The consequential carbon burden of animal disease outbreaks

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Abstract

Livestock is a key source of greenhouse gas (GHG) emissions that lead to global warming. Animal diseases increase emissions through biological and production inefficiency that occurs at the farm level. These emissions are also affected by disruptions in downstream markets that result from shifts in consumption towards cheaper alternative meat products in response to reduced production and increased prices of affected meat products. We employ a vector error correction model to capture the dynamic market impact of disease outbreaks on livestock production and the subsequent changes in GHG emissions from consumption switching in these markets. Four animal diseases are considered: African swine fever, sheep pox, bluetongue virus, and foot and mouth disease. By associating the subsequent consumption switching with emissions factors, we identify the consequential carbon impact of livestock disease. The indirect costs of all animal diseases considered individually range from £1 million and £53 million, whilst the net reduction from meat supply and consumption in GHG emissions ranged between 0.005 and 0.67 million tonnes of CO_2e, which valued between £0.4 million and £44 million. This opens a debate over the role of government compensation schemes for disease outbreaks and argues for holistic approaches between targets for net zero compared to support for sustaining and restructuring livestock sectors.

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Introduction

Livestock is a key source of greenhouse gas (GHG) emissions that lead to global warming. Animal diseases and poor animal health exacerbate this problem by increasing emissions from livestock. An array of endemic diseases exists at various levels of prevalence on livestock farms and may be undetectable or present difficulties in controlling. For instance, parasitic worms "Gastrointestinal nematode parasites" found in most sheep has been found to increase GHG emissions by 10% and Johne's disease, an infectious wasting condition of cattle and other ruminants, has shown to increase emissions by 25% (Kenyon et al 2013; Skuce et al 2016).

The mechanism in which animal diseases increase emissions is through biological and production inefficiency. These inefficiencies can take several forms such as prolonging periods for the livestock to reach its optimal weight – thus increasing the emissions from that animal, fewer and lower quality outputs (e.g. milk, wool, and meat) – thus raising the emissions intensity (the amount of GHG equivalents emissions emerging per kg of livestock product), as well as reduced reproductive performance and premature death of animals (SEFARI 2019).

Aside from the suffering caused by these diseases for the animals and the emotional toll on livestock keepers, these animal disease infections have been reported as causes for increased emissions. A key parameter in assessment of this additional GHG burden is the short life span of animals and the consequential high rate of replacement of diseased animals that contributes to higher emission rates (Özkan et al 2015).

Beyond the farm gate, animal disease also disrupts downstream meat markets by shifting the consumption patterns towards cheaper alternative meat products in response to reduced production and increased prices of affected meat products (Soliman et al 2023; Barratt et al 2019). This consumption shifts between different meat markets will also impact overall GHG emissions from the livestock sector. In some situations where a disease outbreak stimulates consumption to switch from high to low emitting meat product (e.g. from beef or lamb to poultry or pork), overall emissions from the meat markets will unexpectedly decrease. This is because higher demand on poultry or pork, incentivises more production of these meat products but less production of beef or lamb leading to lower emissions overall from all the meat markets. This effect is likely to be temporary as imports and later restocking by domestic farmers will revert prices and consumption patterns and subsequently GHG emissions back to normal levels.

A comprehensive agricultural compensation policy, including income support and livestock replacement assistance, is vital for farmers to recover from the economic hardship caused by animal disease outbreaks. Such policy supports livestock farmers to financially recover from an animal disease outbreak, but also accelerates the rebound of the GHG emissions to its high pre-outbreak levels through restocking.

Our study aims to assess the consequential economic and carbon impacts of four economically important diseases (African swine fever, sheep pox, bluetongue virus, and foot and mouth disease) as well as discussing the unintended role of compensation policy in pushing the GHG emissions back to its pre-outbreak level, potentially erasing the reductions achieved during the outbreak. This offers an extension to the current literature and widens discussions on the greenhouse gas burden of livestock disease and the importance of formulating compensation policy that simultaneously considers economic growth and progress towards zero carbon target.

Materials and methods

A disease outbreak is expected to disrupt livestock markets by decreasing the domestic supply of the infected livestock products and increasing the supply of substitute products. Consequently, prices would also change to achieve market equilibrium between supply and demand of affected products.

We fitted a time series (vector error correction) model to historical data to predict the magnitude of change in market prices and quantities (Ren et al 2020, Ryu et al 2020). Based on these predictions, changes in market revenues due to a disease outbreak could then be estimated which we defined in our analysis as "indirect economic costs". The data set for the time series model was collected from various public and private sources such as Quality Meat Scotland (QMS), and the Scottish Government (ESRA 2020; QMS 2021). It includes 84 observations representing monthly producer price and quantity data of five Scottish livestock and feed markets (i.e. Cattle/beef, sheep/lamb, pigs/pork, poultry/chicken, and wheat feed) and available between January 2012 – December 2018.

Our time series model has been developed through three main stages: collection of time series data, determining the suitable specification of our time series model, and estimating the indirect economic effects. This process involved the application of several diagnostic tests for stationarity, cointegration and prediction accuracy (Dickey & Fuller 1979; Zivot & Andrews 1992; Lee & Strazicich 2003; Stock & Watson 2003; Jiang and Liu 2011). This includes Augmented-Dickey-Fuller (ADF), Phillips-Perron (PP), Zivot-Andrews (ZA), Elliott, Rothenberg and Stock (ERS), Lee-Strazizich LM, Johansen's trace statistics, Mean Absolute Percentage Error (MAPE) and Theil's inequality coefficient U). We also assumed three hypothetical outbreak scenarios, which will lead to 5, 20, and 35 percent of the total herd to be lost or culled. These three scenarios represent small, medium, and large ranges which help in providing the likely range of impacts from a potential outbreak.

Changes in GHG emissions due to a disease outbreak are quantified by estimating the changes in the supply of all modelled commodities and then multiply these changes by emissions intensity factors, where the emissions intensity factors represent the amount of GHG emitted per kg of meat. To value the emissions from changes in market supply, we multiply the estimated changes in GHG by a carbon price. We use the UK ETS price for non-traded sectors to value the change in GHG emissions.

Results

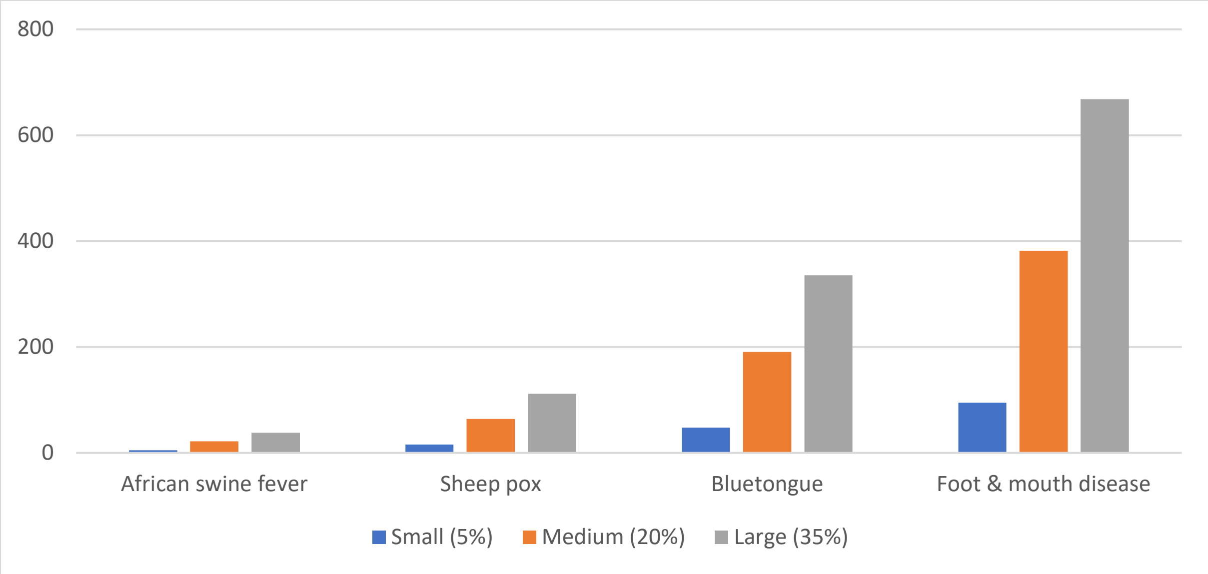
The indirect costs of all animal diseases, which were considered individually, were estimated approximately between £1 and £53 million. Foot and mouth disease led to the largest adverse impacts among all the diseases considered in our analysis which was estimated to range between £4 and £53 million, while African swine fever led to the smallest impact estimated between £1 – £6.9 million.

Table 1. Indirect costs of animal disease outbreak assuming a small, medium and large sizes of an outbreak (£ million)

Disease	Small (5%)	Medium (20%)	Large (35%)
African swine fever	-0.99	-3.95	-6.90
Sheep pox	-1.55	-6.03	-10.26
Bluetongue virus	-1.67	-6.58	-11.36
Foot & mouth disease	-4.17	-23.52	-53.14

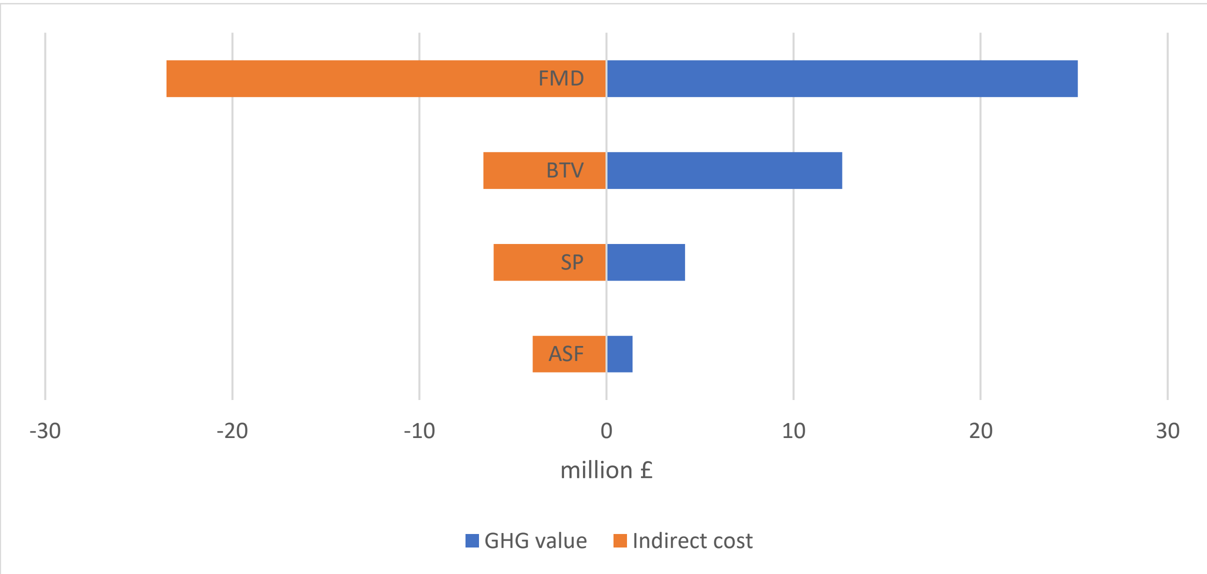
Depending on the disease and size of the outbreak, all modelled diseases led to net reduction in GHG emissions ranging between 5 and 668 thousand tonnes CO_2e, which were valued between £0.3 and £44 million using the Emissions Trading System (ETS) price of the UK. A foot and mouth disease outbreak has the largest reduction in GHG emissions which was valued between £6 – £44 million, while African swine fever has the smallest reduction in GHG emissions, which was valued between £0.4 – £2.5 million.

Figure 1. Reductions in GHG emissions (1,000 tonnes CO2e) from a small, medium, and large outbreaks of the four analysed diseases.



Our results show that the estimated indirect costs are almost equivalent to the benefits of averting GHG emissions from lost production and shifting in demand due to a disease outbreak. These findings highlight the trade-offs between the consequential economic costs on the industry and the unintended benefit of reducing GHG emissions if restocking didn't occur.

Figure 2. Trade-offs between indirect cost and the benefit of averted GHGs from animal disease outbreaks (£ million)[1,2].



[1] FMD: foot & mouth disease; BTV: Bluetongue virus; SP: Sheep pox; ASF: African swine fever
[2] The monetary value of GHG was estimated using the UK emission trading system price

Conclusion and discussion

Climate and biosecurity policies are highly interconnected. An animal biosecurity policy that can minimise the risk of animal disease outbreaks and maintain a healthy livestock population can minimise the animal health component of the UK's net zero aims. It is therefore crucial to implement a more holistic approach to GHG ambitions with support for maximising animal health. A key pillar of this is maintaining robust surveillance systems for animal health, and minimising infection and spread of emerging and endemic diseases (Scottish Government 2023). This includes border checks, agreements on trade policies, increased monitoring and prevention within domestic production as well as deploying targeted control and eradication programmes. This requires mobilisation of effort and increasing scarce public resources, however if the GHG burden were included in assessments of animal health management measures, this would provide a more compelling argument for intervention by both public and industry actors.

We also argue that a compensation payment that accounts for GHG impacts of restocking should be considered. Presently, for some diseases, a mandatory partial or full cull of animals may be needed and compensation for restocking should incentivise replacement with higher yielding breeds, or in some cases multi-use cattle, such as Norwegian Red (Geno group 2023). This challenges current farming systems but offers a transition to more regenerative and climate smart approaches expected from new agricultural payment regimes in the UK (DEFRA 2023).

Compensating livestock farmers to be able to restock and recover from an animal disease outbreak is essential to restore lost incomes, employment, and minimise adverse economic consequences on closely related sectors and the wide economy. However, ensuring a holistic approach by the government between targets for net zero and support for sustaining and restructuring livestock sectors paves the way towards a more resilient and carbon-neutral livestock sector.

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