Food Policy 49 (2014) 418–424

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Issues and strategies in *ex-post* evaluation of intervention against animal disease outbreaks and spread

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ARTICLE INFO

Article history:
Available online 25 October 2014

Keywords:
Animal disease outbreaks
Avoidable losses
Incremental benefits
Ex-post impact assessment

ABSTRACT

Animal disease outbreaks pose a significant threat in terms of potential economic losses, reduced productivity, and negative impacts on public health, food security and nutrition. This paper considers four issues in *ex-post* evaluation of animal disease interventions: firstly, a counterfactual involves simulating disease trajectories without the intervention. But some diseases can become endemic or become dormant after an outbreak, making it a challenge to know the true trajectory without the intervention. Secondly, without adequate design of controls and treatments, how can the estimated impacts be attributed to a given intervention? Thirdly, how do we assess costs saved by the intervention? Fourthly, given data uncertainty, would a stochastic simulation give better estimates than a deterministic one in solving for key variables? This paper addresses these issues and proposes solutions that bridge the gap between household level analysis and macro-level simulations in modelling the impact of animal diseases outbreaks.

Introduction

Examples of the negative impact of animal disease outbreaks abound. Reported outbreaks of foot and mouth disease in Botswana in 2009 resulted in temporary ban to its prime export destination, the European Union for three years. At the processing level alone, this ban resulted in estimated losses of US$12 million in 2009, US$18 million in 2010 and increased to US$31 million by 2012 for the Botswana Meat Commission (Newel, 2013). South Sudan, a region where 90% of the population is estimated to have income of less than US$1 per day, loses US$ 25 per cow per year due to FMD (Barasa et al., 2008). The outbreak of highly pathogenic avian influenza (HPAI) in Nigeria would have caused economic losses amounting to US$145 million had no intervention been taken against the disease (Fadiga et al., 2014). Following the outbreak of the Rift Valley Fever in 2007 in Kenya, Rich and Wanyoike (2010) found wide-ranging impacts on the livestock sector. At a macro-economic level, they estimate that the total value of domestic supply fell by US$32 million. They found significant losses among downstream actors in the livestock value chain including production losses, employment losses especially for casual labour, and a reduction in operating capital among slaughterhouses and butchers. These potential economic losses necessitate timely interventions to limit the spread of the disease, or to eradicate it. The costs of intervention can be considerable as shown in various studies (McLeod and Rushton, 2007; OIE, 2007; Narrod, 2008; Fadiga et al., 2014).

Policy makers seek accurate assessments of potential losses and cost savings to formulate (*ex-ante*) or evaluate (*ex-post*) impacts of interventions against animal disease. Both *ex-ante* and *ex-post* assessments require epidemic and economic models for accurate assessments (Paarlberg et al., 2005; Pritchett and Johnson, 2005). Research (Rich and Winter-Nelson, 2007; Bennett, 2003; Gueye, 2007; Egbendewe-Mondzozo et al., 2013; Rushton, 2009; Perry and Grace, 2009; Randolph et al., 2002) has addressed the potential *ex-ante* economic impacts of animal diseases and mitigation measures. But there is little work on *ex-post* evaluation of interventions against animal diseases. An *ex-post* evaluation of intervention against animal diseases can inform future control strategies, in terms of effectiveness and of cost. This paper considers four problems in *ex-post* evaluation and proposes some techniques and ideas to solve them. In addressing these issues, we use the case of the highly pathogenic avian influenza (HPAI) outbreak in Nigeria in 2005 to illustrate and support the logic in the arguments made, and to illustrate the techniques proposed in the paper.

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http://dx.doi.org/10.1016/j.foodpol.2014.10.007
0306-9192/

Impacts of an animal disease outbreak and intervention options

As noted before the impact of animal disease outbreaks includes both direct and indirect impacts. Direct impacts include deaths of animal, testing, slaughter and production losses. For instance, the highly pathogenic avian influenza (HPAI) has a case fatality rate of 100% (World Health Organization, 2014). Hence, infected birds are certain to die from the disease itself or by culling used as a control measure to stop its spread. Nigeria suffered major outbreaks of HPAI in 2006 and 2007 that resulted in 1.5 million birds lost of which 767 thousand were culled (World Bank, 2010). Other animal diseases such as the African swine fever (ASF) have very high mortality rate (100%). Hence, an outbreak can be disastrous, especially to smallholder livestock keepers.

Furthermore, some animal diseases affect consumer and human health. Trypanosomosis is transmitted by blood-sucking tsetse fly and causes morbidity and mortality in both humans and livestock (Rushton et al., 1999). There have been increasing bird-to-human transmissions with avian influenza, especially with HPAI, leading to severe and fatal human infections. Fear of human pandemics lead consumers to reject the animal related products reducing income of all the chain actors like producers, traders, distributors and processor. The resultant change in demand, consumer behaviour and trade bans have repercussions throughout the livestock supply chain. In some countries where livestock keeping is a primary source of income, an animal disease outbreak can have direct negative impacts on livelihoods and food security including losses due to death and stunting of animals.

Long-term impacts of animal disease outbreaks include lowered productivity and output through reduced growth rates and fertility, and reduced efficiency use of inputs such as feed and labour. Lowered levels of fertility results in fewer calves or no calves being born, which changes the herd structure, and this further limits a farmer's capacity to maintain or improve the herd through selection. The impacts of animal disease outbreaks differ by production systems and the coping capacity of the supply chain actors. For example, smallholder livestock keepers in an extensive system on communally owned land may face different levels of systemic risk related to animal disease exposure and they have different coping capacity compared to commercial farmers who keep animals in confined privately owned land where restricting animal movement is technically easier and less costly. Many studies using different methods and approaches, document the impacts of animal diseases. In a nutshell, animal disease outbreaks can be catastrophic.

Once an animal disease breaks out, several intervention strategies can be implemented including (1) culling the affected and susceptible animals that are in contact with sick animals, (2) quarantine or movement restrictions, (3) vaccinating all susceptible animals (4) preventive vaccination of herds as soon as an outbreak is diagnosed, and (5) improving animal husbandry practices to prevent re-infection and to control infection rate. In some cases, a combination of the above interventions is employed. Whatever the chosen intervention in response to an animal disease outbreak, it is essential to evaluate its impact. The key objective of such an evaluation is not only to measure economic, animal and human losses, but equally important, to influence decisions and inform future interventions. However, there are several issues that make *ex-post* impact assessment of an intervention against an animal disease outbreak challenging. We address four key issues in the next section.

Issues in *ex-post* evaluation of animal disease outbreaks

Many unknown factors can influence the trajectory of the disease yet, assessing the impact of the intervention is important. The question is how decision makers can attribute the outcomes to the chosen intervention. There are different types of losses that actors in livestock supply chain incur related to disease outbreaks. What losses should be considered in informing decision makers regarding the cost of an intervention? Further, in an environment characterised by data uncertainty, what would be the best approach to account for changes in the salient variables on the outcome? Some studies propose a deterministic analysis based on responding to the question "what if". Should a stochastic simulation approach be used to capture the underlying data uncertainty and conduct a probabilistic sensitivity analysis on key output variables? We discuss each issue in detail next.

Definition of a counterfactual

A counterfactual refers to what could have happened if an observed aspect of the process being considered were different from those prevailing at the time (Perasan and Smith, 2012). In the context of this paper, the focus is to compare an *ex post* realised outcome with a counterfactual outcome that could have been obtained under certain assumptions regarding the policy on intervening against a certain animal disease outbreak. The examples provided in the previous section show that animal disease outbreaks cause production losses and induce welfare losses at a societal level. For these reasons governments are generally risk averse when faced with potential disease outbreaks and spreads. As a result, they design interventions to minimize potential losses on expected social welfare. Accurate measurements of the economic impacts of animal diseases require information on both the epidemiology and the economic aspects of the disease. Rich and Winter-Nelson (2007) applied an integrated epidemiological and economic model to study the spatial and temporal impacts of foot-and-mouth disease outbreak in the southern cone of South America. Paarlberg et al. (2005) and Pritchett and Johnson (2005) advocated the necessity to integrate epidemic and economic models for a more accurate assessment of the impact of intervention against animal disease. Fadiga et al. (2014) defined an expected damaged function, proxied by the direct and indirect costs of HPAI outbreak, that decision makers seek to minimize, to measure the economic impact of the intervention against HPAI in Nigeria.

To further elucidate, let us assume as in Narrod (2008) an expected social welfare function defined as follows:

$$EW(\phi_i) = p(\phi_i)W_D(\phi_i) + [1 - p(\phi_i)]W_F(\phi_i) - r(\phi_i) \quad (1)$$

where W_D and W_F represent the welfare, aggregate of consumer and producer surplus, under the diseased and disease-free situations respectively with $W_F > W_D$. They are weighted by the composite risk parameter $p(\phi_i)$ and its complement $1 - p(\phi_i)$, $r(\phi_i)$ represents the cost of the intervention. This composite risk parameter is the product of the risk of spread $s(\phi_i)$ and the mortality risk $m(\phi_i)$, because the *ex-post* analysis deals with an event that has already occurred. The risk of spread is defined as the proportion of states that are affected given that the country is infected (Bett et al., 2014) while the mortality risk refers to the probability that a bird is infected given that the state is affected. The risk of infection is the same as mortality risk for diseases with fatality rate reaching 100%. Hence we could formally write the composite risk parameter as:

$$p(\phi_i) = s(\phi_i) \times m(\phi_i) \quad (2)$$

Deriving the risk parameters under the counterfactual scenario is difficult. One approach is to use a combination of historical data before the intervention starts or borrow from studies with similar focus in comparable environment. An epidemiological model is needed to derive the risk of spread, which could be done with respect to farms, villages, or states (in the case of Nigeria). In practice, the level of aggregation one chooses is more often dictated by