and stock horses; and owners are not able to afford vaccines. Here, horses form a large part of people's livelihoods, and their death can have devastating effects on people's income and welfare as a result.

There is a need for improved data collection methods, and perhaps it would even be prudent to build a culture of data recording amongst stakeholders. Effective models rely on credible data sources, and at present, some of the data is produced by estimation. The African Horse Sickness Trust has put together an online database that acts as an early warning system to horse owners, but this can only reach certain sectors of the equine economy, as many stakeholders do not have access to the internet, or do not report cases to the Trust.

7. LOSS-EXPENDITURE FRONTIER

McInerney *et al.* (1992: 142-143) point out that economic evaluations which report the total costs of a disease fail to recognise that, for technical reasons, most diseases cannot be completely eradicated. "It is not the total economic cost of the disease that is useful information, therefore, but rather the avoidable costs." (McInerney *et al.,* 1992: 143). The avoidable costs are thus the ones that are able to guide decisions based on economic considerations.

A loss-expenditure frontier (LEF) can be used to identify endemic disease control strategies that minimise total costs by finding an optimal balance between output loss and control expenditure (Stott and Gunn, 2008: 180). The LEF provides a method of making decisions based on the optimization of loss and expenditures so that the economic impact of a disease can be minimized (Houe, 2003: 138; McInerney *et al.*, 1992: 141). Control expenditures are plotted against production losses, and when the former are increased, the latter will decrease. It is only justifiable to increase control expenditures as long as the marginal rand produces a reduction in production losses worth more than a rand.

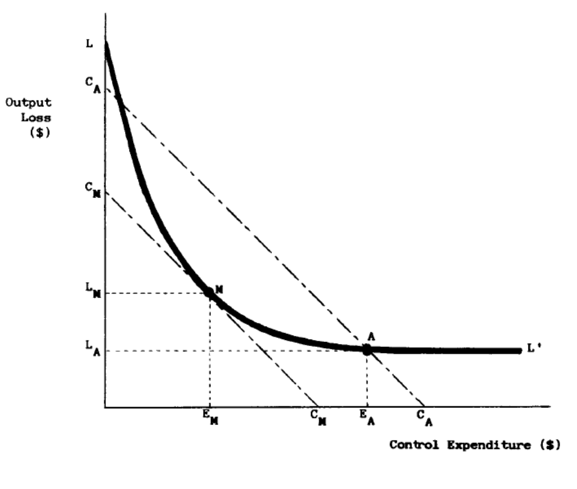

Figure 1: The loss-expenditure frontier (McInerney et al., 1992: 141).

In Figure 1, if nothing was spent on control, output losses would amount to L. The line LL' shows the minimum level of output loss that can technically be attained at each level of expenditure, and therefore represents the efficient set of control options and their corresponding expenditures and output losses (McInerney *et al.*, 1992: 143). Points below the line are unattainable due to a lack of knowledge. The curve's diminishing downward slope indicates the postulation that increases in expenditures become progressively less effective in reducing losses (McInerney *et al.*, 1992: 142). The asymptotic nature of the curve on the y-axis indicates that it is not possible to completely remove output losses. For diseases that can be eradicated or avoided completely, the graph would intersect the x-axis. However for most diseases, the technical point of efficiency is represented by point A on the graph. The objective here is to find the economic optimum, the point on the curve where economic cost, L + E, is minimized. This can be found at point M, closest to the origin and corresponding with expenditures of and output loss of . At this point, the marginal unit of expenditure on control is just covered by the gain in reduced output losses, represented by ( ), and total costs equal). At this point, the avoidable costs of the disease have been minimized to zero.

To illustrate the application of this model, consider the example of a study conducted on Mastitis control strategies in the Netherlands (McInerney *et al.,* 1992). Figure 2 shows how the LEF is derived by plotting combinations of output loss and control expenditure.

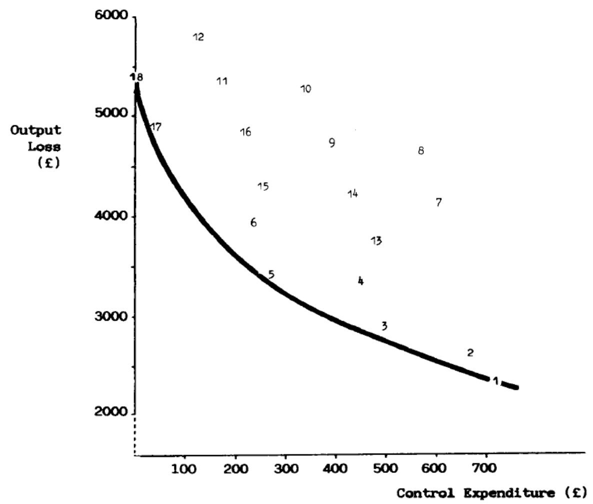

Figure 2: Output losses and control expenditures for different farms in a Mastitis Survey. (Numbers refer to the 18 different control procedures) (McInerney et al., 1992: 146).

Each point in the quadrant represents the combination of output losses and control expenditures associated with different control strategies for Mastitis in the Netherlands (McInerney *et al.*, 1992: 146). The LEF is revealed as the lower boundary of each of these observations, and the point of optimum control expenditure can be identified as that which is tangent to a line with a slope of -1, closest to the origin.

The current study assessed the effectiveness of the LEF as a tool for advising on efficient control strategies in the case of AHS. Both output losses and control expenditures are already calculated in the model, where the former is simply equal to *P* (production losses) and the latter is equal to *M* (cost of control measures). In the case of AHS, it was hypothesised that the LEF could give an indication of the optimal level of control expenditure that yields an efficient level of output loss, providing useful information for stakeholders in the industry.

Plotting the combinations of output losses and control expenditures for the four farms surveyed in this study did not reveal a pattern that might indicate an LEF. However, it is not unreasonable to predict that a significantly larger data set would reveal one. It would also be necessary to consider that, without the loss of horses on a farm, the researcher cannot be certain that infected midges were present on the farm (unless there were horses on the farm that were infected but survived), and thus the absence of mortality may not reflect the efficiency of the level of control present on that farm. Thus it might be necessary to remove observations where output losses were not incurred and where there was no evidence that AHS was present on the farm. Moreover, it was concluded that sport-horse values are much more disparate than other livestock values, due to their being based on much more subjective and diverse factors such as conformation, temperament, sport performance (or potential to perform), and so on. In the case of AHS, as the value of horses lost on each farm contributes significantly to output losses, and given the fact that there can be such vast disparity between the values of any two sport horses; the LEF is in fact not a useful indicator of the optimal level of control expenditure for sport-horse breeders. Unlike the case of diseases affecting, for example, cattle and sheep, where the disease reduces outputs such as milk, wool or meat, horses infected with AHS either recover or die. This means that output losses are determined solely by mortality, whereas the LEF model was constructed to reflect a wider range of losses that are valued by the market rather than the farmers themselves.

Drawing from the idea of the LEF, however, it may be useful to construct an instrument that plots the number of horses lost against the level of control expenditure on each farm, allowing breeders to evaluate and consider the potential losses risked at each level of expenditure.

8. FURTHER COMPLEXITIES

There are several dynamics related to the control of AHS which complicate the effectiveness of any control strategy, and thus limit the ability of an extensive deterministic model and an LEF-type approach to inform action. Some of these are outlined here.

Equids in rural areas (especially donkeys, which act as a reserve of AHS, but are not affected by the disease) are seldom vaccinated, as owners either cannot afford to vaccinate; do not have access to vaccination or the refrigeration required to keep it; or are not aware that they should vaccinate. It is thus important that the price of vaccine be significantly reduced in order to lessen the occurrence of the disease in these areas, and hence its spread to other areas too. This could be achieved by the production of the vaccine by more companies, bringing the price down, encouraging more people to buy the vaccine, and also creating the opportunity for the development of vaccination clinics which could reach a much wider population.

Zebras also act as a reservoir of the disease, but because they show no signs of being infected, they are not vaccinated. This undermines the efforts of other equine stakeholders to limit the spread of the disease through vaccination. This is a particularly problematic issue, as the increase in the development of private game farms around the country results in increased potential for exposure to the disease. The vaccination of zebras is also likely to be a difficult task, with little or no benefit to the game farms, and is therefore something that requires further research.

Even if the whole equid population in South Africa was vaccinated regularly, the vaccine does not provide complete protection against AHS, and so losses may still occur (Niven, 2005). This highlights the significance of the need for further scientific research in the area. It is proposed that a comprehensive study on the economic impacts of AHS in South Africa conducted with the aid of an extensive version of the model developed in this study would motivate stakeholders and funders to encourage such research.

9. CONCLUSION

This study set out to construct an appropriate deterministic model for the calculation of the economic impact of AHS to the equine breeding industry in South Africa and to run the model using data from a small number of stud farms in the Eastern Cape over the 2007/2008 outbreak period. A satisfactory model was developed, though some limitations of its scope were identified. Of particular importance is the limitation created by the subjective valuation of horses lost, especially given that output losses constituted 83.9% of the total economic impact of AHS to the four farms surveyed. The modelling of equine values was thus identified as a key area requiring more research. The model serves as a good starting point for the development of a more extensive model, able to calculate the impact of the disease to other equine sectors. It was noted that the inclusion of losses incurred in rural and informal areas is imperative, as this loss is particularly devastating to horse-owners and this area is frequently overlooked.

The study then illustrated the usefulness of the application of a Loss-Expenditure Frontier to the case of AHS in South Africa, as it showed potential as a tool in identifying efficient control strategies for stakeholders and the realistic potential for better preventative measures to reduce losses. However, it was concluded that the LEF was not appropriate for the case of AHS, due to the extent of disparities in the prices of horses. It was suggested that a similar model, plotting control expenditures against the number of horses lost in each case, would be more useful.

It is proposed that an extended model based on the one developed here, which tackles the problem of equine valuation and includes a much larger range of sectors, has the potential to encourage and enable increased research into improved prevention, control and treatment methods.

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