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**My health or my livestock health? Understanding variation in farmers’ antibiotic treatment preferences in northern Tanzania**

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**Abstract**

**Background:** Tackling antibiotic resistance (ABR) requires an understanding of treatment seeking choice behaviours at the interface between human and livestock health especially among subsistence farming communities of low-and-middle-income countries (LMICs). Our study (i) quantifies and compares trade-offs between different treatment attributes of urinary tract infections in human and contagious bovine pleuropneumonia (CBPP) in cattle, as exemplars, and (ii) disentangles the variation in treatment preferences based on farmers’ attitudes towards antibiotic use and bacteria sources, and socioeconomic factors.

**Methods:** Using a digital face-to-face survey inclusive of a discrete choice experiment (DCE), we collected data on antimicrobial treatment choices for humans and livestock from 404 respondents across three livestock production systems in three districts of northern Tanzania. We analysed the data using a hybrid discrete choice model.

**Findings:** Willingness to pay (WTP) for a visit to a doctor was higher than that for consulting a vet, although WTP for human self-treatment was still high. Respondents were more willing to pay for antibiotics to treat UTI than CBPP in their cattle. We identify unique group of farmers based on their socioeconomic factors after linking latent variables with antibiotic treatment preferences. More specifically, female farmers who had not received formal training, had lower income and were unaware of ABR had a lower WTP to consult a doctor and were more likely to self-treat.

**Interpretation:** Human and livestock antibiotic use and treatment seeking behaviours are linked.High propensity to self-treat, especially to tackle human conditions, poses ABR risks. These findings are useful to prioritise limited health resources, for example by targeting specific groups such as women.

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**Keywords:** antimicrobial resistance, attitudes, antibiotics, trade-offs, treatment attributes, behaviour, hybrid discrete choice model

1. **Introduction**

Low-and-middle-income countries (LMICs) face the highest share (84%) of the global disease burden 8,55. They also have poor healthcare infrastructure and access to professional advice 33, 13 meaning individuals are often faced with difficult choices when tackling infections. Some of the poor choices that households make for themselves, and their herds include self-treatment, for example, using antimicrobials without professional advice, a practice that can result in the development and spread of antimicrobial resistance (AMR) 53,54. AMR in human and livestock populations threaten global public health and agricultural economies 48, 27. As a result, in the fifteenth World Health Assembly, a global call was made urging individual governments to develop national action plans to reduce the prolonged effects of AMR that is likely to diminish the therapeutic choices of antibiotics available for use in humans and livestock 43.

In response to this call, Tanzania as an example of a LMIC setting developed a national action plan for AMR upon which this study is premised. Situational analysis of AMR in Tanzania shows high antibiotic resistance in both humans and livestock 43. For instance, a 90% resistance of *Escherichia coli* to Ampicillin and 30-50% resistance to other commonly used antibiotics has been reported in the country 43. Additionally, antibiotics for both humans and livestock are easily accessible due to weak policies which have made it hard to regulate their use. This is exacerbated by profit-driven drug dispensers who promote uncontrolled use and access among communities without a prescription 43. Evidence seeking to identify antimicrobial use practices that could inform human and livestock health policies is generally limited 65. In particular, economic assessments of antibiotic choice patterns and the value individuals place on treatment attributes related to infectious diseases in humans and livestock are lacking65. Therefore, the rationale behind this study is to quantify antimicrobial use behaviours in human and livestock and determine whether knowledge and awareness of AMR, and attitudes and socioeconomic factors explain them. We use this analysis to define socioeconomic profiles that help identify vulnerable groups towards whom health resources, communication and awareness creation, and AMR monitoring could be directed. A similar approach has been used to quantitatively classify the Swedish population based on their knowledge and attitudes towards antibiotic use and ABR in order to identify groups in the population in greater need of education on ABR 67.

We use the discrete choice experiment (DCE) method and an attitude scoring scheme, to assess farmers’ treatment preferences for bacterial infections in humans and livestock with antibiotics being one possible treatment option in northern Tanzania. In a DCE study, a respondent is presented with hypothetical choice scenarios with two or more options from which an individual chooses the best combination 47. An attitude scoring scheme contains questions that are phrased as positive or negative statements accompanied by a point-likert-scale from which a respondent chooses a score 24. We apply these two methods on three predominant livestock production systems in East Africa, agro-pastoral, pastoral and rural smallholder. Here, to establish points of intervention, we jointly examine human and animal health processes. More specifically, we aim to: (i) estimate and compare the trade-offs between the choice of antibiotics and other medicine types, and between self-treatment and access to human and livestock health experts; (ii) model the heterogeneity associated with farmers’ attitudes towards antibiotic use and potential sources of bacteria (i.e. water and milk); and (iii) identify the characteristics of farmers whose heterogeneity is associated with identified knowledge and attitudes.

Several studies 52, 17, 51, 36 have shown the value of focusing on knowledge, attitude and behaviour of healthcare providers (responsible for human and animal health matters) and patients around antimicrobial use and resistance in order to identify areas for intervention. However, existing knowledge, attitude and practice (KAP) studies are subject to limitations. For instance, most focus on asking too many questions placing emphasis on quantity over quality of scores 61. They also suffer from courtesy bias resulting from respondents giving answers that they think interviewers want to hear but that do not necessarily reflect what they do 61. Further, this type of research in LMIC settings suffers from several ABR specific limitations. First, only a few studies focus on antibiotic use in communities rather than in health care facilities. This is an important omission since people in such settings have often very limited access to health facilities 52 and veterinary services 36, and therefore unregulated access to antibiotics is common. Second, behaviour is typically defined as comprising already established patterns of antibiotic use which are made up of practices and attitudes as observable factors driving an individual to choose one antibiotic use practice over another 17, 50. Third, the studies available are limited methodologically in that they use statistical approaches (e.g., chi-square tests, logistic regressions, mean attitudinal scoring schemes, etc) 38, 17, 50 that limit the determination of the causal relationships between attitudes, preferences and antibiotics use practices 38, 54.

From an economic perspective, behaviour is defined by treatment preferences, while, from a medical psychology perspective, attitudes and perceptions represent the unobservable factors driving preferences and thus choices 31. Preferences are reflected in the choices from which an individual obtains the highest amount of satisfaction 4. Attitudes consist of the evaluation of alternatives (negative, neutral and positive) by the individual and the subsequent choice that best describes their interest 18. The attitude of an individual is shaped by their experiences, thoughts, opinions and personality 3, which affect the preferences we observe 56. This means we often do not observe the same behaviour in different choice contexts 18. Individuals exhibit different behaviours based on their preferences and the context within which choices are made.

Health-seeking behaviour is, in economic terms, therefore, defined based on four main elements, namely the *action taken* by an individual towards a *target*, made within a certain *context* at a particular *time* 18. In the context of human and livestock health, when a person or an animal experiences certain disease clinical signs and symptoms, based on the *context* of the disease and primary caregiver, a particular *action* is taken to treat these,at the *time* they are observed. Here, behaviour is represented by the observable *action taken* 18 targeting a person or an animal. It is an outcome of a process of information synthesis by the person themselves or primary caregiver on different treatment options, influenced by their attitudes 30. Furthermore, attitudes are an underlying, often unobservable component that plays a major role in the observable behaviour of an individual through their choices. Therefore, we are only able to observe people’s behaviour and infer preferences from this behaviour, but we cannot observe their attitudes directly unless we keep them under prolonged observation. While we recognize value in the approaches (i.e. chi-square tests, logistic regressions, mean attitudinal scoring schemes, etc) that existing studies24 have used, we argue that they are prone to error because attitudes are psychological latent constructs that are not observable by the analyst. As such, they cannot be interpreted directly without examining the choices that they co-determine.

In this study, we use the hybrid discrete choice model to quantify and disentangle preference heterogeneity based on attitudes, individual’s opinions and socioeconomic factors in human and livestock disease management choices in a LMIC setting. The hybrid choice model is the most suited to address these gaps because it treats attitudes (here, attitudes towards antibiotic use and individual opinions on bacteria sources (water and milk)) as latent variables 24 which are modelled using indicators 34. This is a powerful approach that treats answers to attitude statements as latent variables which are incorporated into the standard mixed logit model to explain an individual’s choice behaviour 11. This method further allows us to separate different sources of heterogeneity of an individual’s choice behaviour 58 in humans and livestock.

Livestock are important sources of food and income, and a store of wealth 62 and symbol of prestige, culture and religion63 among farming communities. Depending on the farming community, financial resources may be allocated differently to humans compared to livestock health. For instance, pastoral communities devote greater resources than agro-pastoralists to livestock health because of the importance of livestock to their livelihoods 64. Identifying trade-offs across a range of livestock production systems will help us understand the differential value placed on human and livestock health and choice behaviours that could pose ABR risks. We are also able to separate and compare choice behaviour due to attitudes, and group farmers based on their socioeconomic characteristics. From this analysis, we draw insights that enable us to provide targeted recommendations to enable farmers to optimise antibiotic use towards health improvements in themselves and their herds. The study also helps us to understand the role farmers’ attitudes and socioeconomic factors play in the design of comprehensive stewardship programs to counter the ABR crisis.

**2. Materials and Methods**

**Study system**

This study was conducted in rural settings of northern Tanzania, and it focused on comparing practices around treatment in humans and animals. AMR is a widespread problem in the country with a clinical prevalence of multi-drug resistant bacteria ranging between 25-50% 54. Antibiotics are classified as prescription-only drugs but their sale without a prescription is common 40, 28. In some cases, pharmacies sell incomplete doses of antibiotics without a prescription and without informing patients/buyers of the potential consequences in terms of AMR 28.

Our study comprised three livestock production systems (smallholder, pastoral and agro-pastoral) in *Mwanga* (Kilimanjaro Region), *Ngorongoro* (Arusha Region)and *Misungwi* (Mwanza Region) districts, respectively.Pastoralists tend to keep livestock only, although they also embark in sporadic agricultural activities15. Agro-pastoralists grow crops but maintain a strong cultural and economic inclination towards livestock keeping 44, 15. Smallholder farmers keep smaller herd sizes and engage to a large extent in commercial and subsistence crop growing 15. In terms of socio-economic and health status, smallholder farmers tend to have higher income, experience less ill-health, and have better access to health experts compared to pastoral and agropastoral communities 10. Infectious disease burdens are typically higher amongst pastoralists and their livestock compared to agro-pastoralists and smallholder farmers 10, 15. In the three livestock production systems, cattle are more valuable than “small stock” such as goats and sheep, which are often sold to generate income to finance health expenditure 10, 29.

**Study design and questionnaire content**

We administered questionnaires among 404 respondents, (including the head of household and their spouse to ensure gender parity) in villages representative of the three livestock production systems described above – two villages per production system. In each study district/region, two villages were selected at proximal and distal locations relative to their regional hospitals. Comparability across regions was ensured based on criteria for village selection, i.e. population size, number of sub-villages, presence/absence of governmental, non-governmental or private health/veterinary services, drug shops and health facilities. Multi-stage random sampling, including village, sub-village- and household-levels, was used to recruit participants.

The design of the questionnaire was informed by a qualitative study carried out between April and May of 2019. This preliminary phase consisted of 12 focus group discussions (FGDs) with ~10 members per group, and 4 in-depth interviews with participants drawn from the community, and human and livestock health experts in each of the study districts. This preliminary data collection enabled us to define attributes for the discrete choice model and long-term qualitative research, including the disease scenarios of focus based on the most common diseases affecting humans and livestock in the three production systems of interest. We also collected information on the types of treatment available and their cost. For the analysis we present in this study, we focused on the comparison between two common bacterial infections across the three districts, urinary tract infection (UTI) in humans and contagious bovine pleuropneumonia (CBPP) in cattle.

Based on the information generated during the preliminary data collection, we designed a web-based survey in Lighthouse studio (Sawtooth Software) for data collection using a tablet computer. The questionnaire was pre-tested in October and November 2019 in the Kilimanjaro region. The main data collection took place across the three selected districts between January to August 2021. After consenting, study participants were interviewed by well-trained local research assistants who understood local languages, *Swahili, Maasai or Sukuma.*

The questionnaire elicited information on individual and household-specific details, and on knowledge and awareness around antibiotic use and resistance in humans and cattle. After providing socio-economic, including information on household consumption, income, and expenditure, and cattle demographic details (e.g. herd size and composition), participants were presented with choice cards related to the choice experiment (described below in greater detail). Four cards were designed to elicit treatment choices for UTI in humans and four to obtain responses for treatment of CBPP in cattle. Thus, each respondent completed 8 choice tasks related to hypothetical but realistic treatment options for both human and cattle diseases. Subsequently, they were presented with attitude statements on the use of antibiotics and the importance of treating water and boiling milk before consumption (see below for details). Finally, the participant addressed attitude statements on antibiotic access and use in cattle. All farmers responded to the choice experiment questions related to human and cattle health, while responses to attitudinal statements were elicited only if farmers had prior knowledge of the word “antibiotics”.

**Hybrid choice model specifications**

We use a stated preference discrete choice experiment (DCE) to estimate people’s preferences towards treatment options 22, 26. DCE is founded in Lancaster’s characteristics theory of value 32, which states that individuals choose a good or service based on its attributes 35. The method has widely been used to study decision-making on medicine and treatment types, health policies and health interventions, and to estimate people’s preferences for care services 14, 26. In this approach, respondents are presented with hypothetical choice sets made up of two or more alternatives from which an individual chooses the option from which they obtain the highest satisfaction. These choice data collected are analysed econometrically using different discrete choice models to estimate trade-off rates between different attributes levels, and to describe preferences.

In our case, we used the hybrid (latent variable) discrete choice model since this allows us to model attitudes as latent variables 37. The hybrid choice model is an extension of the standard discrete choice model combined with an ordered logit model. In the standard discrete choice model, the behaviour of an individual , follows a logit discrete choice and is made up of two parts: a random component ( and an error term ( 21. The hybrid choice model has three sub-components: a mixed logit model, a structural model defined by a latent variable and a measurement model defined by an ordered logit model 23. The utility that an individual obtains from choosing a set of health care alternatives 16, 34 is formulated as follows:

where is a vector of the treatment attributes for each alternative, the individual’s socioeconomic factors, is a vector of latent variables (attitudinal and income indicator variables) and is the error term. If we go a step further to separate the structural component that links each latent variable to attitudinal indicators and socioeconomic factors 16, then we formulate the equation as follows 34.

where ASC is the alternative specific constant, is a vector of individual socioeconomic factors, their coefficient estimates, and is the error term. Education level, gender, age and income have been found to influence treatment preferences in livestock 2, 47. Contextual variables such as previous disease experiences, and time to medicine sources also affect treatment preferences and access to antibiotics 47, 67. The measurement component is framed on the assumption that the latent variable is linked to the attitudinal indicators captured through the Likert scale. For the indicators the equation is formulated as follows 34.

where, represents a vector of attitudinal and income indicators that associate with latent variable (, denotes the alternative specific constant, is the coefficient estimate of each attitude and income indicators and is the error term.

**Choice experiment scenarios**

As part of the choice experiment, we analysed choices between treatment options for UTI (humans) and CBPP (cattle) as sought by respondents in real-life situations. For both conditions, the characteristics of the hypothetical treatment options over which people were asked to make choices were described by 4 attributes (Tables 1 and 2).

Regarding the scenario related to human health (UTI) (Table 1), the actions we presented to respondents were a visit to a medical doctor, a pharmacy to buy medicines, or a traditional healer. Medicine options were antibiotics, antimalarials or herbal medicine, taken as either in full or incomplete doses. Treatment costs ranged between TSh 4,000 - 20,000 ($1.72 - $8.60).

**Table 1: Attribute and attribute levels used in the choice experimental design to investigate treatment behaviours related to human health in northern Tanzania. Urinary Tract Infection (UTI) was used as the infectious disease scenario.**

|  |  |
| --- | --- |
| **Attribute** | **Levels** |
| Action taken | 1. Visit traditional healer |
| 2. Visit pharmacy |
| 3. Visit medical doctor |
| Medicine type | 1. Medicine type A – Herbal medicine |
| 2. Medicine type B – Antimalarial treatment |
| 3. Medicine type C – Antibiotics |
| Medicine dosage | 1. Incomplete dose |
| 2. Complete dose |
| Cost of treatment in  Tanzania shilling (TSh) | 1. TSh 4000 ($1.72) |
| 2.TSh 6000 ($2.58) |
| 3. TSh 8000 ($3.44) |
| 4.TSh 12000 ($5.16) |
| 5.TSh 15000 ($6.45) |
| 6. TSh 20000 ($8.60) |
| Exchange rate TSh to dollar $1= 2,326.65 (Xe.com 04.06.2022) | |

For the attribute and attribute levels of CBPP in cattle a farmer had the option to seek medical advice from either friends/relatives/neighbours, or self-treat the affected cattle based on their judgment, or else consult a livestock health expert. The medicine acquired were either antibiotics or anti-parasites or pain killers that could be sourced from open-air markets, or relatives/friends/neighbours or agrovet shops. The cost of the treatment was between TSh 5,000 - 15,000 ($2.15 - $6.45).

**Table 2: Attribute and attribute levels used in the choice experimental design to investigate treatment behaviours related to cattle health in northern Tanzania. Contagious Bovine Pleuropneumonia (CBPP) was used as the infectious disease scenario.**

|  |  |
| --- | --- |
| **Attribute** | **Levels** |
| **Action taken** | * Call friends, relatives or neighbours |
| * Treat by yourself |
| * Call livestock officer |
| **Medicine type** | * Medicine type A – Painkillers |
| * Medicine type B – Anti-parasites |
| * Medicine type C – Antibiotics |
| **Medicine source** | * From vendors in open-air market |
| * From friends/relatives/neighbours |
| * From agrovet/veterinary drug shops |
| **Cost of treatment in Tanzania shilling (TSh)** | * TSh 5000 ($2.15) |
| * TSh 9000 ($3.87) |
| * TSh 12000 ($5.16) |
| * TSh 15000 ($6.45) |
| Exchange rate TSh to dollar $1= 2,326.65 (Xe.com 04.06.2022) | |

Participants were asked to choose their most preferred treatment option, including a “do nothing” option, for UTI in humans (Figure 1) and CBPP in cattle (Figure 2) over a sequence of four choice cards.

In both human and livestock, the attribute level, visit to pharmacist and visit to agrovet is assumed as an act of self-treatment as it does not involve the use of a prescription from a doctor and a vet.

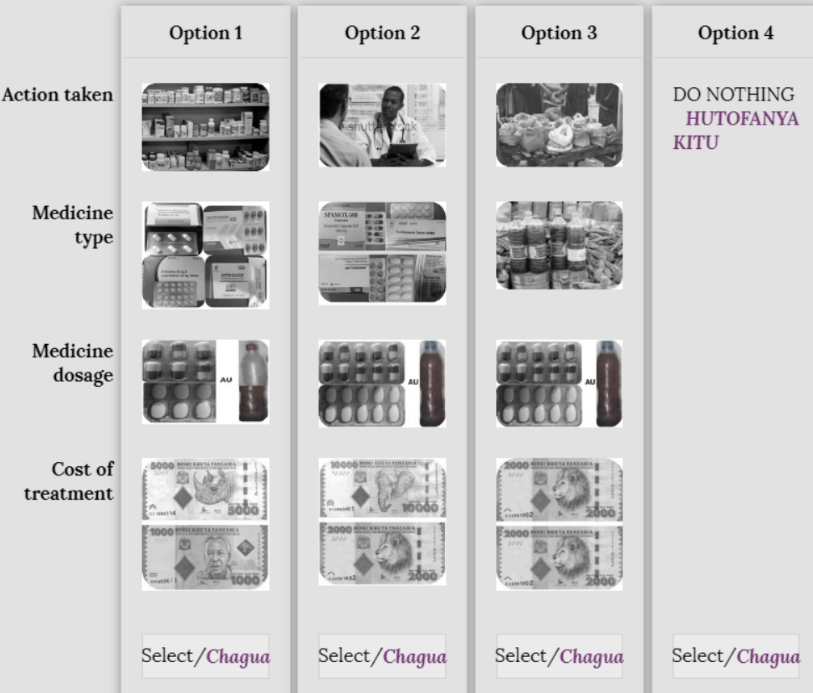


Figure 1: An example of a choice card presented to respondents to investigate treatment behaviours related to human health in northern Tanzania.

Urinary Tract Infection was chosen as the infectious disease scenario. Respondents were enquired about choices they would make for themselves and their children to assess whether they value treatment differently in humans.

For cattle Contagious Bovine Pleuropneumonia (CBPP) was chosen as the infectious disease scenario because it was common in the study area.

Graphical user interface, application

Description automatically generated

Figure 2: An example of a choice card presented to respondents to investigate treatment behaviours related to cattle health in northern Tanzania.

**Representing the effects of attitudes on choices**

In this section, we conceptualize how intentions (i.e. treatment attributes), attitudes and socio-economic factors enter the hybrid discrete choice model and we describe how data on these factors were collected. Through the household questionnaire we generated data that led to 12 attitudes’ indicators concerning human and cattle health. For human health we designed attitude statements related to (1) attitudes towards antibiotic prescription (two statements), i.e. whether antibiotic use requires a prescription or not; (2) attitudes towards antibiotic use (three statements), including on the appropriateness of keeping leftover antibiotics for future use, sharing them with others and not completing the course; and (3) attitudes towards infection prevention (two statements), specifically opinions on whether water and milk treatment before use are important to prevent transmission. For cattle health, attitudinal statements related to: (1) attitudes towards antibiotic use to improve cattle productivity, health and growth (three statements); (2) attitudes towards prescription/professional advice as a prerequisite to use antibiotics in cattle (one statement); and (3) attitudes towards antibiotic access, specifically in terms of keeping veterinary antibiotics at home for ease of use (one statement).

The education level was included to represent the respondent’s level of formal training. Income characteristics were described by two variables: (1) farmers’ perception of the amount of income made in the previous months compared to that at the time of data collection (i.e. was the current income better, worse or the same?); and (2) monthly household-level income. Income characteristics are important in explaining the reasons behind varying treatment cost preferences. We also included gender, age and individual’s prior knowledge of antibiotic resistance upon which further attitudinal questions were asked. Diagrammatically, the hybrid discrete choice model for both humans and cattle are illustrated in Figures 3 and 4, respectively.

**Indicators of Latent variables**

**Observable variables**

**Human treatment attributes**

Dosage

Att1: One should take antibiotics prescribed/advised only by a medical doctor

Att2: It is appropriate to buy antibiotics from the pharmacy without medical doctor’s prescription/advice

Att3: A single course of antibiotics can be shared among family and friends

Att4: One should take antibiotics and once they feel better abandon the course

Att5: One can keep left over antibiotics for future use

Gender

Age

Monthly income and income perception

Action taken

Medicine type

Cost

Utility/satisfaction

Knowledge of ABR

**Antibiotic treatment behaviour in humans**

**Key:**

ABR – Antibiotic resistance

Att - attitude

You think it is important to boil milk before you drink it

You think it is important to boil water before you drink it

Figure 3: Structure of the hybrid discrete choice model used to quantify antibiotic treatment behaviours related to human health among farmers in northern Tanzania.

Indicators of latent variables

Observable variables

Action taken

Medicine sources

Medicine type

Cost

Monthly income and income perception

Gender

Age

Att1: Minimizing the use of antibiotics in cattle will lead to reduction of productivity

Att2: Use of antibiotics in cattle promotes growth in calves

Att3: Giving cattle antibiotics reduces chances of infectious diseases

Att4: You should not give your cattle antibiotics not recommended by a livestock field officer

Att5: Livestock antibiotics can be bought and kept at home for ease during disease outbreaks

Utility/satisfaction

**Antibiotic treatment behaviour in cattle**

Knowledge of ABR

**Key:**

ABR – Antibiotic resistance

Att - attitude

**Figure 4:** Structure of the hybrid discrete choice model used to quantify antibiotic treatment behaviours related to cattle health among farmers in northern Tanzania.

Attitudinal statements were ranked on a Likert scale of 5, from strongly disagree (1) to strongly agree (5) 23, 24. The responses were elicited using the think-aloud strategy 12. To enhance understanding and measure the strength of the feeling of respondents for each of the attitudinal statements, the Likert scale was described using stones (see Figure 5) with one (1) stone representing ‘strongly disagree’ and five stones (5) ‘strongly agree’.

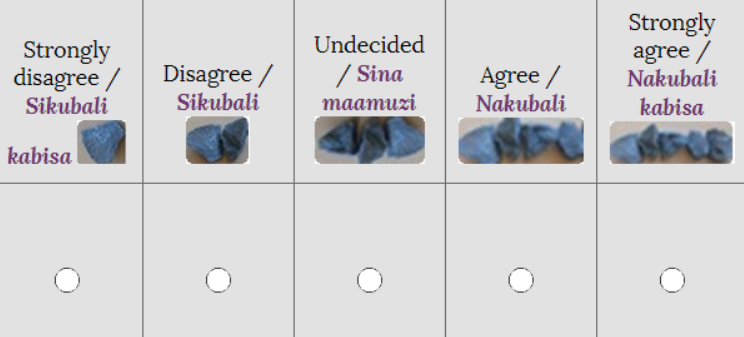


Figure 5: Likert scale for measuring attitudes

**Data analysis**

We estimated separate hybrid discrete choice models for (i) UTI in humans and (ii) CBPP in cattle using the Appolo package in R 23. Each model consisted of three components: a discrete choice model (mixed logit model) containing treatment attributes, a structural model containing socio-economic factors (i.e., age, gender, monthly income, education), knowledge of antibiotic resistance and a measurement model containing attitude and income perception indicator responses. The association between the utility functions of the discrete choice model and the attitudes and perception variables of the measurement model was achieved through a latent variable (LV). This LV forms the basis for the structural model that helps establish the links between individuals’ choices and behavioural traits 37. Further, to test for non-linear relationships, we used a hybrid coding scheme (see supplementary material 1) for the treatment attributes and a discrete specification for the cost attribute (for more information on this hybrid coding scheme 46. The socioeconomic factors were dummy coded, and the attitudinal statement followed a 5-likert scale continuously and consistently coded based on whether a level was chosen or not, including fixing some outlier levels to the starting values for the model to converge (see supplementary material 1). Further, for the attitudinal and income perception indicators, one of the levels was set as the base/lower threshold automatically during specification and analysis 23.

For the choice model we used the mixed logit model to generate coefficient estimates which using the Delta method 25, 6 we estimated the willingness to pay. The non-cost attributes followed a normal distribution while the cost attribute was fixed 39. The willingness to pay for the non-cost treatment attributes was estimated as follows 39, 47.

where is the willingness to pay for treatment attribute k e.g., call veterinary officer or visit to a doctor etc, while is the standard error estimated using Delta method and represents each draw from the standard normal distribution of the non-cost attribute k and is the cost coefficient estimate.

**3. Results**

A total of 404 respondents answered questions on human (adult and children) and cattle health. Table 3 describes socioeconomic characteristics and farmers’ perception of income changes. In brief, almost half of the respondents (53%) were classified as young and low-income earners (62%) based on their income level. In terms of farmers’ opinions on income at the time of the survey compared to previous months, 33% said “it was the same”, 27% said “it was worse”, 9% answered “it was better”, while 31% “did not know” the difference. Most of the respondents (65%) had received formal education. Only 33% and 19% of respondents had heard of antibiotic resistance in humans and cattle, respectively.

Figures 6 and 7 (see supplementary material 2) contain summarised scores on attitudes towards antibiotic treatment in humans and cattle, respectively. Of those who had heard of antibiotics, about 38% of respondents strongly agreed to take antibiotics prescribed only by a medical doctor and 63% strongly disagreed with buying antibiotics in pharmacies without a doctor’s prescription. About 45% of them strongly disagreed with keeping leftover medicines for future use and 72% with sharing a single dose with family and friends. Around 73% of study participants strongly disagreed with interrupting antibiotic treatment once they felt better. Regarding preventative measures, 62% and 55% of respondents strongly agreed to the importance of boiling milk and water, respectively, before consumption.

Respondents had a positive attitude towards prophylactic use of antibiotics with about 58% of them strongly agreeing with giving cattle antibiotics to reduce chances of infection. Around 42% of farmers strongly disagreed with using antibiotics to promote the growth of calves. Most farmers (62%) strongly disagreed with giving cattle antibiotics without a recommendation from a livestock field officer but 32% strongly agreed with keeping medicines at home for use during disease outbreaks.

In subsequent sections, we integrate these attitudinal responses into a hybrid discrete choice model to establish the link between treatment preferences and characteristics of respondents.

**Table 3: Characteristics of sampled participants in a study in northern Tanzania investigating behaviours related to human and cattle treatment. The respondents were presented with two disease scenarios related to human (Urinary Tract Infection) and cattle (Contagious Bovine Pleuropneumonia) health.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Cattle** | | **Human** | |
|  | **N** | **%** | **N** | **%** |
| **Gender** | | |  |  |
| Male | 201 | 50 | 201 | 50 |
| Female | 203 | 50 | 203 | 50 |
| **Age** | | |  |  |
| Young (20-50 years) | 214 | 53 | 214 | 53 |
| Old (>= 51 years) | 190 | 47 | 190 | 47 |
| **Income level1** |  | | | |
| Low income (Tshs.1 -300,000 (($0.00043 - $129.65)) | 250 | 62 | 250 | 62 |
| High income (Tshs. > 300,000 (>$129.65)) | 115 | 28 | 115 | 28 |
| **Education** | | |  |  |
| No formal training | 264 | 65 | 264 | 65 |
| Formal training | 140 | 35 | 140 | 35 |
| **Monthly income perception compared to previous months’** | | | | |
| Was it better | 36 | 9 | 36 | 9 |
| Was it worse | 108 | 27 | 108 | 27 |
| Was it the same | 135 | 33 | 135 | 33 |
| Do not know | 125 | 31 | 125 | 31 |
| **Knowledge of antibiotic resistance** | | | | |
| Yes | 76 | 19 | 132 | 33 |
| No | 328 | 81 | 272 | 67 |
| 1Respondents who chose the “Does not want to answer” for income level were treated as “missing” based on the assumption that people do not live on zero income. The proportion of the respondents who gave this response was 10% of the overall sample. | | | | |

**Hybrid discrete choice modelling**

We estimated two-hybrid discrete choice models - one for cattle (Table 4) and the other for humans (Table 5). Each table (4 and 5) includes results made up of a choice, structural and measurement model with many parameter estimates. The structural model results consist of coefficient estimates of socioeconomic factors (age, gender, income, education) and knowledge of antibiotic resistance. The choice model results consist of coefficient estimates of treatment attributes levels, i.e. action taken, medicine type, medicine source or dosage, and cost attributes. The measurement model contains the estimates from the ordered logit model that represent attitudinal indicators of antibiotic use, bacterial sources, and income perceptions. The socioeconomic and attitudinal scores have either a negative or positive effect on the treatment preferences for UTI in humans and CBPP in cattle.

Due to our central focus on disentangling underlying attitudes on treatment preferences, we first interpret the findings (see Table 4 and 5) of the measurement model containing attitudinal and income indicators. First and foremost, based on our estimates (Table 4 and 5) we can distinctly split our sample into two groups - people with positive and negative attitudes. Generally, we interpret the results of the measurement model, as follows: as the magnitude of the Likert scale increases, the parameter estimates become larger and positive which implies a farmer’s stronger agreement with an attitudinal statement. A smaller estimate with a negative sign denotes the reverse i.e. stronger disagreement. The difference in the levels of the Likert scale parameter estimates shows us the magnitude of change in attitude between two score levels, with a larger gap implying a higher affinity to change. We capture the link between the preferences and attitudes and opinions on income indicator indirectly through the latent variable (LV) parameter estimate. A positive and highly significant LV estimate denotes a strong influence of attitudes on respondents’ choices of treatments.

Further, in the human measurement model, we report a positive and significant estimate for respondents who agree with keeping leftover antibiotics for future use, sharing a single dose of antibiotics between family and friends, and abandoning antibiotics when they feel better without completing doses. In the cattle measurement model, we also report a positive and significant estimate for attitude towards home storage of antibiotics, use of antibiotics to increase cattle productivity and promote growth in calves. Overall, our measurement model results show that all attitude and income-related statements denote a significant influence on stated treatment preferences.

The choice model results (also in Tables 4 and 5) show evidence of preference heterogeneity based on the identified underlying farmers’ attitudes. Important to this study is the relationship between treatment choices and LV which is positive and significant, implying higher marginal utility and willingness to pay for different treatment attributes of UTI (Table 4) and CBPP (Table 5). Farmers prefer to self-treat CBPP in cattle while they prefer to visit a medical doctor when they suffer from UTI. However, the marginal utilities for a call to a veterinary officer in cattle and a visit to a pharmacist in humans are still positive and statistically significant, indicating a high preference potential to consult a vet and self-treat UTI and CBPP. Antibiotics are the preferred medicine type in both humans and cattle but the marginal utility in humans is higher compared to that in cattle. Compared to human illness, the marginal cost coefficient in the context of cattle illness is slightly more negative and lower, implying a higher decrease in utility as the cost of treating CBPP increases over that of UTI.

**Table 4: Choice, structural and measurement parameter estimates of the model related to human health in a study that aimed to investigate treatment behaviours in northern Tanzania (LV = latent variable).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | |  | | |  | |
|  | | **Coefficient estimates**  **(std. errors)** | | | **Standard Dev.**  **(std. errors)** | |
| **Choice model** | | | | | | |
| **Action taken** | | | | | | |
| a. Visit a doctor | | 7.4153\*\*\* | (0.4655) | | 9.3217\*\*\* | (0.4638) |
| b. Visit a pharmacist | | 2.7676\*\*\* | | (0.2488) | 5.2841\*\*\* | (0.2629) |
| c. Visit the traditional healer | | -10.1828 | |  |  |  |
| Medicine type | |  | |  |  |  |
| a. Antibiotics | | 0.9351\*\*\* | | (0.1814) | 3.8209\*\*\* | (0.1901) |
| b. Antimalarials | | -0.8133\*\*\* | | (0.1754) | 5.1093\*\* | (0.2542) |
| c. Herbal medicines | | -0.1218 | |  |  |  |
| Medicine dosage | | | | |  |  |
| Dosage | | 0.7099\*\*\* | | (0.0943) | 2.3128\*\*\* | (0.1151) |
| Cost of treatment | | -0.0639\*\*\* | | (0.0178) |  |  |
| No choice alternative | | -14.6319 | | (64.4191) |  |  |
| **Structural model** | | | | | | |
| Education | | 0.6768\*\*\* | | (0.0085) |  |  |
| Gender | | -0.0446\*\*\* | | (0.0077) |  |  |
| Income level | | -0.0100\*\*\* | | (0.0001) |  |  |
| Knowledge of antibiotic resistance | | 0.2143\*\*\* | | (0.0097) |  |  |
| Age | | 0.0037 | | (0.0091) |  |  |
| Main effect LV | | 0.5532\*\*\* | | (0.1693) |  |  |
| **Measurement model** | | | | | | |
| **Attitude towards antibiotic use** | | | | | | |
| a. One should take antibiotics prescribed/advised only by a medical doctor | | | | | | |
| Strongly disagree | -1.7159\*\*\* | | | (0.1838) | 2.6975\*\*\* (0.1342) | |
| Disagree | | 0.0348 | | (0.1557) |
| Undecided | | 0.2080 | | (0.1572) |
| Agree | | 1.2510\*\*\* | | (0.1803) |  |  |
| b. It is appropriate to buy antibiotics from the pharmacy without medical doctor’s prescription/advise | | | | | | |
| Strongly disagree | | 0.1057 | | (0.1571) | 2.5988\*\*\* (0.1293) | |
| Disagree | | 1.2115\*\*\* | | (0.1661) |
| Undecided | | 1.6606\*\*\* | | (0.1796) |
| Agree | | 2.4962\*\*\* | | (0.2246) |
| **Attitude towards antibiotic dosage** | | | | | | |
| a. One can keep left-over antibiotics for future use | | | | | | |
| Strongly disagree | | -1.3795\*\*\* | | (0.1833) | 2.9820\*\*\* (0.1484) | |
| Disagree | | -0.1744 | | (0.1554) |
| Undecided | | -0.0495 | | (0.1543) |
| Agree | | 1.3728\*\*\* | | (0.1770) |  |  |
| b. A single course of antibiotics can be shared among family and friends | | | | | | |
| Strongly disagree | | -0.1418 | | (0.1703) | 4.4500\*\*\* (0.2214) | |
| Disagree | | 0.5084\*\*\* | | (0.1685) |
| Undecided | | 0.8155\*\*\* | | (0.1728) |
| Agree | | 1.5696\*\*\* | | (0.2001) |
| c. One should take antibiotics and once they feel better abandon the course | | | | | | |
| Strongly disagree | | -0.4188\*\* | | (0.1790) | 5.5844\*\*\* | (0.2778) |
| Disagree | | 0.7650\*\*\* | | (0.1822) |  |  |
| Undecided | | 0.9276\*\*\* | | (0.1870) |  |  |
| Agree | | 1.7254\*\*\* | | (0.2261) |  |  |
| **Attitude towards bacterial sources** | | | | | | |
| You think it is important to boil water before you drink it | | | | | | |
| Strongly disagree | | -2.2951\*\*\* | | (0.1231) | 3.3886\*\*\* (0.1686) | |
| Disagree | | -1.2053\*\*\* | | (0.0888) |
| Undecided | | 0.1250 | | (0.0776) |
| Agree | | 1.1489\*\*\* | | (0.0882 |
| You think it is important to boil water before you drink it | | | | | | |
| Strongly disagree | | -11.9430\*\*\* | | (1.5159) | 55.6876\*\*\* | (5.3290) |
| Agree | | 10.9704\*\*\* | | (1.0489) |  |  |
| **Monthly income perception compared to previous month** | | | | | | |
| Was it better | | -2.2713\*\*\* | | (0.0957) | 0.0828 | (0.0629) |
| Was it worse | | -0.5353\*\*\* | | (0.0666) |  |  |
| Was it the same | | 0.8616\*\*\* | | (0.0704) |  |  |
| Number of observations 404  Log-likelihood -8706.47  Akaike information criterion (AIC) 17524.93  Bayesian Information Criteria (BIC) 17923.45 | | | | | | |
| ⁎⁎⁎ = p < .01 , ⁎⁎ = p < .05 , ⁎ = p < .1 | | | | | | |

**Table 5:** **Choice, structural and measurement parameter estimates of the model related to cattle health in a study that aimed to investigate treatment behaviours in northern Tanzania.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **coefficient estimates**  **(std. error)** | | | **Standard Dev**  **(std. error)** | | |
| **Choice model** | | | | | | |
| **Action taken** | | | | | | |
| a. Call a veterinary officer | 0.3617\*\*\* | (0.1073) | 2.4023\*\*\* | | (0.1195) | |
| b. Self-treatment of cattle | 0.3708\*\*\* | (0.0778) | | 2.8236\*\*\* | (0.1405) | |
| c. Call friends/relatives/neighbours | -0.7325 |  | |  |  | |
| Medicine type |  |  | |  |  | |
| a. Antibiotics | 0.42977\*\*\* | (0.07276) | | 1.9189\*\*\* | (0.0955) | |
| b. Anti-parasites | -0.2654\*\*\* | (0.0743) | | 3.9560 | (0.1968) | |
| c. Pain killers | -0.1054 |  | |  |  | |
| Medicine sources | | | | | | |
| a. Agrovet shops | 0.7905\*\*\* | (0.1069) | | 2.3199 | | (0.1154) |
| b. Friends/relatives/neighbours | -0.13037 | (0.11048) | | 2.6467\*\*\* | | (0.1317) |
| c. Open air-market | -0.8725 |  | |  |  | |
| Cost of treatment | -0.0671\*\*\* | (0.0152) | |  |  | |
| No choice alternative | -14.1167 | (42.8378) | |  |  | |
| **Structural model** | | | | | | |
| Education | -0.4360\*\*\* | (0.0506) | |  |  | |
| Gender | -0.5817\*\*\* | (0.0191) | |  |  | |
| Income level | 0.0008\*\*\* | (0.0002) | |  |  | |
| Knowledge of antibiotic resistance | -0.0725\*\*\* | (0.0525) | |  |  | |
| Age | 0.3802\*\*\* | (0.0231) | |  |  | |
| Main effect | 0.3648\*\*\* | (0.0941) | |  |  | |
| **Measurement model** | | | | | | |
| **i. Attitude towards antibiotic use** | | | | | | |
| a. Minimizing the use of antibiotics in cattle will lead to reduction of productivity | | | | | | |
| Strongly disagree | -2.5615\*\*\* | (0.2596) | |  |  | |
| Disagree | -1.3380\*\*\* | (0.1769) | | 4.0782\*\* | (0.2029) | |
| Undecided | -0.2678\* | (0.1477) | |  |  | |
| Agree | 0.8247\*\*\* | (0.1567) | |  |  | |
| b. Use of antibiotics in cattle promotes growth in calves | | | | | | |
| Strongly disagree | -28.0299\*\*\* | (6.9912) | | 51.2290\*\*\* | (12.2763) | |
| Agree | 11.7778\*\*\* | (3.3038) | |  |  | |
| c. Giving cattle antibiotics reduces chances of infectious diseases | | | | | | |
| Strongly disagree | -2.7707\*\*\* | (0.3241) | |  |  | |
| Disagree | -1.5688\*\*\* | (0.22085) | | 9.0871\*\*\* | (0.4521) | |
| Undecided | -0.7024\*\*\* | (0.1835) | |  |  | |
| Agree | 0.8354\*\*\* | (0.1889) | |  |  | |
| **ii. Attitude towards antibiotic recommendation/prescription** | | | | | | |
| You should not give your cattle antibiotics not recommended by a livestock field officer | | | | | | |
| Disagree | -0.48567\*\*\* | (0.15933) | | 3.1880\*\*\* | (0.1586) | |
| Undecided | -0.27432 | (0.16458) | |  |  | |
| Agree | 0.54555\*\*\* | (0.19315) | |  |  | |
| **v. Attitude towards antibiotic access** |  |  | |  |  | |
| Livestock antibiotics can be bought and kept at home for ease of access during disease outbreaks | | | | | | |
| Disagree | -0.6224\*\*\* | (0.1189) | | 3.8109\*\*\* | (0.1896) | |
| Undecided | -0.2749\*\* | (0.1234) | |  |  | |
| Agree | 0.7710\*\*\* | (0.1498) | |  |  | |
| **Monthly income perception compared to previous month** | | | | | | |
| Was it better | 0.2840 | (0.2369) | | 6.2571\*\* | (0.3113) | |
| Was it worse | 1.5959\*\*\* | (0.3214) | |  |  | |
| Was it the same | 4.7814\*\*\* | (0.8148) | |  |  | |
| Number of individuals 404  Log-likelihood -3637.643  Akaike information criterion (AIC) 7367.29  Bayesian Information Criteria (BIC) 7647.77 | | | | | | |
| ⁎⁎⁎ = p < .01 , ⁎⁎ = p < .05 , ⁎ = p < .1 | | | | | | |

Based on the latent variable results, we can compare farmers’ trade-offs between different treatment attributes using their willingness to pay (WTP) estimates. Positive attitudinal and perception coefficient estimates mean higher WTP, while negative ones mean a lower WTP. Willingness to pay estimates (Tables 6 and 7) show that farmers would pay an additional TSh 110,705 ($47.61) to seek the services of a doctor when treating a human health problem in the household compared to consulting a vet to treat a cattle disease. However, farmers would spend more further TSh 37,791 ($16.25) to self-treat UTI over CBPP in cattle. Furthermore, they place a high value on antibiotics and would pay an additional TSh 8,230 ($3.54) for antibiotics meant to treat UTI in humans compared to antibiotic treatment for CBPP in cattle.

**Table 6: Willingness to pay for treatment of urinary tract infections (UTI) in humans in a study investigating treatment behaviours in northern Tanzania.**

|  |  |
| --- | --- |
| **Treatment attributes** | **Mean willingness to pay in Tanzania shillings**  **(95% Confidence Interval)** |
| **Action taken** | |
| Visit a doctor | 116,100  (41,502 190,698) |
| Visit a pharmacy | 43,320  (15,743 70,897) |
| Visit traditional healer | -159,420 |
| **Medicine type** | |
| Antibiotics | 14,640  (893 28,387) |
| Antimalaria | -12,730  (-22,724 -2,736) |
| Herbal medicine | -1,910 |
| **Medicine source** | |
| Dosage | 11,110  (4,946 17,274) |
| **No choice alternative** | |
| No choice alternative | -299,0000  (-451,821 -146,179) |

**Table 7: Willingness to pay for treatment of contagious bovine pleuropneumonia (CBPP) in cattle in a study investigating treatment behaviours in northern Tanzania.**

|  |  |
| --- | --- |
| **Treatment attributes** | **Mean willingness to pay in Tanzania shillings (95% Confidence Interval)** |
| **Action taken** | |
| Call a livestock health officer | 5,395 |
| (1,783 9,007) |
| Treat by yourself | 5,529 |
| (1,007 10,051) |
| Call friends/relatives/neighbours | -10,924 |
| **Medicine type** | |
| Antibiotics | 6,410 |
| (-2,760 10,060) |
| Anti-parasites | -3,958 |
| (-7,588 -328) |
| Pain killers | -319 |
| **Medicine source** | |
| From Agrovet shop | 11,790 |
| (7,139 16,441) |
| From friends/relatives/neighbours | -1,944 |
| (-5,074, 1,186) |
| From open-air market | -9846 |
| **No choice alternative** | |
| No choice | -210,500 |
| (-332,824 -88,176) |

Through the structural model, we can explain the variation of preferences and establish the socioeconomic characteristics of the farmers who display the identified attitudes and perceptions and who are likely to have a lower or higher WTP for treatment of UTI and CBPP in humans and cattle, respectively. According to our results (Tables 4 and 5), most of the farmer characteristics are significant and, as such, we can establish socioeconomic profiles from the link between latent variables and antibiotic treatment preferences. For instance, positive and significant monthly income and age coefficient estimates suggest that farmers with higher incomes (>300,000 (>$129.65)) and aged between 20-50 years have a higher probability of paying to consult a vet. In contrast, female farmers who have not received formal training, have lower income and are unaware of antibiotic resistance have a lower WTP and are more likely to self-treat. Further, WTP for the treatment of UTI and CBPP is not likely to be higher than the estimated amounts because farmers do not perceive a possible current income increase compared to the amount earned in previous month. Furthermore, the coefficient estimates of the perception question: “compared to the past 6 months, how was the current monthly income?” – is larger, positive, and statistically significant in both humans and cattle for the variable/response “remains the same?”.

**4. Discussion**

The design and implementation of public communication programs on AMR need to consider individual preferences towards treatment choices and sources of variation in treatment seeking behaviours associated with farmers’ attitudes towards antibiotic use and sources of bacteria (water and milk), and socioeconomic factors. In addition, an understanding of the relative value of the human and animal health interface is important to help identify points of interventions where financial and human resources could be directed to improve treatment behaviours and change attitudes promoting antibiotic use practices that contribute to AMR. The main aim of our study was to quantify and compare trade-offs of antibiotic treatment attributes at the human and livestock interface among subsistence farming communities of northern Tanzania. We also sought to establish whether socioeconomic and attitudinal factors explain antimicrobial treatment seeking behaviours in human and livestock. Overall, improvements to human health are needed and valued more than improvements to livestock health – respondents were more willing to consult a doctor than they were to invest in veterinary advice. WTP for self-treatment/visit to pharmacist was also higher in humans while antibiotics were the preferred medicines for treating UTI compared to CBPP in cattle. This may be because the use of antibiotics has no curative effects on CBPP in cattle, although it reduces disease pressure and mortality rates 47. We also identified attitudes towards treatment that interventions should target for change, while also creating an enabling healthcare environment that will prevent individuals from practices that pose ABR risk. When socioeconomic factors were considered, we found that women who had not received formal education and had low income were more likely to show attitudes that increase the risk of ABR.

Our findings on trade-offs conform to existing literature on human and livestock health in three ways. First, we show that human and livestock health are intertwined, although human health is more valued over livestock health, if given a direct choice and specific hypothetical scenario. However, health seeking behaviours in humans during illness tend to increase based on the number of cattle owned 57. Second, WTP estimates show that WTP for self-treatment/visit to a pharmacist in humans is higher compared to cattle – meaning the riskier population that may harbour resistant bacteria would be humans. The use of antimicrobials without prescription has been shown to lead to AMR in humans 1. However, self-treatment in livestock points to this population as especially at risk of contributing to AMR 42, although resistant bacteria arising from self-treatment in humans can also reach livestock indirectly, for example through the environment. Third, the low WTP to consult a vet and considerable WTP for a visit to an agrovet shop/self-treatment also suggest that livestock is a potential risk population in the transmission of resistant bacteria to humans 42, 59.

Descriptive statistics of attitudinal scores showed that farmers had overall positive attitudes towards appropriate practices around antibiotic use, for example consulting a doctor/veterinarian to obtain a prescription. This might be due to two reasons: (i) Likert scores may give biased results 24 as we are unable to distinctly separate respondents based on either positive or negative effect of each attitudinal statement, and (ii) data collection shortcoming as our responses were elicited from participants who had prior knowledge of the word ‘antibiotics’ and thus probable awareness of the need to seek professional medical advice. While our results are consistent with other findings 45, 38, in another study 60 good knowledge of antibiotics is associated with self-treatment because antibiotics are easily accessible in pharmacies without a prescription 20. We then disentangled heterogeneity preferences using a hybrid discrete choice model which allows us to classify participants’ responses based on whether an attitudinal score and socioeconomic factors have a positive or negative effect on treatment preferences.

These include antibiotic use without seeking professional advice, sharing of antibiotics with friends and relatives, not completing the antibiotic course once one feels better, using antibiotics in cattle prophylactically, promoting growth in calves and storing antibiotics at home for ease of access during disease outbreaks. Positive attitudes towards self-medication, antibiotic sharing and use of leftover antibiotics have been reported previously 60, 5. Similarly, in this study we found positive and significant preferences and willingness to pay for self-medication in both human and cattle models.

Acquiring antibiotics from pharmacists without a prescription may lead to misuse due to a lack of professional guidance on correct use 60. Practices such as self-medication, which are common in these contexts 24, raise concerns in terms of AMR risk. However, these practices are also driven by a broad range of complex reasons largely associated with poverty and limited access to quality healthcare 33, 13. These inadequacies are particularly acute in LMIC agricultural settings, including our study context. Indeed, in our study, most farmers do not perceive improvements to their income over time. The cost of antibiotics, seeking professional help and income are correlated, an indication that behaviours around antibiotic use may arise from financial vulnerabilities 2.

We find that groups with lower socio-economic status and education levels (e.g. women) have a higher probability of engaging in self-medication of cattle and humans. One reason for this finding might be that, in sub-Saharan Africa, healthcare decisions related to women and children in the household are often made by men 49, 41, indicating that women may not have the ability and the financial resources to choose professional help as opposed to self-treatment. Fewer opportunities for formal education also mean that knowledge of ABR amongst women in these communities is likely to be low. Indeed, low knowledge of antibiotic resistance and high financial vulnerability of respondents have been linked to preferences for different antibiotic characteristics 2. Further, women have a lower ability to earn income arising from differential gender-related financial resource allocations for health matters in households, especially in the sub-Saharan Africa (SSA) region 19. Combined, these factors suggest that resorting to self-medication among women – typically more convenient and inexpensive - may not necessarily be a matter of preference but rather derived from a lack of choice 13.

Methodologically, the benefits and relevance of using the hybrid discrete choice model to quantify preferences and the impact of latent variables on observable treatment preferences conform to those articulated in previous literature 37, 58, 24. Although we believe that using the hybrid discrete choice model is powerful in dealing with analytical biases, we acknowledge that it may not eliminate courtesy bias that arises from attitudinal scoring system where study participants give responses that match with what they think interviewers want to hear during data collection 61.

**5**. **Policy recommendations and conclusions**

Overall, our study has improved our knowledge of antimicrobial treatment seeking behaviours at the interface between humans and livestock health. Humans may play a particularly important role in facilitating the transmission of antibiotic resistant bacteria owing to the higher WTP for self-treatment of UTI using antibiotics. Based on socioeconomic profiles, women are more likely to perpetuate ABR due to their low knowledge and income to consult a doctor. Further, agrovets and pharmacies are potential stakeholders in the growth of ABR as self-treatment is widespread in the study area.

Overall, our results inform the Tanzanian NAP-AMR as well as NAPs from similar contexts in multiple ways. First, the study provides much-needed research evidence on antibiotic use choice patterns among communities in humans and livestock. Second, the findings help prioritise limited health and financial resources by targeting specific groups in the population, particularly women who have low knowledge of ABR and are more vulnerable to practising self-treatment. Third, the findings point to promoting national vaccination programs to prevent CBPP and other livestock diseases, monitoring and regulatory systems to reduce access to antibiotics without professional guidance and antimicrobial stewardship programs tailored to both the human and animal sectors. Fourth, this study highlights hygiene practices amongst treatment preferences for UTI and CBPP, and thus boiling of milk and treatment of water should be encouraged to prevent the potential spread of microbes and resistant bacteria in humans and livestock. Finally, this study provides economic methodology applied to the study of AMR that could form the basis of specialised training.

**Supplementary material – S1**

Tables S1.1, S1.2 and S1.3 shows the data type and coding schemes for the attributes and covariates included in the model. For the attitudinal and income indicators, starting values were stated for j-1 levels and were increasing as in the likert scale i.e., from -3, -2, -1 and 1.

**Tables S1.1: Treatment attributes and attribute levels coding - Human**

|  |  |  |
| --- | --- | --- |
| **Attribute** | **Levels** | **Data type and Hybrid coding** |
| **Action taken** | Visit a doctor | 1 if choice is visit to a doctor, -1 if choice is traditional healer, 0, otherwise |
| Visit a pharmacy | 1, if choice is visit to a pharmacy, -1 if choice is visit a to traditional healer, 0, otherwise |
| **Medicine type** | Medicine type A - Antibiotics | 1 if medicine type is antibiotics, -1 if herbal medicine, 0, otherwise |
| Medicine type B – antimalaria | 1 if medicine type is antimalaria -1 if herbal medicine, 0, otherwise |
| **Medicine dosage** | Complete dose | 1 if choice is complete medicine dose, -1 if incomplete dose, 0, otherwise |
| Incomplete |  |
| **Cost of treatment in Tanzania shillings**  **($ equivalent)** | 1. 4000 tshs ( $1.74) 2. 6000 tshs ($ 2.60) 3. 8000 tshs ($ 3.47) 4. 12000 tshs ($ 5.21) 5. 15000 tshs ($6.51) 6. 20000 tshs ($8.68) | Discrete |

**Tables S1.2: Treatment attributes and attribute levels coding - Cattle**

|  |  |  |
| --- | --- | --- |
| **Attribute** | **Levels** | **Data type and Hybrid coding** |
| **Action taken** | Call livestock health officer | 1 if a farmer calls livestock health officer, -1 if call to friends, relatives or neighbours, 0, otherwise |
| Treat by yourself | 1 if a farmer treats cattle by himself/herself, -1 if call friends, relatives or neighbours, 0, otherwise |
| **Medicine type** | Medicine type C – Antibiotics | 1 if a farmer chooses antibiotics, -1 if the choice is pain killers, 0, otherwise |
| Medicine type B – Anti-parasites | 1 if a farmer chooses anti-parasites, -1 if the choice is pain killers, 0, otherwise |
| **Medicine source** | From agrovet/veterinary drug shops | 1 if a farmer chooses to obtain medicines from agrovet shop, -1 if it’s an open-air market, 0, otherwise |
| From friends/relatives/neighbours | 1 if a farmer choose to borrow medicine from friends/relatives/neighbours, -1 if the medicine source is open air market, 0, otherwise |
| **Cost of treatment in Tanzania shillings** | 1. 5000 tshs ($2.17) | Discrete |
| 2. 9000 tshs ($ 3.90) |
| 3. 12000 tshs ($ 5.21)  4. 15000 tshs ($6.51) |
|  |

**Tables S1.3: Dummy coding of covariates**

|  |  |
| --- | --- |
| **Covariates** | **Description, data type and dummy coding** |
| Age | 1 if a farmer is young (20-50 years) and 0, if a farmer is >=50 years old |
| Gender | 1 if a farmers’ gender is male, 0, if a farmer is female |
| Education level | 1 if a farmer has formal training – primary school education level and above, 0 if a farmer has never gone to school |
| Income level | 1 if income is > 300,000 (, and, 0, otherwise |
| Knowledge of  antibiotic resistance | 1 if a farmer says yes, and, 0, otherwise |

**Supplementary material 2**

Figure 6: Summary of scores related to attitude statements included in the hybrid choice model for human health in a study conducted in northern Tanzania to investigate treatment behaviours.

Figure 7: Summary of scores realted to attitude statements included in the hybrid choice model for cattle health in a study conducted in northern Tanzania to investigate treatment behaviours.

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