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COMPARING AWARENESS OF ANTIBIOTIC RESISTANCE IN SRI LANKA AND THE EUROPEAN UNION

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Abstract

Antimicrobial resistance (AMR) is one of the greatest threats, particularly in low-and middle-income countries (LMIC) where antibiotics are readily available for consumption. Global disparities in AMR levels can be attributed to various factors. In this study, we have used historical and latest surveys in Europe and Sri Lanka to understand potential socio-economic and cultural drivers of national and regional variations in AMR awareness. Our EU-Sri Lanka comparative study has indicated that the AMR awareness in the selected four regions of Sri Lanka remains relatively low compared to four socio-economically comparable regions in the European countries. Our analysis has also highlighted that improving underlying socio-economic conditions, such as providing better social safety nets, can be crucial to significantly reduce AMR. In addition, implementing targeted interventions to efficiently utilise limited funding in LMIC settings is critical, as large-scale communication programmes are often resource intensive.

Key words: Antimicrobial resistance, awareness, culture, Eurobarometer, science communication, Sri Lanka, socio-economic drivers

INTRODUCTION

Antimicrobial resistance (AMR) is one of the biggest challenges in global public health. Low- and middle-income countries (LMICs) are particularly vulnerable to the threat, which is more than simply an increase in healthcare costs (KPMG LLP 2014; Founou et al 2017; Dadgostar 2019). The rate of AMR in LMICs is generally greater compared with high income countries, even though their per-capita consumption of antibiotics is often lower (Klein et al 2018).

Collignon et al (2018) argue that various socio-economic determinants (e.g., poverty) are the major but often neglected factors driving global disparities in the AMR level in addition to more commonly acknowledged irrational antibiotic use in clinical and agricultural settings. This implies that, not only science and technology, but also social and cultural understanding is urgently needed to combat multifaceted health-related challenges, such as AMR (Charani et al 2022). Yet, present efforts to address AMR fail to consider the complex socio-economic dimensions (Charani et al 2021). Gaysizis et al (2017) claim that socio-economic drivers, cultural values and national characteristics shape cross-national differences in antibiotic use within Europe. Haenssgen et al (2019) also argue that understanding local contexts in terms of response to AMR in LMIC settings is crucial, though, there are relatively limited studies examining these issues empirically.

Higher AMR rates in LMICs can be attributed to factors such as excessive usage of antibiotics in food animal production, since growth promoters in animal feeds is a fairy common practice in many countries that directly contributes to the emergence of AMR (Reverter et al 2020). An intensive and ever industrialised farming activity to meet the growing global food demand leads to the rising consumption of antibiotics without sufficient technical knowledge being transmitted. Together with low standards of biosecurity, hygiene & sanitation, and lax regulations for antibiotic use in the food animal sector have accelerated the emergence of antibiotic resistance (Goutard et al 2017).

Lack of knowledge and awareness of AMR can result in irrational use of antibiotics, which is one of the major drivers of the prevalence of AMR (Tangcharoensathien 2021). However, socio-economic conditions of AMR (e.g., food security, poverty alleviation, healthcare access, culture) tend to be neglected in typical awareness raising communication campaigns (Kakkar et al. 2018; Collingnon, Beggs 2019). Borg (2012) suggests that knowledge can improve behaviour and thus potentially decrease the cultural influence on antibiotic use. Thus, understanding antibiotic consumption patterns over time and across countries could well inform policies to minimise AMR rates (Klein et al 2018). There is evidence that public communication campaigns promoting responsible antibiotic use have contributed to a

decrease in antibiotic consumption, particularly in Europe, however, other key global hot spots (e.g., many developing Asian countries except Thailand) have not yet delivered similar effective interventions. For example, Sri Lanka has developed multiple AMR programmes and strategic plans, though, communication efforts have often been randomly initiated by mainly healthcare organisations, and highly restricted to one-off events as well as promotion of sensible medicine uses (Godinho et al 2017).

Sri Lanka's health department recognises the higher incidence of AMR in Sri Lanka compared with other regions such as the European Union. There is, however, currently lack of data on practices and beliefs among the diverse communities in relation to the development and spread of AMR within Sri Lanka, prompting urgent calls for further research (Liyanapathirana and Thevanesam 2016). This chapter, therefore, explores how local contexts as well as cultural perspectives related to community understanding of AMR by conducting a comparative study of AMR awareness based on the survey analysis in diverse settings, i.e., Sri Lanka and the European Union. Such an in-depth analysis may facilitate culturally-informed community engagement initiatives to be formulated by creating trust from local communities, which could lead to an increased uptake of AMR related communication campaigns, hence potentially positive health outcomes.

METHODOLOGY

We have analysed the existing EU Eurobarometer (EB) data sets with the focus on AMR as well as newly acquired household survey data in Sri Lanka to better understand key socio-economic drivers that could potentially influence the antibiotic consumption behaviour. We have reviewed the survey findings in terms of local conditions from social scientific perspectives (e..g, urban/rural, affluent/poor, other household characteristics etc). We have compared the Sri Lankan and EU cases in order to enhance our understanding on the regional variation in AMR awareness, which will enable us to identify priority areas to address in effective AMR communication activities.

DATABASE

We have used several waves of EU EB survey data from 1989 to 2018[1], as well as the household data collected in Sri Lanka during December 2020 and January 2021. In this study, we rely on secondary analysis of several EU EB surveys, which contain one or several items on AMR awareness. We found questions related to AMR and general science attitudes in five EU EB surveys in 1989, 1992, 2001, 2002, and 2005. These surveys are part of an integrated database on 'science culture' and allows for time-series analysis. Additionally, there are four more recent EB surveys on the specific topic of AMR, in 2009, 2013, 2016 and 2018. Hence, we have examined nine EB surveys in total for our analysis.

The household survey conducted in Sri Lanka is much more comprehensive compared with the EU EB surveys and contains the following eight sections that are selected as important AMR determinants during the literature review on AMR[2]: 1) introduction, informed consent, and screeners (WHO 2015); 2) infrastructure facility access (Collingnon, Beggs 2019); 3) general 'science' culture (Bauer et al 2012); 4) AMR perceptions (WHO 2015; EB AMR survey 2018); 5) culture & attitude (Touboul-Lundgren et al 2015; Gayzisiz et al 2017; Thillekeratne et al 2017; Krockow, Tarrant 2019); 6) livestock/aquaculture/agriculture activity (Brunton et al 2019; Bokma et al 2018); 7) AMR knowledge (WHO 2015; EB AMR Survey 2018); 8) socio-demographic information (WHO 2015).

KEY INDICATORS OF AMR AWARENESS

We are using two basic indicators related to public perceptions of AMR:

- **AMR awareness** is measured by a correct assessment of the survey question 'antibiotics kills viruses?'[3]. Respondents have to express that this statement is 'false'

[1] Eurobarometer is the survey instrument of the European Commission; several times per year 1000 nationally representative respondents in all EU countries, and also candidate countries [total N>30,000, 248 regions], are asked about various issues related to EU policy making. While the core of these questions mostly relates to issues of EU integration, surveys also carry one or several specific topics such as AMR.

[2] The survey questionnaire can be accessed upon request

[3] in some years we have a version 'antibiotics kills viruses as well as bacteria'

to score a correct answer. We take the percentage of correct answers as an index of AMR awareness.

- **AMR confidence** is measured by the percentages of 'don't know' (DK) responses to the above question. The less DK responses there are, the more confident respondents are with the language and the topic of antibiotics; they are happy to answer the antibiotics question either correctly or incorrectly. There is an independent element of attitude indicated by 'confidence' as respondents can confidently give the wrong answer.

We also consider further indicators of general science culture rather than the ones specific to AMR. Finally, we analyse the impacts of socio-demographic variables (such as age, level of education, income, and gender) on AMR awareness.

CASE STUDIES

We have selected the following four comparative matching regions based on typical livelihood sources available from Sri Lanka and the EU (See Table 1, Figure 1 and Appendix A1).

EU regions	Sri Lankan regions
Mazowieckie Poland leading livestock area, specially poultry but also dairy	**Dompe** urban high-density area, poultry & dairy
North East Italy (Nord-Est Italy) clam farming & textile manufacturing	**Polgahawela** urban aquaculture, rubber & garment
North Sweden (Övre Norrland Sweden) remote and rural area with only indigenous community in Europe	**Hambegamuwa** remote and rural community with no organised livestock farms

Central Greece (Sterea Ellada Evia Greece)	**Kalpitiya**
rural fishing community, kitesurfing tourism, aquaculture	rural fishing community, kitesurfing, tourism, aquaculture

Table 1: The matching regions in Sri Lanka and the EU

Figure 1. Map of the selected four regions in Sri Lanka

FINDINGS: SRI LANKA – EU COMPARISON

The EU EB data shows that, by 2018, AMR awareness, measured by correctly answering the 'antibiotics kills virus' question, reaches 40% of the surveyed EU population. The minimum awareness level has steadily doubled from below 10% to over 20% between 1989 and 2018. The level of AMR awareness varies hugely within Europe, e.g., 23% in Greece and 72% in Sweden. Our second indicator of respondents' confidence with the topic of antibiotics, the DK responses, shows a clear trend overall. The average confidence level is declining from 20%

in 1989 to below 10% by 2018 in the EU, while the maximum confidence level declines from 37% to 17% in the same period. Clearly, Europeans became more confident of venturing an opinion on antibiotics when being asked, whether rightly or wrongly. Overall AMR awareness is increasing across Europe in the 1990s, it has since stabilised and in some places declined again. The ceiling of AMR awareness in Europe is between 70% and 80% and remains stable since the early 2000s.

Table 2 shows the baseline figures for the four matching regions in Sri Lanka and the EU. The EU regions tend to show higher AMR awareness (41%) compared to the Sri Lankan regions (16%), while the Sri Lankan region of Kalpitiya is at the similar level as Greece as a whole (22%). The level of inconfidence to talk about the topic of AMR remains much higher in Sri Lanka (22%) than it is across Europe (9%); in Kalpitiya this reaches 41%. Sri Lankans appear to remain less confident to engage in a conversation about AMR when asked in a survey context. This is however not the case in the region of Polgahawela, where the level of DK-responses is very low (1%). However, we should note that the correct response in Polgahawela was also very low (14%), in fact, lower than the national average of 16%.

Within different regions of Sri Lanka, there is a significant variation in AMR awareness; 22% of respondents in Kalpitiya provided a correct answer for antibiotics awareness, whereas only 9% in Hambegamuwa. Our survey shows an interesting trend between two groups of regions, one group with the higher AMR awareness and lower confidence than the national average of Sri Lanka (Kalpitiya & Dompe) while the other group with the complete opposite results (Hambegamuwa & Polgahawela). It is worth investigating the reasons behind this and we will address them in the later section.

	Correct	DK
EU27	**0.41**	**0.09**
Central Greece	0.31	0.03
Greece	0.23	0.05
North-East Italy	0.31	0.03
Italy	0.3	0.07
Mazowiecke	0.44	0.07
Poland	0.41	0.13
North Sweden	0.67	0.07
Sweden	0.72	0.05
Sri Lanka	**0.16**	**0.22**
Dompe	0.20	0.29
Hambegamuwa	0.09	0.19
Kalpitiya	0.22	0.41
Polgahawela	0.14	0.01

Table 1 Baselines for AMR awareness in Sri Lanka and the EU as a % of the respondents providing a correct answer to the survey question 'antibiotics kills viruses? *("Correct") and "DK" (don't know). Data Source: Eurobarometer 2018 & Sri Lanka Household Survey 2020/21*

AMR Awareness Over Time In The EU Regions

With the time-series data of EU EB from 1989 to 2018, we have examined the trends of our four EU regions in relation to the trends in the countries overall. There is little surprise in this. All regions behave in the same way as the country overall. Italy, Greece and Poland exhibit a general increase in AMR awareness; while in Sweden, where AMR awareness is generally higher than other countries, we surprisingly find a decline. This prompts us to assume that there could be a threshold peak level that might be difficult to go beyond. Figure 2 shows these trends as fitted lines for both the region and the country in each figure. It appears that in all regions, the national trend is slightly more accentuated in the region under consideration, e.g. when AMR awareness is increasing in Greece between 1989 and 2018 from below to above 20% of the surveyed population, this trend is slightly stronger for the region we selected in our study (Central Greece); and such patterns are also observed in all the other regions.

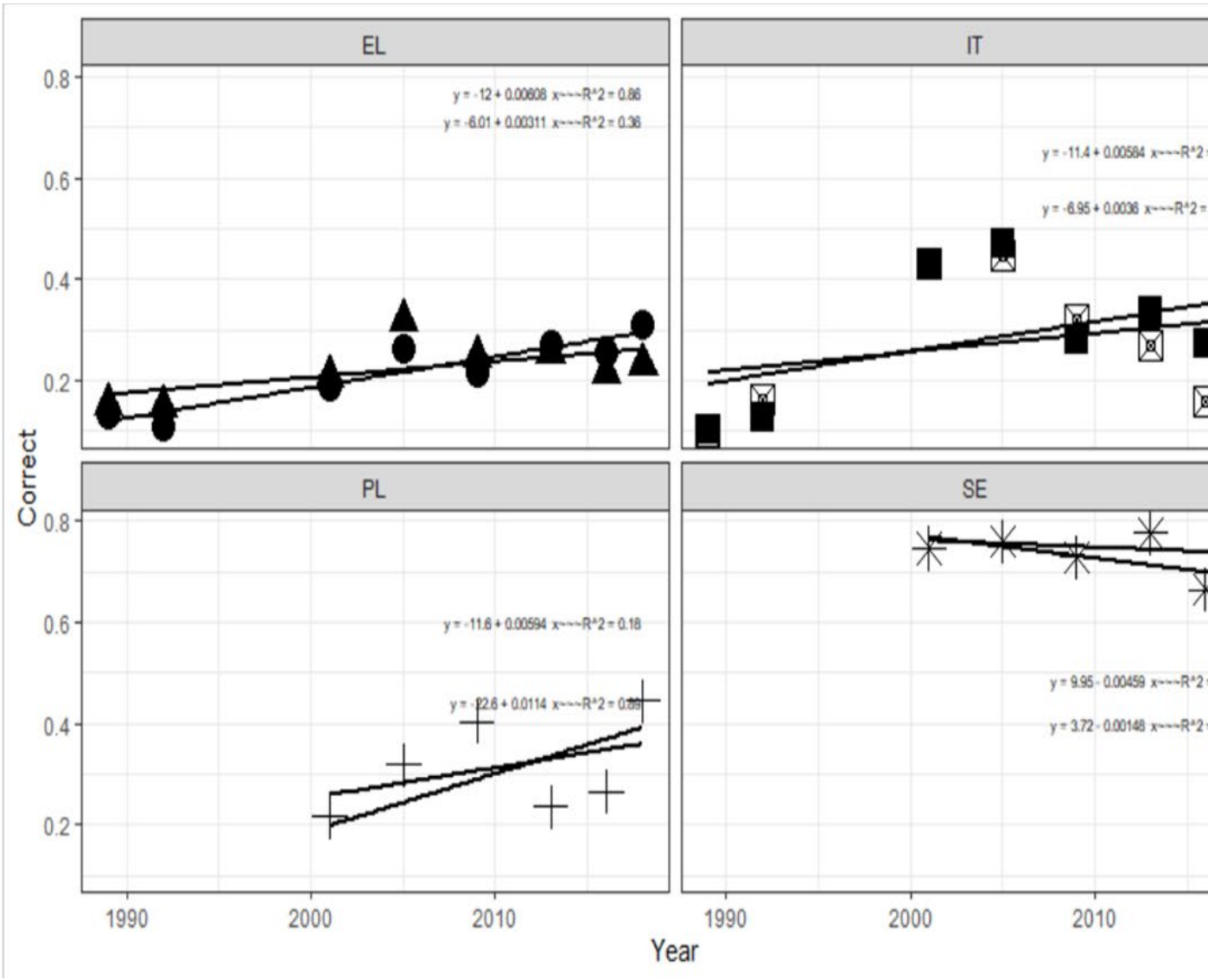


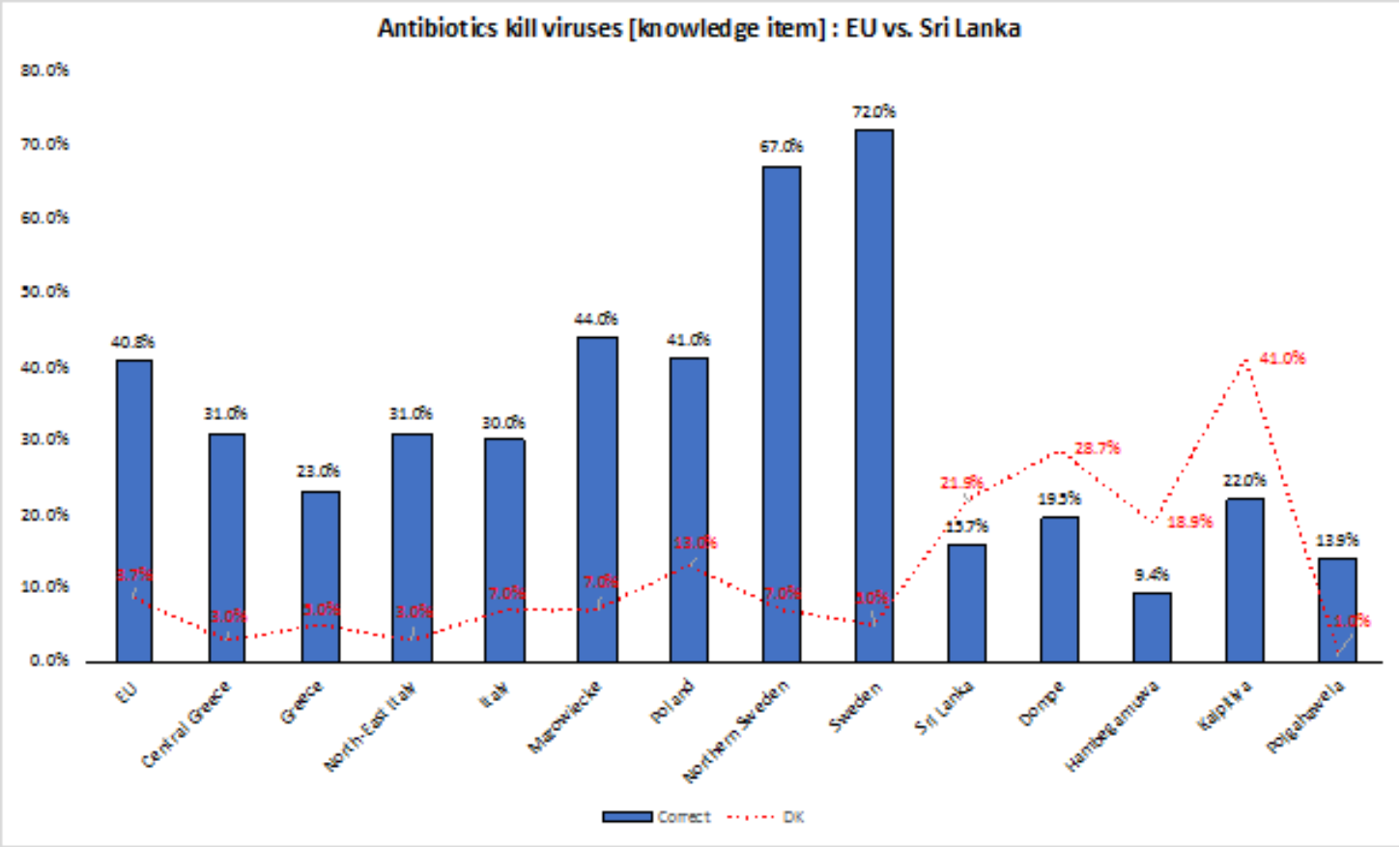
Figure 2. Trend lines in AMR awareness in different EU regions and the countries in 1989-2018. EL (Greece), IT (Italy), PL (Poland), SE (Sweden). The Y-axis shows the proportion of the surveyed population with AMR knowledge, which is between 0 and 1 (0-100%). Data Source: Eurobarometer 1989-2018

We have no similar historical data for Sri Lanka, but we can compare the EU EB 2018 and Sri Lanka 2020/21 household survey data, to take the most recent years for a comparison.

When we further investigate the four matching regions between Sri Lanka and the EU, we observe an interesting trend as seen in Figure 3. Both Culture 1 (urban region with highly active livestock sector) and Culture 4 (rural region with highly active aquaculture sector)

indicate higher antibiotic awareness than their national average, which might be due to the fact that the respondents in these regions are more exposed to antibiotics in their daily life as many of them could be involved in livestock or aquaculture farming. Culture 2 (urban region with active aquaculture sector) indicates higher confidence level when answering about antibiotics but possesses a similar antibiotic awareness level to their national average. This result might imply that the residents in these regions may be relatively familiar with antibiotics and confident to talk about antibiotics. Culture 3 (remote and rural regions) demonstrates lower antibiotic awareness as well as a lower confidence level in terms of expressing their understanding of antibiotics than their national average. Based on this, we could hypothesise that remote rural communities may have less access to health information.

(a)



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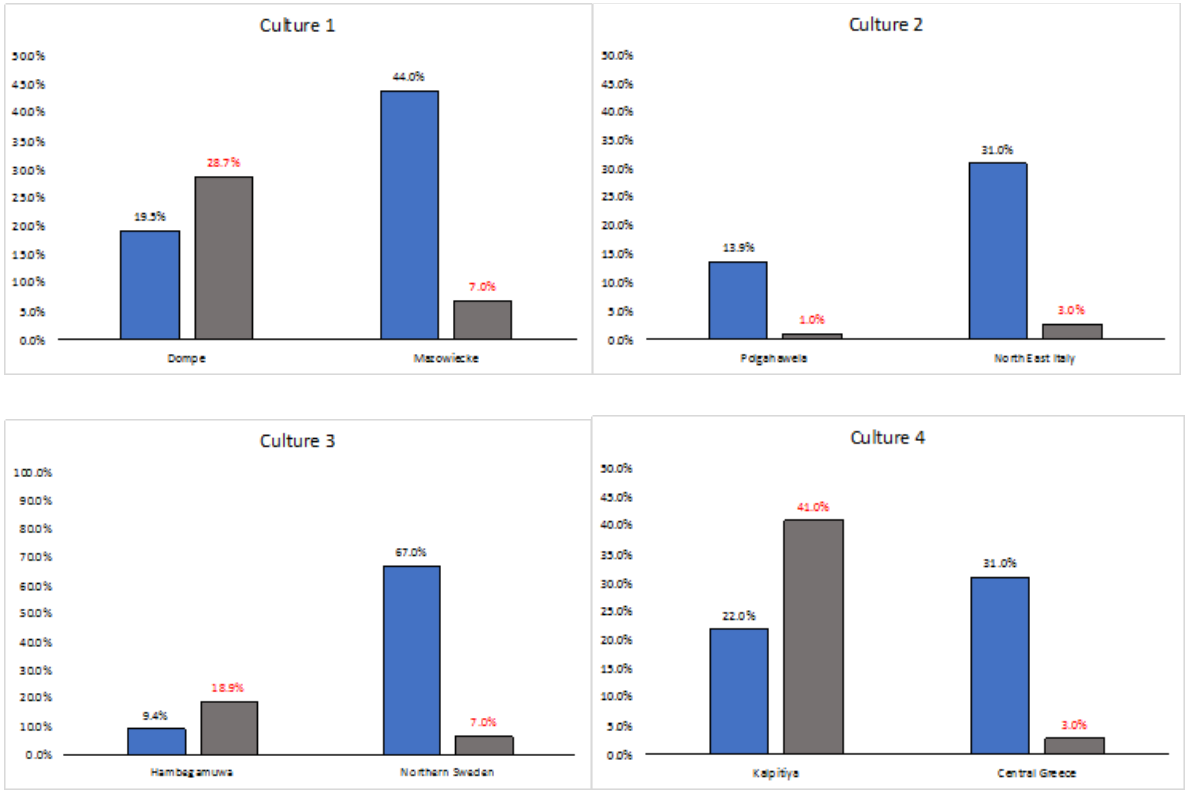


Figure 3. AMR awareness: Sri Lanka - EU comparison (a): Antibiotics awareness in the EU and Sri Lanka: The Y-axis shows the percentage of the respondents who answered correctly that are represented in blue histogram and DK ('don't know') in red line, (b): Antibiotic awareness in Sri Lanka among different culture groups (culture 1: urban region with highly active livestock sector, culture 2: urban region with active aquaculture sector, culture 3: remote and rural regions, culture 4: rural region with highly active aquaculture sector)

Structural drivers of AMR awareness across the four regions of Sri Lanka and Europe

In the last step of our analysis, we have assessed how AMR awareness is distributed in social space across the four regions of Sri Lanka and Europe by showing how much socio-demographic variables are associated with AMR awareness. In the first instance we have simply used bi-variate associations as criterion[4]. Table 2 below illustrates the significant associations of AMR awareness with education, gender, age, type of occupation and social class.

[4] Contingency coefficient derived from Chi^2 distribution

Table 2 depicts that, AMR awareness is socially structured at the country level in Europe: the more educated, the older and the better situated in social class have generally higher awareness of antibiotics; in Sweden the data seems to indicate a gender gap in addition. This general pattern is in line with the findings from some of the previous studies (e.g., Waaseth et al 2019). Our results also confirm the findings of the *WHO Antibiotics Awareness Survey 2015* - the less awareness is found in the rural populations compared to their urban counterparts.

Such findings are less clear in the regional analysis (see Table 2), in part due to smaller sample sizes where the relationships are no longer statistically detectable. However, education remains a key potential drivers for improving AMR awareness in Central Greece, Northern Sweden, Polgahawla, Dompe and Hambegamuwa; while in Kalpitiya, Northern Italy and Central Poland (Mazowiecke), education appears to make little difference for AMR awareness. Older age may contribute to raise AMR awareness in Central Greece and Kalpitiya, while a gender gap seems to exist in Hambegamuwa.

EU countries [baselines]	Greece	Italy	Poland	Sweden
Education [lo to hi]	0.18	0.10	0.16	0.22
Gender [male-female]				0.14
Age [young to old]	0.09	0.12	0.13	
Occupation - Last job	0.16		0.24	
Social class [lo to hi]	0.14	0.13	0.19	0.12
AMR awareness [correct] - %	0.23	0.3	0.41	0.72
AMR awareness [DK] - %	0.05	0.07	0.07	0.07

European regions	Central Greece	North East Italy	Mazowiecke	Northern Sweden
Education	0.22			0.17
Gender				
Age	0.21			
Occupation - Last job	0.34			
Social class				
AMR awareness [correct] - %	0.31	0.31	0.44	0.67
AMR awareness [DK] - %	0.03	0.03	0.07	0.07

Sri Lanka regions	Kalpitiya	Polgahawela	Dompe	Hambegamuwa
Education		0.30	0.40	0.33
Gender				0.17
Age	0.32			
Occupation - Last job			0.29	
Social class				
AMR awareness [correct] - %	0.22	0.14	0.20	0.09
AMR awareness [DK] - %	0.41	0.01	0.29	0.19

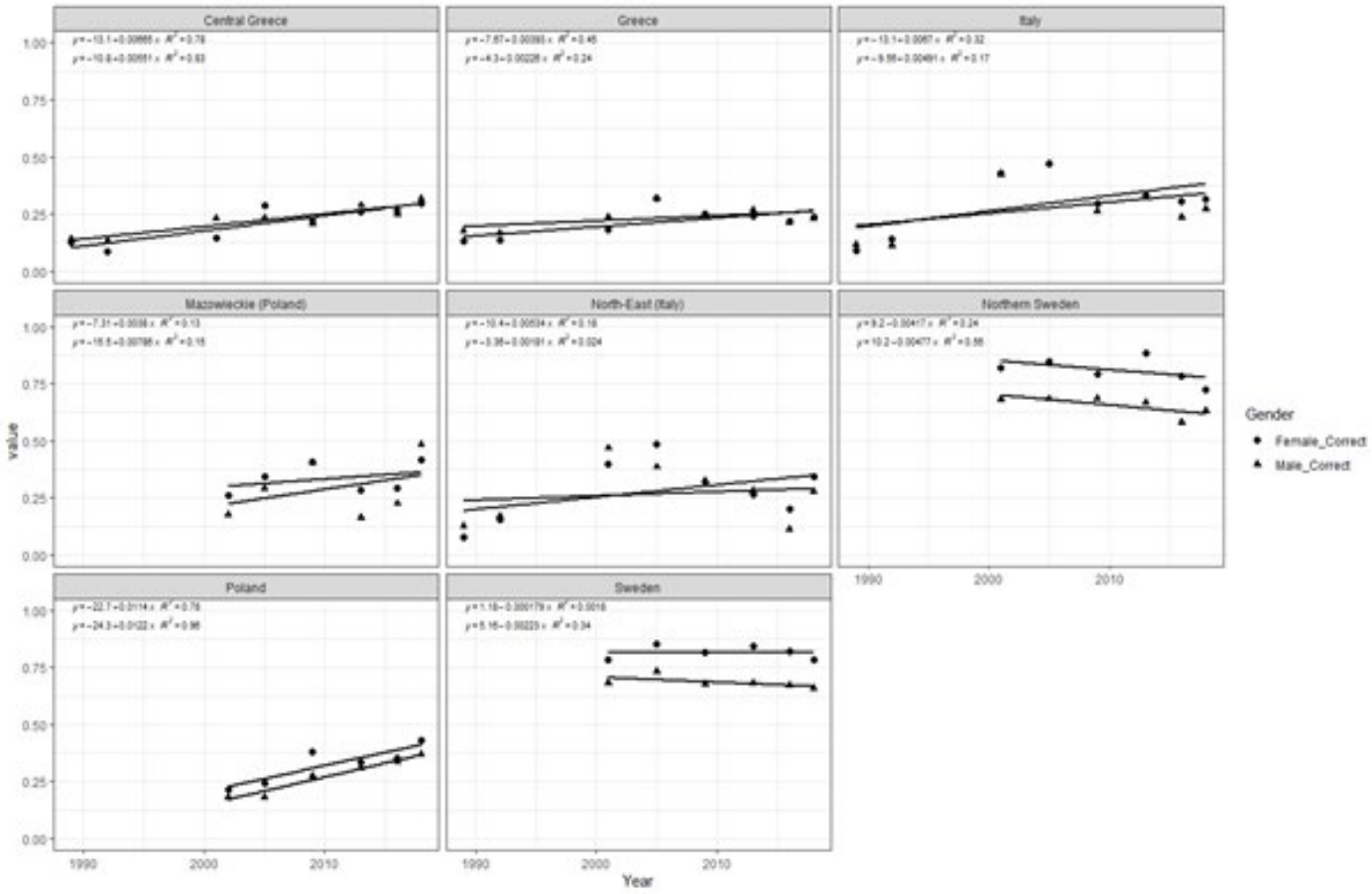
Table 2: Associations between AMR awareness and various socio-demographic variables and the level of AMR awareness in the countries and regions. The AMR awareness is expressed as a % of the surveyed population providing the correct answers, while the AMR confidence as a % of the surveyed population stating DK ('don't know'). Source of data: EB 2018 and Sri Lanka Household Survey 2020/21

Figure 5 (a) shows the trends in AMR awareness by gender in Europe in 1989-2018 : i) awareness is generally rising among men and women between 1989 and 2018; ii) this is however not the case in Sweden, where the trend is declining from a much higher level than elsewhere; iii) there is little evidence for a consistent gender gap in AMR awareness over time, except in Sweden, where women are generally more aware of AMR, and this trend persists over the years.

Figure 5 (b) depicts the trends in AMR awareness by the level of education in 1989-2018: i) citizens with primary education show little changes in AMR awareness in Greece; their awareness increases in Italy and Poland; in Sweden there is a decrease from a higher level; ii) the education gap seems to widen in Greece, while remaining stable in all other regions; iii) citizens with secondary and tertiary education increase their AMR awareness in all regions, except in Sweden and Italy; iv) a curious reversal of AMR awareness among higher and lower educated respondents in Northern Italy - those higher educated with lower AMR awareness, while those lower educated with higher AMR awareness. This indicates that as if staying in education longer might not mean sufficient levels of AMR awareness training would be provided in this region. Moreover, primary school education might be the best place to offer AMR awareness improvement interventions, according to the data from Poland's Mazowiecki region.

Figure 5 (c) offers a relevant observation across Europe on antibiotics awareness concerns among different generational cohorts. While AMR awareness is increasing overall in the most of European countries, it diverges if we compare age cohorts across the different surveys in 1989 - 2005: AMR awareness peaks among the Baby boom generation in some countries, whereas there is a linear trend with growing awareness across the generations in others. An earlier peak of AMR awareness for Baby boomer generations, which declines towards the 'new order' born after 1977, can be found in several countries including Sweden, Hungary and Poland, according to the EU EB integrated data 1989-2005. It appears that AMR awareness is at a greater risk among the younger generations, as they lack the historical experience of 'deadly infections' and the collective memory of the antibiotics breakthrough that was achieved with Alexander Fleming's Penicillin during and after the World War II.

(a)


Central Greece
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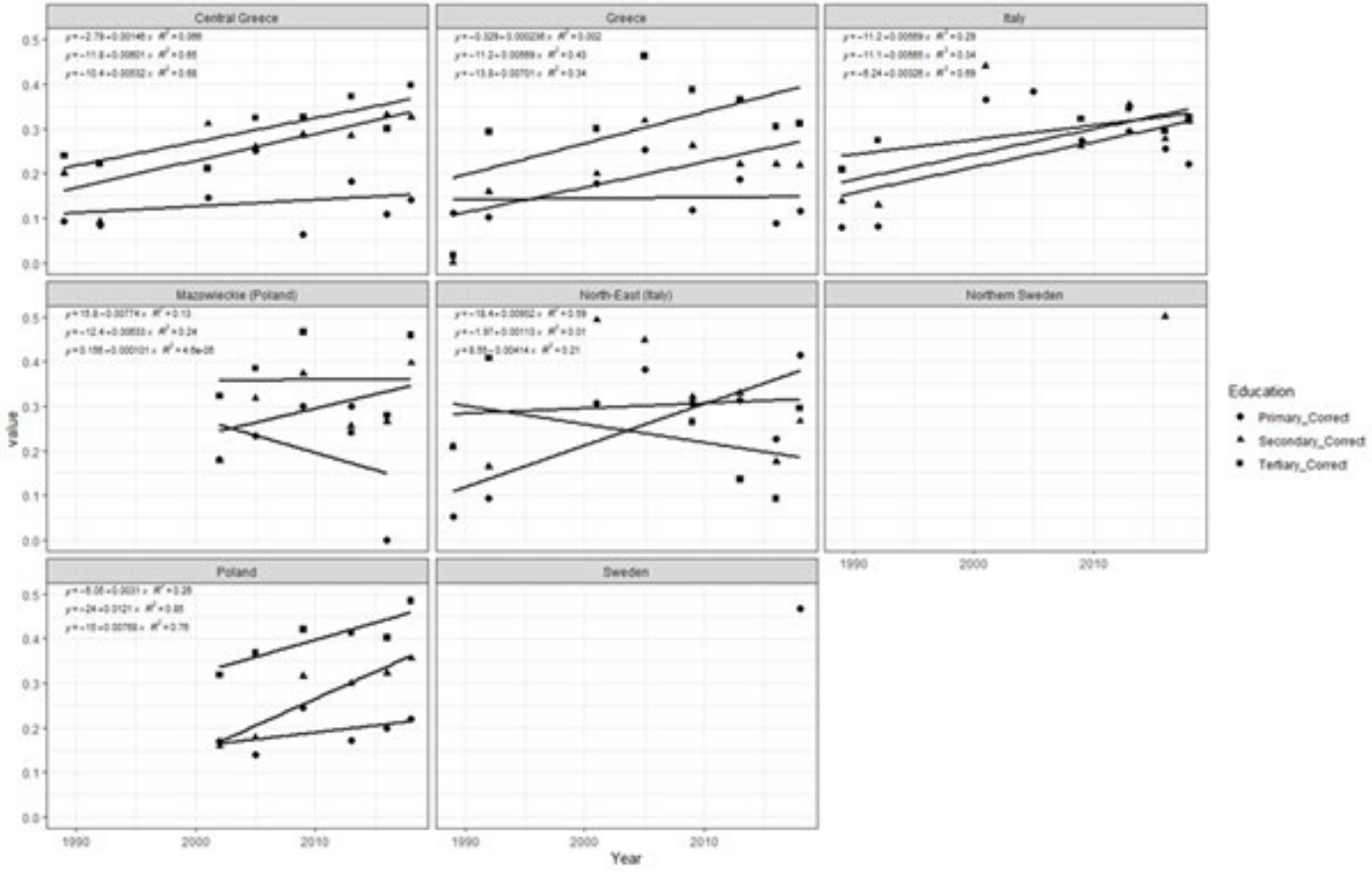
(b)



(c)

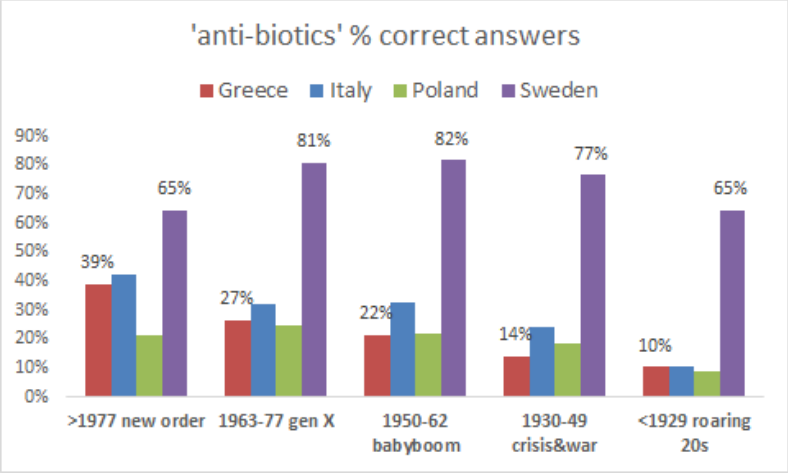


Figure 5 (a) European AMR awareness trends by gender in 1989-2018 expressed as a proportion of correct answers. (b) European AMR awareness trends by the level of education in 1989-2018 expressed as a proportion of correct answers. (c) AMR awareness by generation expressed as a percentage of correct answers [only EU-4, 1989-2005]. Data source: Eurobarometer 1989-2018

Science Culture Distance and Awareness

To examine how wider 'cultural context' might influence AMR awareness, we have included a series of other questions related to everyday life of respondents in our Sri Lankan household survey[5]. Our analysis shows that in Hambegamuwa, which has the lowest level of AMR awareness, the responses on AMR are mostly structured by co-variates; 30 other items show a statistical association (see Appendix A2)[6]. We consider six sets of structural variables which have variable associations with AMR awareness in Sri Lanka: socio-demographic characteristics, politics, business related activities, medical culture, traditional mentality and science culture.

An interest in politics is strongly related to AMR awareness in three regions in Sri Lanka (Dompe, Hambegamuwa, Polgahawela), but not in Kalpitiya. Business related concerns are strongly related to AMR awareness in Hambegamuwa; while in Kalpitiya and Polgahawela, AMR relates to regaining normality and keep working to earn daily wages. This does not seem to be relevant in Dompe as much. This could be explained by the fact that Dompe tends to have achieved a greater economic and social development with higher education and income levels compared with the other three regions. Household hygiene factors (water supply, waste disposal, toilet type etc) are related to AMR awareness across all regions, however mostly so in Hambegamuwa, a remote isolated area. Distance to health care centre seems to make a difference in Dompe and Polgahawela, where water supply, toilet types and an ability to pay a doctor also appear to affect AMR awareness. These findings emphasise the significance of underlying key socio-economic drivers that potentially influence AMR awareness.

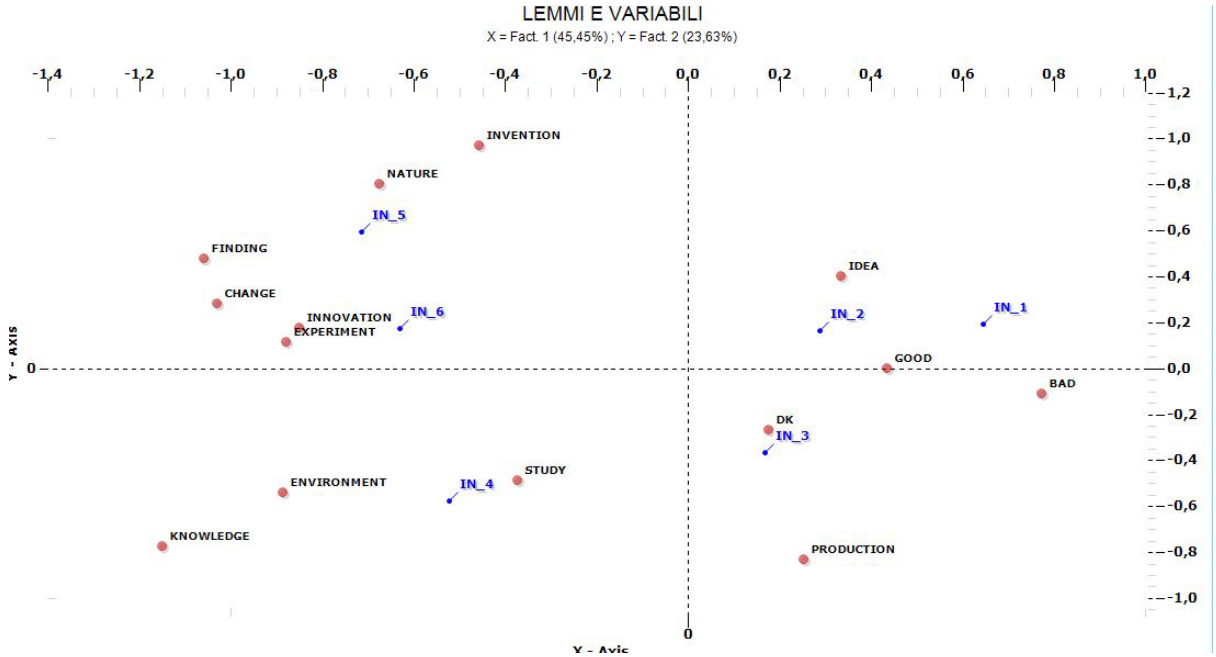
In terms of science culture, there seem to be noticeable differences among the regions in Sri Lanka. In Polgahawela, AMR awareness is related to engagement with science in terms of being interested and taking part in science-related events. AMR is also associated with consulting horoscopes, natural healing powers as well as taking a 'wait and see' attitude. In Kalpitiya, AMR awareness is a matter of believing in the positive power of science to improve

[5] The EU EB does not include this theme.
[6] measured by coefficient of association

lives, sort out problems and to avoid harms. In Hambegamuwa, AMR awareness is linked to technocratic beliefs that science can explain all things, has no limits and one has little option but to trust those who govern science. Here we also find an interest in horoscopes and natural healing powers. General scientific knowledge appears to be related to AMR awareness in all four regions. In Dompe, harbouring suspicions about science affects AMR awareness; some people perceive no importance for science in everyday life or see things changing too fast.

A second cultural index is the science culture, i.e., the everyday meaning of the word 'science'. Our survey respondents answered to a question 'what does science mean for you?' with a series of free associations which we analysed by their collocations. These collocations, frequently mentioned terms that go together, can be mapped into background variables such as region, income and education. In this way we can show that the meaning of science in Sri Lanka depends on the region. In Dompe, science is differentiated by terms such as environment, experiment, study and findings. For respondents in Hambegamuwa, science is simply a matter of being either good or bad, or both. Finally, in Kalpitiya and Polgahawela, the word 'science' has little meaning and the most characteristic answer is 'I don't really know'.

If we split responses to 'what is science for you' by level of income, we find a clear picture. On the left quadrants in Figure 6 are those with 'higher income levels': science is many different things such as study, invention, innovation, nature, findings, change, experiments, environment, or knowledge. On the right quadrants in Figure 6 are those with 'lower income levels': for these Sri Lankans science means simply DK, ideas, good or bad things, and the production of goods.



IN_1 = Below 10,000 Rs (US$54)
IN_2 = 10,000 (US$54) -19,000 Rs (US$ 103)
IN_3 = 20,000 (US$108) - 29,000 Rs (US$157)
IN_4 = 30,000 (US$162) - 39,000 Rs(US$211)
IN_5 = 4 0,000 (US$216) - 49,000 Rs (US$ 265)
IN_6 = Over 50,000 Rs (US$270)

Figure 6 the meaning map of 'science' in Sri Lanka by level of income

CONCLUSION

This chapter has shown that the AMR awareness in four regions of Sri Lanka remains relatively low compared to four socio-economically comparable regions in the European countries. However, Sri Lanka could potentially increase the AMR awareness significantly using high impact communication activities as demonstrated by the European experience in the last decades. Our analysis has also highlighted that improving underlying socio-economic conditions, such as providing better social safety nets, could be crucial to significantly reduce AMR. Moreover, implementing targeted interventions in order to efficiently utilise limited funding in LMIC settings is critical, as large-scale communication programmes are generally resource intensive. Our EU-Sri Lanka comparative study has highlighted the importance of contextualisation in AMR awareness raising activities by presenting possible socio-economic and cultural drivers of national and regional variations in AMR awareness.

According to our survey analysis, female and older population groups tend to possess greater knowledge on AMR compared with their respective counterparts, which confirms the results from other studies (e.g., Waaseth et al 2019). Jimah et al (2020) further claim that prudent antibiotic use was observed more widely among women as opposed to men, therefore we may be able to hypothesise this specific 'knowledge-behaviour' pathway. Our finding, hence, calls for enhanced action plans to increase the antibiotic knowledge level with a particular focus on specific interest groups (e.g., gender/youth targeted initiatives, integrate into primary school curriculum or poverty alleviation strategies of marginalised households) as well as geographical areas (e.g., a targeted approach to rural areas with less access to WASH (water, sanitation, hygiene) and healthcare facilities) for successful as well as cost effective interventions. This study also highlights the role of structural determinants in antibiotic consumption behaviour. For example, self-medication and overuse of antibiotics may only be the symptom of a larger problem of precarious living conditions and lacking social support. Locally specific conceptions, belief, and practices around antibiotics could also dampen communication efforts. Therefore, any awareness enhancement interventions should address context-specific drivers of antibiotic consumption in a culturally relevant way (Haenssgen et al 2019). The use of effective communication tools adapted to the preferences of the target population, including visual aids and interactive campaigns, in raising antibiotic awareness and positive behavioural change advocating activities should also be promoted (Cambaco et al (2020)). For instance, we can learn from how climate change message was successfully transmitted via engagement with youth and wider audience through media (e.g., films) and social activism.

Furthermore, our research has demonstrated that there seem to be clear differences between the regions within Sri Lanka in terms of science culture, which might indicate the needs for contextualisation of locally adjusted public health communication programmes. In LMICs, control of antibiotic usage along with development of new drugs have been the key priority initiatives, though, spread of resistant bugs due to a broader set of socio-economic as well as cultural determinants, is likely the dominant factor affecting the prevalence of higher levels of AMR (Collignon, Beggs 2019). This implies that blanket approach to AMR

communication will be ineffective or even wasteful if not context appropriate (Charoenboon et al 2019). Moreover, focusing on public engagement rather than education is essential, as science communication has evolved from "knowledge deficit to dialogue" (Leshner, 2003; Retzbach, Maier, 2014). Public engagements are important to obtain comprehensive understanding of the communities. For example, widespread conception about antibiotics as a 'quick fix' or 'magic solution', implies that patients often demand and expect to obtain antibiotics (Tillekeratne et al., 2017). Although education and awareness raising campaigns are a standard component of global policy approaches to influence AMR behaviour, our current knowledge on their relevance, impact, and side-effects is inadequate to build a knowledge base of cost-effective, target group specific, and locally appropriate activities (Charoenboon et al 2019). Science communication may further exacerbate inequalities by giving systematic disadvantages to marginalised groups during the production and transmission of the communication (Dawson, 2018). According to Bull et al (2010), AMR communication activities are prone to yielding heterogeneous and potentially problematic interpretations among the target population, therefore, understanding target group heterogeneity and contextual factors can effectively shape the outcomes of public engagement. Paying adequate attention to those crucial socio-economic factors and establishing collaborative public engagement could be the key for impactful AMR communication campaigns.

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Appendix

A1: Matching regions in Sri Lanka and EU

Mazowieckie Poland:

Mazowieckie is located in central Poland and its largest city is the capital Warsaw. The total area is 35,558 km^2 with the population of 5.37 million. Mazowieckie is one of the largest regions in livestock production, especially poultry and swine (approx. 1 million herds each in 2016 Eurostat data). Large number of dairy producers are located in Mazowieckie (Milk Market, October 2018, Institute of Rural Economics). Mazowieckie is also a leading region in producing cereal and potato, while the region also holds paper & board production as well as pharmaceutical industry (BIC country report: Poland 2016 BIC%20Country%20Report%20Poland.pdf)

North-East Italy:

The total area is 62,310km2 with the population of 11,660,998 (Eurostat 2019). Shellfish culture, mainly mussels, clam and, recently, oyster farming, is a well-established activity in this area that is one of the most important sites in Europe. Mussel farms were located in the northern Adriatic Sea, along the coastline of the Emilia-Romagna region nearby the River Po Delta. The total annual production of mussels in the Sacca di Goro lagoon is about 10,000 tonnes, which covers about 50% of the regional production. Mussel farming is locally characterized by a complex system, where ancient traditions have survived for a long time together with modern and efficient farming techniques. The transformation process towards farming practices that has made it possible to overcome the artisanal character of this activity took place with the introduction, in the second half of the 1980s, of the suspended long-lines, the most diffused mussel farming system in Italy and all around the world (Tamburini et al 2020). Tamburini et al 2020, “Sustainability of Mussel (Mytilus Galloprovincialis) Farming in the Po River Delta, Northern Italy, Based on a Life Cycle Assessment Approach” Sustainability 2020, 12, 3814

Ovre Norrland Sweden:

Övre Norrland or Upper Norrland makes up one third of the total national territory of Sweden with an overall area of more than 154,000 km² with the population of 520,651 (Eurostat 2019). Upper Norrland has contrasting landscapes including plains where the biggest urban centres are located, sand archipelagos by the coasts, rocks, mires and hills in the interior, and mountain areas and glaciers in the west. Upper Norrland is also home to a considerable number of natural reserves, bird sanctuaries and national parks. Upper Norrland is a multi-cultural and multi-lingual area where indigenous communities inhabit. The main economic activities in the region includes mining natural resources, woods, fish, pastures for reindeer and animal husbandry. The region also hosts numerous and hugely diverse research and innovation institutions from medical science to aerospace.

Evia Greece:

Central Greece is one of the least populous geographical regions of Greece and the second largest in total area of the country with the area of 15,549 km², 2nd largest in Greece in total area and permanent population of 547,390 inhabitants (5% of the total population). Agricultural and livestock production is a key source of income and employment, Evia covering 22.73% of the agricultural land. There is a large concentration of fishery & aquaculture as well as island tourism including kitesurfing in the region. About 34% of the total domestic aquaculture fish is produced in this region, in which 80% of this production is exported. Evia is the second largest island in Greece. There is also a sizeable export-oriented manufacturing sector, such as metals, chemicals, plastics and processed food. Enterprise Greece (https://www.enterprisegreece.gov.gr/images/public/pdf-files/synergassia/Synergasia_2016_Profile_Central_Greece.pdf)

Dompe

Dompe is a small town in Gampaha district covering 176.0 km² in area. It has approximately 54,005 Population with 875.0 persons /km² Population Density (Census 2012. Gampaha is near Colombo, the commercial capital of Sri Lanka. This proximity has given Gampaha district a higher economic and social development with higher education and income levels. Nevertheless, there are pockets of sub regions like Dope, that are still relatively remote.

Polgahawela

This is a small town in Kurunegala district with 65,156 Population; 95.00 km² in area and 685.9persons /km² population density (Census 2012). In Kurunagala district, mostly people depend on agriculture-related employment while considerable percentage depend on services and industry related livelihoods.

Hambegamuwa

This is a small town in Monaragala district, one of the poorest areas in Sri Lanka. Hambegamuwa has approximately 26,683 Population in 633.0 km² area with population density of 42.15 persons/km² (Census 2012). Hambegamuwa is close to forest reserves and human-wildlife conflicts are a frequent battle for residents. Monaragala is mainly an agricultural district with many smallholder farmers. Livestock and poultry industry is popular in most parts of Monaragala district.

Kalpitiya

Kalpitiya is a small town, in Puttalam district with 86,405 population in 167.0 km² in area and population density of 517.4 persons/km² (Census 2012). Kalpitiya peninsula is located in the north-west coast of Sri Lanka and it is bordered by the Indian Ocean from the west, and Puttalam lagoon from the east. Main livelihood in Kalpititya is fishing while agriculture, aquaculture and tourism are increasingly adopted by the villages as secondary income sources. There are considerable number of people migrate to Kalpitiya from neighbouring areas for fishing.

Specific of Sri Lanka database					
variable name	Dompe	Hambegamuwa	Kalpitiya	Polgahawela	active
Healthcare distance	0.34			0.28	2
Water supply		0.30		0.39	2
Sufficient water quantity		0.17			1
Food shortage		0.26			1
Able to pay doctor		0.26		0.31	2
Type of toilet		0.27		0.34	2
Hygiene facility in household		0.19	0.26		2
Waste disposal		0.34			1
Covid financial assistance	0.22				1
Politics [INT]	0.36	0.28		0.25	3
New inventions [INT]	0.26	0.24	0.27		3
Arts&Litterature [INT]				0.24	1
Read articles on science [ENG]		0.27		0.37	2
Talk about S&T [ENG]				0.38	1
Attend meetings S&T [ENG]				0.42	1
Petitions&Demonstrations [ENG]				0.39	1
S&T sort out problems [Myth]			0.35		1
S&T life improving [Promise]			0.29		1
Inventions avoid harm [Myth]			0.28		1
Science will explain [Myth]		0.41			1
No limits [Myths]		0.27		0.31	2
Trust those who govern [TTOL]		0.28			1
Science is not important [Reserve]	0.37				1
Horoscope: reading		0.25		0.29	2
Horoscope: how frequently				0.32	1
Horoscope: how serious	0.30				1
Too little faith [Reserve]		0.33			1
Science changes too fast [Reserve]	0.34				1
Natural healing power		0.28		0.37	2
Illness is a natural prenomenon			0.30		1
Wait & see attitude				0.43	1
Vaccination up to date		0.27			1
Giving leftovers to someone else	0.32	0.30			2
Test before taking		0.32			1
AB-When stop taking		0.27			1
Source of information	0.59		0.50		2
Change views			0.55	0.35	2
Future use			0.40		1
Trust in doctors				0.34	1
Look up the doctor				0.33	1
illness threat		0.42			1
Cause and treatment		0.24			1
Medical related education	0.26				1
AB effective to go back to normality		0.41	0.30		2
AB go back to daily routine		0.41			1
AB price (among farmers)		0.32			1
Reason for using (farmers)		0.28			1
AB to keep working		0.40		0.39	2
Centre of the earth	0.39		0.29		2
Oxygen	0.28				1
Radioactive milk	0.36				1
Around the sun		0.21	0.26		2
Father's gene				0.27	1
Ab effective for cold	0.54				1
Unnecessary use		0.26			1
Side effects of AB		0.32			1
[correct] - %	19.5%	9.4%	22.0%	13.9%	
[DK] - %	28.7%	18.9%	41.0%	1.0%	
active	14	30	12	20	

Yellow=socio-demografic
Red=politics
Grey=Knowledge items
Light red = business mentality
Purple/blue=medical culture
Orange= traditional mentality
Green=Scientific mentality

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