Measuring pig farmers' practices concerning the use of antimicrobials: A case study of four European Countries

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Abstract

Pig farming has been identified as one of the sectors in which antibiotics use drives the development of antimicrobial resistance (AMR), hence resulting in increasing public concerns. However, to minimise AMR (specifically antibiotics resistance) pig farmers may need to embrace technological innovations and practices that are specifically targeted. This study investigates Strategies, Attitudes and Practices (SAP) of pig farmers towards biosecurity measures and potential technological measures that could lead to the reduction of antibiotics at the farm level. In this light, a survey, based on a randomly selected sample, with pig farmers (N=600) across four EU member states (Germany, Italy, Netherlands and Spain) was conducted in January 2021. Results show some statistically significant differences in the practices employed by farmers in reducing antibiotic use between countries. We also explored the practical feasibility of adopting some technological and innovations measures (e.g., environmental enriched provisions, real-time warning of individual behaviour, sound equipment and accelerometers) that could help pig farmers to minimise the usage of antibiotics. To achieve this, Principal Component Analysis and Binary Logistic regression to identify the factors influencing the adoption of the proposed technologies are employed. Results show that most of the farmers are more likely to adopt some measures/practices (e.g., environmental enriched provision such as deep straw) to reduce antibiotic use. The study also reveals some clear statistically significant differences across the countries. This is particularly useful in exploring the adoption of various practices and innovation strategies that would best suit each country in reducing antibiotics usage in pig farms across the entire EU.

Keywords:
AMR, antibiotics usage, pig farmers attitudes, technological innovations, Principal Component Analysis (PCA), binary logistic regression, EU

1. Introduction

The pig sector has been identified as one of the sectors in which the use of antimicrobials drives the development of antimicrobial resistance (Rushton et., 2014), thus resulting to some growing concerns in both human and animal populations (World Health organisations, 2014). Antimicrobials may become less effective due to the selection pressure exerted towards resistant bacteria, hence the most strategic way to fight against the risk of antimicrobial resistance is to reduce the use of antimicrobials especially in pig farming (Rushton et., 2014). The impact of reducing antimicrobial use differs by country and some noteworthy differences have been found among European countries concerning the reduction of antimicrobial use (European Surveillance of Veterinary Antimicrobial Consumption, 2013). Although it has been suggested that the differences in antimicrobial usage between countries are related to differences in the herd sizes in the pig farming sector in the different countries and also in the availability of certain types of antimicrobials in the different countries (De Briyne et al., 2014), it is important to investigate cross country differences regarding pig farmers' attitudes and practices towards antimicrobials in different countries.

In many European countries, the antibiotic usage is relatively high especially in pig farming (Grave et al., 2010). Thus, in order to keep antibiotics as effective as possible and as a great therapy option, it is important to reduce their usage in pig farming sector: the extensive use of antimicrobials is known to enhance the development of bacteria that are resistant to antibiotics and as such there is bound to be a growing problem in animal and health management (EFSA and ECDC, 2013). More so, lack of reducing antimicrobials especially in animal agriculture is known to promote the development of bacteria. Hence, a successful reduction of antibiotic use depends on whether farmers are willing to use alternative measures such as biosecurity and technological innovations to defend farms against the entrance of pathogens

Farmers' decision making and their practices regarding antibiotics can be determined by various factors such as external/physical factors (e.g., the number of pigs categories kept on their farm or the housing condition of the pigs) and by personal variables (e.g., farmer's age, gender etc.) (V.H.M. Visschers et al., 2014). Additionally, internal variables might also have an impact on farmers antibiotic usage and this may include, attitudes and practices of farmers towards antibiotics use as well as their attitudes towards biosecurity and potential technological innovations. In order to develop an effective intervention or technology that reduces the use of antibiotics among farmers, it is important to explore the details of the physical, internal and external variables related to antibiotic reduction. Several studies have investigated pig farmers attitudes and practices which includes the use of alternative measures such as biosecurity in order to prevent, treat and control diseases in their pigs (e.g., Fraser et al., 2010; Simon-Grifé et al., 2013). However, to the best of the authors' knowledge, no studies have been published on farmers attitudes and practices towards some proposed technological innovations as explored in this study.

A study which investigated the attitudes of pig farmers towards antimicrobials found that pig farmers were much less aware of the disadvantages attached to the use of antibiotics than veterinarians (20% versus 60% respectively) (Marvin et al., 2010). Very few studies have examined which variables are related to the usage of antibiotics in pig farmers (Visschers, V.H.M et al., 2014). More labour input defined by hours of labour per 100 kg slaughter weight was related to less antibiotic usage among Dutch pig farmers, whereas their higher age was associated with more antibiotic usage (Dolman et al., 2012). Thus, relatively little is known about pig farmers' attitudes towards the use of antibiotics and the possible technologies/interventions that can aid its reduction. As such, we wanted to investigate the relation between physical, external, internal characteristics and antibiotic usage.

2. Material and methods

2.1. Instrument and measurement

A short and effective structured questionnaire with closed ended questions was used to execute the objectives of the study. The questions consisted of some filter items, 5-point Likert scale statements, ranking questions and general descriptives. The filter questions are based on farmers' years of experience (farmers who have less than 1 year of experience are exempted from participating in the study), farmers involvement in decision making (is categorised as final decision maker or partly involved in decision making process while farmers not involved in decision making are excluded from the study), the number of pigs category kept on farm (one of the inclusion criteria is the presence of at least 150 Sows/Gilts and 1.000 pig fattening capacities) and farm types.

Regarding farm types, respondents were asked about their pig operations, hence farms with sows, piglets and finisher pigs are specified as farm types with closed/farrow-to-finish practices, farms with sows and piglets only are categorised as pure breeders while farms with finisher pigs are pure finisher farms. Farms belonging to other categories aside these three classifications are excluded from taking part in the survey. Thus, we settled for three main categories of farm types (farrow-to-finish, pure breeders and pure finishers). The filter questions help to ensure that the sample is representative in relation to the population of each country being investigated-Germany, Italy, Netherlands and Spain (hereafter GINS).

The first section comprised six items/questions regarding farmers' practices towards antibiotic use. GINS pig farmers were asked about the number of times (at least once a week/month/year/never) they use animal health products (antibiotics and antiparasitic) on the farm, they were also asked to provide information regarding the percentage of antibiotic treatments (Prophylaxis, Metaphylaxis and Therapeutic)[1] and its method of applications (feed, drinking water, injection) used for each category of pigs (Sows and gilts, Weaners and Finisher pigs). In addition, they were asked where they seek information from regarding the correct choice of antibiotics and the correct dosing (veterinarian, animal pharmacy, peers/other farmers, other advisers such as feed companies, attached product information, or online) and where they buy their animal health products from. Respondents were required to provide simple answers or choosing the appropriate answer from multiple choice responses.

The second section focussed on participants attitudes towards the use of antibiotics for pigs. A total of 11 items were presented in this section. Specifically, the items entailed the necessity of antibiotics as a tool in preventing, treating and controlling diseases in pigs. Questions relating to management practices in relation to reducing antibiotics to a minimum, improved animal welfare in increasing the resilience of pigs/reducing the use of antibiotics and a couple of others were

[1] Prophylaxis is a treatment used to prevent diseases in individual or a group of animals. Metaphylaxis on the other hand is a treatment of a whole animal group to stop the spreading of a disease while Therapeutic is a treatment of sick animals.

answered by the farmers under investigation. All the items in this section required 5-point Likert scale responses anchored by 1 (strongly disagree) to 5 (strongly agree) (Ary et al., 2012).

GINS farmers practices towards antibiotic use were evaluated in the third section. A total of five items similar to those presented in the previous section were explored in the section. For example, the nature of the items includes seeking advice from professionals, peer farmers or farmers organisation when pigs are sick as well as management practices that involves using antibiotics for all pigs in a pen or only in pigs showing disease. The last part of the question involves asking whether good husbandry practice is key to reduce the use of antibiotics use on pig farms. Respondents were required to give their responses on a 5-point Likert scale.

Section four of the survey instrument comprised 23 items/questions and it relates to participants attitudes towards biosecurity and potential technological innovations. The first five items were anchored on a 5-point Likert scale ranging from strongly disagree to strongly agree. These five items were used to explore farmers attitudes and practices towards antibiotic use and biosecurity whereas the last fourteen items, which assessed the usefulness/adoption of the proposed technological innovations in antimicrobials reduction, were assessed on a 5-point Likert scale anchored by 1 (not very useful) to 5 (very useful) and 1(not very likely) to 5 (very likely) respectively.

The remaining four items are used to rank the four strategies (starting with the most important) that helps in reducing the use of antibiotics. The four strategies include- Improving biosecurity on farms, improving resilience in pigs, early detection of diseases and targeting the use of antibiotics on individual pigs. All the questions are closed ended and used for the description of participants in a bid to gain a better understanding of GINS pig farmers. Thus, it is important to note that these questions were used to describe participating farmers and used as a tool to investigate farmers' practices and attitudes towards antibiotic use, biosecurity and potential technological innovations. The questions also explored farmers' interactions with significant others like advisors, colleagues, veterinarian, animal pharmacy etc. The demographics of the farmers in terms age, gender, their highest level of education adapted by each country investigated and an indication of the percentage of conventional and organic methods that applies on the farms were also documented in the demographics section.

2.2. Data collection

A cross-sectional study was conducted among 600 pig farmers located in Germany (n = 150), Italy (n=150), Netherlands (n = 150) and Spain (n = 150), referred to GINS in this study. Hence, the survey was distributed in geographically representative four EU countries. A purposeful quota sampling technique was used in order to obtain samples representing pig farmers in each of the four (GINS) countries surveyed.

The questionnaire included 50 items which encapsulates sections such as demographics, participants' practices and attitudes towards antibiotic use and participants' attitudes towards biosecurity and potential technological innovations. The questionnaire was drafted in English and translated to German, Italian, Dutch and Spanish. All questionnaires were distributed online through a social research agency, called Produkt & Markt between 15th March and 22nd April, 2021. Thus, these questionnaires were collected and cross-checked in order to proceed to the data analysis stage.

2.3. Data Analysis

Data collected in other languages aside English was translated back to English and then entered into SPSS. All statistical analyses were carried out using SPSS statistics version 22 (IBM Corp.). Descriptive analyses included frequencies and percentages for categorical variables and means and standard deviations (SD) for continuous variables. Thus, descriptive statistics were calculated for GINS farmers' demographic characteristics, strategies, attitudes and practices. However, Analysis of Variance (ANOVA) was used to compare farmers attitudes and practices between countries, and this was calculated for continuous variables whereas Chi-square test (using Phi and Cramer's V) was used for frequencies and categorical variables.

To test the reliability of the Likert scale questions for the section exploring participants attitudes towards the use of antibiotic in pigs, we checked for the internal consistency of the items identified in this section and items were considered to have satisfactory reliability if the Cronbach's alpha is greater than 0.6 (Field, 2013). A Categorical Principal Component Analysis (CATPCA) was conducted in order to break down the items into various components, explore the likert scale responses and identify the structure. The inter-related variables were then regrouped into components thereby presenting a loading that signifies the correlation between each original variable and the respective components (Linting and van der Kooij, 2012). To check whether the data is suitable for the use of CATPCA, we did several checks which include Kaiser-Meyer-Olkin Measure of Sampling Adequacy [(KMO; (Kaiser, 1960)], inspection of the correlation matrix and the anti-image matrix, Bartlett's test of sphericity and assessment of the determinant. To assess whether variables are correlated, we used the table of correlation matrix to check for multicollinearity and singularity in the data. Together with a scree plot (Catell, 1966), all factors with an Eigen value greater than one were retained, because the criteria for deciding how many factors to include in the analysis were based on the Kaiser criterion.

As a result, only items having a factor loading greater than 0.4 were retained. We assess the face validity of the factors by evaluating the items that had loaded onto each factor. Component loadings are correlations between the variables, thus in total there are 35 Likert statements treated as ordinal data of which 14 items were selected for CATPCA analysis. Scree plot analysis showed that a *3-dimension solution* was most suitable for analysing our data. Component loadings of 0.40 or higher were regarded as sufficient to calculate object scores for each dimension and were saved for further analysis (Speknijder et. al., 2015). Hence, a component loading greater than 0.40 was considered significant (Sadiq, et. al., 2018). Each component was then assigned a descriptive summary name and the association between component means and independent variables were assessed with the use of ANOVA. All statistical tests were two-tailed and were considered statistically significant if $p < 0.05$. We used this procedure to categorise the proposed technologies into components.

For the section exploring participants attitudes towards potential innovation, separate binary logistic regression was used to evaluate the effect of GINS pig farmers' demographic characteristics on the usefulness and adoption of potential technological innovations (CATPCA selected components) such as environmental enriched provision with deep straw bedding (yes=1/no=0; model 1), free range farrowing pens to ensure behavioural freedom of sows during pregnancy and farrowing (yes=1/no=0; model 2), real time warning signals of individual feeding behaviour and food consumption (yes=1/no=0; model 3), real time warning signals of individual drinking behaviour and water consumption (yes=1/no=0; model 4), accelerometers incorporated in ear tags to monitor specific pig behaviour (yes=1/no=0; model 5), pig sound equipment to monitor vocalisation and coughs (yes=1/no=0; model 6), automatic weighing system which measures individual pig weights (yes=1/no=0; model 7). Based on the items with Eigen value >0.4, the PCA selects the main components the 14 items (usefulness and adoption of technology). We then recoded the selected items into two binary variables where strongly agree and agree responses are coded as 1 and otherwise coded as 0 in order to be able to account for the likely factors that determines the usefulness and adoption of the technology among investigated farmers in the GINS countries.

To sum, comparisons between categories of farmers by country and farm types were performed with the appropriate tests and post hoc analyses for the different types of data (nominal, ordinal, continuous) were carried out. Principal component analysis was performed to reduce the attitudinal variables to a number of uncorrelated components (dimensions) that represent the data and could further be analysed to produce a picture of the actual differences in behaviours and attitudes between countries and of the practical feasibility of the proposed innovations. This is geared towards finding the differences in attitudes between (pig) farmers and possible explanatory variables (Linting and van der Kooij, 2012) across GINS. As the data in our study consisted of nominal, continuous, and ordinal variables, non linear analysis was chosen rather than a linear one to analyse the data. Categorical Principal Component Analysis (CATPCA) can manage possibly nonlinearly related variables with different types of measurement level and its particularly adapted to analysing Likert scale type of variables.

CATPCA converts categorical variables to quantitative variables using optimal quantification and reduces the dataset to a smaller number of dimensions (Linting and van der Kooij, 2012). So, while descriptive statistics provided a general overview of the responses, the CATPCA aggregated the attitudinal questions into meaningful components of perception. Hence it allows the general structures in respondents answers to be identified. Thus, the potential problem of multicollinearity between answers to related questions is reduced.

3. Results

3.1. Descriptive characteristics of the study population

Tables 1 and 2 summarises the respondents' demographic characteristics both in terms of continuous variables (means) and percentages (categorical variables) respectively. This shows the characteristics of the participants and their farm operations in each of the GINS understudied countries. Thus, to compare antimicrobial use for GINS farms, cross tabulation was used, and graphs were prepared to visualize the results.

Table 1: Demographic Description of the samples in each participating country

Countries	Number of farms	Age	YOE	Number of Pigs Mean	
GINS	n	Mean $_{(SD)}$	Mean $_{(SD)}$	Sows	Finishers
Germany	150	$50_{(11)\ a}$	$29_{(11)\ a}$	200_b	$2\ 008_b$
Italy	150	$53_{(9)\ b}$	$30_{(11)\ a}$	293_b	$2\ 606_b$
Netherlands	150	$53_{(8)\ a,b}$	$31_{(9)\ a}$	341_b	$2\ 924_b$
Spain	150	$51_{(8)\ a,b}$	$26_{(9)\ a,b}$	1949_a	$29\ 954_a$
Total	600	$52_{(10)}$	$29_{(10)}$	696	9 373

Notes: SD stands for standard deviation around mean. Values within a column having different letters (a and b) differ significantly at $P < 0.05$. *YOE* signify year of experience.

In total, 600 farmers participated in the survey, 552 males and 48 females. Netherlands and Spain have the highest number of male pig farmers while the number of female pig farmers or managers appeared higher in the German sample than in the other three countries. Overall, the pig industry represented in the GINS countries are dominated by males. Thus, the table shows that the subsamples of the four countries differed in their gender distributions. The mean age of the participants differed significantly between countries especially between German and Italian pig farmers. The mean age was 52 years (SD = 10) and they had on average 29 years of experience in pig farming (SD =10). Spanish farmers had significantly the lowest years of experience compared to other farmers in the sample. Moreover, the herd sizes based on the number of sows of the participating farms differed between countries, but Spanish farmers had significantly more sows and finisher pigs than German, Italian and Dutch farmers. The average number of pigs in Spanish sample appeared to have larger herds than the average number of pigs per farm in the respective countries.

Table 2: Characteristics of participants by GINS countries, farm types, educational levels and whether they are conventional or organic.

GINS	Gender (%)		Educational levels (%)					Farm types (%)		
Countries	Male	Female	Pq	TePD	TeUD	USE	SEL	SPFpigs	SPonly	FPonly
Germany	82	18	0	0	47	33	19	23	13	65
Italy	92	8	23	1	22	24	30	23	17	60
Netherlands	97	3	0	2	13	12	73	13	31	56

Spain	97	3	31	0	18	0	51	35	23	41

Notes: Educational levels- Pq = Professional Qualification, TePD = Tertiary education- postgraduate degree or diploma, TeUD = Tertiary Education undergraduate degree or diploma, USE = Upper Secondary Education, SEL = Secondary Education or less- GSCEs equivalent. All the categorical variables Farm types- SPFpigs = An operation with sows, piglets and fattening pigs (closed system/farrow-to-finish), SPonly = An operation with sows and piglets only (pure breeder), FPonly = An operation with fattening pigs only (pure fattener).

Most of the Dutch, Italian and Spanish farmers are GSCEs[2] or equivalent holders while most of the German respondents held a bachelor's degree. A large number of the participants across the countries understudied raised finisher pigs only, which is an operation with pure finishers as their main type of production. The majority of the respondents (almost 93%) indicated that they are mostly conventional farmers, this means that only 7% of the respondents had some experience in organic agriculture.

3.2. Explored **Strategies** targeted to the reduction of antibiotic use

Respondents were presented with four major strategies that are said to help in reducing the use of antibiotics and asked to rank the four items starting with the most important items. The strategies include improving biosecurity on the farm (Strategy 1), improving resilience in pigs (Strategy 2), early detection of diseases (strategy 3) and targeting the use of antibiotics on individual pigs (Strategy 4). GINS farmers ranked the four major strategies related to antibiotic reduction significantly differently. Considering the strategies highly ranked (given the first rank) as shown in Figure 1, Improving resilience in pigs was given the highest first rank by 36% of respondents in Germany and 53% in Netherlands while Improving biosecurity on your farm was highly ranked by 38% of respondents in Italy and 36% in Spain.

[2] GSCE = General Certificate of Secondary Education

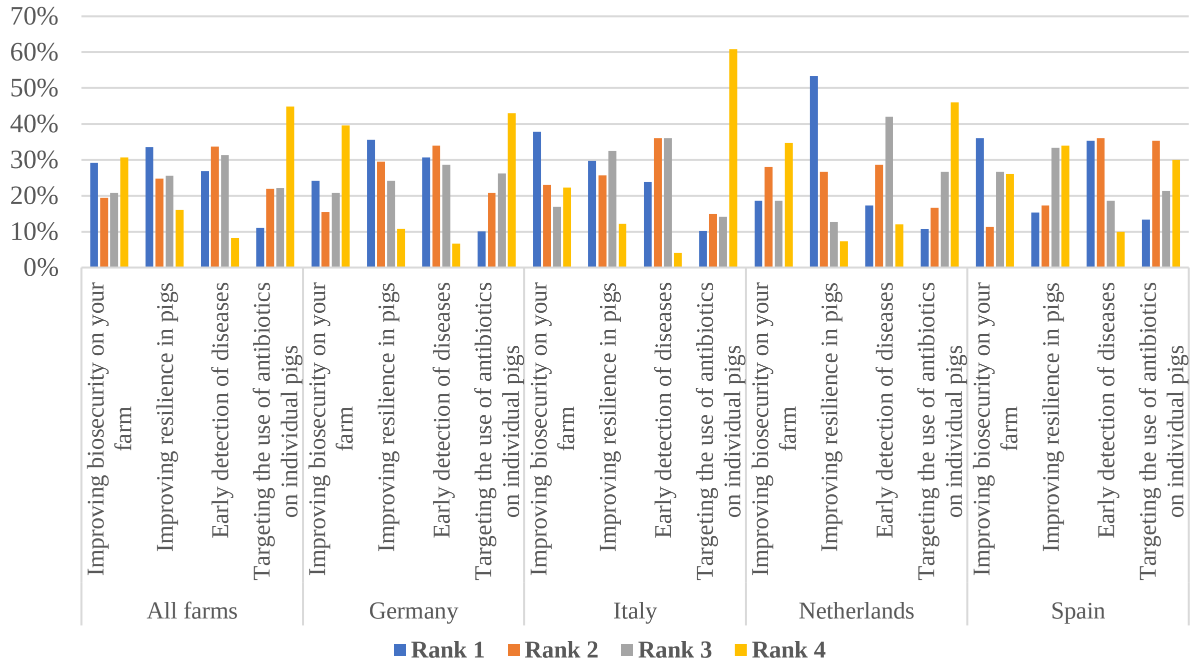

Figure 1: Participants (percentages) strategies towards antibiotic use for pigs (All farms n=600; GINS n=150)

Early detection of diseases was ranked second by 34% of respondents in Germany, ranked both second and third by 36% of the respondents in Italy (that is, 36% ranked it second and 36% ranked it third), ranked third in Netherlands by 42% and ranked third by 19% of respondents in Spain. Lastly, targeting the use of antibiotics on individual pigs was ranked fourth by 43% of farmers in Germany, 61% in Italy, 46% in Netherlands, and ranked second by 35% of the respondents in Spain. All the p-values shows that there are significant differences in the strategies used between countries since the p-values are greater than the chosen significant levels ($\alpha = 0.05$). Hence, we conclude that there is enough evidence to suggest an association between GINS countries and ranked strategies. The impact of the ranked strategies differs significantly among the four countries. Strategy 1, $X^2(9) = 39$, $p < .05$, Strategy 2, $X^2(9) = 95$, $p < .05$, Strategy 3, $X^2(9) = 33$, $p < .05$, Strategy 4, $X^2(9) = 41$, $p < .05$.

Probably the lower ranks attributed to “improving biosecurity” in Germany and the Netherlands and the higher ranking this strategy receives in Italy and Spain is due to the fact that German and Dutch pig farmers already have done a lot of investments in biosecurity with respect to the Italian and Spanish farmers. Overall, improving resilience in pigs was highly rated by all the participants in the GINS countries while early detection of diseases was the least preferred strategy.

3.3. Explored **Attitudes** towards Antibiotic use in pigs’ production

The response of farmers on items regarding attitude towards antimicrobial use and biosecurity are shown in Tables 3a and b. These explore the attitudes of GINS farmers and farm types towards the use of antibiotics in pigs’ production.

Table 3a: Farmers responses to items regarding their attitudes towards Antibiotic use and Biosecurity (n = 150 x 4 = 600) – By Country

Items	Countries (Percentage of respondents)			
	Germany	Italy	Netherlands	Spain
Part A. Attitudes towards Antibiotic Use				
Antibiotics are a necessary tool to:				
- prevent diseases in pigs	9	25	22	29
- treat diseases in pigs	94	87	89	95
- control diseases in pigs	50	56	49	81
I aim to reduce antibiotic use to a minimum.	96	79	95	93
Improved animal welfare increases the resilience of pigs.	49	87	65	69
Improved animal welfare leads to a reduction in the use of Antibiotics.	47	59	55	73
Antibiotics should be used whenever a pig stops eating and/or stops drinking.	18	35	29	17
When an animal is sick, I prefer to immediately apply antibiotics to prevent further exacerbation of the disease.	49	59	71	61
Reducing antibiotics use to a zero level could compromise the health and welfare of pigs.	74	49	75	79
Reducing antibiotics use to a zero level could compromise the productivity of animals.	63	39	58	73
The pig industry should not completely eliminate all use of antibiotics.	89	40	84	85
Part B: Attitudes towards Biosecurity				
I consider biosecurity to be vital to a healthy herd.	82	88	68	95
Systematic assessment of the biosecurity risks on my farm is vital to keep disease out of a pig unit	69	79	66	91
There is room for improving biosecurity level on my farm	44	63	57	67
Professional advice from vets on biosecurity helps to improve herd health.	85	80	75	93
Professional advice from farm advisers on biosecurity help to improve herd health.	65	82	61	88

Note: Results are presented in the table for 'strongly agree' and 'agree' responses between GINS countries

The table shows that more than half of the farmer's indicated that Antibiotics are a necessary tool to treat and control diseases in pigs. In contrast, the percentage of respondents across GINS who believed that Antibiotic were used to prevent diseases in pigs were lower compared to those who believed that antibiotics were used in treating or controlling diseases, infact the percentage of respondents who believed in using antibiotics for treatment were much higher than those who believed it is a necessary tool for controlling diseases in pigs. When asked if the GINS farmers aim to reduce antibiotic use to a minimum, they all responded in affirmation, and this is corroborated by their responses when asked if Antibiotics should be used whenever a pig stops eating and/or stops drinking. Just a lower percentage of them agrees to administer antibiotics to pigs when they stop eating or drinking. More than half of the respondents (except Germany with the lowest percentages i.e., 49 and 47% respectively) agrees that improved animal welfare increases the resilience of pigs thereby reducing the use of Antibiotics.

In addition, more than half of the respondents from each country except Germany, mentioned that they prefer to apply antibiotics immediately when an animal is sick. With the exception of Italy, most respondents from each country believes that reducing antibiotic use to a minimum could compromise the productivity of animals. Most of them except Italy, also opined that the pig industry should not completely eliminate the use of antibiotics. All the questions regarding GINS farmers' attitudes to biosecurity received high responses from respondents with most of the participants expressing their interests to support biosecurity measures on their farm. More than half of the respondents except Germany (44%) agrees to the fact that there is room for improving biosecurity levels on their farm.

3.4. Explored **Practices** towards Antibiotic use in pigs' production

This section presents the practices of farmers based on their methods of applications and how often they use antibiotics on their farms. In addition, the usefulness and the likely adoption of the proposed technologies are also presented in this section. The latter will explore the factors which determine the likely adoption and usefulness of the proposed technologies by using Categorical Principal Component Analysis (CAPCA) and binary logistics regression analysis (and see section 2.3).

The first part of the section exploring farmers methods of application investigated how often the participants use animal health products (in percentages) with a further exploration of the percentages of antibiotics accounting for methods of application such as feed, drinking water, injections and other applications. Figure 2 below shows the percentages of GINS farms stating how often they use animal health products such as Antiparasitic and Antibiotics and the results shows that 82% farms in the Netherlands reported using antibiotics at least once a week whereas around 75% of farms in Spain were reported to use antibiotics at least once a month. Less than 45% of farms in Germany were reported to use Antiparasitic and Antibiotics at least once a year. Around 25% in Germany indicated that they use Antibiotics at least once a week while it is around 18% for Italian farmers who indicated the same.

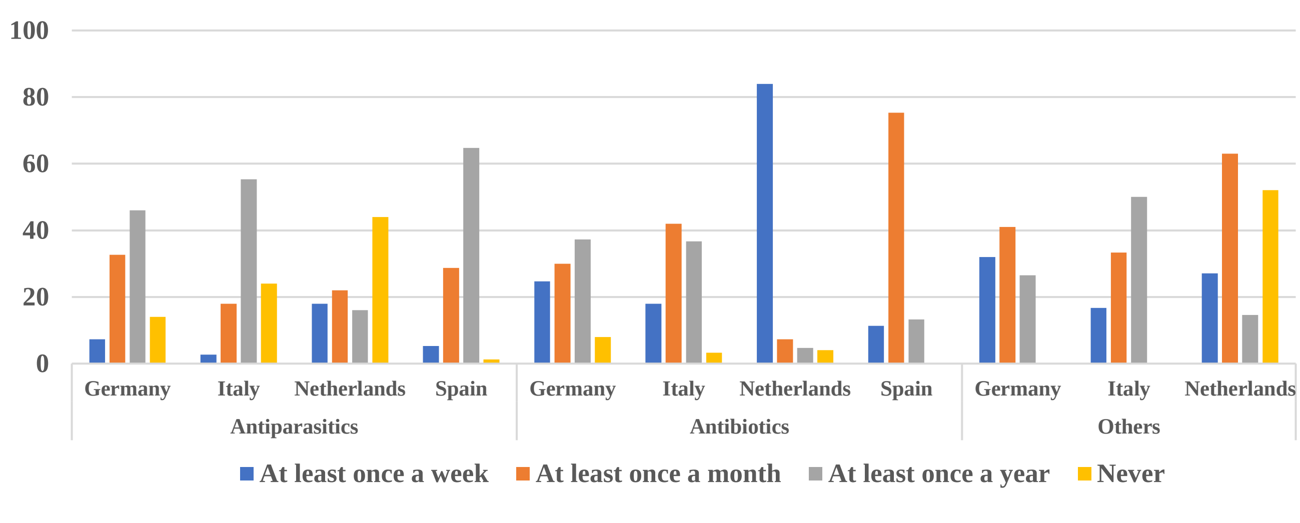

Figure 2: Percentage of farmers responding to how often they use animal health products

When asked about the percentage of antibiotic treatment by method of application (Figure 3), most of the respondents across all farm types within the countries investigated responded that they apply therapeutic treatment which is a kind of treatment targeted to sick animals. Considering the farms using Prophylaxis treatment, 16% Italian of farms indicated they apply prophylaxis treatment as a preventive measure in individual pure breeders (weaners) or a group of animals from contracting diseases. In all four countries the weaners are subjected to some extent to prophylaxis or metaphylaxis, with the highest percentages for these two practices found in Italy followed by Germany. In the Netherlands prophylaxis and metaphylaxis are less used.

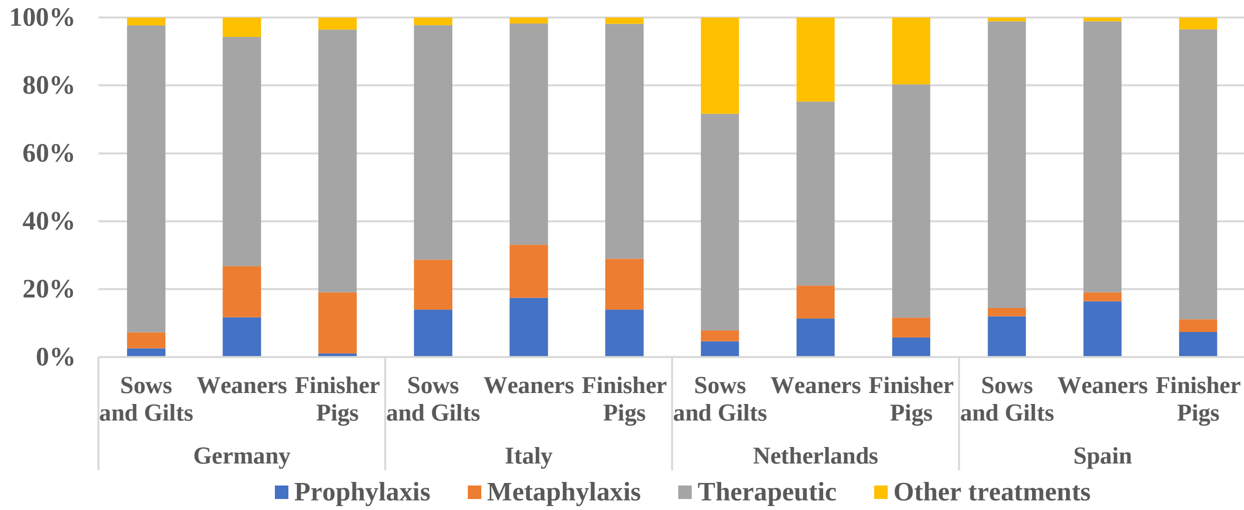

Figure 3: Percentage of antibiotic treatment by method of application and by (GINS) Country

Farmers were also asked about the percentage of antibiotics accounting for each method of application by Country and farm types. Most of the respondent in all the countries investigated except Italy indicated that they apply by Injection, thus reporting similar practices while most of the Italian farmers noted mostly feed and Drinking water as their main methods of applying antibiotics. 38% of Germans pure breeder farms indicated they apply antibiotics through feed on weaners (as seen in Figure 4).

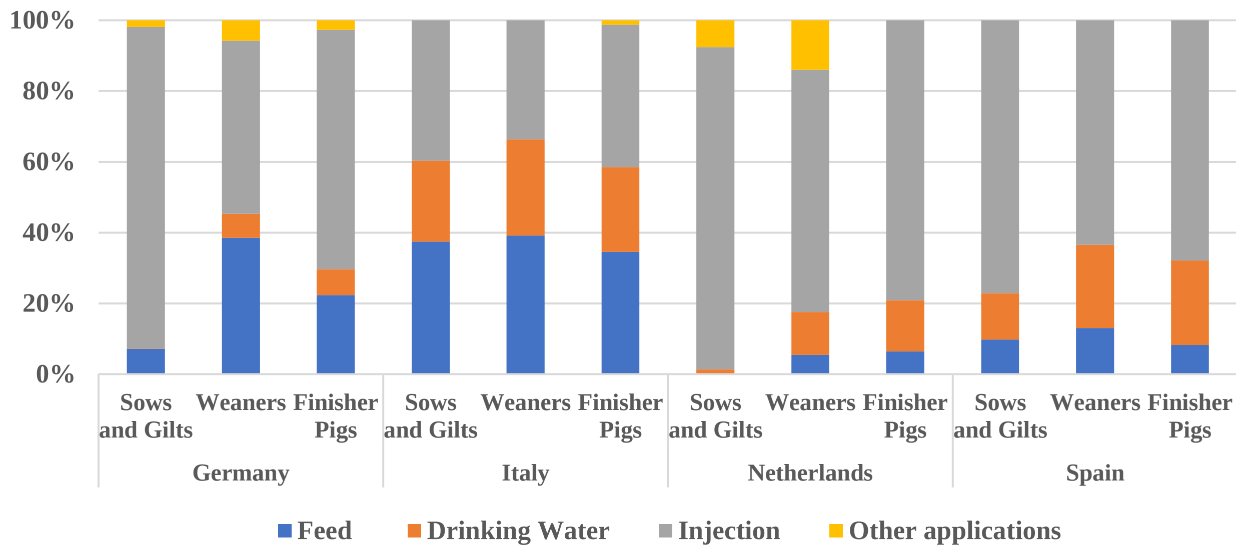

Figure 4: Percentage of antibiotic treatment accounting for each method of application by Country

Table 4 explores participants self-reported practices towards antibiotic use for their pigs. There was a trend towards Italian farmers being less likely to purchase antibiotics from a veterinarian than from an Animal pharmacy (38% vet and 68% animal pharmacy; $p < 0.001$) whereas most of them would prefer to seek advice from veterinarian when their pigs are sick than from an Animal pharmacy (95% versus 4%, $p = 0.002$). In contrast, all German, Dutch and Spanish pig farmers would likely buy Antibiotics from a veterinarian than buying it from other providers. This corroborates their actions or practices in terms of seeking advice from veterinarians when their pigs are sick.

Table 4: Participants self-reported practices towards antibiotic use (percentages)

Self-reported practices	Germany	Italy	Netherlands	Spain	P-value
When my pigs are sick, I seek advice from*					< 0.05
A veterinarian	100	95	97	99	
An animal pharmacy	0	4	0	1	
Attached product information (e.g., leaflets)	6	10	7	2	
Peers/other farmers	0	3	0	7	
On line	3	0	1	3	
I do not seek advice	8	0	1	0	
I decide how much antibiotics I use per treatment by					< 0.05
Following recommendation on dosing completely	82	99	86	99	
Applying a lower dose than recommended	13	1	6	1	
Applying a higher dose than recommended	5	0	8	0	
I buy antibiotics from*					< 0.05
A veterinarian	100	38	100	97	
An animal pharmacy	2	68	0	0	
Other providers	0	2	0	5	

*Participants could select multiple responses for these questions. P-values are computed for Pearson Chi-square statistic between farm types and comparison is within rows and $p < 0.05$ is significantly different. In Germany, 138 responded to these questions, 145 in Italy, 144 in Netherlands and 150 in Spain. In total 577 farmers responded.

When asked about how farmers decide the amount of antibiotics they use per treatment, almost all Italian and Spanish pig farmers reported that they follow recommendations on dosing strictly and completely leaving them with no farms that applies a lower or higher dose. On the contrary, 13 % of German pig farmers and 6% of Dutch farmers reported that they apply antibiotic at a lower dose than recommended while 5% and 8% of these two categories of farmers were reported to apply a higher dose of antibiotics than recommended. Thus, a further investigation is made on these categories of farmers to explore whether they will find some proposed set of technologies useful in reducing the use of antibiotics.

3.5. Categorical Principal Component Analysis of GINS farmers' responses

Seven types of proposed technologies are shown in Figure 5 and participants are asked to rate the usefulness of these technologies. These seven proposed technologies are classified into two major categories in order to indicate whether the technologies will be useful in early detection of diseases or whether they will be useful in increasing resilience in pigs. Out of the seven proposed technologies, 35 % (very useful plus slightly useful responses) of the respondents agreed that they will find an automatic weighing system as well as pig sound equipment very useful in measuring individual pig weights and monitoring vocalisation and coughs respectively. Nevertheless, only 23% of them indicated they will likely adopt the use of such technology.

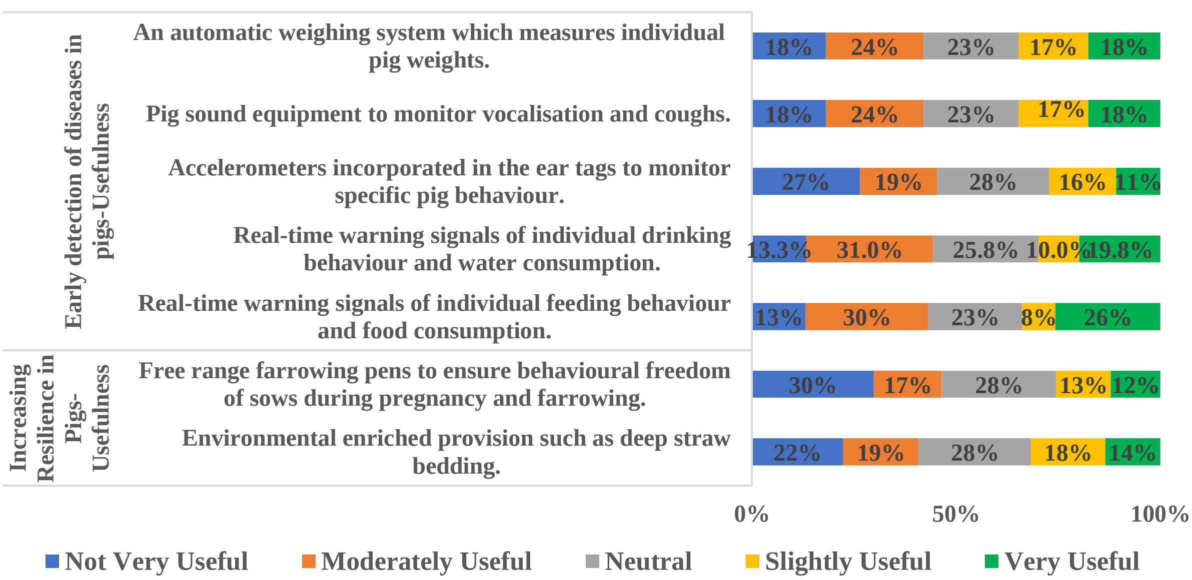

Figure 5: Distribution of responses based on the usefulness of the proposed technologies to address antimicrobial use (all GINS farms).

On the other hand, most of the respondents (47%) reported that they do not find free range farrowing pens as a useful technology (Figure 5) and may not be keen to likely adopt it (Figure 6). This may infer that the GINS farmers would prefer a technology that detects diseases early to the one that is geared towards increasing resilience in pigs. Surprisingly, most of the respondents are very unlikely to adopt the proposed technologies.

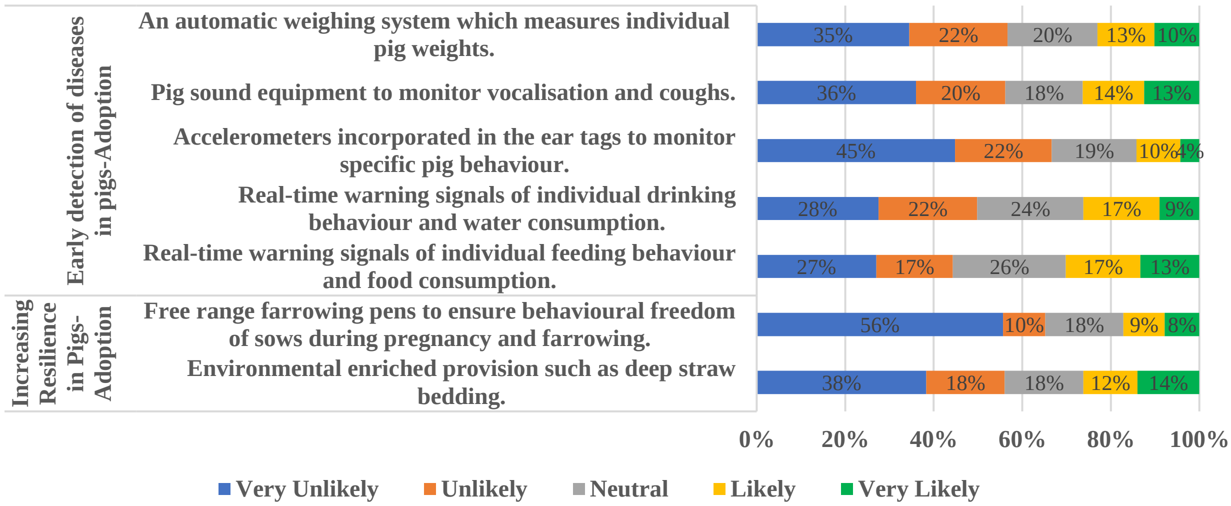

Figure 6: Distribution of responses based on the adoption of the proposed technologies to address antimicrobial use (all GINS farms).

We checked for the Cronbach's alpha of all the items used to explore the technological usefulness and adoption and we found that the Cronbach's alpha is 0.84, hence indicating a high measurement of internal consistency and reliability of the scales and items used in this analysis. To determine how many constructs to be measured by the scale, we explore the answers to the seven questions (separately for usefulness and adoption) in combination with the details from the CATPCA and this tends to provide an input that could be used to explore the concerns that farmers associate with the use of antibiotics. Thus, the loadings of the Likert type scale variables onto components are presented in Table 5. Forty-Six percent of the variations explained by the CATPCA (as seen in the usefulness of the technology) was the first component extracted. Out of the 5 technologies categorised as early detection of diseases, only 3 items load on to the first component because only the components with loadings greater than 0.4 were retained. The three retained items are Real-time warning signals of individual drinking behaviour and water consumption, Real-time warning signals of individual feeding behaviour and food consumption and lastly accelerometers incorporated in the ear tags to monitor specific behaviour. The second component explained twenty-three percent of the variation and the variables included free range farrowing pens and environmental enriched provision. Thus, the technologies supporting increasing resilience in pigs loads on to the second component.

The table below presents the rotated component matrix which shows the loading between individual variables regarding measures or technologies that addresses antimicrobial use and the components extracted by CATPCA analysis. Thus, the PCA with varimax rotation was conducted to assess how the seven (technologies) clustered. Table 5 displays the items and component loadings less than .40 was omitted to improve clarity. Results show that real time warning signals and accelerometer form a coherent component and should not be aggregated with other measures relating to free range farrowing pens and deep straws.

Table 5: CATPCA analysis- usefulness and adoption of proposed technologies

Items	Component loading (Usefulness)		Component loading (Adoption)	
	1	2	1	2
Real-time warning signals of individual drinking and water consumption	.890		.888	
Real-time warning signals of individual feeding behaviour and food consumption	.876		.866	
Accelerometers incorporated in the ear tags to monitor specific pig behaviour	.569			
Free range farrowing pens to ensure behavioural freedom of sows during pregnancy and farrowing		.878		.766
Environmental enriched provision such as deep straw bedding		.814		.827*
Pig sound equipment to monitor vocalisation and coughs				.609
Eigenvalues	2.28	1.14	2.26	1.03
% of variance	45.51	22.72	45.19	20.56

Note. Loadings <0.4 are not displayed. *Loads first in the second component.

On the other hand, the component loading of the adoption of the proposed technology loads two items on the first component and three on the second components. 45% of the variation was extracted by the first component and 21% for the second which has 3 items. The three retained items are Deep straw bedding, farrowing pens and pig sound equipment while real time warning signals of drinking and water consumption and that of feeding behaviour and food consumption loads on to the first component. Table 5 therefore shows the most pronounced characteristics of the two components for usefulness and adoption of the proposed technologies. The first component captures the relation between using real time warning signals as the most preferred technology and accelerometers to measure pigs' behaviour.

The technologies/practices that farmers found useful and would like to adopt are real time warning signals of individual drinking/feeding and water/food consumption, free range farrowing pens and deep straw bedding. This leaves us with the possibility to explore two technologies from early detection of diseases as well as two technologies indicating increasing resilience in pigs. We therefore investigated these four measures using a Binary logistic regression.

3.6. Factors predicting the usefulness and adoption of the proposed measures

Last, we wanted to explore which factors could predict the acceptance and adoption of the four technologies (see Table) from CATPCA. Thus, to assess the characteristics of the four main technologies, a binary logistic regression was applied to investigate their association with the independent variables thereby exploring the factors associated with the proposed measures in reducing antibiotics use. Since these technologies were measured on a 5point Likert scale, we converted it to a binary variable which are adopt and not adopt. Where only very likely and likely are categorised as adopt while others are assigned a 'not adopt' variable.

Table 6: Participant's selection of Not Adopt (NA) versus Adopt of the selected technologies (%)

GINS Countries	Warning SignalsW		Warning SignalsF		Free Range		Deep Straw	
	NA	Adopt	NA	Adopt	NA	Adopt	NA	Adopt
Germany	77	23	70	30	83	17	59	43
Italy	61	39	50	50	57	43	63	37
Netherlands	71	29	75	25	95	5	83	17
Spain	86	14	85	15	97	3	91	9
All	74	26	70	30	83	17	74	26

Farmers in Germany will most likely find Free range farrowing pens and Deep straw bedding useful (and adopt) than their other counterparts while Italian farmers will likely adopt all four technologies due to the interest indicated by the farmers in this country to adopt the technologies. Overall, 30% of all GINS farmers indicated a preference for Warning SignalsF and there are significant differences as regards farmers usefulness and adoption of the four technologies between countries. In addition, we found a strong correlation between usefulness and adoption of all the identified technologies.

This is further explored using a binary logistics regression with adopt and not adopt as the dependent variable.

4. Discussion

This study investigated GINS pig farmers Strategies, Attitudes and Practices (SAP) of the usefulness and adoption of some proposed technologies that aids the reduction of Antimicrobial Use. Our sample was representative of the pig farmer populations in the investigated countries and our result revealed three key findings. Firstly, we found out that there are differences between farmers from different countries regarding the Strategies they use, their Attitudes and Practices towards the use of antibiotics. Secondly, we found that Deep Straw bedding systems able to increase pig resilience is the most embraced technology among the countries investigated to reduce antimicrobial use. Third, we found that veterinarians may be the most appropriate channel to inform pig farmers about antimicrobials use as the farmers reported being satisfied with the advice from Veterinarians. Other studies also showed that veterinarians are preferred source of information regarding pig farming (Garforth et., 2013, Xiaocheng et al., 2013).

The direction of this study is in three folds. Firstly, we explore farmers Strategies used in antimicrobial usage. Secondly, we examined pig farmers' attitudes towards antibiotic reduction and biosecurity, Thirdly, we investigate the main factors (demographics, farm characteristics and items of SAP) influencing farmers usefulness and adoption of technologies in different GINS countries.

4.1. GINS farmers strategies and attitudes towards Antimicrobial use

To the best of our knowledge, our study was the first to investigate, in detail, pig farmers' strategies of antibiotic reduction as well as attitudes and practices related to antibiotic usage. The results show that out of all the first ranked strategies, improving resilience in pigs and improving biosecurity are the first highly ranked strategies within the understudied countries. These were ranked over early detection of diseases and targeting the use of antibiotics on individual pigs.

A quarter of the respondents believes that it is important to use antibiotics whenever a pig stops eating and or drinking. However, our binary logistic regression results show that farmers with this strong believe would likely adopt Free range as a method to reduce Antibiotics Use. More than half of the respondents indicated that professional advice from veterinarians would be helpful in improving the herds health. The role of veterinarians is very important in advising pig farmers as regards the need or ways to reduce the need for antibiotics such as internal and external biosecurity, improved management and improved feeding routines and strategies (Eltayb et al., 2012; Visschers et al., 2014).

4.2. GINS farmers practices towards Antimicrobial use

Seven technologies were proposed in this study and participants were asked to rate the usefulness and adoption of the technologies. Thus, in a first step, CATPCA was used to categorise the technologies into two components, 46% of the variations explained by the CATPCA while the second component explains 23% of the variation. Two items were finally retained for the first component and another two items for the second components. The technologies that farmers would like to adopt are real time warning signals of individual drinking behaviour and water consumption as well as real time warning signals of individual feeding behaviour and food consumption. These are categorised under early detection of diseases and increasing resilience in pigs respectively.

In a second step, the factors that predict the acceptance and adoption of the technologies were further investigated using a binary logistic regression. In terms of physical characteristics, the result shows that younger farmers would very likely adopt the Warning SignalsW and Warning SignalsF technologies than older farmers. In addition, the farmers years of experience would have a significant impact especially for farmers who are most likely to adopt free range technology. Lastly, the findings in table 7 (provided in a full version of the paper) demonstrated a high adoption of deep straw practices and this was found to be significantly higher in Germany, Italy, Netherlands than in Spain. Farms operating a sow, piglet and fattening pigs being very likely to adopt the technology than finishing farms only. The study also shows the impact of veterinarian in reducing Antibiotic Use and which is seen in the mirror of accepting deep straw able to pig resilience as a technology. Our results therefore show that in the four countries, pig farmers differ in their Strategies, Attitudes and Practices in reducing Antimicrobial Use.

5. Conclusion

Our study was the first to examine pig farmers' SAP regarding antibiotics and the proposed technology interventions to reduce antibiotic usage. We were able to investigate some important characteristics that play a role in pig farmers antibiotic usage. The results indicated that improving resilience in pigs and improving biosecurity are the most preferred strategies indicated by the respondents in our sample. The results show that there is a high possibility to adopt Free Range by the countries under investigation. Lastly, the interaction between farmers and veterinarian is investigated in this study and we concluded that the role of veterinarians in reducing Antibiotics is crucial. Participants in our study showed high level of confidence in veterinarians and this suggests that veterinarians play an essential role in educating farmers on using antibiotics more responsibly.

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