Extended Abstract
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Paper Title	Understanding the economic impacts of a highly pathogenic avian influenza housing order on commercial free range egg layers

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***

Recent annual outbreaks of Highly Pathogenic Avian Influenza (HPAI) have led to mandatory housing orders on UK commercial free-range flocks. Indefinite periods of housing, after poultry have had access to range, may have welfare, production and economic consequences for free range egg producers. The impact of these housing orders on performance of commercial flocks is seldom explored at a business level, predominantly due to the paucity of relevant data. We applied weekly data for production, revenue and feed usage, gathered during two housing orders, in 2020/2021 and another in 2021/22, provided by a number of commercial free-range poultry units. These time periods cover two complete flock cycles and an average of 100,000 laying hens.

We employ a random intercept linear model to accommodate differences in shed environment and breed and found few adverse impacts of a housing order on mortality and overall egg production, though feed and feed costs were significantly affected. This is a consequence of increased control over diet intake in housed compared to ranged birds. An increase in revenues was also noted, ostensibly due to an increase in very large and large eggs. Overall, large commercial poultry sheds were able to mitigate some of the potential adverse economic effects of housing orders. However, increases in feed costs since these housing orders may outweigh the ability of producers to manage future outbreaks.

Keywords	Avian Influenza; Multilevel models; Animal Health Economics
JEL Code	Q18; Q12

Introduction	100 – 250 words

Avian Influenza (AI) has been present in birds for at least 100 years (Fouchier et al., 2013; Capua and Alexander, 2009). Highly pathogenic variants of AI (HPAI) are the result of the evolution of these strains and result in broad transmission pathways across wild and domestic species (Olsen et al., 2006; Smith et al., 2009). AI can be zoonotic and the recent H5N1 variant has caused some concern that infection has led to a number of deaths in humans (WHO, 2021; Gashaw, 2020). Its zoonotic potential makes AI a particularly pertinent example of a potential vector for a future pandemic (Av Inf Working Group, 2008).

A range of measures have been proposed for managing HPAI in commercial flocks, including mass vaccination, culling and heightened biosecurity (Sims, 2007; Liu et al., 2020). Western Governments have tended to impose housing orders on free-range flocks, coupled with heightened biosecurity, as the main preventative measure (Kaleta et al., 2007; Verhagen et al., 2021; EFSA, 2021;2022;2023). The aim of a housing order is to separate poultry from wild birds and other potential sources of HPAI by imposing a set period in which poultry remain housed and restricted from ranging.

The UK has the highest proportion of free-range egg production across Europe (AgraCEAS, 2017). It is estimated that the UK produce approximately 10.4 billion eggs annually with a value of £1.3bn. Free range eggs represent around 65% of the market (British Egg Industry Council, 2023). A housing order could therefore have a significant impact on the industry. A number of previous studies have outlined the financial impacts of a housing order on the sector as a whole (Paarlberg et al.,2007; Boni et al., 2013; Ramos et al., 2017).

The purpose of this paper is to explore the range of impacts that may occur to commercial free-range flocks during a housing order. We exploit a rarely available commercial data set of UK poultry sheds which provide weekly cost, revenues and production dynamics which span the two most recent outbreaks.

Methodology	100 – 250 words

Production data were collected from a range of commercial poultry sheds from individual farms for production cycles for the period 2021/22 and 2022/2023 which relate to the latest housing orders. Table 1 summarises these over the two periods. These total around 100,000 layers per cycle across nine farm sheds. Moreover, a key issue in performance is the nature of the housed system and these generally relate to flat or multi deck systems with multi deck reflective of a higher stocking density for a given building floor area and presents several challenges to hens relative to single deck systems. In order to explore the impact of a housing order a series of indicator variables were generated from the data set. These are presented in the table below as proxies for welfare impacts (weekly mortality), production impacts (feed intake, feed conversion) and financial impacts (feed costs, total revenue).

The environmental influences within a shed will vary due to, amongst others the structure of the shed, the stocking density and production cycle. We take a mixed linear regression approach and apply a random intercept model to control for variance within the environments that birds operate. These models accommodate both a fixed part, which equates to the explanatory variables, and a random part, which aims to reflect differences in operating environment across the sheds. Whilst not previously applied to the condition of free-range poultry farming, this modelling framework has proven popular in studies of other farmed species outbreaks and animal species generally (Varga et al., 2009; Schielzeth et al., 2020; Persson et al., 2022). As such our random intercept approach takes the form:

$$y_{it} = (\beta_1 + \zeta_t) + \beta_2 x_{2it} + \beta_3 x_{3it}^2 + \beta_4 x_{4it} + \beta_5 x_{5it} + \beta_5 H_{it} + \beta_6 P_{it} + \beta_7 D_i + \epsilon_{it}$$

Where y_{it} is the outcome of interest, *i* is the shed in which the poultry were housed, and *t* is a *weekly* time step. The intercept (β_1) is augmented with a random intercept error term (ζ_t) as the permanent error component, e.g., of the lasting characteristic of the different sheds including breed used and (ϵ_{it}) the transitory component, e.g., of the individual production effects. Modelling poultry growth and production is a non-linear process further complicated by management and breed (Aggrey, 2002; Narinc et al., 2017; Selvaggi et al., 2015).

Results	***100 – 250 words***

Across the financial outcomes a range of variables are all significant and tests indicate a strong fit. Bird age is positive on revenue and margins and the non-linear terms are negative and significant on all outcomes, indicating that the rate of effect, whilst positive, declines as birds age. Changing feed prices and feed intake dictate overall cost and revenue outcomes and we would expect them to have a positive influence on these outcomes. As these show the behaviour of large commercial enterprises, we would expect them to respond in a rational way to changing prices.

There were no impacts of the different deck structures on the financial indicators within these sheds, however costs and revenues were negatively affected in the second cycle relative to the first production cycle. Notably, the housing order had a positive effect on all three financial variables, though this is strongly significant for feed costs ($p<0.001$) compared to other economic inputs (revenue, $p<0.01$, margin, $p<0.05$). Given the increase in feed intake from housing (shown in table 4), the housing order positively affected the feed cost per hen by an estimated £0.006 per week. Nevertheless, revenues increased during this period, potentially due to the shift towards larger egg grades. Notably, whereas previous studies have identified an increase in feed cost they did not find a change in output, though the result below may have been compounded by changing egg prices during the outbreak period.

Table 1. Draft Results

	Feed Cost per bird			Revenue per bird		
	Est.		SE	Est.		SE
Fixed Part						
(β_2) Bird age	-0.0003		*(0.000)*	0.019	***	*(0.004)*
(β_3) Bird age^2	0.000		*(0.000)*	-0.0001	***	*(0.000)*
(β_4) Feed intake	0.003	***	*(0.000)*	0.008	***	*(0.002)*
(β_5) Feed price	0.001	***	*(0.000)*	0.0002		*(0.000)*
(β_6) Bird age*feed intake	0.000		*(0.000)*	-0.0001	***	*(0.000)*
(β_7) Av. egg weight				0.020	***	*(0.001)*
Deck (reference: Single tier)						
(β_8) MultiDeck	0.011		*(0.007)*	-0.283	***	*(0.050)*
Production Cycle (reference: 1st cycle)						
(β_9) 2nd Production Cycle	-0.036	***	*(0.001)*	-0.044	***	*(0.011)*
Housing order (reference: Free Ranged)						
(β_{10}) Housing order	0.006	***	*(0.001)*	0.025	**	*(0.009)*
Random Part						
$\sqrt{\psi_{11}}$	0.006		*(0.002)*	0.019		*(0.006)*
$\sqrt{\phi}$	0.011		*(0.000)*	0.110		*(0.003)*
Wald Chi^2	5802.7	***		1241.2	***	
Log Likelihood	2756.5			692.6		
LR Test	3647.9	***		11.2	***	

Discussion and Conclusion	*100 – 250 words*

Housing orders are an increasingly regular intervention for mitigating some of the consequences of AI incursions. The firm level consequences of a housing order are an underexplored facet of the restrictions imposed to mitigate AI incursions. Only a small amount of literature explores the consequences of an AI housing order at this scale, and we add to the small literature that has explored this theme through the oppourtunity to access data over two recent housing orders.

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