



1 Article

## 2 Economic and welfare impacts of providing good life 3 opportunities to farm animals <sup>†</sup>

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10 <sup>†</sup> Short title: Quantitative impacts of positive welfare provision

11 **Simple Summary:** An input-based framework to evaluate positive welfare opportunities for farm  
12 animals presents a case for incorporating quality of life measures into farm assurance schemes,  
13 thereby encouraging more producers to deliver higher welfare. Using an original dataset of UK  
14 laying hen farms that uniquely connects input-based measures of positive welfare to outcome-based  
15 measures of both positive and negative welfare, this study investigates the feasibility of evaluating  
16 positive welfare within certification schemes from both scientific and financial viewpoints.

17 **Abstract:** Existing animal welfare standards for legislation and food certification programmes are  
18 primarily designed to avoid harms to the livestock, with minimal consideration given to their  
19 behavioural freedoms. Recent research has shown, however, that animal welfare should not only be  
20 evaluated by the absence of negative states but also by the presence of ‘good life’ or positive  
21 experiences enjoyed by animals. The objective of the present study is to investigate the scientific  
22 validity and on-farm cost implications of utilising potential input-based measures of positive  
23 welfare as part of evaluation criteria for farm assurance schemes. Building upon the Farm Animal  
24 Welfare Council’s concept of good life opportunities, an assessment was undertaken on 49 non-  
25 caged laying hen farms across the UK by measuring on-farm resources to facilitate positive  
26 experiences alongside commonly measured metrics for welfare outcomes. The financial cost of  
27 providing these resources on each enterprise was also estimated using a farm-scale costing tool. The  
28 results suggested that 63% of resource needs that facilitate the behaviour opportunities of laying  
29 hens are already being provided by these producers, far above legal and commercial requirements.  
30 This practice attracts no reward mechanism or direct financial benefit under the current market  
31 structure. Additional provision of opportunities was positively associated with behavioural  
32 outcomes, but only limited impact was observed on health and productivity measures. Economic  
33 modelling indicated that significant room exists to further improve welfare scores on these farms,  
34 on average by 97%, without incurring additional costs. Together we argue that these results can be  
35 seen as evidence of market failure since producers are providing positive welfare value to society  
36 that is not being currently recognised. It is therefore contended that measuring and rewarding the  
37 supply of good life opportunities could be a novel policy instrument to create an effective  
38 marketplace that appropriately recognises high welfare production.

39 **Keywords:** quality of life; positive experience; resource tiers; economic analysis; laying hens

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### 41 1. Introduction

42 Certification schemes for animal-originated food products provide an effective means to assure  
43 consumers of the farm’s compliance with welfare standards [1]. Traditionally founded on input-  
44 based assessment through measurements of resource provision [2,3] some recent programmes

45 recognise the need for outcome-based assessment [4,5] and employ hybrid approaches that integrate  
46 information regarding on-farm resources, welfare outcomes and evidence of continuous  
47 improvement [6]. Beyond the primary purpose of consumer assurance, the analytical framework  
48 behind each certification scheme can also be utilised for on-farm decision support, scientific research  
49 as well as investigations into future legislative requirements [7].

50 Regardless of whether input-based or outcome-based, the majority of existing welfare-focused  
51 certification schemes are designed to reduce negative behavioural, health and physical outcomes on  
52 the farm by providing environments and management that are thought to safeguard the animal's  
53 quality of life. While this method of certification holds a clear merit of excluding welfare-  
54 inconsiderate farms from supply chains, it has now been widely accepted that animal welfare should  
55 not only be evaluated by predominantly the absence of negative subjective states but also by the  
56 increasing presence of positive experiences [8,9]. This concept reflects the view that, in order to  
57 provide animals with good lives, it is essential to understand what they want as well as what they  
58 need to stay fit and healthy throughout their lifecycles [10].

59 Beyond the ethical perspective, there are multiple reasons why positive welfare should be  
60 considered as part of certification schemes. Improving positive welfare opportunities does not only  
61 enhance the animal's living experiences but is also likely to reduce negative behavioural, health and  
62 physical outcomes [8], although the exact mechanism of this causal relationship is not well-  
63 understood. Furthermore, rewarding good outcomes is often considered to be a more effective  
64 method to induce farmers' behavioural changes than penalising poor performances, as pride in stock  
65 is generally a stronger motivator than the desire to avoid difficulties arising from non-compliance  
66 [11]. These rewards also improve wellbeing of farmers through a higher level of job satisfaction  
67 [12,13,14], an oft-forgotten requirement to ensure long-term welfare of *animals*. Finally, evidence of  
68 the animals' good life can add significant economic value to final products, as consumers are  
69 consistently shown to value positive welfare when appropriately informed [15].

70 Although it is recognised that increasing positive welfare is important, direct quantification of  
71 positive welfare involves complex challenges. Despite the considerable efforts made to identify  
72 suitable proxy measures for positive emotional state, e.g. through utilising the expressive quality of  
73 behaviour [16], there is little consensus as to how best to quantify positive welfare, particularly in a  
74 commercially feasible setting. While an increasing number of studies discuss positive welfare as a  
75 concept, evaluation methodologies have not progressed in any substantial manner [17] since Boissy  
76 et al. concluded that 'there are as yet no feasible animal-based measures indicative of good welfare'  
77 [18]. Further validation and refinement are required to more effectively process on-farm information,  
78 including body language [19], vocalisation [20] and behavioural expressions such as play [21], before  
79 large-scale implementation of positive welfare measurements becomes a reality.

80 As an alternative approach, the Farm Animal Welfare Council (FAWC) proposed that positive  
81 welfare can, at least in part, be quantified by the level of provision of *good life opportunities*, or  
82 'resources that an animal does not need for biological fitness but are valued by the animal' [5]. Central  
83 to this concept is the conjecture that animals, like humans, value 'variety to choose their preferred  
84 resource from' and, therefore, their welfare can be evaluated by the diversity of choice within their  
85 living environment. As resource inputs on the farm are more easily quantifiable and verifiable than  
86 the emotional state of animals, the adoption of this approach will likely result in a wider collection of  
87 objective evidence, a crucial prerequisite for incorporation of positive welfare assessment into private  
88 certification schemes and public policy intervention.

89 Motivated by this observation, the objective of the present study was to investigate the  
90 feasibility, concerning both scientific validity and potential cost implications for commercial farms,  
91 of utilising input-based measures of positive welfare as part of evaluation criteria for food  
92 certification schemes.

## 93 2. Material and methods

94 Assessments of welfare-enhancing resource inputs and welfare outcomes were carried out on 49  
95 non-caged laying hen farms in the UK recruited from the pool of members requiring an inspection

96 between November 2013 and March 2014. With a current market share of 56% that is continuing to  
97 grow, the non-caged system is the most common egg production methods in the country [23]. Pre-  
98 existing data was not available to guide a formal sampling strategy although care was taken to  
99 include a diverse range of farms, with regards to their location, environment, size, breed of birds and  
100 the scheme they participate in, so as to create a sample as closely representative of the industry as  
101 practical constraints permit (Supplementary Table S1). As per most non-caged farms in the UK, all  
102 sample farms were either a member of the *RSPCA Assured* (non-organic) or *Soil Association* (organic)  
103 assurance schemes, which is a *de facto* market requirement to ensure a price premium. Visits were  
104 made by five experienced scheme assessors and scheme advisors, all of whom were previously  
105 trained in the *AssureWel* outcome assessments for predominantly negative welfare [1]. Prior to data  
106 collection, they also attended an on-farm training session on the resource tier framework, during  
107 which the practicalities of flock assessment as well as the scoring criteria were discussed and  
108 standardised. All training sessions included feedback on consistency of assessment.

109 For input-based measures of positive welfare, the resource tier framework [22] was applied to  
110 each study farm. The framework consists of 13 *resource needs* categorised under five *opportunities*  
111 of comfort, pleasure, confidence, interest and healthy life (Table 1). For each resource need, farms were  
112 evaluated on a scale of 0 to 3 (no score, Welfare +, Welfare ++ and Welfare +++) based on physical  
113 resources available, on-farm environment and proactive management activities above what is  
114 stipulated by law [24] and codes of practice [25]. Depending on the category, the assessment was  
115 conducted by means of visual inspection, producer interviews or both (Table 1). The scoring system  
116 was designed to be additive across resource needs, and thus the maximum possible value for the total  
117 score, here labelled as *good life score*, was 39. As the original research [22] was solely designed to be a  
118 proof of concept study, this was the first time the framework was implemented for subsequent  
119 quantitative analysis.

120 For outcome-based measures of positive and negative welfare, six indicators commonly used by  
121 assurance schemes were collected on each farm (Table 2). An increase in these scores (feather loss,  
122 beak trimming, antagonistic behaviour, flightiness, mortality and litter score) represents a loss in  
123 quality-adjusted life expectancy of birds in the flock [16,1] and is therefore considered to be  
124 undesirable. For outcome-based measures of positive and negative welfare, qualitative behavioural  
125 assessment (QBA) was conducted by assessors on one study flock on all 49 farms using 15 descriptors  
126 originally developed by [26,27] and later adopted by the *Welfare Quality* protocol [16]. Following a  
127 flock observation of approximately five minutes, assessors used visual analogue scales to record a  
128 score for each descriptor. Principal Component Analysis (covariance matrix, no rotation) was used  
129 to derive components, the meaning of which were determined using the loadings of descriptor.  
130 Where more than one flock was present on the farm, the oldest flock was used for all welfare outcome  
131 assessments.

132 A detailed resource provision plan was created to match the conceptual 'tiers' defined by [22] to  
133 actual resources required, which were subsequently linked to best-available price information, in  
134 GBP (£) as at August 2019, to derive the total cost of interventions (Supplementary Table S2). To  
135 accurately represent the 'tiers' concept of the framework, the cost structure for the three tiers within  
136 each resource need was designed to be incremental; in order to reach an upper tier, all resources  
137 required for lower tiers must also be present on the farm. This cost information was further combined  
138 with the results of on-farm assessments and, based on the actual scores awarded under each resource  
139 need, the outlay made by each farm to enhance positive welfare opportunities of animals was  
140 estimated. All costs were annualised and expressed as forgone net margins per dozen of eggs  
141 (~0.7kg).

142 Following data collection, four patterns of correlations were examined using Pearson's correlation  
143 coefficient ( $r$ ): (1) amongst resource tier scores for five opportunities; (2) between resource tier scores  
144 and outcome-based measures; (3) between estimated costs and resource tier scores; and (4) between  
145 estimated costs and outcome-based measures. Pearson's correlation coefficient was selected over  
146 Spearman's rank correlation coefficient due to the cardinal (rather than ordinal) nature of the  
147 variables studied. Furthermore, in order to explore opportunities to reduce on-farm costs and

148 encourage further adoption of higher welfare production by commercial producers, the relationship  
 149 between a farm's good life score and its total cost on welfare-enhancing resources was also  
 150 investigated. Finally, estimated costs by sample farms were compared against the least cost, or the  
 151 mathematically minimal outlay required to achieve the same good life score. In this comparison, the  
 152 discrepancy between a farm's actual expenditure and the derived least cost represented the degree  
 153 of potential to improve the cost effectiveness of higher welfare production.

154 **Table 1.** Resource tier framework and methods of assessment.

Opportunity	Resource need	Observations	Interviews
Comfort	Physical environment	√	
	Thermal environment	√	√
	Minimising harms	√	
Pleasure	Cognitive enrichment	√	√
	Food choices	√	√
Confidence	Positive experiences	√	√
	Nesting choices	√	
	Social experiences	√	
Interest	Enriched environment	√	√
	Positive outdoor environment	√	√
Healthy life	Dustbathing	√	
	Effective management		√
	Genetic selection		√

155 **Table S1.** Sample characteristics ( $N = 49$ ).

Variable	Mean (range)	
Flock size (birds)	8,015 (110 – 16,000)	
Flock age (week)	42 (18 – 132)	
Breed	Lohmann Brown	26
	Hy-Line	5
	British Blacktail	7
	Warren	3
	Shaver Brown	2
	Novogen breeds	3
	Other traditional breeds	3
Participation in certification scheme	RSPCA Freedom Food	39
	Soil Association	10

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**Table 2.** Outcome measures used for validation of resource tier framework.

Type	Measure	Method	Source
Negative welfare	Feather loss	Number of birds, out of 50 samples randomly selected from the flock, with visible bare skin > 5cm in the head/neck and back/vent areas	Main et al. (2012)
	Beak trimming	Whether beak is routinely trimmed before 10 days of age (1) or not (0)	
	Antagonistic behaviour	Number of antagonistic behaviour (aggressive behaviour and injurious feather pecking) observed during the farm visit	
	Flightiness	Whether the flock is best described as flighty (2), cautious (1) or calm (0)	
	Mortality	Mortality rate of the flock immediately previous to that observed during the farm visit	
	Litter score	Condition of litter, as evaluated in the scale of 1–6: 1: Completely dry and friable 2: Small moist/capped areas around drinkers/pop holes 3: Large capped areas but sufficient space to dust bathe 4: Largely wet or capped with few friable areas 5: Largely capped or wet 6: Largely wet or soggy	
Positive welfare	Mood dimension score	General ‘mood’ of the flock, as expressed by the first principal component resulting from quantitative behavioural assessment	Welfare Quality (2009)

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Note: For negative welfare indices, a larger value indicates reduced animal welfare. For mood dimension score, a larger value indicates improved animal welfare.

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**Table S2.** Costs considered in economic analysis.

Resource need	Welfare +	Welfare ++ <sup>1</sup>	Welfare +++ <sup>1</sup>
Physical environment	<ul style="list-style-type: none"> <li>• Two types of litter substrates</li> <li>• Two types of perches</li> <li>• Labour cost for installation and maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Two types of perches for pellets</li> <li>• Multiple flooring types during rearing</li> </ul>	<ul style="list-style-type: none"> <li>• Substrate flooring</li> </ul>
Thermal environment		<ul style="list-style-type: none"> <li>• Windbreaks</li> <li>• Artificial shelters</li> </ul>	<ul style="list-style-type: none"> <li>• Pop hole covers</li> </ul>
Minimising harms		<ul style="list-style-type: none"> <li>• Ramps between pop holes, litter, slats, house and nest boxes</li> </ul>	<ul style="list-style-type: none"> <li>• Labour cost for extra monitoring of keel bone damages</li> </ul>
Cognitive enrichment	<ul style="list-style-type: none"> <li>• Log piles, fallen branches and fallen trees</li> <li>• Labour cost for weekly replacement of enrichments</li> </ul>	<ul style="list-style-type: none"> <li>• Additional log piles, fallen branches and fallen trees</li> <li>• Labour cost for weekly replacement of additional enrichments</li> </ul>	<ul style="list-style-type: none"> <li>• Puzzle feeders</li> </ul>
Food choices	<ul style="list-style-type: none"> <li>• Wholegrain oats provided separately from other feeds</li> <li>• Insoluble grit provided separately from other feeds</li> </ul>	<ul style="list-style-type: none"> <li>• Feeders and drinkers on every level <ul style="list-style-type: none"> <li>• Pecking blocks</li> </ul> </li> <li>• Labour cost for scattering grain on litter</li> </ul>	<ul style="list-style-type: none"> <li>• Different feeders and drinkers on every level</li> <li>• Chicory and clovers provided separately from other feeds</li> </ul>
Positive experiences		<ul style="list-style-type: none"> <li>• Labour cost for extra monitoring of flock experiences</li> </ul>	<ul style="list-style-type: none"> <li>• Labour cost for regular handling of birds</li> <li>• Labour cost for handfeeding pullets</li> </ul>
Nesting choices	<ul style="list-style-type: none"> <li>• Extra nest boxes</li> </ul>	<ul style="list-style-type: none"> <li>• Enhanced substrates for nest boxes with wood shavings, buckwheat and oat husks</li> </ul>	<ul style="list-style-type: none"> <li>• Individual nest boxes</li> </ul>
Social experiences	<ul style="list-style-type: none"> <li>• Labour cost for managing pariah birds</li> </ul>	<ul style="list-style-type: none"> <li>• Visual barriers to create smaller groups</li> </ul>	<ul style="list-style-type: none"> <li>• Inclusion of cockerels</li> <li>• Capital and labour costs for reducing stocking density</li> </ul>

Enriched environment	<ul style="list-style-type: none"> <li>• Alfalfa blocks, straw nets and pecking blocks</li> <li>• Labour cost for placing and managing enrichments</li> </ul>	<ul style="list-style-type: none"> <li>• Alfalfa blocks, straw nets, pecking blocks for pellets</li> <li>• Labour cost for placing and managing additional enrichments</li> </ul>	<ul style="list-style-type: none"> <li>• Projector and screen</li> </ul>
Positive outdoor environment	<ul style="list-style-type: none"> <li>• Trees and hedges to cover 5% of the range</li> <li>• Artificial shelters immediately outside pop holes <ul style="list-style-type: none"> <li>• Roofed sandpits</li> </ul> </li> <li>• Animals (alpacas) kept on the range</li> </ul>		<ul style="list-style-type: none"> <li>• Establishment of an orchard to cover half the range</li> </ul>
Dustbathing	<ul style="list-style-type: none"> <li>• Enhanced litter with woodchip and sand <ul style="list-style-type: none"> <li>• Covered verandas</li> <li>• Extra drinkers</li> </ul> </li> </ul>		<ul style="list-style-type: none"> <li>• Deeper litter (15 cm)</li> </ul>
Effective management	<ul style="list-style-type: none"> <li>• Labour cost for weekly health and welfare outcome assessments</li> </ul>	<ul style="list-style-type: none"> <li>• Frequent health and welfare reviews with the vet (at each laying cycle)</li> </ul>	<ul style="list-style-type: none"> <li>• Participation in welfare initiatives</li> </ul>
Genetic selection		<ul style="list-style-type: none"> <li>• Reduced production as a result of welfare-focused selection</li> </ul>	<ul style="list-style-type: none"> <li>• Increased pullet cost for 'high maintenance' breeds</li> </ul>

Note: Where cells are blank there is no extra cost associated with the positive welfare tier.

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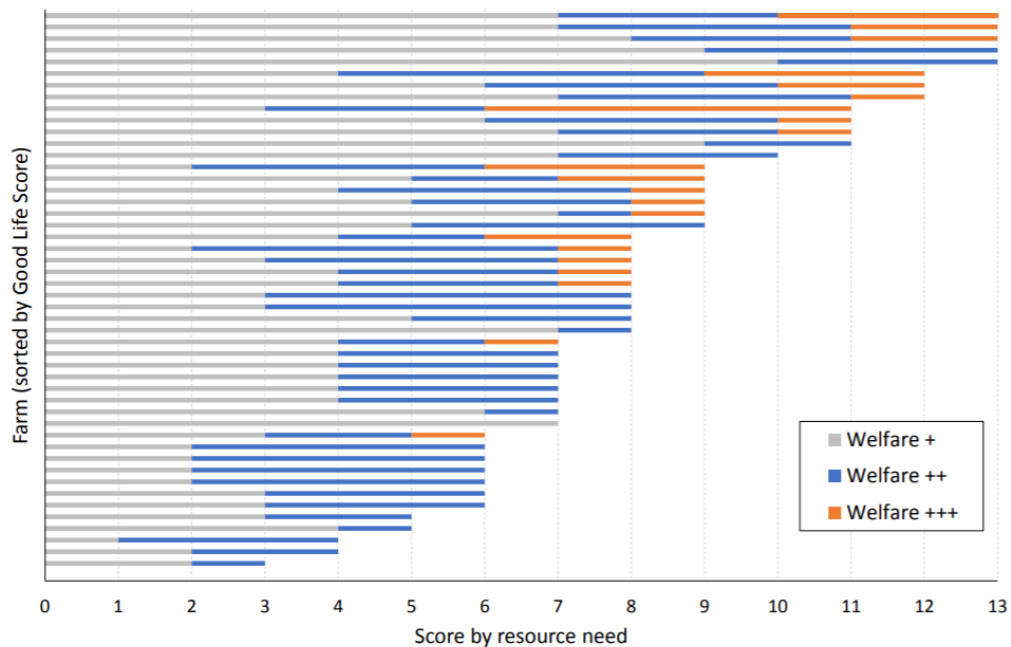
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168 **3. Results**

169 *3.1 Input-based measures*

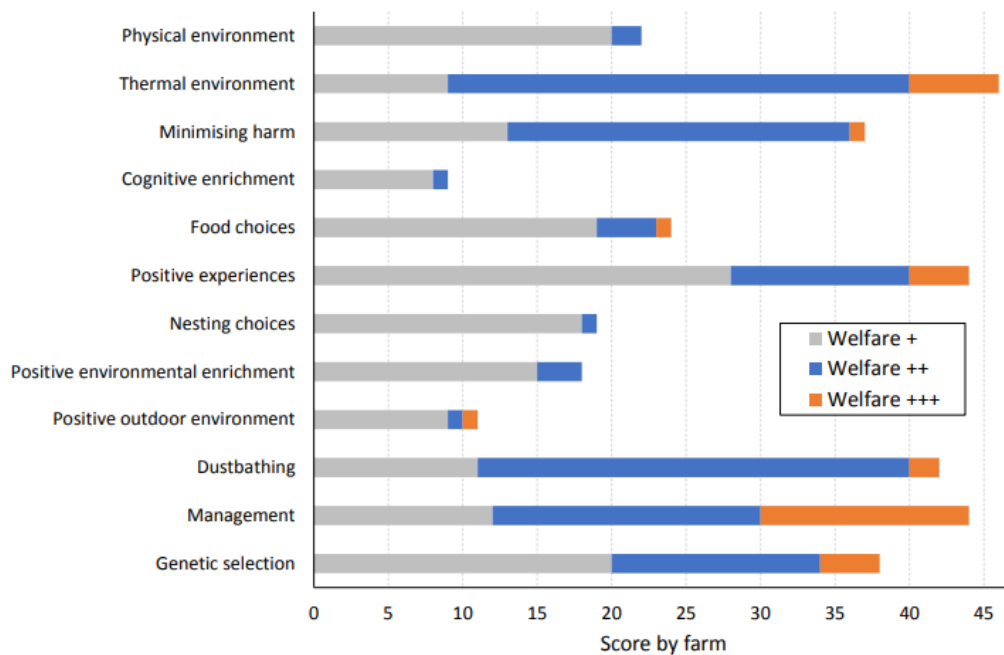
170 Across 637 (49 x 13) combinations of flocks and resource needs, 63% achieved a score of Welfare  
 171 + or above (Figure 1). A high degree of inter-farm variability was found within the flocks assessed;  
 172 one farm scored no Welfare + or above under any resource need, while five satisfied all 13 resource  
 173 needs at Welfare + or above. The proportions of farms satisfying higher tiers were also different across  
 174 resource needs. For example, as many as 46 flocks (96%) marked Welfare + or above for *social*  
 175 *experiences*, whereas only 9 flocks (18%) achieved Welfare + or above for *cognitive enrichment* (Figure  
 176 2). The result was similar at the upper end of the tiers, with 14 farms (29%) recording Welfare +++ for  
 177 *effective management* but no farms qualified at the same level under four resource needs (*physical*  
 178 *environment, cognitive enrichment, nesting choices and enriched environment*). The maximum good life  
 179 score is 39. This study found the average good life score across all sample farms was 12.6, with the  
 180 range of 0–24.



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 182 **Figure 1.** Number of resource needs (out of 13) achieved by each of 49 flocks.

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**Figure 2.** Number of flocks (out of 49) that achieve each of 13 resource needs.

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### 3.2 Outcome-based measures

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Feather losses at head/neck and back/vent areas were observed, respectively, amongst 9% and 10% of birds assessed on sample farms. Beak trimming was carried out, routinely before 10 days of age, at 37 farms (76%). Sixteen flocks (33%) had one or more instance of antagonistic behaviour, with 11 (22%) displaying aggressive behaviour and 5 (10%) observed to be feather pecking. Thirty-one flocks (63%) were recorded as calm, 14 (29%) as cautious and 4 (8%) as flighty. The median mortality of the previous flock was 5.4%, with the range of 2.6–20%. Seventeen farms (35%) achieved the perfect litter score of 1, whereas fourteen (29%) recorded undesirable scores of 4 and above. The QBA component that appeared to relate most closely to ‘mood’ was the first component, , which explained 50.4% of variance and had descriptors with loadings over 0.6 of Content, Calm, Happy at one end, and Depressed, Bored, Frustrated, Scared, Fearful, Distressed, Nervous, Tense, Agitated at the other. This component had a wide range of values between –2.59 and 1.55. As a standardised variable, however, these values are only informative in the context of within-sample comparisons.

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### 3.3. Cost structure

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Across 13 resource needs, the average cost required to satisfy each tier (Welfare +, Welfare ++ and Welfare +++) was estimated to be £0.34, £0.55 and £1.21/doz, respectively (Supplementary Table S3). The estimated cost to achieve the perfect good life score (39) was £27.23/doz. Incrementally, some ‘upgrading’, or movement towards an immediately upper tier, was found to be significantly more cost effective than others. In particular, the marginal cost to achieve Welfare + under five resource needs, Welfare ++ under two and Welfare +++ under four were estimated to be less than £0.05/doz (Supplementary Table S4).

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**Table S3.** Total cost to satisfy each resource tier (£).

Resource need	+	++	+++
Physical environment	0.27	0.98	1.12
Thermal environment	0.00	0.08	0.14
Minimising harms	0.00	0.08	0.09
Cognitive enrichment	0.30	0.60	0.62
Food choices	0.18	0.28	0.31
Positive experiences	0.00	0.07	0.23
Nesting choices	0.24	0.33	0.71
Social experiences	0.02	0.47	5.97
Enriched environment	0.68	0.91	0.95
Positive outdoor environment	0.77	0.77	0.98
Dustbathing	1.85	1.85	2.11
Effective management	0.07	0.28	0.34
Genetic selection	0.00	0.45	2.13

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Values are foregone net margins per dozen eggs (~0.7 kg) compared to a production system with no welfare enhancement.

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**Table S4.** Incremental cost to satisfy higher resource tiers (£).

Resource need	+	++	+++
Physical environment	0.27	0.71	0.13
Thermal environment	0.00	0.08	0.06
Minimising harms	0.00	0.08	0.01
Cognitive enrichment	0.30	0.30	0.02
Food choices	0.18	0.09	0.03
Positive experiences	0.00	0.07	0.16
Nesting choices	0.24	0.09	0.38
Social experiences	0.02	0.45	5.50
Enriched environment	0.68	0.23	0.04
Positive outdoor environment	0.77	0.00	0.21
Dustbathing	1.85	0.00	0.27
Effective management	0.07	0.21	0.06
Genetic selection	0.00	0.45	1.68

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Values are foregone net margins per dozen eggs (~0.7 kg) compared to the resource tier one level below.

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### 214 3.4 Correlation analysis

215 Positive correlations were observed amongst resource tier scores for five opportunities recorded  
 216 by the same flock, suggesting that farmers who create a positive welfare environment for animals  
 217 tend to do so across multiple areas of farm management (Supplementary Tables S5 and S6). The good  
 218 life score and the estimated total cost also showed a correlation ( $r = 0.822$ ,  $p < 0.001$ ), confirming that,  
 219 the asymmetric cost structure notwithstanding, producers achieving positive welfare opportunities  
 220 have generally invested more resources into the farm to improve the animals' quality of life.

221 The correlation matrix between resource tier scores and outcome-based measures of welfare  
222 indicates that investment into on-farm resources is generally associated with reduction of negative  
223 outcomes (*Table 3 and Supplementary Table S7*). Most notably, correlations were observed between  
224 comfort and flightiness ( $r = -0.383$ ,  $p = 0.007$ ), confidence and flightiness ( $r = -0.287$ ,  $p = 0.046$ ), as  
225 well as pleasure and beak trimming ( $r = -0.414$ ,  $p = 0.003$ ). The litter score was found to be negatively  
226 correlated with resource tier scores for all five opportunities, the good life score ( $r = -0.357$ ,  $p = 0.012$ )  
227 and the estimated cost ( $r = -0.322$ ,  $p = 0.024$ ), suggesting that the litter condition may be a useful  
228 resource indicator of the overall level of animal welfare on the farm. Feather loss was not found to be  
229 associated with any score or cost variable.

230 The mood dimension score, an output-based measure of positive and negative welfare, was  
231 positively correlated with resource tier scores for all five opportunities as well as the good life score  
232 ( $r = 0.360$ ,  $p = 0.011$ ). The estimated cost was also positively correlated with the mood dimension score  
233 ( $r = 0.249$ ,  $p = 0.084$ ), suggesting that investment in on-farm resources may increase the likelihood of  
234 creating enhanced positive welfare outcomes for animals.

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**Table S5.** Correlation coefficients amongst resource tier scores and estimated cost.

Opportunity	COM	PLE	CON	INT	HEA	TOT	COS
Comfort	1						
Pleasure	0.422	1					
Confidence	0.504	0.612	1				
Interest	0.628	0.536	0.383	1			
Healthy life	0.303	0.370	0.401	0.338	1		
Total score	0.741	0.739	0.787	0.719	0.724	1	
Estimated cost	0.452	0.664	0.791	0.521	0.596	0.822	1

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COM: Comfort. PLE: Pleasure. CON: Confidence. INT: Interest. HEA: Healthy life. TOT: Total score. COS: Estimated cost.

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All values are  $p < 0.05$ ; actual  $p$ -values are listed in Supplementary Table S6.

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**Table S6.**  $P$ -values for correlations amongst resource tier scores and estimated cost.

Opportunity	COM	PLE	CON	INT	HEA	TOT	COS
Comfort	0						
Pleasure	0.003	0					
Confidence	< 0.001	< 0.001	0				
Interest	< 0.001	< 0.001	0.007	0			
Healthy life	0.034	0.009	0.004	0.018	0		
Total score	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0	
Estimated cost	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	1

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COM: Comfort. PLE: Pleasure. CON: Confidence. INT: Interest. HEA: Healthy life. TOT: Total score. COS: Estimated cost.

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**Table S7.** *P*-values for correlations between resource tier scores and welfare outcome measures.

Opportunity	FL1	FL2	TRM	ANT	FLT	MRT	LIT	MDD
Comfort	0.407	0.609	0.474	0.125	<b>0.007</b>	0.210	<b>0.014</b>	<b>0.038</b>
Pleasure	0.948	0.958	<b>0.003</b>	0.935	0.358	0.393	0.575	<b>0.046</b>
Confidence	0.893	0.561	0.121	0.146	<b>0.046</b>	0.645	0.118	<b>0.019</b>
Interest	0.584	0.120	0.653	0.272	0.152	0.060	<b>0.019</b>	0.084
Healthy life	0.223	0.937	0.235	0.877	0.131	0.143	<b>0.042</b>	0.184
Total score	0.397	0.541	0.169	0.320	<b>0.017</b>	0.208	<b>0.012</b>	<b>0.011</b>
Estimated cost	0.617	0.677	<b>0.012</b>	0.277	0.115	0.622	<b>0.024</b>	0.084

244

FL1: Feather loss (head and neck). FL2: Feather loss (back and vent). TRM: Beak trimming. ANT: Antagonistic behaviour. FLT: Flightiness. MRT: Mortality. LIT: Litter score. MDD: Mood dimension score. **Bold** values indicate  $p < 0.05$ . Corresponding correlation coefficients are listed within the main article (Table 3).

245

246

247

**Table 3.** Correlation coefficients between resource tier scores and welfare outcome measures.

Opportunity	FL1	FL2	TRM	ANT	FLT	MRT	LIT	MDD
Comfort	0.121	−0.075	0.105	−0.222	<b>−0.383</b>	−0.217	<b>−0.350</b>	<b>0.297</b>
Pleasure	0.010	−0.008	<b>−0.414</b>	0.012	−0.134	0.149	−0.082	<b>0.287</b>
Confidence	0.020	−0.085	−0.224	−0.211	<b>−0.287</b>	−0.081	−0.226	<b>0.334</b>
Interest	0.080	−0.225	−0.066	−0.160	−0.208	−0.322	<b>−0.335</b>	0.249
Healthy life	0.177	0.012	−0.173	0.023	−0.219	−0.253	<b>−0.292</b>	0.193
Total score	0.124	−0.089	−0.200	−0.145	<b>−0.340</b>	−0.218	<b>−0.357</b>	<b>0.360</b>
Estimated cost	0.073	−0.061	<b>−0.356</b>	−0.158	−0.228	−0.086	<b>−0.322</b>	0.249

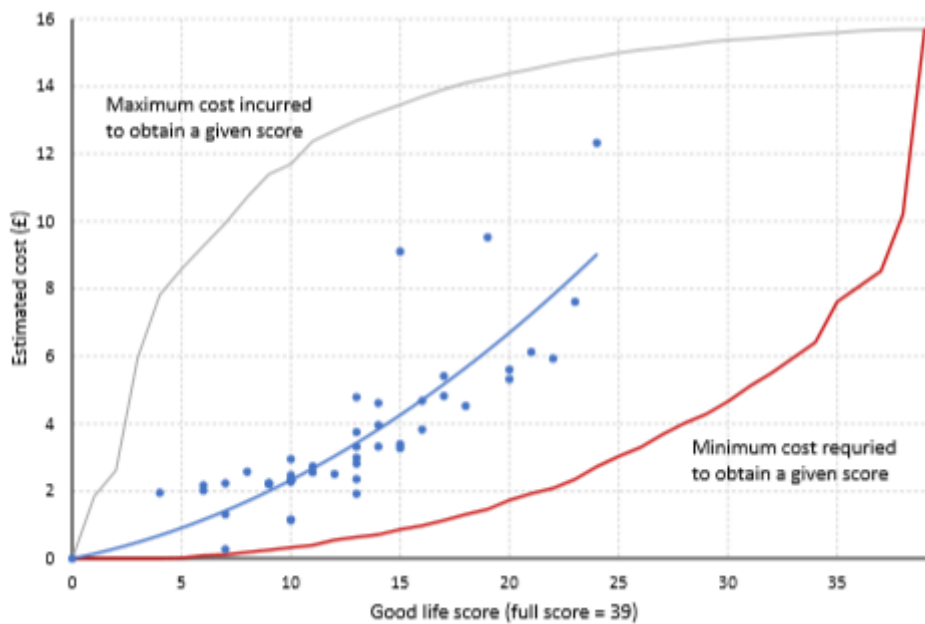
248

FL1: Feather loss (head and neck). FL2: Feather loss (back and vent). TRM: Beak trimming. ANT: Antagonistic behaviour. FLT: Flightiness. MRT: Mortality. LIT: Litter score. MDD: Mood dimension score. **Bold** values indicate  $p < 0.05$ ; actual  $p$ -values are listed in Supplementary Table S7.

249

### 250 3.5 Least-cost strategy

251 A higher good life score was generally associated with a higher level of estimated investment.  
 252 A closer investigation revealed, however, that this relationship was likely to be nonlinear (Figure 3),  
 253 as the incremental cost to achieve Welfare ++ and Welfare +++ status tends to be higher than that to  
 254 achieve Welfare + (Supplementary Table S4). The majority of sample farms were found to have spent  
 255 considerably more on resources than theoretically required to achieve the same score (Figure 3),  
 256 suggesting that significant room exists to further improve positive welfare opportunities without  
 257 incurring additional costs. On average across 49 farms, the cost saving potential under the former  
 258 approach was 81% of current total expenditures. Under the latter approach, the potential  
 259 improvement in good life score was 12.2, or approximately twice the current average score.



260

261 **Figure 3.** Relationship between resource tier score and estimated cost to achieve them at sample  
 262 farms ( $N = 49$ ). Quadratic trend curve suggests an exponential cost structure ( $y = 0.01x^2 + 0.13x$ ,  $R^2 =$   
 263  $0.71$ ), while the discrepancy between observed data (blue) and the minimum cost required to obtain  
 264 a given score (red) shows the potential to reduce the expenditure without compromising the overall  
 265 level of positive welfare.

## 266 4. Discussion

267 In this study the resource tier framework, a positive welfare scoring method assessing the  
 268 resources which can provide good life opportunities of comfort, pleasure, confidence, interest and  
 269 healthy life developed by the authors' group [22], was applied on commercial laying hen farms  
 270 located across the UK, creating a unique dataset linking input-based measures of positive welfare  
 271 opportunity to outcome-based measures of both positive and negative welfare. Furthermore, the  
 272 degree of investment currently being undertaken by producers to provide animals with good life  
 273 opportunities was quantified and, based on these data; the efficacy of such investment vis-à-vis the  
 274 predicted level of welfare status was examined. To the best of our knowledge, this is the first research  
 275 exploring options to improve positive welfare of farm animals while explicitly considering their cost  
 276 implications.

277 The above analysis revealed the extent to which farmers provide positive welfare opportunities  
 278 that exceed current legal and commercial requirements. In total across the assessment of 13 resource  
 279 tiers on all 49 flocks, 63% of assessments achieved a welfare + or above. Given that all sample  
 280 farms are scheme-certified, these findings suggests that some farmers are providing positive welfare  
 281 opportunities beyond what are required by law, code of practice and scheme guidelines and,  
 282 crucially, not fully rewarded for these additional inputs. These good life opportunities, originally

283 proposed by FAWC [5], were defined upon scientific evidence that additional resources are valued  
284 by animals even if they do not result in short-term changes in health and production parameters.  
285 Indeed, the derived relationship between resource tier scores and commonly assessed welfare  
286 outcomes indicated that provision of additional behavioural opportunities, while positively  
287 influencing the animal's arousal (reduced flightiness) and mood (higher QBA score), was not  
288 associated with production performance (feather loss and mortality) of UK laying hen farms. Some  
289 may, therefore, be surprised to observe that a large proportion of farms are providing their stock with  
290 behavioural opportunities that do not necessarily contribute to their profitability; it is contended here  
291 that this result demonstrates the genuine interest held amongst commercial producers in providing  
292 an on-farm environment that promotes the animal's positive experience. At the same time, the finding  
293 also indicates that good life opportunities should be seen as a complementary, rather than  
294 substituting, component of animal welfare, which would not be captured by existing legal  
295 requirements or outcome-based welfare assessments — such as the *AssureWel* animal welfare  
296 assessment that have been incorporated into certification schemes for the UK laying hen industry [1].  
297 There was also significant variation between farms with 5 units achieving welfare + or above in all 13  
298 resource tiers and 1 farm achieving welfare + or above in only 3 resource tiers. This means that the  
299 approach could be also used to promote continuous improvement toward higher welfare.

300 The positive correlation between mood dimension score with resource tier scores for all five  
301 opportunities as well as the overall good life score is consistent with [28], who reported a similar  
302 relationship on UK pig farms. As input-based methods are less likely to suffer from the assessor bias  
303 than outcome-based methods, the ability to use the former may provide a valuable solution to  
304 incorporate positive welfare assessment into large-scale certification schemes.

305 Given that some commercial producers are already providing positive welfare opportunities  
306 beyond existing requirements without any existing recognition or reward, their motives for doing so,  
307 and in particular non-financial incentives of providing additional resources, such as pride, social  
308 capital and value of animal wellbeing, warrant further investigation. If providing positive welfare  
309 resources is more motivating for farmers than making step changes to reduce negative welfare, a  
310 policy shift towards positive welfare may carry the potential to induce substantive human  
311 behavioural change throughout the supply chain [17]. It has previously been argued that animal  
312 welfare is a public good [29,30] as an important recent example, the UK Agriculture Bill  
313 (<http://services.parliament.uk/bills/2017-19/agriculture.html>) proposes how farmers and land  
314 managers should be paid for public goods, including higher animal welfare standards. Under this  
315 concept, rewarding investment in good life opportunities could be a novel policy instrument to  
316 facilitate welfare improvement on the farm and, therefore, accumulation of social capital. This point  
317 is especially pertinent in light of the above result, namely that substantive production benefit may  
318 not exist for providing these opportunities.

319 In this context, perhaps the most important finding from the economic analysis was that  
320 significant opportunities lie ahead for producers to improve animal welfare without incurring further  
321 costs. The marginal cost to achieve at least some “good life opportunities” i.e. welfare + across all five  
322 categories of resource needs was less than £0.05/doz. This suggests that there is a degree of market  
323 failure in the current market of high welfare products, which is preventing commercial farmers from  
324 rationally allocating resources to maximise the ‘production’ of positive animal welfare. From the  
325 public economics perspective, this calls for research on the optimal mechanism of intervention, e.g.  
326 how to induce investment into resources of which marginal costs are lower than those currently  
327 supplied. With similar studies on negative welfare already advancing the knowledge in this area  
328 [31,32], such investigations could potentially lead to a ‘hybrid’ approach, under which cost-effective  
329 provision of good life opportunities is combined with measures to reduce negative welfare outcomes.

330 Finally, it is worth recognising that appraising scientific validity of a welfare assessment method  
331 is a complex process [33], not least because there are numerous and often contradicting definitions of  
332 animal welfare [34]. The principle approach employed at the development of the resource tier  
333 framework was to safeguard content validity, or holistic inclusion of additional opportunities  
334 previously shown to be valued by animals [22]. It is noted however that the degree to which

335 increasing levels of resource provision proposed by the current framework delivers an incremental  
336 increase in positive welfare requires further investigation. Validation in terms of both substantiate  
337 and demarcate the different levels of resource provision using *positive behavioural outcomes should be*  
338 *employed*. As outlined by FAWC [5], care must be taken before implementing this principle into  
339 product requirements, as provision of behavioural opportunities based on the animal's desire could  
340 potentially be harmful. In the present study, however, there was little quantitative evidence to  
341 support that this was the case. If anything, good life opportunities were weakly associated with  
342 *reduced* mortality and, across five opportunities (comfort, pleasure, confidence, interest and health),  
343 no statistically significant case was detected where an improved opportunity was met by a reduced  
344 welfare outcome. Nonetheless, it is acknowledged that the limited sample size and relatively narrow  
345 scope of data collected relating to known risk factors for poor feather loss and other outcomes  
346 precluded a more detailed assessment of individual resources and their effects on outcomes and  
347 performance in this study. Also, the further inclusion of other key negative welfare outcomes such as  
348 keel bone damage, foot pad dermatitis, and health outcomes would facilitate a more comprehensive  
349 analysis. Further work to fully understand whether improving positive welfare opportunities can  
350 also reduce any negative behavioural, health and physical outcomes is required. To this end,  
351 additional work is being planned to further explore behavioural and health impacts of resources that  
352 appear to be particularly valued by animals.

353 In summary, this study has demonstrated that many UK laying hen farms are providing  
354 additional resources beyond that required by either legislation or certification requirements for which  
355 there was often no financial reward. Provision of these additional "good life opportunities" was  
356 positively associated with the mood dimension score, a behavioural outcome measure, but limited  
357 impact on health and productivity measures. Furthermore, economic modelling suggest that  
358 achieving good life opportunities across all five resource needs can be achieved with minimal  
359 additional cost.

360 **Supplementary Materials:** Supplementary tables S1- S7 are available online at .....

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