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1 **Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in**
2 **cattle in England and Wales**

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10

11 **Abstract**

12 There has been growing concern about bacterial resistance to antimicrobials in the farmed
13 livestock sector. Attention has turned to sub-optimal use of antimicrobials as a driver of
14 resistance. Recent reviews have identified a lack of data on the pattern of antimicrobial use
15 as an impediment to the design of measures to tackle this growing problem. This paper
16 reports on a study that explored use of antibiotics by dairy farmers and factors influencing
17 their decision-making around this usage.

18 We found that respondents had either recently reduced their use of antibiotics, or planned to
19 do so. Advice from their veterinarian was instrumental in this. Over 70% thought reducing
20 antibiotic usage would be a good thing to do. The most influential source of information used
21 was their own veterinarian. Some 50% were unaware of the available guidelines on use in
22 cattle production. However, 97% thought it important to keep treatment records.

23 The Theory of Planned Behaviour was used to identify dairy farmers' drivers and barriers to
24 reduce use of antibiotics. Intention to reduce usage was weakly correlated with current and
25 past practice of antibiotic use, whilst the strongest driver was respondents' belief that their
26 social and advisory network would approve of them doing this. The higher the proportion of
27 income from milk production and the greater the chance of remaining in milk production, the
28 significantly higher the likelihood of farmers exhibiting positive intention to reduce antibiotic
29 usage. Such farmers may be more commercially minded than others and thus more cost-
30 conscious or, perhaps, more aware of possible future restrictions.

31 Strong correlation was found between farmers' perception of their social referents' beliefs
32 and farmers' intent to reduce antibiotic use. Policy makers should target these social
33 referents, especially veterinarians, with information on the benefits from, and the means to,
34 achieving reductions in antibiotic usage. Information on sub-optimal use of antibiotics as a
35 driver of resistance in dairy herds and in humans along with advice on best farm practice to
36 minimise risk of disease and ensure animal welfare, complemented with data on potential
37 cost savings from reduced antibiotic use would help improve poor practice.

38 Keywords: antimicrobials; farmers' attitude; veterinarians; disease prevention; on-farm costs.

39

40 **1. Introduction**

41 At a therapeutic level, antimicrobials are vital medicines for treatment and control of bacterial
42 infections. However, there are increasing reports of resistance to antimicrobial drugs used in
43 veterinary medicine and, also, concerns about the threat that may pose to both animal and
44 human health, through the selection of resistance (WHO, 2000; Marshall et al., 2011; WHO,
45 2014a). Development of antimicrobial resistance also threatens to restrict the effectiveness
46 of existing drugs used on farms and the treatment of veterinary bacterial pathogens.

47 There is increasing evidence that overuse and sub-optimal use of antimicrobials may be a
48 factor in the development of bacterial resistance to veterinary antimicrobials (e.g. Barbosa
49 and Levy, 2000). Antimicrobial stewardship is now internationally recognised as a challenge.
50 A multifaceted approach – concerted effort between industry and government bodies and a
51 variety of initiatives including alternatives to antibiotics and a better consumption recording
52 system - is required to optimise the use of antibiotics (Prescott, 2014).

53 In response to these concerns, several countries (Denmark, France, the Netherlands and
54 the UK) have developed strategies for monitoring incidents of bacterial resistance in farm
55 animals, as a first step towards designing measures to reduce antimicrobial usage and for
56 promoting prudent and responsible use of antimicrobials by farmers, farm staff and
57 veterinarians (Anon, 2007; Anon, 2012a; Anon, 2013; Anon, 2014a; EPRUMA, 2008;
58 Landers, 2012; Levy, 2014; OIE, 2013 and WHO, 2014b). In 2011, the European
59 Commission (EC) launched a 5-year action plan, including 12 actions to tackle antimicrobial
60 resistance covering areas such as ‘development of new effective antimicrobials or alternative
61 treatment’, ‘improving surveillance and monitoring in human and animal medicine’ and
62 ‘making sure antimicrobials are used appropriately’ (Anon, 2011).

63 In the UK, various guidance on best practice for the responsible use of antimicrobials in
64 livestock is available to farmers and veterinarians such as that published by Responsible
65 Use of Medicines in Agriculture (RUMA) alliance (RUMA, 2004). The British Veterinary

66 Association (BVA) has actively promoted responsible use of antimicrobials to veterinarians,
67 most notably by publishing a poster with a simple and effective 8-point plan (Anon 2009). In
68 2013, the UK Government published the 'UK Five Year Antimicrobial Resistance (AMR)
69 Strategy 2013 to 2018', in line with the 2011 EC strategy, which proposed actions to slow the
70 development and spread of AMR (Anon, 2013) and in 2014, the British Cattle Veterinary
71 Association published a poster on medicine residues in milk for farmers (BCVA, 2014). While
72 guidance documents have been published, there has been little or no assessment of the
73 impact of the recommendations on farming practices and on antimicrobial consumption.
74 Antibiotic sales for all food producing animals have remained relatively stable between 2008
75 and 2013 despite the guidance. Furthermore, recommendations on the appropriate first and
76 second antimicrobial treatments for specific conditions have been adopted in other European
77 countries (e.g. the Netherlands (Teale and Moulin, 2012) and Denmark (Pedersen et al.,
78 1999)) but not in the UK.

79 The Veterinary Medicinal Product Directive 2001/82/EC sets out the control on veterinary
80 medicines. This EC Directive provides the basis for UK controls which are applied through
81 the Veterinary Medicines Regulations. All veterinary medicines, including those containing
82 antibiotics, require authorisation before they are marketed or administered to animals. All
83 antibiotic veterinary medicines in the UK must be prescribed by a veterinarian. Routine
84 prophylactic use of antibiotics is not a recommended practice by the Veterinary Medicines
85 Directorate (VMD) in the UK (Anon., 2014c); and the prophylactic use of antibiotics at very
86 small doses in animal feed - better known as growth promoters - has been banned in the
87 European Union (EU) since 2006 (Regulation 1831/2003/EC on additives for use in animal
88 nutrition).

89 Nevertheless, how medicines are prescribed is down to the professional judgement of the
90 veterinarian which can be influenced by various factors. A study suggested that widely
91 differing patterns of antimicrobial usage exist between 10 European countries. These

92 patterns could not be explained by simple differences in animal species demographics which
93 suggests that other factors, such as farm management or social factors were involved
94 (Grave et al., 2010). The Heads of Medicines Agencies across the EU worked in
95 collaboration with the Federation of Veterinarians of Europe to explore antimicrobial
96 prescribing habits and influencing factors among veterinarians for food producing animals,
97 companion animals and equines (De Briyne et al., 2013). That survey confirmed that
98 veterinarians were most likely to prescribe antimicrobials following sensitivity test results but
99 also based on their experience and ease of use in the absence of test results. Similarly,
100 another study which looked at antimicrobial use in a companion animal teaching hospital in
101 Italy concluded that there was a need to improve procedures for antimicrobial prescription;
102 published guidelines with further implementation of policies of prudent prescriptions were
103 suggested (Escher et al., 2011).

104 Although veterinarians are usually responsible for choosing the appropriate antimicrobials for
105 treatments, choices may also be influenced by farmers' own opinions and needs based on,
106 for example, cost and profit margin, ease of medicine administration and withdrawal period
107 (De Briyne et al., 2013; Gibbons et al., 2013). Then, once prescribed, little is known on how
108 medicines are administered and managed by the farmers and whether alternative practices
109 are taken into consideration by the farmer to reduce reliance on antibiotics.

110 Until 2013, direct marketing of veterinary antimicrobials by animal health companies to
111 farmers was permitted in the UK, unlike in mainland Europe, where such advertising has
112 been banned since 2011 (Anon, 2012b), on the grounds that information supplied may not
113 be used or interpreted adequately by farmers. Indeed, in a study which explored farmers'
114 knowledge and attitudes towards antimicrobial usage in livestock, a lack of knowledge about
115 antimicrobials and bacterial resistance was highlighted (Friedman et al., 2007). For example,
116 it was found that farmers mostly relied on their own or a neighbour's experience rather than
117 scientific evidence or advice from their veterinarian to decide which treatment to adopt.

118 Though veterinarians were the main source of information, limited finances for expenditure
119 on veterinary support was a key barrier to seeking out antibiotic protocols (Friedman et al.,
120 2007). If factors other than those directly related to the effective treatment of disease (whilst
121 minimising the emergence of resistance) have a large impact on the eventual therapy
122 selected and subsequently applied, then these factors (e.g. marketing, price, availability,
123 neighbour's experience) are potentially an important issue to consider.

124 Clearly, legislation would over-ride any drivers and barriers but in the absence of legislation
125 to reduce antimicrobial usage the question remains:

126 'What factors (knowledge, social, economic) could influence farmers' perceptions,
127 attitudes and behaviours in participating in an animal health management programme
128 relating to prudent usage of antimicrobials?'

129 To help ensure the responsible use of antimicrobials as a disease control measure on dairy
130 farms, further research is needed to understand farmers' and veterinarians' behaviour and
131 attitudes towards their use, and to identify which factors and motives are most important in
132 influencing current and proposed practice (Busani et al., 2004).

133 Understanding farmer attitudes and the factors that influence decision-making and the
134 translation of intentions into sustained changes in behaviour, is seen as an increasingly
135 useful discipline in policy making and health scheme implementation. The relatively small
136 scale survey described here is part of the larger Emerging and Major Infectious Diseases in
137 Animals (EMIDA) initiative. The overarching objective of the EMIDA project was to gain
138 insight into the determinants of behaviour that influence farmers' willingness to participate in
139 animal health management programmes. As a starting point, this pilot study aimed to: look
140 into the extent to which recommended guidance on responsible veterinary use of
141 antimicrobials in England and Wales is being followed by farmers; explore reasons why

142 deviations from prudent use by farmers may be occurring; and identify the factors influencing
143 farmers' decisions on antimicrobial usage.

144 **2. Method**

145 **2.1 Procedure**

146 Data on farmer attitudes and behaviours connected with antimicrobial use were collected by
147 a postal survey of dairy farmers in England and Wales. The researchers developed a
148 questionnaire based on the Theory of Reasoned Action (TORA) and Theory of Planned
149 Behaviour (TPB) and relevant literature (e.g. Ajzen, 1991; Fishbein and Yzer, 2003; Garforth
150 *et al.*, 2006 and Garforth *et al.*, 2013). It was then piloted with 5 farmers.

151 The questionnaire had 7 sections with questions on: the farmer and their dairy enterprise;
152 use of antibiotics and attitudes towards use of antibiotics; and knowledge on guidelines for
153 their use. Attitudinal questions were framed on a 5-point Likert scale system, while a choice
154 of answers was provided for the socio-demographic questions.

155 The 8 page A4-size questionnaire was sent out in July 2013 with a covering letter explaining
156 the survey objectives with a reply-paid envelope. It went to 118 farmers who had agreed to
157 be involved in the research out of the 250 random sample of dairy farmers initially
158 approached to take part. Questionnaires in both English and Welsh were provided to farmers
159 in Wales. A copy of the questionnaire is available from the corresponding author. To
160 maximise response rate, a reminder letter with a duplicate copy of the questionnaire was
161 sent out in August 2013 and again in September 2013. The survey was closed on 30
162 September 2013.

163 **2.2 Survey representativeness**

164 Demographic characteristics were verified to ensure that the sample was representative of
165 the population from which it was drawn. Table 1 shows some characteristics of the
166 respondents and their dairy herds. Survey farmers were mostly (64%) over 50 years and

167 experienced with an average of 35.3 years working in the dairy industry. These
168 demographics compare well with official statistics which show that the mean age of farmers
169 in the UK in 2010 was 59 years old, with only 39% under 55 years old (Defra, 2013a).

170 The mean herd size of the respondents was 180 adult cows, while the England mean for
171 2013 was 134 (DairyCo, 2013). The mean yield of the respondents' cows was 7487 l/cow
172 and the mean price for their milk was 31.1 p/l; Defra (2013a) figures were 7445 l/cow and
173 28.1 p/l. Thus, for five measures, the survey sample matched dairy farmers overall well,
174 although the sample herd size was somewhat larger than the national average.

175 Survey non-response bias was assessed by comparing the observable characteristics of the
176 first 30% replying against those of the last 30% replying. When the comparison was made
177 for these measures, it was found that there were no statistically significant differences
178 between the 'early' and 'late' responders and that 'non-response' bias was unlikely to be
179 present. If there had been a significant difference it could have been concluded that those
180 not replying at all would be likely to be comparable to the 'late' responders (Armstrong and
181 Overton, 1977; Barclay et al., 2002; Groves, 2006; MacDonald et al., 2009).

182 **2.3 The theoretical model used**

183 To develop successful interventions to change particular behaviours, such as reducing
184 farmers' use of antibiotics, it was necessary to understand the determinants of that
185 behaviour. In recent years there has been more recognition of the usefulness of behavioural
186 theory in understanding the determinants of behaviour (e.g. Fishbein and Cappella, 2006).
187 While several behavioural theories have been developed, taken together they have shown
188 that only a few variables need to be taken into account in understanding, and even
189 predicting, a given behaviour (Fishbein, 2000). A model that brings together these variables,
190 capturing both internal (i.e. psychological) and external (e.g. cultural and population) factors
191 is TPB (Ajzen, 1991; Fishbein and Yzer, 2003).

192 The theory states that a person's 'intention' to perform a particular behaviour is the best
193 predictor of whether they actually do so. The theory also identifies three determinants that
194 influence the intention to perform a behaviour:

195 i) attitude towards the expected outcome of the behaviour (Outcome Attitudes) i.e. what
196 they expect the outcome of their behaviour to be, and the value placed on it;

197 ii) beliefs about what valued others expect them to do in relation to the behaviour
198 (Normative Referents); and

199 iii) beliefs about their ability to implement the behaviour (Perceived Behavioural Control).

200 TPB suggests that more favourable attitudes towards the outcomes of the behaviour, more
201 favourable opinions of valued peers towards the behaviour, and greater perceived
202 behavioural control strengthen the intention to perform the behaviour.

203 The TPB framework allowed us to understand why some members of the target population
204 intended to undertake this behaviour and others not, through identification of the relative
205 influences of attitudes (towards reduced use of antibiotics), normative referents (opinions of
206 peers) and perceived behavioural control perceptions, as well as socio-demographic
207 characteristics, on behavioural intent (intent to reduce use of antibiotics in the next year). A
208 focus was made on the roles of the above as drivers and barriers to the development of this
209 intention. Once understood in this way, these drivers and barriers will inform the design of
210 messages and other interventions to impact well on this target behaviour.

211 **2.4 Statistical analysis**

212 Data were transcribed from the returned questionnaires to create an electronic Excel
213 dataset. Data quality checks were carried out to ensure correct data entry and accurate
214 transcription. Data analysis was carried out using SAS Version 9.3, SAS Inc., Raleigh,

215 North Carolina, USA. The questionnaire elicited three types of information relating to
216 farmers' use of information to support their decisions on livestock disease control measures:

- 217 i) frequency of use of the different sources;
- 218 ii) a rank for the amount of information obtained from each source; and
- 219 iii) a rank for the value placed on the opinions of each source.

220 These information types were put into a combined measure of the broad level of influence (I)
221 of each source. First, the ranking of the amount of information provided ($\bar{x}a$) was weighted
222 by the value placed on each source ($\bar{x}b$). The product ($\bar{x}a.\bar{x}b$) was then weighted by the
223 frequency of nomination of each source (n) and then divided by the number in the sample
224 (N) to rebase to a zero to 25 rating scale. In equation form, the calculation was:

$$225 \quad I_j = \frac{((\bar{x}a_j \times \bar{x}b_j) \times n_j)}{N}$$

- 226 Where:
- 227 I_j = Influence of source (j)
 - 228 N = Total number in sample ($N=71$)
 - 229 n = Number nominating source (j)
 - 230 $\bar{x}aj$ = Mean rank of amount of information supplied from source (j)
 - 231 $\bar{x}bj$ = Mean rank of value attached to source (j)

231 The questionnaire had no single direct measures for two of the behavioural components
232 traditionally used in TPB analysis i.e. outcome attitudes (OA) (beliefs about the outcomes of
233 reduction in antibiotic use) and perceived behavioural control (PC). These components were
234 measured indirectly via a suite of targeted questions. In the case of normative referents i.e.
235 subjective norms (SN), there was a candidate for direct measurement which was assessed
236 alongside a composite construction of the same component. Composite variables were
237 calculated for each of the components (OA, SN and PC) by summing the rank scores over
238 the contributing questions (i). All SN, and some PC, 5-point rank scores (b) were weighted

239 by a 5-point importance score (e) before aggregation, while all OA and some PC questions
240 were un-weighted.

241 Cronbach's Alpha was calculated to test the coherence of each of the three composite
242 components. A high Cronbach's Alpha (>0.6) indicated that the items contributing to a
243 measure, when summed, produced a coherent composite measure. Because of the variation
244 in the ranges of the TPB measures, the standardised Cronbach's Alpha Coefficient was
245 used. In each of the three composite TPB measures, even when coherence based on
246 available items exceeded 0.6, one or more of the contributing questions was deleted in order
247 to maximise coherence.

248 The coherence of each of the three composite components of behaviour are shown in Table
249 7. One or more of the contributing questions deleted from the analysis were included
250 individually in the correlation analyses reported below and are in italicised text in Table 9.

251 The TPB variables identified as correlated with intent were used with variables representing
252 farmers' socio-demographic characteristics in a regression model to predict intention (the
253 dependent variable) to reduce antibiotics use over the next 12 months. As the dependent
254 variable was based on an ordinal scale, and some of the independent variables had ordinal
255 or binary scales, a multivariate logistic regression was undertaken. Specifically, a
256 cumulative logit model was fitted using the SAS LOGISTIC procedure. Variables were
257 manually removed from the regression model where they yielded non-significant Maximum
258 Likelihood Estimates (MLE), beginning with the variable with the highest P>Chi Sq value.
259 This process was repeated until all remaining variables had significant MLEs.

260 **3. Results**

261 **3.1 Descriptive measures of the respondents and their dairy herds**

262 Seventy one sufficiently completed responses were received (28.4% of those initially
263 approached). Only one spoilt questionnaire was returned and, thus, was excluded from the

264 dataset. Of the total sample of respondents of 71, 60 (85%) farmed conventionally with the
265 remaining 11 respondents being wholly, or largely, organic. Most respondents (80%) housed
266 their dairy cows for at least 6 months of the year. The mean total milk production was 1.17
267 million litres per farm per year with a range from 250,000 litres to 6.1 million litres.

268 The Rolling Somatic Cell Count for a 12 month period ranged widely from 65,000 per ml to
269 337,000 per ml with a mean of 186,708 per ml. The national mean for 2013 was 199,000
270 cells/ml (Anon., 2014). It can be concluded that the survey respondents had a marginally
271 better Somatic Cell Count than dairy farmers nationally.

272 All respondents had farm income sources other than from their dairy enterprise, with a third
273 deriving 25% of their farm income from non-dairy activities. The mean milk price obtained by
274 respondents at the time of survey was 31.1 pence per litre ranging from 24.7 to 38.0 pence
275 per litre. Some 30 different milk buyers were listed by the respondents with the most
276 common being: ARLA, Dairy Crest, First Milk, Mueller, OMSCO and Wiseman.

277 Membership of Assurance and Certification Schemes was common for survey farmers with
278 67 of the 71 belonging to at least one Scheme. Of respondents who were in an Assurance
279 Scheme, some 50% were required by that Scheme to act relating to antibiotic use.

280 Almost all (69) of the 71 respondents had a Herd Health Plan and, for the 48 who indicated
281 when it was last revised, the mean year was 2012; of these respondents, 58% stated when
282 they last consulted their plan, with a mean year of 2008. It was found that 7% had a routine
283 visit from their veterinarian weekly, 23% fortnightly, and 70% monthly or less.

284 Those surveyed were asked 'Looking ahead, how likely is it that your dairy enterprise will still
285 be operating in 5 years' time?'. This needs to be contextualised by figures in DairyCo (2013)
286 that showed a steady decline in the number of UK dairy herds over the last decade to less
287 than 10,000. Around 16% of respondents said they were either very unlikely or unlikely to be
288 still operating in 5 years' time, 8% said they were neither likely nor unlikely to be, whereas

289 69% said they were either likely or very likely to be still running their dairy enterprise in 5
290 years' time. The remaining 7% said they did not know what they would be doing.

291 Respondents were asked to indicate their highest level of educational attained. The most
292 commonly experienced type/level of education by 44% was 'Further education (agriculture
293 related)'. This is consistent with Defra (2013b) findings for farmers in the Farm Business
294 Survey. The proportion having a university degree in an agriculture related subject (26%)
295 was somewhat higher than that reported by Garforth et al. (2006) and Tranter et al. (2011).

296 **3.2 Current and future use of antibiotics**

297 Almost 59% of respondents reported that their antibiotic use was 'about the same as a year
298 ago' and 37% said 'less frequently than a year ago'. The reasons for the decline in the use of
299 antimicrobials were circumstantial, rather than planned i.e. a fall in the incidence of mastitis,
300 and drier weather leading to healthier cows and less lameness. In terms of intentions
301 regarding antibiotic usage over the next year, 42% said they strongly intended to reduce
302 antibiotics use, while 52% were neutral and only 6% were weakly motivated to do so.

303 Table 2 shows how respondents ranked these statements by their level of agreement where
304 the lower the mean ranking score, the higher their level of agreement with the statement.
305 The highest level of agreement was achieved with the statement about following best
306 practice in all aspects of antibiotic use and fully recording such use.

307 For the other eight statements there was more variation in responses. For example, there
308 was little agreement on whether 'The use of antibiotics in dairy herds leads to antibiotic
309 resistance in dairy cows' (mean ranking score: 2.78) and 'Preventative use of antibiotics in
310 the dairy herd helps me meet production goals' (mean ranking score: 3.03). Whilst only 6%
311 agreed that antibiotic usage in dairy farming was a major cause of antibiotic resistance in
312 humans, 22% agreed that 'If every dairy farmer followed best practice, there would be less

313 resistance to antibiotics in the human population'. Nevertheless, 68% agreed that human
314 infections resistant to antibiotics were a serious problem (mean ranking score: 2.26).

315 Almost 60% of the respondents agreed with the two resource-use based statements - 'If all
316 dairy farmers followed best practice in the use of antibiotics, overall use of antibiotics would
317 fall' and 'Antibiotics are expensive and I minimise usage to reduce costs' - although, with the
318 second of these statements, 25% disagreed, implying that cost was not a factor in how they
319 used antibiotics. Finally, 55% seemed not to ask advice from their veterinarian before using
320 antibiotics on their cows, with just 17% doing so (mean ranking score: 3.42). This implies,
321 possibly, that farmers used antibiotics, from time to time, from those 'held back' from
322 previous prescriptions as a perceived way of saving money and such 'under-dosing' is an
323 important risk factor for antibiotic resistance.

324 To gauge respondents' current antibiotics use practice, they were presented with a set of 12
325 health problem scenarios that might occur in a dairy herd and asked how likely or unlikely
326 (on a 5 point scale) they would be to use antibiotics in the next year to treat them. This
327 allowed a more comprehensive review of practices, rather than one limited to recent
328 personal experience. Table 3 summarises respondents' answers. Farmers were more likely
329 to use antibiotics for some health conditions than others, with the most likely being: 'Clinical
330 mastitis with watery milk' (90% of the respondents); 'Calf pneumonia' (89%); and 'Clinical
331 mastitis clots' (83%). In contrast, the health problem scenarios that they were least likely to
332 use antibiotics for were: 'High cell count cows and cows with repeated cases of clinical
333 mastitis' (71%); 'digital dermatitis' (71%); and 'Lame cow before trimming' (67%).

334 **3.3 Attitudes towards use of antibiotics in their dairy herds**

335 Just over 70% of respondents agreed with the statement that 'Reducing the use of
336 antibiotics in my dairy herd over the next year would be a good thing to do' with only 6%
337 disagreeing with it. Around 58% agreed that 'People I respect in the industry would approve
338 of my reducing the use of antibiotics in my herd over the next year'.

339 Nearly 59% of respondents said they had the skills and knowledge needed to reduce
340 antibiotics use in their herds in future, whilst 39% were not sure. Almost 32% agreed that
341 'Reducing the use of antibiotics in my dairy herd over the next year would be difficult to
342 achieve' but 19% disagreed with this statement and the remaining 49% were not sure.

343 Table 4 shows why farmers thought it would be good to reduce antibiotic usage in their herd.
344 The most cited benefit was cost reduction (64% of respondents). Only 18% thought that milk
345 output would decline, and 15% thought it would decrease resistance in the human
346 population if farmers reduced their antimicrobial usage, but there was a high level of
347 uncertainty on the impact on the health of their cows (56% unsure). When asked whether
348 reductions in antibiotic usage would lead to loss of animal welfare, there was a fairly even
349 spread of responses with 27% agreeing, 37% disagreeing and 36% being unsure. There
350 was considerable uncertainty in relation to health, however, with 56% not sure and 20%
351 believing that health would be worse. There was also much uncertainty over whether
352 reducing antibiotic use would reduce the incidence of bacterial antibiotic resistance with 45%
353 uncertain and 18% believing that this benefit would not be delivered.

354 Farmers were asked to rank a list of business and management outcomes in terms of their
355 importance to assess a range of motivations and goals that underpin their business
356 decisions (Table 5). Dairy enterprise profitability, and animal health and welfare, were highly
357 important drivers of farmer decision-making, with cost minimisation close behind. In addition,
358 quite highly rated was concern that consumers remained confident in milk safety, as this
359 underpinned the marketability of milk and the price obtained. Relative to these concerns, the
360 issue of antibiotic resistance was viewed as of lesser importance, especially in connection
361 with such resistance in humans. This may be a reflection of the farmers' view of these being
362 issues over which they had little direct control.

363 **3.4 Sources of information used to inform disease control**

364 Farmers looked to a range of different people and organisations for advice on farming
365 matters including on the use of antibiotics in dairy herds. Respondents were, therefore,
366 asked the extent to which these social referents would approve of them reducing their use of
367 antibiotics over the next year. The results are summarised in Table 6.

368 Few farmers thought that any of their social referents would disapprove of them reducing
369 their use of antibiotics in the next year except for 14% of respondents who thought their
370 private veterinarian would. However, there was variation in the perceived level of approval.
371 Based on approval ratings, the social referents were divided into two groups. The higher
372 approval group was the end users, or consumers, of the milk produced (milk buyer and retail
373 consumer) whereas the lower approval group was the industry or peers (family, other
374 farmers and the NFU). Private veterinarians fell between these two groups.

375 The most influential source of information on antimicrobial use was farmers' own veterinarian
376 (Figure 1). Indeed, veterinary source scores were close to the theoretical upper maximum
377 possible for this measure. As all respondents scored this source highly, there was little
378 variation in appreciation of the source across sub-groups in the sample.

379 **3.5 Knowledge of guidelines on use of antibiotics**

380 Around 53% reported some level of awareness of the RUMA (2004) guidelines on use of
381 antimicrobials in cattle production, but half of these admitted to an incomplete knowledge.
382 For those aware of the guidelines, 36% followed the guidelines fully, 39% partially followed
383 them and 25% remembered the broad outline of the details only.

384 Those not aware of the RUMA (2004) guidelines were further questioned to determine the
385 extent to which they unwittingly followed the guidelines. This revealed that 89% agreed that
386 it is important to have written protocols for administering antibiotics to minimise mistakes,
387 even though 70% thought this was time-consuming and just 31% said they always consulted
388 their veterinarian if they had left-over antibiotics they wanted to use.

389 Some 80% of respondents always finished the prescribed course of antibiotics even if their
390 animals stopped showing signs of illness, while 14% modified the dosage either for
391 convenience or because the animals did not respond as expected. As many as 96% agreed
392 with the statement 'I always store medicine in the required conditions'. Around 97% agreed
393 with the statement 'It is important to keep treatment records'. Despite this, it should be
394 acknowledged that there might be a gap between what respondents said they will do and
395 what they actually do, the so-called social desirability bias (Crowne and Marlow, 1960).

396 Respondents were asked whether they were aware of concerns about inappropriate use of
397 third and fourth generation cephalosporins leading to increased antibiotic resistance in both
398 people and animals: 66% were aware. Level of awareness of the issues was not correlated
399 to attitudes to first use of cephalosporins in the treatment of a range of conditions, with
400 exception of 'a lame cow before hoof trimming'. In this case, there was a significant positive
401 correlation ($P \leq 0.0168$) suggesting that higher levels of awareness resulted in a lower
402 likelihood of cephalosporins use as a first choice for treatment. A follow-on question asked
403 whether they agreed or not that cephalosporins should not be used for preventative
404 treatments in healthy animals: 48% agreed, 32% were neutral and 20% disagreed.

405 **3.6 Intention to use antibiotics using the TPB framework**

406 Correlation of 'intention' measures revealed a strong positive linear relationship (Spearman's
407 $Rho = 0.477$, $P < 0.0001$) which suggested that combining them would add little, if any, new
408 information. For the purpose of this analysis therefore, the single measure of strength of
409 personal intent to reduce antibiotic usage was employed as the dependent variable.

410 Intention to reduce antibiotic usage was only very weakly correlated with a number of
411 variables capturing current antibiotic use practice as measured by monetary expenditure on
412 antibiotics (Pearson's $Rho = 0.186$, $p = 0.2994$), and recent changes in the frequency of
413 antibiotic use (Spearman's $Rho = 0.142$, $p = 0.2401$). These variables were, therefore,
414 excluded from further analysis of the drivers of intention to reduce usage of antibiotics.

415 Correlation analysis showed that, of the three composite measures, only the OA measure
416 had any significant relationship to intent. In light of this, the composite SN measure was
417 dropped and the single direct measure was substituted, as this variable was seen to be
418 correlated with intent. This SN measure was based on the following question, with elicited
419 responses ranked on a 5-point Likert scale:

420 'People I respect in the industry would approve of my reducing the use of antibiotics in my
421 herd over the next year.'

422 Figure 2 shows the correlations between the OA, SN (single question direct measure), and
423 perceived behavioural control measures with intention to reduce use of antibiotics. Because
424 intention is reflected using an ordinal scale, Spearman's Rho statistics (r_s) were generated to
425 help decide which variable to keep for further analysis. Both OA and SN were seen to be
426 positively and significantly correlated with intention, while perceived behavioural control was
427 not significantly correlated.

428 As shown in Figure 2, OA were positively correlated with SN, but uncorrelated with
429 perceived behavioural control (Table 8). As only the OA variable showed significant
430 correlation with intent, intent was correlated with individual OA questions only. A significant
431 positive correlation between an attitude question and intention indicated a cognitive driver
432 and a significant negative correlation indicated a cognitive barrier. Table 9 shows that just 4
433 of the 13 attitudinal questions (i.e. attitudes to perceived outcomes of reducing antibiotic use)
434 were significantly correlated with intent, with only three showing relatively strong
435 associations (i.e. r_s values of near 0.3 or greater) being:

- 436 i) 'Reduced use of antibiotics in my herd over the next year would be a good thing to do';
- 437 ii) 'Reduced use of antibiotics over the next year would lower my costs'; and
- 438 iii) 'Reduced use of antibiotics over the next year would increase consumer confidence in
439 the safety of milk and milk products'.

440 It is noteworthy that the questions correlating most strongly with intent were based on
441 outcomes specific to the issue of reduced use of antibiotics in the respondent's herd, rather
442 than issues related to the use of antibiotics in livestock production more generally. It should
443 be noted that the lower the mean ranking score attached to each question in Table 9, the
444 stronger respondents' agreement with the proposition contained in that question.

445 The regression model results used to predict intention to reduce antibiotics use are shown in
446 Table 10. It can be seen that while some individual OA measures were significantly
447 correlated with intent, the predictive power of the composite measure was only borderline
448 statistically significant and other variables were better predictors. The single directly
449 measured SN measure was the most significant predictor of intent to reduce antibiotic use.
450 The negatively signed estimate suggests that for every 1 unit decline in rank score on the
451 SN measure, there was a 1.44 decline in intention rank (where 1=strong agreement with
452 intention and 5=strong disagreement with intention). Because lower scores mean higher
453 intention and greater agreement, the signs must be reversed when interpreting the results
454 i.e. the opinions of respected peers were seen to be a strong positive driver of intent to
455 reduce antibiotic use.

456 A list of 31 socio-demographic variables were tested in the regression model, with three of
457 these proving to be significant predictors of intent: the proportion of farm income derived
458 from the dairy enterprise; the likelihood of still being in dairy production in five years; and the
459 importance of increased consumer confidence in the safety of milk and milk products. This
460 latter question captured a background business-related attitude i.e. the importance, to the
461 respondent, of increasing public confidence in milk safety in the coming year. In the context
462 of reduced use of antibiotics, respondents may have understood this statement in two ways.
463 First, that reducing antibiotics use might increase consumer confidence by reducing potential
464 antibiotic residues in milk. Second, that reduced use of antibiotics might decrease consumer
465 confidence as it could be associated with higher disease risks in dairy herds. Reversing the

466 sign on the MLE estimate for this variable (Table 10) showed that increased intent was
467 associated with a decrease in concern over consumer perceptions of milk safety.

468 **4. Discussion and conclusion**

469 This paper reports on how we used the well-established social psychology TPB to explore
470 the drivers and barriers that existed to intention to reduce antibiotic use among dairy farmers
471 in England and Wales. The analysis was based on 71 dairy farmers, around 0.75% of the
472 target population, a sample size considered large enough, relative to the size of the
473 population, to provide an acceptable confidence interval. On all but one of the measured
474 dimensions, the sample was very representative of the industry, providing confidence in the
475 generalizability of the survey results. The exception to this was herd size. While a random
476 sample draw was the objective, some well-understood self-selection bias towards larger
477 producers was inevitable and has occurred. However, this over-representation of larger
478 herds on the representativeness of the sample is lessened significantly by current re-
479 structuring trends in the UK dairy sector, with producer numbers falling heavily each year
480 and average herd sizes rising. The self-selection bias seen in the sample, therefore,
481 provided some measure of future-proofing for the survey results for two reasons. First,
482 because those with larger farms, who enjoy economies of scale, are more likely to remain in
483 farming than their smaller counterparts and, second, as time passes, the more
484 representative of farming the sample will become.

485 Animal health and welfare issues were of great importance to the survey dairy farmers,
486 ranking equal to the profitability of their dairy enterprise amongst their business goals. In
487 terms of treatments for animal health problems, farmers were prepared to purchase
488 antibiotics as necessary. Almost all the sample had a recent Herd Health Plan, although
489 these would only be useful in disease prevention if farmers actually used them.

490 There was some indication from the survey responses that use of antibiotics for clinical
491 mastitis and calf pneumonia had reached a limit as over 70% of the respondents thought

492 that reducing antibiotic use in their dairy herds would be a good thing to do. However, whilst
493 farmers were well aware of concerns about antibiotic resistance in cows and humans, their
494 primary motivation for wanting to reduce use of antibiotics was not to reduce the risk of
495 bacterial resistance but, rather, to save on medicine costs to their business.

496 Around 30% of respondents were not aware of concerns about the use of third and fourth
497 generation cephalosporins leading to increased antibiotic resistance in bacteria in both
498 people and animals. Whilst 90% of respondents believed they followed best practice, almost
499 50% were not aware of the RUMA guidelines on use of antimicrobials in cattle production;
500 most farmers reported applying good practices and 14% admitted modifying the advised
501 dosage. Just over 80% of respondents said they always finished the prescribed course of
502 antibiotics and almost all thought it was important to keep treatment records.

503 Most farmers (60%) believed that they already had the necessary skills to successfully
504 reduce their use of antibiotics. The most influential source farmers used to help them make
505 decisions on controlling and treating livestock disease was their own veterinarian. As almost
506 70% of respondents believed that their veterinarians would approve of them reducing future
507 antibiotic usage, this strongly suggests that there is a positive advisory environment to
508 achieving this goal. However, this should not be taken to mean that veterinarians, as the key
509 advisory source, were necessarily advising this course of action.

510 There was a clear suggestion that around half of all respondents had either recently reduced
511 their level of antibiotic usage, or were planning to do so. Whilst the reasons behind this were
512 not elicited directly, some assumptions can be made based on respondents' beliefs and
513 attitudes towards antibiotic usage. Whether such reduction was circumstantial or planned, is
514 not clear. Nevertheless, before accepting this statistic as final, some thought should be
515 given to the issue of the 'value action gap'. The Theory of Reasoned Action states that
516 behaviours are shaped by attitudes towards those behaviours, subject to social norms
517 (Fishbein and Ajzen, 1975). On this basis, attitudes towards reducing antibiotics and stated

518 intention use should be a good indicator of actual buying practice. However, numerous
519 researchers have identified a difference between the values derived from consumer attitudes
520 and behavioural intentions and actual behaviour (see, for example, Barr, 2004; Blake, 1999;
521 and Lane and Porter, 2007). To the extent that societal pressure exists to reduce antibiotic
522 use in livestock production, it is safe to assume that the effects of social desirability bias will
523 be experienced here and so the percentage of farmers who stated an intention to reduce
524 antibiotic use in the next 12 months should be treated as an upper estimate.

525 The relationship between personal attitudes and the perceived attitudes of peers need not
526 necessarily mean a causal relationship as positive attitudes towards the outcomes of
527 reducing antimicrobial use, if they are well attested, will be shared with peers. The lack of
528 significant correlation between own attitude, or attitudes of peers, and perceived behavioural
529 control implies that farmers' perception of whether they can achieve reduced antibiotic usage
530 are not completely influenced by their perceptions of the value of the outcome.

531 Statistical analysis showed that intention to reduce future antibiotic use was only very weakly
532 correlated with current and past antibiotic use practice, whilst the strongest driver appeared
533 to be respondents' belief that their social and advisory network would approve of them doing
534 this. Desire to reduce costs, where this would not impair the health and welfare of their
535 stock, was also found to be a strong driver. Wider societal concerns about inappropriate
536 antibiotics use appeared to resonate with the survey farmers in terms of public confidence in
537 the safety of the milk they produced i.e. in terms of risk to the viability of their business. This
538 outcome makes perfect sense if respondents assumed that consumers associate reduced
539 antibiotic use with increased disease risk and, therefore, decreased milk safety. It is also
540 reasonable, here, that respondents who were least motivated by consumer concerns over
541 milk safety would have fewer qualms about the effect that reduced antibiotic use would have
542 on consumer opinion. However, the way in which respondents interpreted this question
543 about consumer confidence in milk is unclear, because use of antibiotics might have been

544 seen as both creating a health risk (due to antibiotic residues in milk) and reducing health
545 risk (by reducing disease incidence in lactating cows). The value of this socio-economic
546 variable in explaining farmers' attitudes to reducing antibiotic use may be, therefore,
547 somewhat impaired. In this case, it might be appropriate to introduce a 'benchmark' figure so
548 that farmers can compare themselves with others. This business sustainability imperative is
549 also reflected in the socio-economic variables identified as best predictors of intention to
550 reduce the use of antibiotics over the next year i.e. the proportion of farm income from milk
551 production, and the stated likelihood of farmers remaining in such production. The higher the
552 scores on these variables, the greater was the likelihood of positive intention to reduce
553 antibiotic usage, suggesting that those with firm intent to remain in milk production wanted to
554 avoid 'problems' in the years ahead.

555 **5. Recommendations for policy**

556 It has been seen above that farmers most likely to reduce antibiotic use were those who
557 derived a higher than average share of farm income from the dairy enterprise and were
558 planning to continue operating a profitable dairy enterprise for the foreseeable future (i.e.
559 have no immediate retirement plans). They were aware of, and concerned about, both the
560 risk of misuse of antibiotics in causing antibiotic resistance in the dairy herd and also in the
561 human population as well as consumer concerns about antibiotic residues in milk. They held
562 the belief that, undertaken correctly, reductions in use of antibiotics could yield financial
563 benefits to them, primarily in the form of reduced costs, without affecting the animal welfare
564 of their dairy cows or their herds' milk output.

565 The strong correlation between farmer perception of the beliefs of social referents and intent
566 to reduce antibiotic use, strongly suggests that policy makers should target these advisory
567 groups and institutions with information on the means to achieving reductions in antibiotic
568 use. Amongst these dairy industry social referents, priority should be given to veterinarians
569 who were found to be, by far, the most influential bearing in mind that the majority of the

570 respondents (71%) met with their veterinarian monthly or more frequently. The information
571 that needs to be supplied to farmers would include: the role that sub-optimal use of
572 antibiotics has in causing antibiotic resistance; advice on best practice in antibiotic use i.e.
573 specific management actions or alternative treatments that would permit reductions in
574 antibiotic use without financial losses; data on cost savings that might be obtained from
575 reduced antibiotic use; and assurance that there are low risks to animal welfare from
576 reduced antibiotic use. Care will need to be taken as to how this information is provided to
577 dairy farmers as not all of them will be amenable to electronic communication. With the
578 absence of a publicly-funded advisory service, postal delivery of hard-copy brochures may
579 well be appropriate.

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584

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