Governance and Public Engagement from the Perspectives of Antimicrobial Resistance Experts: An Explorative Study

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Background: Antimicrobial resistance (AMR) has long been a threat to medicine as it reduces the efficacy of antimicrobials that once saved millions of lives. AMR is a multifaceted issue that has many drivers and thus, multiple actors need to be involved for an effective solution. Current prescribing practices, non-compliance issues, and even climate change are accelerating the rate at which AMR is occurring, hence current and future plans need to focus on hindering its propagation. AMR is a One Health problem that involves many sectors and in essence a social issue that necessitates proper governance structures across sectors as well as effective public engagement.

Objectives: The main objective of this study was to identify and compare governance and public engagement elements that emerged from Swedish and Malaysian AMR experts' discussions during two workshops held on September and October 2020 on the effectiveness and sustainability of taxation and Infection Prevention Control measures in tackling AMR in the future. Specifically, the objectives of this study were to: (i) identify and compare governance elements emerging from Sweden and Malaysia, (ii) identify public engagement elements emerging from Sweden and Malaysia, and (iii) identify and compare context-specific governance and public engagement challenges and opportunities in both contexts.

Methods: A secondary data analysis was conducted on pre-existing data collected from 18 AMR experts in Sweden and Malaysia that discussed taxation and infection prevention control measures as effective interventions to tackle AMR in 2030 and 2050. These data were analyzed for governance and public engagement elements using Anderson's governance framework and the sociocognitive theory, respectively. NVivo software was used to analyze and organize the data

based on the governance and public engagement frameworks selected; new elements of governance and public engagement that emerged were also added as necessary.

Results: Swedish and Malaysian AMR experts discussed all 18 of Anderson's governance elements. Swedish and Malaysian AMR experts described governance as needing proper diagnostics, a One Health surveillance system, investment into research and development, lesson learning, and collaboration across industries and countries. Swedish AMR experts discussed all 6 elements of public engagement, whereas Malaysian experts discussed only four. Malaysian experts did not discuss 'goals' and 'sociocultural facilitators.' While Swedish AMR experts discussed people's willingness to pay for antibiotic-free products and needing quick fixes, Malaysian AMR experts discussed the issue of food safety in wet markets in Southeast Asia. Context-specific opportunities and challenges differed across the two contexts. Two new elements of governance were identified through Swedish AMR experts' discussions: incentivization of pharmaceutical companies to develop antimicrobials and raising AMR priority among policymakers. No new elements of governance were revealed through Malaysian experts' discussions. Consistent messaging was a new element of public engagement revealed through Swedish AMR experts' discussions, while two new elements were revealed through Malaysian AMR experts: AMR message delivery and conflict of interest. Interactions were observed within governance elements, public engagement elements, and between the two frameworks.

Conclusion: This study highlighted the multidisciplinary nature of a complex issue like AMR. It is the first to use Anderson's governance framework to evaluate AMR discussions presented by experts from Sweden and Malaysia and employ the sociocognitive theory, which is often underrepresented in the AMR literature. The discovery of new elements of governance, public

engagement, and the overall interactions between the two concepts shows that there is much yet to know about AMR and its driving factors.

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Table of Contents

Author's Declaration II
Abstract III
Acknowledgements VI
List of Figures IX
List of Tables X
List of Abbreviations XI
Chapter 1- Introduction and Literature Review 1
1.1 Introduction 1
1.2 Literature Review 4
1.2.1 Factors Implicated in the Surge of AMR 4
1.2.2 Debilitating Consequences of AMR 4
1.2.3 Global Impacts of AMR 6
1.2.4 Economic and Social Impact of AMR 8
1.2.5 State of AMR in Europe and Sweden 9
1.2.6 State of AMR in Southeast Asia and Malaysia 10
1.2.7 Governance 11
1.2.7.1 Governance and AMR 12
1.2.7.2 Governance of AMR in Europe and Sweden 14
1.2.7.3 Governance of AMR in SEA and Malaysia 15
1.2.7.4 Andersons' Framework and AMR Governance 16
1.2.8 Public Engagement 18
1.2.8.1 Public Engagement on AMR 18
1.2.8.2 Public Engagement on AMR in Europe and Sweden 19
1.2.8.3 Public Engagement on AMR in Southeast Asia and Malaysia 21
1.2.8.5 Sociocognitive Theory as a Framework to View Public Engagement 22
1.2.9 Combining Governance and Public Engagement to Tackle AMR 23
1.3 AMResilience: Research Assessing AMR Drivers in Food System 24
Chapter 2: Study Rationale and Objectives 27
Chapter 3: Methods 28
3.1 Research Design 28
3.2 Ethics Approval 28
3.2 Theoretical Foundation 29
3.3 Ontological and Epistemological Orientation 36
3.4 Data Analysis 36

3.4.1 Coding 36
3.4.2 Coding Phases 37
3.4.3 Revisiting Transcript Audio and Video 38
3.4.4 Organization of Data Based on Time Frame and Agent 39
3.4.5 Linking Governance and Public Engagement 39
3.4.6 Ensuring Rigour 40
Chapter 4: Results 41
4.1 Elements of Governance Emerging from Sweden 41
4.2 Elements of Governance Emerging from Malaysia 58
4.3 Comparing Governance Elements Emerging from Sweden and Malaysia 72
4.4 Components of Public Engagement Emerging from Sweden 78
4.5 Components of Public Engagement Emerging from Malaysia 82
4.6 Comparing Public Engagement Components Emerging from Sweden and Malaysia 84
4.7 Existing and Future Governance and Public Engagement Elements Emerging from Sweden and Malaysia 85
4.8 Interaction Between Governance and Public Engagement 98
4.9 Context-Specific Challenges and Opportunities Emerging from Sweden and Malaysia....103
4.10 New Elements of Governance Emerging from Sweden....104
4.11 New Elements of Public Engagement Emerging from Sweden 105
4.12 New Elements of Public Engagement Emerging from Malaysia 106
Chapter 5: Discussion 108
5.1 Governance and AMR 109
5.2 Public Engagement and AMR 120
5.3 New Governance Elements 121
5.5 Synergy between AMR Governance and Public Engagement 123
Chapter 6: Conclusions 125
References 128
Appendices 158
Appendix A. 158
Appendix B 159

List of Figures

Figure 1. An Interaction Diagram Between Governance and Public Engagement Elements Constructed Through Swedish AMR Experts' Conversations During Two Workshops Held on September 10 and 11, 2020 About the Effectiveness of Taxation and Infection Prevention Control in Curbing AMR in 2050.

Figure 2. An Interaction Diagram Between Governance and Public Engagement Elements Constructed Through Malaysian AMR Experts' Conversations During Two Workshops Held on October 7 and 8, 2020 about the Effectiveness of Taxation and Infection Prevention Control in Curbing AMR in 2050.

List of Tables

Table 1. The 18 Domains of Anderson's Governance Framework, organized by the 3 Governance Areas, with Original Definitions, Adapted Definitions, and Indicators.

Table 2. Current and Future Elements of Governance Discussed by AMR Experts in Sweden and Malaysia.

Table 3. Current and Future Elements of Public Engagement Discussed by AMR Experts in Sweden and Malaysia

Table A1: Governance and Public Engagement Elements Node Connections and Explanations Emerging from Swedish AMR Experts Conversations About the Effectiveness of Taxation and Infection Prevention Control in curbing AMR in 2030 and 2050 That Resulted in The Construction of Figure 1.

Table A2: Governance and Public Engagement Elements Node Connections and Explanations Emerging from Malaysian AMR Experts Conversations About the Effectiveness of Taxation and Infection Prevention Control in curbing AMR in 2030 and 2050 That Resulted in The Construction of Figure 2.

List of Abbreviations

AMR- Antimicrobial Resistance

LMICs- Low- and Middle-Income Countries

HICs- High-Income Countries

SDGs- Sustainable Developmental Goals

NAPs- National Action Plans

SEA- Southeast Asia

IPC- Infection Prevention Control Measures

SCT- Sociocognitive Theory

CDC- Centers for Disease Control and Prevention

WHO- World Health Organization

OECD- The Organisation for Economic Co-operation and Development

Chapter 1- Introduction and Literature Review

1.1 Introduction

Antimicrobial drugs were an important discovery that revolutionized medicine and contributed to many positive health outcomes over the last eight decades (Laxminarayan et al., 2016). Antimicrobials are classes of drugs designed to kill microbes such as bacteria, viruses, parasites, and fungi in humans, animals, and plants (Travis et al., 2018). In the 1940s, a Scottish microbiologist named Alexander Fleming discovered and introduced penicillin, which saved the lives of many soldiers during World War II (Saga & Yamaguchi, 2009). The period between the 1940s and 1960s represented a "golden era" for antibiotic discovery, where a rapid number of antibiotics were found (Hutchings et al., 2019). Since 1909, human life expectancy increased by an average of 23 years (Hutchings et al., 2019).

The reductions in morbidity and mortality rates observed in the twentieth century can largely be attributed to the use of antimicrobial agents to treat various infections such as tuberculosis, pneumonia, and foodborne diseases (Adedeji, 2016; Aminov, 2017). The observed decline in infectious diseases played an essential role in changing disease profiles, where noncommunicable diseases such as diabetes and cardiovascular diseases began to outnumber infectious diseases (Adedeji, 2016; Jasovsky et al., 2016). However, the positive impacts and promises of antimicrobials were short-lived due to antimicrobial resistance (AMR) (Woolhouse, 2016).

During the early stages of antimicrobial use, scientists were optimistic about the potential promises of antimicrobials and that, the battle against infectious diseases may have been won; however, the challenge of AMR was soon realized (Reygaert, 2018). Although penicillin and many other antibiotics were initially effective and safe in combatting bacterial infections, traces

of resistance can be detected in the 1950s, when bacterial strains began to produce penicillinase, a protein implicated in the disruption of antibacterial action of penicillin (Hutchings et al., 2019; Lobanovska & Pilla, 2017). AMR is a natural phenomenon characterized by microbes' evolvement and eventual development of resistance against antimicrobial agents once used to kill them (Broom et al., 2021). Through natural selection, these microbes develop mechanisms to evade antimicrobial drugs (Hasan et al., 2021). Alexander Fleming predicted the emergence of resistance to antimicrobials as he famously stated, "There is probably no chemotherapeutic drug to which in suitable circumstances the bacteria cannot react by in some way acquiring 'fastness' [resistance]" (Lobanovska & Pilla, 2017, p.139).

To put antibiotic resistance into perspective, more than 150 antibiotics have been discovered after penicillin, yet most bacterial strains targeted by these antibiotics developed resistance (Lobanovska & Pilla, 2017). In a recent report by the World Health Organization (WHO), 17 new antibiotics have entered the clinical phases between 2021-2023, with 13 receiving market approval and only two being classified as novel (World Health Organization, 2024). With ever-increasing rates of antibiotic resistance and an insufficient number of new classes of drugs being developed, among other factors, the O'Neill report predicts that AMR will become the primary cause of death by 2050 (O'Neill, 2016). This report sheds light on AMR and policy recommendations that will help curb AMR, such as increased funds towards vaccination programs, infection prevention control measures, among other things (O'Neill, 2016).

AMR is a globally complicated and challenging problem to combat in humans, animals, and the environment, and has the potential of becoming a pandemic (Cameron et al., 2022). Resistant microbes can transfer between hospitals, farms, and the environment, making it especially challenging to tackle AMR (Graham et al., 2019). To address AMR, economic,

political, and social changes need to be implemented (Cameron et al., 2022). AMR will place significant financial burdens on the healthcare system and contribute to increased poverty (Pulingam et al., 2022). On the political end, AMR requires proper governance mechanisms that regulate and provide leadership in antimicrobial stewardship, such as monitoring and surveillance of antimicrobial use (Spruijt & Petersen, 2022). In addition, tackling AMR requires engaging with the different sectors and the broader society on better practices to curb AMR (Ashiru-Oredope & Hopkins, 2015).

Governance and public engagement are important interventions in the fight against AMR, alongside vaccinations, hand hygiene, and proper use of antimicrobials (Cameron et al., 2022). Combining a governance top-down approach and a public engagement bottom-up approach may concurrently help tackle AMR more effectively. Although multiple Scandinavian countries successfully reduced the burden of AMR within their borders, AMR remains a threat in other parts of the world and needs governance and public engagement mechanisms that transcend national boundaries (Ashiru-Oredope & Hopkins, 2015). The literature review below summarizes current knowledge on AMR, governance as a mechanism to tackle AMR and behavioural theory as a tool to evaluate public engagement and its relationship with AMR. It will also further describe the differing status of AMR governance and public engagement in two example settings, Sweden and Malaysia. It will also explain a research project that sheds light on governance and public engagement in AMR.

1.2 Literature Review

1.2.1 Factors Implicated in the Surge of AMR

Although AMR was predicted to occur, various factors have led to the unprecedented increase in AMR across the One Health system, involving humans, animals, the environment, and their interactions (Lomazzi et al., 2019; Gajdacs, 2021). The One Health approach to AMR highlights the multi-layered and interconnected nature of AMR that can involve farms, hospitals, and industry (McEwen & Collignon, 2018). Recognizing the unavoidability of AMR, multiple factors have been associated with the accelerated resistance rates observed throughout the One Health system (Kelly & Davies, 2017). Notably, the misuse of antimicrobials, patient nonadherence to recommended doses, over-prescription of antimicrobials, and inadequate Infection Prevention Control (IPC) measures (Jindal et al., 2015). The misuse and overuse of antibiotics, in particular, can be observed even during the golden era of antibiotic discovery, when clinicians started to use antibiotics not only in severe cases of infections but also to treat mild diseases that sometimes resolve naturally, consequently leading to resistance in mild diseases (Powers, 2004). A worrying trend has been the increase in the use of last-resort antibiotics, ideally only used for severe infections, to treat mild infection cases, resulting in increased difficulty in treating serious infections due to acquired resistance (ECDC et al., 2022).

1.2.2 Debilitating Consequences of AMR

The overuse and misuse of antimicrobials by health professionals can be rationalized as it achieved significant drops in mortality; for example, sulfanilamides lowered the mortality rate due to meningococcal meningitis from 70-90% to 10% upon its introduction (Powers, 2004). Unwarranted use of antibiotics extended beyond the medical sector, where veterinary and agricultural sectors are also large users of antimicrobials (Ahmad et al., 2021). The consumption

of antimicrobials increased by more than 30% between 2000 and 2010, with low- and middle income countries (LMICs) contributing to a large portion of this increase (Kumar et al., 2022). LMICs consume more antimicrobials due to increased infectious disease rates, easy access, and relatively low cost of antimicrobials (Kumar et al., 2022). A further challenge in LMICs is the non-prescription use of antibiotics, which varies depending on the location (Morgan et al., 2011). In Asian countries like Bangladesh and Vietnam, 86% and 62% of antimicrobials are bought without a prescription, respectively, compared to Indonesia and India, where that figure is around 18% (Morgan et al., 2011). In Nigeria and Sudan, 100% of antimicrobials are sold without a prescription (Morgan et al., 2011). In South America, 25% and 46% of antimicrobials in Peru and Brazil are bought without a prescription, respectively (Morgan et al., 2011). This variability in non-prescription use of antimicrobials is evident not only across different LMICs but even in HICs. For example, in North Europe (e.g. Belgium and England) and Scandinavian countries (e.g. Sweden and Denmark), 3% of antimicrobials are given without a prescription, in comparison to Eastern Europe (e.g. Lithuania and Romania) where it is around 30% (Morgan et al., 2011). This variability in non-prescription use of antimicrobials across the world further highlight the need to understand the contextual factors driving AMR in each country.

In addition to the non-prescription use of antimicrobials, it has been estimated that worldwide, 50% of antibiotic prescriptions are deemed inappropriate or unnecessary (Ahmad et al., 2021). Although different studies from North America, Europe, Asia, and Africa showed different numbers of inappropriate antimicrobial prescriptions, interpretation of these numbers is difficult as each study had a different definition of what is considered appropriate (Magill et al., 2021; Machowska & Lundborg, 2019; Mao et al., 2015; Mboya et al., 2018). While inappropriateness is defined differently, common reasons include unsuitable treatment selection

and duration in addition to the absence of microbiological evidence and symptoms (Magill et al., 2021). Much of the inappropriate prescribing practices can be rooted in the lack of knowledge and awareness of healthcare workers and patients as well as financial incentives and poor regulatory mechanisms (Mao et al., 2015). Compounding the issue further is that many of the classes of antibiotics being discovered today are not necessarily new; they are derived from already-existing compounds (Hutchings et al., 2019). Before 2000, 1968 was the last year a novel class of antimicrobials was discovered (Powers, 2004). Hence, pharmaceutical companies' production of new antimicrobials has been halted early on, a trend that continues today.

1.2.3 Global Impacts of AMR

In addition to the factors mentioned above, AMR needs to be understood within the context of other pressing global issues with which it has been closely associated. AMR poses a significant threat to progress efforts intending to achieve the United Nations' (UN) Sustainable Developmental Goals (SDGs) that seek to provide judicious and sustainable living standards for individuals globally (Jasovsky, 2016; Gajdacs, 2021). The SDGs are 17 goals addressing environmental, social, and healthcare issues, including climate action, poverty and gender inequality, and access to healthcare (Gajdacs, 2021). Specifically, AMR makes achieving more than 50% of the SDG targets, such as no poverty, no hunger, access to clean water, good health and well-being, and climate action difficult (Gajdacs, 2021; Jasovsky, 2016). For example, AMR raises the costs needed to treat animals and reduces production which influences farmers' income and food availability, impeding the goal of 'no hunger' (WHO, 2021). The sensitive relationship between AMR and SDGs can also be observed in deprived conditions where individuals experience poverty and unsanitary living conditions that increase their vulnerability to infections

that are costly to treat, hence increasing their reliance on cheap and accessible antimicrobials (Alvarez-Uria et al., 2016; Ateshim et al., 2019).

Another pressing global issue tightly linked to AMR is climate change since an increase in temperature is associated with increased cases of food and water-borne diseases (Jiang et al., 2015; Semenza et al., 2012). A cost analysis of foodborne diseases in the USA revealed that the approximate cost of foodborne diseases is $75 billion annually, with non-typhoidal *Salmonella* alone costing $17.1 billion (Hoffmann et al., 2024). Globally, WHO reported 153 million cases of non-typhoidal *Salmonella*, with 57,000 deaths in 2010 (Kirk et al., 2015). The relationship between climate change and AMR can also be observed, where climate change causes disproportionate changes to water availability, where some places will suffer droughts, and some will experience flooding (Burnham, 2021). Individuals living in areas affected by droughts will experience poor sanitary conditions as water will be shared, and crowded conditions will propagate the transmission and development of infections (Burnham, 2021). A study examining blood cultures of 135 individuals from different hospitals in the USA found that the number of Gram-negative bacterial infections peaks during the summer months (Eber et al., 2011). According to USA hospitalization data, compared to months when the temperature is around 6ºC, an increase to 28ºC increased the odds of a diagnosis with urinary tract infections by 20% (Simmering et al., 2018). Given that increased temperatures foster greater numbers of infections, efforts to minimize global warming are required.

The connections between AMR, SDGs, and climate change highlight the urgency and multi-layered nature of AMR and the globality of tackling AMR. More recently, AMR has been exacerbated by the COVID-19 pandemic, where studies report an increase in the prescription of antibiotics for patients hospitalized due to COVID-19 (Verroken et al., 2020). However, most of

these antibiotic prescriptions were unwarranted, as 71% of COVID-19 patients received antibiotics, but very few presented with a bacterial infection (Rodríguez-Baño et al., 2021). The Centers for Disease Control and Prevention (CDC) reported that antibiotic resistance increased by 15% in the USA during the first year of the COVID-19 pandemic, resulting in 29,400 deaths (CDC, 2022).

1.2.4 Economic and Social Impact of AMR

AMR results in significant expenses varying by country, and in the USA alone, AMR-related costs amount to approximately $55 billion annually (Allcock et al., 2017). Europe expends approximately €1.5 billion yearly towards AMR, with 40% of the costs resulting from productivity loss due to work absences and mortality (Prestinaci et al., 2015). Given the current AMR condition, the USA spends approximately $3 trillion annually towards AMR (Ahmad et al., 2021). By 2050, *Mycobacterium tuberculosis* alone will cost $16.7 trillion (Dadgostar, 2019). The European Centers for Disease Control and Prevention (ECDC) reported that 2 million people possess resistant pathogens, and of those, 25,000 die annually (ECDC, 2019). In the USA alone, 23,000 individuals die due to AMR-associated issues (Ahmad et al., 2021). An alarming statistic has shown that by 2050, AMR will kill an individual every 3 seconds (Kumar et al., 2022). Other studies have predicted that 10 million individuals will die from AMR-related causes by 2050 if effective worldwide action is not generated (Allison et al., 2017; Cama et al., 2021). Of these 10 million individuals, more than 80% are in Asia and Africa, highlighting once again the need for a global collaborative effort to curb AMR (Prestinaci et al., 2015).

AMR is anticipated to drive individuals from low-income countries into conditions of extreme poverty and, consequently, significant reductions in productivity due to infection (Ferri et al., 2017). The predicted loss of productivity in society and increased pressures on the

healthcare system due to increased resistance and mortality rates may lead to long-lived social and financial impacts (Michael et al., 2014). In addition, increased AMR rates will present a greater challenge to public health as more individuals can infect others for extended periods due to resistance (Jindal et al., 2015). The persistence of the AMR issue and projected increases necessitates evaluating current interventions. Before evaluating existing interventions, it is crucial to understand the current AMR situation in Europe, particularly in Sweden and Southeast Asia, focusing on Malaysia.

1.2.5 State of AMR in Europe and Sweden

A study examining the rate of resistant infections in countries belonging to the European Union (EU) found 671,689 cases of antibiotic resistance in 2015, equivalent to an incidence of 131 cases per 100,000 and 7 deaths per 100,000 (Cassini et al., 2019). Of the European countries selected for examination, Italy (201,584 cases) and Greece (18,472 cases) had the highest rates of antibiotic resistance, and Scandinavian countries had some of the lowest rates of antibiotic resistance (Cassini et al., 2019). Sweden, for example, reported 4571 cases of antibiotic resistance in 2015 (Cassini et al., 2019). Given the relatively low rate of antibiotic resistance reported in Sweden, it is important to analyze further AMR trends and the type of interventions implemented by Sweden to achieve some of the lowest rates of antimicrobial resistance in Europe.

Sweden began to recognize that AMR was a problem in the mid-1900s and began banning antibiotics for growth promotion purposes in 1986 (Wierup et al., 2021). As Sweden became part of the EU in 1995, its ban on antibiotics for growth promotion purposes was challenged, yet Sweden provided evidence for the need to eliminate antibiotics for growth promotion, which was adopted in 2006 by the EU (Wierup et al., 2021). According to programmes designed to monitor

the sale of antibiotics, Sweden has the lowest use of antibiotics in the animal and human sectors (Mölstad et al., 2017). Between 1996 and 2016, the number of prescriptions per year decreased by 43% and 73% in adults and children in Sweden, respectively (Mölstad et al., 2017). The success achieved by Sweden in tackling AMR can be explained by the multitude of efforts put forth to control the use of antibiotics. Some of these efforts include limited import and trade of animals to reduce and prevent the introduction of new infectious diseases, increased hygienic and biosecurity measures, and stringent animal welfare standards (Wierup et al., 2021). To implement these efforts, Sweden had an early awareness of antimicrobials, financial incentives, and access to data on sales of antibiotics and AMR, which allowed them to implement early action against AMR (Wierup et al., 2021).

1.2.6 State of AMR in Southeast Asia and Malaysia

In comparison to Europe and Sweden, Malaysia and other countries in Southeast Asia (SEA) were reported to have more cases of AMR (Ab Rahman et al., 2016). The number of AMR cases emerging from SEA is said to be underestimated due to the scarcity of data and lack of proper surveillance systems (Zellweger et al., 2017). Recent data from studies spanning multiple hospitals in Malaysia showed that *E. coli* was resistant to penicillin, with resistance ranging from 68-100% (Naeemmudeen et al., 2021). Healthcare in Malaysia is either private or public, and recent studies have found that the number of antibiotic prescriptions is higher in private clinics (31%) in comparison to public clinics (7%) (Naeemmudeen et al., 2021; Ab Rahman et al., 2016).

Drivers of AMR in SEA include self-medication, easy access to antimicrobials, inappropriate food handling, poor hygiene and infection control, among others (Zellweger et al., 2017). The Southeast Asian region represents a hotspot for AMR, with countries such as

Indonesia and Thailand being listed by WHO as possessing the highest rates of multidrug-resistant tuberculosis (Liverani et al., 2020). Other major burdens in the Southeast Asian region include drug-resistant malaria and penicillin (Liverani et al., 2020). Key challenges faced in fighting AMR in the Southeast Asian context include disjointed surveillance systems, weak laboratory systems, and the heavy presence of private sectors, making monitoring and identifying AMR trends difficult (Liverani et al., 2020). Given the different AMR drivers in Sweden and Malaysia, it is crucial to implement appropriate interventions to halt or minimize AMR. Governance and public engagement have been identified as essential interventions in tackling AMR.

1.2.7 Governance

The concept of governance emerged as a response to the discontent citizens demonstrated toward the state-controlled economy, which dominated the Eastern bloc and many developing countries between the 1950s and 1970s (Weiss, 2000). These state-controlled economic models failed to accommodate and recognize the significant roles that could be played by actors other than the state, in addition to the role of technology in advancing socioeconomic development (Weiss, 2000). Internationally recognized organizations such as the World Bank and the UN defined governance differently from one another, increasing the complexity of defining the concept (Peters & Savoie, 2000). Although varying organizations define governance slightly differently, one can describe governance as the ability of public institutions to respond to public demands in an appropriate manner, that is, in a transparent, accountable, and effective manner that honours collective opinion (Katsamunska, 2016). Governance can also be defined in a traditional or modern sense, with traditional focusing on the state's role in policy development, while modern governance focuses on the need for public involvement in decision-making

(Katsamunska, 2016). A modern definition of governance states that governing involves the crosstalk between regulatory bodies and the public to arrive at a unified solution to a collective concern (Kooiman, 2003). The modern definition of governance is especially relevant in the AMR context as AMR is a multi-faceted problem that requires not only the involvement of policymakers but the participation of individuals as well (Birgand et al., 2018). Given the complexity of AMR, I will be using the modern definition of governance for the purpose of this thesis.

Although the concept of governance achieved popularity within the business realm to monitor unethical behaviour (Felo, 2011; Ruhanen et al., 2010), its applicability extends beyond and is highly valuable in the fight against AMR. AMR is unbound to borders, and tackling it requires national and international governance mechanisms to regulate and limit its spread (Padiyara et al., 2018). Governance of AMR is often criticized for being a top-down approach that may focus and narrow efforts towards one area (e.g., infection prevention control) rather than others (e.g. antimicrobial stewardship and multisectoral collaboration) (Birgand et al., 2018). As a result, the governance of AMR has generally shifted to accommodate multiple nonstate actors that work collaboratively at the international or local scene (Legido-Quigley et al., 2019).

1.2.7.1 Governance and AMR

Globally, organizations such as the WHO, Food and Agricultural Organization (FAO), and World Organization for Animal Health (WOAH) have led the way in identifying Global Action Plans (GAPs) critical in the fight against AMR (WHO, 2018). These GAPs are important components of effective governance and can include enhanced AMR surveillance, IPC measures, AMR awareness, and innovation by developing new classes of antimicrobials (Ruckert et al.,

2020). Although 194 WHO states initially supported the GAPs proposed in 2015, a two-year multi-sectorial approach to AMR, only 79 countries developed plans to fight AMR by 2017 (WHO, 2018). By 2020, only 40% of responding countries reported developing AMR National Action Plans (NAPs) that aligned with GAPs (WHO, 2021). Although a 20% increase is observed in countries developing aligned AMR NAPs from 2017-2020, most countries have a long path ahead in complying with and adapting GAPs (WHO, 2021). In addition to non-compliance, only 25% of the participating countries have allocated funding towards curbing AMR through governance strategies, including surveillance and involving the varying sectors influenced by AMR across the One Health system (Aguirre, 2017). The number of countries with allocated budgets for AMR has only increased by 2% from 2017-2020 (WHO, 2021).

It has been estimated that 90% of the 10 million individuals projected to die due to AMR-related causes are in the developing world, where some countries may be unable to finance NAPs on AMR (Mendelson et al., 2016). This emphasizes that High-Income Countries (HICs) and Low and Middle-Income Countries (LMICs) have different capabilities in funding and implementing governance interventions (Mendelson et al., 2016). In some HICs, governance of AMR tends to be a top-down approach where the state assumes the role of governance, which directs and navigates citizens towards a common goal of AMR reduction (Birgand et al., 2018). A study comparing the governance approaches used by European countries such as England, France, and Germany showed that England has a more top-down centralized approach to governance than France and Germany (Birgand et al., 2018). This points out that differences exist not only when comparing AMR governance systems of HICs and LMICs but within high-income European countries as well, and this further reflects the difficulty in aligning governance policies and targets (Birgand et al., 2018). A multivariate analysis conducted in Europe revealed

that the quality of governance is a significant indicator of AMR rates in a given country; specifically, where governmental corruption is rampant, AMR rates tend to increase (Birgand et al., 2018). In addition to corruption, AMR presents different governance challenges in LMICs since some can be characterized by weaker health systems, substandard regulations, and differing priorities than HICs (Iskandar et al., 2021).

1.2.7.2 Governance of AMR in Europe and Sweden

Significant differences can be observed in the governance systems in Europe (Collignon et al., 2015). Some of the disparities in the quality of governance can be captured where Finland scored the highest in governance quality, and Latvia performed poorly, with governance quality exhibiting a negative relationship with AMR rates (Collignon et al., 2015). Similarly, a study conducted in 2018 reported that enhanced governance is a major contributor to lower AMR rates, with antibiotic consumption exhibiting the least influence on AMR rates (Collignon et al., 2018). The Collignon studies investigating numerous factors propagating AMR concluded that quality of governance is the strongest predictor of AMR rates, and variables such as economic prosperity (calculated through gross domestic product) and antibiotic consumption play a more minor role than commonly believed (Collignon et al., 2015; Collignon et al., 2018). Focusing on Europe, Nordic countries have been the most successful in implementing good governance practices to tackle AMR.

Sweden started intensifying its efforts to decrease AMR in the 1980s with a strong policy backbone that guided governmental and non-governmental systems and employing a One Health governance approach to AMR that included multiple sectors (Eriksen et al., 2021). This One Health approach to AMR used in Sweden dictated the involvement of different industries and governing bodies, allowing responses representative of different experts' views (Wierup et al.,

2021). The success of Swedish efforts in decreasing AMR rates is evidence of the employment of effective methods against AMR, as Sweden has some of the lowest antibiotic rates globally (Eriksen et al., 2021). Embedded in the Swedish AMR policy approach is the recognition of other countries' influence on AMR propagation; thus, collaboration and knowledge exchange were identified as crucial (Wierup et al., 2021).

1.2.7.3 Governance of AMR in SEA and Malaysia

Southeast Asia (SEA) represents a different scenario for AMR increase and persistence compared to the European and HICs discussed. Where HICs like Sweden significantly reduced antimicrobial consumption, AMR remains a challenge across much of SEA (Liverani et al., 2020). SEA is defined as a geographical area that consists of 10 countries that are members of the Association of Southeast Asian Nations (ASEAN): Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam (Liverani et al., 2020). LMICs in SEA tend to display poorer quality of governance and regulation on AMR, characterized by poor surveillance and enforcement capacity (e.g., availability of diagnostic facilities) compared to HICs (Lee & Wakabayashi, 2013). The principal contributors to AMR spread in LMICs in SEA include the private health sector and food production systems, which are difficult to regulate (Liverani et al., 2020).

Malaysia introduced their first strategies to combat antibiotic resistance in the 1980s (Lim et al., 1993). Nevertheless, recent reports show that rates of resistance for key bacterial strains in Malaysia are 5-15% higher than the global average (Ismail et al., 2024). Like some LMICs, Malaysia has a conspicuous private health sector that is largely under-controlled and has fewer funds directed toward health than HICs (WHO, 2013). In fact, the majority of primary care in Malaysia is delivered through private practitioners and is concentrated in urban areas (WHO,

2013, p.18). Although the Malaysian government led efforts in decentralizing health care, the system is centralized at its core (WHO, 2013, p.19). The Malaysian Ministry of Health recognized the importance of extending health services to rural areas but the public health sector remains centrally financed and administered, with the majority of healthcare services focused in urban areas (WHO, 2013, p.19). HICs and LMICs have different governance structures and resources to tackle AMR; therefore, it is vital to harmonize governance to ensure AMR is managed effectively and appropriately, considering the available resources and existing infrastructures.

1.2.7.4 Anderson's Framework and AMR Governance

The first AMR governance framework to evaluate NAPs was constructed by Anderson et al. (2019); it used existing health system governance models and critical elements from AMR stewardship. The framework contains three governance areas: monitoring and evaluation, policy design, and implementation tools (Appendix A). Each of the three governance areas contains multiple domains that characterize it, with a total of 18 domains that contain 52 indicators (Appendix A; Anderson et al., 2019). The framework offers a binary system of evaluation for regulators, whereby each indicator is evaluated for its absence or presence (Anderson et al., 2019). The design of Andersons' governance framework is cyclical, highlighting AMR's interdependent, dynamic, and adaptive nature (Anderson et al., 2019). The framework was developed to assist regulators in planning, monitoring, and assessing AMR NAPs. Furthermore, it highlights strengths and gaps in NAPs developed by different countries.

Multiple studies used Andersons' AMR governance framework to analyze NAPs across different regions and countries (Harant, 2022; Özçelik et al., 2022; Patel et al., 2023; Yang et al., 2024). Harant (2022) specifically assessed NAPs for two domains under policy design:

accountability and transparency across 15 African countries, while Özçelik et al. (2022) used Andersons' model with the help of natural language processing to evaluate whether AMR NAPs from G20 countries align with AMR GAPs. Patel et al. (2023) used Andersons' framework to analyze NAPs across 114 countries, while Yang et al. (2024) focused on 44 Chinese AMR NAPs from 2003-2022. Patel et al. (2023) and Yang et al. (2024) made minor modifications to Andersons' model, merging two domains or introducing a new domain (i.e. international collaboration).

The study by Chua et al. (2021), which analyzed AMR NAPs from 10 ASEAN countries, contrastingly made major modifications to Andersons' model. Chua et al. (2021) added two governance areas: sustainability and one health engagement, the latter becoming the model's centre as the One Health concept is all-encompassing. In addition, they regrouped multiple domains and added a new domain, international collaboration (Chua et al., 2021). This adapted framework was later used to assess AMR NAPs in Singapore (Chua et al., 2023). Multiple studies then used the adapted governance framework by Chua et al. (2021) to evaluate NAPs in Latin America, Australia, Tanzania, and Uganda, respectively (Avello et al., 2024; Do et al., 2023a; Frumence et al., 2021; Waswa et al., 2024).

Overall, Anderson's framework offers 3 governance areas, 18 domains and 53 indicators that can be evaluated binarily (Anderson et al., 2019). Although the framework was useful in highlighting gaps in the governance of AMR in different countries, a common concern mentioned by researchers was that a binary system is not sufficient in capturing the nuances and complexities of AMR. Hence, the way the framework assesses each domain does not take into consideration the quality or implementation of said measure but rather the absence or presence

of said domain/indicator. Multiple studies have highlighted that Anderson's framework is rather ambitious, especially within the context of LMICs where some resources may be limited.

1.2.8 Public Engagement

Public engagement is defined as a course of action taken by a government or regulators to communicate reliable information to people on important issues, use their input, and incorporate it into decision-making (Cohen et al., 2008). The Organisation for Economic Cooperation and Development (OECD) defines public engagement in three levels: information, consultation, and active participation (OECD, 2003). Information is a unidirectional relation where governments generate and transmit information to citizens; consultation, on the other hand, involves the public delivering feedback to the government (OECD, 2003). Lastly, active participation involves the public throughout the process, from suggesting policies to enacting them; this level of public engagement acknowledges the need for the public and government to be in continuous and active partnership (OECD, 2003).

The advantages of public engagement include generating an aware and informed public, ensuring the inclusion of citizen ideas, enhancing citizen trust, and elevating the adaptability of research as citizens feel more involved and engaged in the policy development process from the beginning (Cohen et al., 2008). However, many challenges face public engagement efforts, which differ from one country to another, and the multisectoral aspect of AMR makes it more challenging to engage the public. Critical values identified when engaging the public on AMR include clarity, flexibility, equity, and inter-disciplinarity (Mitchell et al., 2019).

1.2.8.1 Public Engagement on AMR

Alongside governance, public engagement also has a major role in fighting against AMR, as increased public engagement on AMR may translate to sustainable changes in behaviour that

perpetuate AMR (Thornber & Pitchforth, 2021). While Andersons' governance framework contains some domains concerned with public engagement, such as participation, public awareness and education (Anderson et al., 2019), the framework is policy-laden. It focuses mainly on civilian participation in decision-making (Anderson et al., 2019). On the other hand, public engagement, beyond decision-making, should consider cognitive aspects of behavioural change, such as internal and external characteristics and factors that determine the likelihood of behavioural change, which are essential for the sustainability of a behaviour (Luszczynska & Schwarzer, 2015). A significant focus in attempting to minimize AMR should be directed towards engaging the public on AMR, which necessitates disseminating knowledge and spreading awareness that translates into sustained behavioural modifications (Mitchell et al., 2020).

The term 'public' needs to be defined when speaking about public engagement. Within the context of complex problems like AMR, the public is not only citizens, but it also involves pharmacists, farmers, policymakers, and industry, given the multidisciplinary nature of AMR (Calvo-Villamañán et al., 2023). This definition of the public uses a One Health perspective that encompasses all levels of society where behavioural change is necessary to fight AMR.

1.2.8.2 Public Engagement on AMR in Europe and Sweden

To demonstrate the need for increased public engagement on AMR, evidence from HICs and LMICs is presented here. Two studies spanning 15 European countries reported that 50-60% of individuals indicated being unaware that antibiotics are ineffective in treating viral infections such as the common cold (Mazińska et al., 2017; Singh-Phulgenda et al., 2023). There is variability in AMR awareness across Europe, where southeastern Europe showed the least general knowledge of AMR (Alexa et al., 2019). A study from Sweden reported that only 19% of

participants falsely stated that antibiotics can be used to cure the common cold (André et al., 2010). Across these studies, individuals who are older, have higher socioeconomic status and live in urban areas were more aware of AMR and the risks associated with it (Alexa et al., 2019; Mazińska et al., 2017; Singh-Phulgenda et al., 2023). These studies also reveal the low level of engagement and knowledge on AMR, which may translate into maladaptive or improper prescribing practices and demands from the consumer side, as antibiotics are perceived to be effective against viral infections.

A UK-based study involving farmers' perceptions about antibiotic use showcases that while farmers performed preventative actions against AMR, they blamed AMR rates on other sectors like veterinary (Doidge et al., 2020). These results are interesting as they demonstrate the shift in responsibility, where farmers consider other sectors more contributing to the AMR epidemic. This can present an opportunity to educate on the shared responsibility toward AMR and a collective need to tackle AMR across sectors. A UK study involving farmers and veterinarians contrastingly reported a sense of shared responsibility towards AMR in each sector, but blame was shifted toward other stakeholders undermining stewardship efforts led by farmers and veterinarians (Golding et al., 2019). Another interesting theme was the misalignment between AMR practice ideals and reality, where farmers expressed concern regarding animal mortality and consequent economic loss when avoiding antimicrobial use (Golding et al., 2019). Hence, many factors are at play that influence the use of antimicrobials at the farmer and veterinarian level, and it is only through the alignment of these practices and AMR goals, with the help of other industries and stakeholders, that AMR can be tackled effectively.

A study on the preparedness of final-year medical students from France and Sweden to prescribe antibiotics showed that 63% and 20% of students believe they need more education on

antibiotic use and feel unprepared, respectively (Dyar et al., 2019). A study assessing the preparedness of Swedish medical students between 2015-2021 found lower levels of preparedness in 2021 regarding the appropriate use of antimicrobials, with 3-40% increases in self-reported need for more education on antimicrobial prescribing (Al-Nasir et al., 2024). This increase was partly explained by the heightened awareness of AMR and its serious impacts, which may have influenced students' sense of preparedness in prescribing (Al-Nasir et al., 2024). The studies presented aimed to highlight that public engagement is needed across all sectors and layers of society in the European context.

1.2.8.3 Public Engagement on AMR in Southeast Asia and Malaysia

A study evaluating perceptions on antibiotic use in Malaysia and Thailand reported that 67% and 52% of the public stated that antibiotics effectively combat illnesses triggered by viral microbes, respectively (Oh et al., 2011; Chanvatik et al., 2019). A cross-sectional study conducted in Malaysian, Indonesian, and Pakistani universities revealed that more than 50% of pharmacy students were unable to indicate proper antimicrobial therapy needed for common procedures like surgical prophylaxis, with 90% of participants stating the need for more training in proper usage of antibiotics (Abubakar et al., 2020). It is equally important to emphasize the differences in access to antibiotics between developed and developing countries; for example, individuals in Poland need a prescription for antibiotics, whereas, in Rwanda, antibiotics are prescription-free (Mazińska et al., 2017; Hwang et al., 2015). Thus, AMR public engagement efforts must account for the local and contextual factors that vary internationally to better address the needs of different communities; different contexts require different solutions. These studies show that engagement on antibiotic use is relatively low in LMICs, even among pharmacy students. Hence, engaging and increasing awareness among these populations is

crucial. These different studies further showcase that misconceptions about antibiotics are highly prevalent in HICs and LMICs, regardless of the quality of governance possessed by these countries.

1.2.8.5 Sociocognitive Theory as a Framework to View Public Engagement

The sociocognitive theory (SCT; Appendix B) was developed by Albert Bandura and is commonly used to predict and modify health behaviours (Luszczynska & Schwarzer, 2015). SCT addresses the psychosocial aspects and motivations (internal and external) that guide sustainable behavioural modifications (Luszczynska & Schwarzer, 2015). Within the SCT, various factors are posited to influence behaviour and learning, including self-efficacy, expectations, and reinforcements (Nabavi, 2012). An important tenet of the SCT is that individuals need a sense of control over life events, and in search of that, they create goals that fulfill this very desire (Schunk & DiBenedetto, 2020). These goals are fueled by motivations formed through self-efficacy that are influenced by personal, environmental, and behavioural factors (Schunk & DiBenedetto, 2020).

The Health Belief Model (HBM) has been used extensively in the literature to examine perceptions and attitudes toward antimicrobials (Champion & Skinner, 2008). Unlike the HBM, SCT addresses the sustainability of behaviour, which is important for a long-term issue like AMR. The SCT has not been used in tackling AMR, but it has been influential in areas such as business, mental health and academic achievement (Luszczynska & Schwarzer, 2015).

The SCT can arguably be used to investigate public engagement as it aims to explain why certain individuals uptake specific behaviours and the underlying cognitive processes. Perhaps a sense of self-agency and responsibility-claiming influences the behaviours people choose to participate in. While most behaviourist theories emphasize observed behaviour, the SCT takes

into consideration the internal and external factors that influence behaviour (Zajda. J, 2023). Further, the SCT acknowledges the important role individuals can play in managing their own behaviour and engagement, which is influenced by cognitive and social processes (Schunk & DiBenedetto, 2020). Self-efficacy and motivation, which are important components of the SCT have been closely associated with public engagement (Szinay et al., 2020), that is, one's increased sense of capability and motivation in achieving a task or participating in a behaviour, has a direct influence on their engagement with said task.

1.2.9 Combining Governance and Public Engagement to Tackle AMR

Undeniably, good governance is important in tackling AMR, but it is a top-down approach as it centralizes the responsibility of tackling AMR on governmental authority (Ruckert et al., 2020). Engaging the public on AMR employs a bottom-up approach that emphasizes the role of local-level factors and individuals' influence on AMR (Felt & Fochler, 2008). Although public engagement may seem like an effort that necessitates the involvement of government and stakeholders, it is a bottom-up approach in the sense that it starts with understanding the needs of the public and using that information to create better campaigns and policies that are relevant to the public. For example, empowering people to change their lifestyles and learning more about human behaviour allows people to have more agency, and simultaneously help governments make better programs. Therefore, a hybrid governance and public engagement method offers a more comprehensive, multi-layered approach to tackling AMR.

Public engagement involves the participation of the public in decisions enacted by regulatory and policy bodies (Rowe & Frewer, 2005). Hence, public engagement on AMR is a governance component whereby regulatory structures and systems maximize opportunities for public involvement through increasing awareness or communicating and consulting the public

on confronting AMR. Therefore, it is important to examine current perceptions, beliefs, knowledge, and attitudes to understand better the need to reassess current AMR public messaging that intends to change AMR-related behaviours. To tackle AMR effectively, a mixture of efforts across society, different sectors, and varying countries is needed to limit the propagation of resistant pathogens (Allison et al., 2017). Governance and public engagement have been identified as key areas implicated in AMR propagation. (Collignon et al., 2015).

If employed properly, a hybrid approach that includes public engagement and governance may be key to tackling AMR. A hybrid approach focuses efforts in two directions that are often viewed independently. Not only is it important to have the proper governance structures in place to control AMR, but it is also important to engage the public in these decisions and allow them to have a sense of autonomy and control over their behaviours, as well as become aware of the consequences of these behaviours. Understanding the rules enforced is likely to improve compliance.

1.3 AMResilience: Research Assessing AMR Drivers in Food System

The AMResilience project was a study aiming to understand what interventions are sustainable and effective against AMR (JPIAMR, 2021). My Graduate Research Assistantship (GRA) consisted of completing tasks for this research. Specifically, I analyzed data to understand the different interventions needed to be in place to tackle AMR and the different conditions needed to ensure interventions are effective and sustainable. The research team previously collected the data I analyzed through two in-depth, virtual group interviews with AMR experts in different fields (e.g., agricultural, pharmaceutical, aquatic) residing in Sweden (Lambraki et al., 2022b) and Malaysia (Lambraki et al., 2022a). The two two-day workshops were recorded and generated 40-50 pages of transcripts each, that were further analyzed (Lambraki et al., 2022). The European workshops engaged 8 participants, whereas the SEA

workshops involved 10 participants, and the workshops explored AMR experts' opinions on what the world will look like in 2050, and the steps needed to be taken to achieve a reality in 2050 where AMR is significantly reduced (Lambraki et al., 2022).

The eight European workshop participants included three AMR experts from Sweden, and the other five were from other European countries who worked within the Swedish context, increasing their familiarity with the Swedish context. These experts represented governmental and non-governmental agencies, regional/national/international public health agencies, research institutes, industry, and healthcare. The 10 Southeast Asian workshop participants included 4 participants from Malaysia, while the rest of the participants worked within the context of Malaysia or SEA as a whole. These experts represented non-profit, non-governmental organizations, academia and research, intergovernmental organizations, industry, multi-lateral organizations, and non-profit research organizations. The professional diversity of these AMR experts produced a very meaningful and diverse set of opinions informed by differing professional realms. While not all participants from the Swedish and Malaysian workshops were Swedish/Malaysian, they were able to speak about broad region trends since they all lived and had professional experiences in the European or Southeast Asian region, respectively (Lambraki et al., 2023). Additionally, while the focus of the Swedish and Malaysian workshops was not on governance and public engagement, the professional backgrounds of participants allowed for sector-specific discussions on policies needed to improve sector-specific practices as well as ways to approach the people who work within those sectors.

Participants were guided through two interventions: taxation and IPC measures (Lambraki et al., 2022). AMR experts discussed the various ways through which the two interventions created success in 2050, given the new reality of climate change (Lambraki et al., 2022). Fully

described protocols and results for the Malaysian and Swedish workshops can be found in the paper by Lambraki et al. (2022). My GRA consisted of transcribing and analyzing the data collected: the 80-page transcript from the Swedish workshop and the 90-page transcript from the Malaysian workshop, along with the accompanying audio recordings. During the analyses I did for my GRA, which focused on identifying elements of success that contributed to AMR reduction in 2030 and 2050 using the two interventions, taxation at the point of sale and IPC, I also noticed that governance and public engagement were often discussed.

Chapter 2: Study Rationale and Objectives

This thesis aimed to investigate how governance and public engagement concepts emerged from Swedish and Malaysian AMR experts' conversations about successful and sustainable factors associated with the success of taxation and IPC measures in combatting AMR in 2030 and 2050.

The specific objectives of this thesis were to:

I. Identify elements of governance that emerged during Swedish and Malaysian AMR experts' conversations about the sustainability and effectiveness of taxation and IPC measures in 2050 and conditions that facilitate success in 2030, and compare these governance elements between the two contexts;

II. Identify elements of public engagement that emerged during Swedish and Malaysian AMR experts' conversations about the sustainability and effectiveness of taxation and IPC measures in 2050 and conditions that facilitate success in 2030, and compare these public engagement elements between the two contexts; and

III. Identify challenges and opportunities related to governance and public engagement that emerged from Swedish and Malaysian AMR experts' conversations about the sustainability and effectiveness of taxation and IPC measures in 2050 and conditions that facilitate success in 2030 and compare these challenges and opportunities between the two contexts.

Chapter 3: Methods

3.1 Research Design

To assess governance and public engagement concepts, this thesis involved a secondary analysis of existing data, specifically the two transcripts and their associated audio and video files. I generated my thesis aim and objectives using a data-focused approach where I first assessed the possible questions that could be answered by the data (Cheng et al., 2014). Following the generation of potential questions, I narrowed down my questions based on the topics I was mostly interested in. Governance was a topic often discussed by participants and is an area of interest to me. Given that social and cultural factors perpetuate AMR, I wanted to include a humanistic lens through which the data can be viewed (Minssen et al., 2020). Hence, the sociocognitive theory was selected to assess public engagement. Given the complexity of AMR and the multitude of factors involved in perpetuating it, a further investigation into governance and public engagement was justified. This thesis used a deductive qualitative design. Deductive qualitative analyses employ a theory or a framework to analyze the data, including whether the data supports the theory or not (Azungah, 2018). The frameworks assessing governance and public engagement I used are described further below.

3.2 Ethics Approval

Since this thesis's purpose fell under the larger project's original aim (ORE# 41781), a new ethics application was not required. However, an amendment was submitted, and my name, my thesis committee members and relevant documents, such as TCPS-2 core certificates, were approved under the original ethics application.

3.2 Theoretical Foundation

This thesis used the AMR governance framework developed by Anderson et al. (2019) and the SCT (Luszczynska & Schwarzer, 2015) for data analysis to organize the data emerging from AMR experts' discussions. The AMR governance model constructed by Anderson et al. (2019) is cyclical in design, indicating that AMR governance is constantly revised and improved upon. The governance framework consists of 18 domains falling under three major governance areas: policy design, implementation tools, and monitoring and evaluation (Anderson et al., 2019). Each domain contains some indicators that can be binarily evaluated (Anderson et al., 2019). A visual illustration of the AMR framework can be found in Appendix A. I used these 18 domains, with some modifications to their definitions (refer to Table 1) as follows, the 18 domains were used as nodes and relevant quotations were contained within the different nodes. New elements of governance outside of Andersons' framework identified through the transcripts were added as extra nodes.

Since Anderson's framework was originally designed to evaluate NAPs, many of Anderson's definitions for the 18 domains required adaptation to be relevant to the data collected. For example, the original governance framework has multiple indicators for the transparency domain. It defines transparency in terms of whether NAPs are publicly available and whether surveillance data is also publicly available (Anderson et al., 2019). However, in my study, NAPs are not discussed as a main topic. Hence, the definition of the domain 'transparency' was modified to be whether there was transparency in reporting, communicating AMR messages, or sharing data across sectors and countries. Table 1 illustrates the 18 domains with Andersons' definitions and my adapted definitions as well as indicators.

Table 1. The 18 Domains of Anderson's Governance Framework, organized by the 3 Governance Areas, with Original Definitions, Adapted Definitions, and Indicators.

Domain	Andersons' Definition (Anderson et al., 2019) and Indicators	Adapted Definition and Indicators
Governance Area: Policy Design		
Strategic Vision	It considers "whether a National Action Plan has drawn on an up-to-date, country-specific situational analysis regarding the extent of AMR and its drivers." Some indicators include: 1) "Are objectives contained within the National Action Plan specific, measurable, and time-bound?" 2) "Is a National Action Plan in place, if not what is the timeframe for developing and implementing the National Action Plan?"	It refers to having future in mind when implementing AMR policies. Some indicators: 1) Are there any tools used to predict how the future will look like and concrete steps needed to be taken to avoid it? 2) Are our goals specific? Quantitative? Are there any specific time frames?
Participation	Refers to "stakeholder participation, both during conception and subsequent implementation of AMR National Action Plans." Some indicators include: 1) "Was a high level of stakeholder participation facilitated throughout the development of National Action Plans?" 2) "Was there support from an advisory group or subject matter experts during the development of these National Action Plans?" 3) "Are the activities in the National Action Plan inclusive across all sectors related to One Health? If so, how, and if not, why not?"	This refers to the participation of stakeholders, varying sectors, and countries in activities aimed at reducing AMR. An indicator: 1) Is there consistency across sectors and countries?
Coordination	Refers to whether there is "coordination between all relevant ministries, high-quality laboratories, medical and veterinary professions and statutory bodies, research and academic institutes, civil society including patient organizations, food and pharmaceutical industries, and wholesale	Is there any coordination between the sectors across the One Health system? Across different countries? Is there a ministry responsible for this coordination?

	and retail distributors, through a multi-sectoral One Health policy approach." Some indicators: 1) "Is coordination between sectors and across different levels of each sector considered?" 2) "Is there a ministry or intersectoral committee, or both, responsible for coordination and implementation?"	
Accountability	This refers to an entity "having the obligation to answer questions regarding decisions and actions." Some indicators: 1) "Is there a ministry or intersectoral committee, or both, responsible for coordination and implementation that is accountable to the government?" 2) "Is a responsible person nominated in each sector and do agreements exist regarding what happens if objectives are not met?"	Is there a system that can allow us to track antimicrobial use and increase accountability? Do we have agreements on who is responsible when objectives are not met? Is there a ministry or certain body held responsible?
Transparency	This is understood as "ensuring that AMR policy development, implementation, and evaluation occur in an open and accessible manner; in terms of AMR National Action Plans, that the plan itself, progress reports, and funding allocations are published with open access to the public." Some indicators include: 1) "Is the complete National Action Plan publicly available?" 2) "Are all progress reports, funding information, and antimicrobial use surveillance data publicly available?"	This refers to transparency in reporting, communicating AMR messages, or data sharing.
Sustainability	"Sustainability should be a key objective of any AMR National Action Plan, as any positive change should aim to be consistent and maintained." Some indicators include: 1) "Is there a written mandate or voluntary agreement from all relevant sectors in place to implement the National Action Plan?" 2) "Are there dedicated budgets in place to implement specific activities in the National Action Plan?"	This relates to the longevity of efforts aimed at reducing AMR. Some indicators: 1) Is there a dedicated budget for AMR-related activities? 2) Is there maintained engagement with stakeholders regarding AMR? 3) Is the future in mind when implementing certain AMR policies?

	3) “Is there an assessment of future budget requirements for different activities listed in the National Action Plan?”	
Equity	This refers to whether there is a “focus on facilitating equitable access to the right antimicrobial, at the right time, based on clinical need; shortages of antimicrobials can drive AMR.” An indicator: 1) “Does the National Action Plan include both encouraging responsible use and facilitating equitable access to existing essential antimicrobials?”	Is there equitable access to antimicrobials across different countries and within countries?
Governance Area: Implementation Tools		
Surveillance	This refers to a monitoring system that is “fundamental for the planning, conduct, and evaluation of all other AMR policies.” This system can “facilitate accountability mechanisms.” Some indicators include: 1) “Is there a national surveillance system for resistant organism across the human, animal, and the environmental health sectors?” 2) “Is there adequate laboratory capacity and capability supported by regular external quality assessments?”	Is there a surveillance system that allows us to monitor antimicrobial use across the One Health system? Is this surveillance system specific and accurate?
Antimicrobial Stewardship	Refers to “a coherent set of actions designed to use antimicrobials responsibly and refers to all actors and stakeholders seeing their responsibilities, ownership, and interest in the issue.” Some indicators include: 1) “Are stewardship programmes across human and animal health sectors?” 2) “Are rapid diagnostic tools widely available and in regular use? If so, do national guidelines regarding their indication and interpretation exit?” 3) “Is there any use of financial and non-financial incentives or penalties in animal and human health to reduce inappropriate use of antibiotics?”	This refers to any actions taken across the One Health system to combat AMR, whether it is certain policies, incentives, or diagnostics tools that can regulate antimicrobial use across the different sectors.
Infection Prevention and Control	This refers to a set of practices that “aim to reduce the transmission of multidrug-resistant bacteria, minimise the overall risk	This refers to any IPC policies across the One Health system (e.g., biosecurity measures,

	of infection, and decrease the overall need for antimicrobials." Some indicators include: 1) "Are there IPC policies across all levels of human, animal, and environmental health sectors?" 2) "Are immunisation programmes used as an approach to prevent infections across human and animal health sectors?" 3) "Are financial and non-financial incentives or penalties for IPC policies used across human, animal, and environmental health?"	hygiene-related, Sustainable Developmental Goals)
Education	A tool that is "key to developing capacity to adopt standards, facilitate control policies, or implement guidelines sufficiently; for all groups of professionals who are in position to prescribe antibiotics or influence antibiotic use." Some indicators include: 1) "Is there certifications or programmes in place to ensure a basic education for all involved groups of professionals to deliver necessary understanding for strategies to tackle AMR?" 2) "Is there a workforce strategy that aims to deliver the sustainable supply of the necessary workforce required to deliver antimicrobial stewardship and IPC policies?"	This involves AMR education and training across all sectors.
Public Awareness	Refers to "public awareness campaigns [that] can be used in a variety of settings to raise awareness and promote best practices for prevention of AMR." Some indicators include: 1) "Are there multimodal public awareness campaigns that focus on AMR and educational programmes (including school children) related to AMR?" 2) "Do the implemented public awareness campaigns have an ongoing character?" 3) "Does the conception of the public awareness campaign consider aspects of behavioural sciences, social science, and psychology?"	This can involve campaigns to raise awareness about AMR, engaging the public through messages and other forms.

Medicines Regulation	Refers to "any laws, accreditation, or financial incentive or penalties in place with the aim of reducing antimicrobial use." Some indicators include: 1) "Are there regulations in place to ensure appropriate use of antimicrobials in human health?" 2) "Is there an authority in place to monitor and enforce legislation, if so, does this authority have a dedicated budget?"	Any mechanisms in place that can control the dissemination of antimicrobials across country borders and locally (at pharmacies, hospitals, etc.)
Fostering R&D and Facilitating Market Access to Novel Products	This refers to whether the National Action Plans include access to "antimicrobials, diagnostics, vaccines, and alternative treatments such as probiotics, metals, or antimicrobial peptides, to foster research and development." Some indicators include: 1) "Is fostering R&D and facilitating market access to novel antimicrobials, diagnostics, vaccines, and alternative treatments in both human and animal health listed as priority in the National Action Plan?" 2) "Is there a dedicated national budget for R&D and development of novel antimicrobials, diagnostics, vaccines, or alternative treatments?"	Any innovative technologies that can help reduce AMR. Some indicators can include: 1) Are there any priorities with regards to access to novel antimicrobials or technologies in the different sectors 2) Is there a dedicated budget for this?
Governance Area: Monitoring and Evaluation		
Reporting	This refers to "annual progress reports [that] monitor and evaluate AMR policies in the interim, these progress reports can also be used by other countries to inform their AMR policies and provide feedback to international public health agencies on national achievement." Some indicators include: 1) "Are annual AMR National Action Plans progress reports published?" 2) "Is there collaboration with and systematic data transmission to international surveillance systems?"	This refers to reporting AMR data at the local and international levels and across the One Health spectrum.
Feedback Mechanisms	"For surveillance to be an effective tool for improvement, data needs to be routinely fed back at the regional and organisational	Are any policies in place to control the misuse and overuse of antimicrobials? Can we use

	level; in practice, effective feedback mechanisms require involving local stakeholders in analysis of what the data show, in which improvement is needed, and their specific data needs; to assess relative performance." Some indicators: 1) "Are there feedback mechanisms in place that relay surveillance data back at both regional and organisational level?" 2) "Are there regular deadlines in place to review progress of specific actions within the National Action Plan?"	any tools to predict the risks associated with certain behaviours or policies?
Effectiveness	This involves determining "which AMR policies are cost-effective and represent value-for-money." Some indicators: 1) "Have there been efforts to evaluate the effectiveness of specific policies or interventions, or both, implemented?" 2) "Have efforts been made to evaluate the cost-effectiveness of specific policies or interventions implemented?"	Are there any efforts to test the effectiveness of certain AMR-related policies? What is working and what is not?
AMR Research	This refers to research that provides "an evidence-base for AMR policies; without a thorough understanding of the drivers of AMR and policies in place to restrict them, resistance will develop to new antimicrobials. This research should also consider including modelling exercises to forecast incidence and prevalence of AMR and the current and future health and economic effect." Indicators include: 1) "Is research to understand both the drivers and effect of AMR and potential policies and interventions identified as a key priority in the National Action Plan?" 2) "Is there a dedicated budget for AMR research in place?"	Is there any research in place on the drivers or impact of AMR and AMR-related technologies? This research could involve AMR messaging and having the right professionals in place to construct messages and carry out campaigns.

The SCT framework contains six different components (Appendix B), and these were used, without any adaptation, as nodes during coding.

3.3 Ontological and Epistemological Orientation

The nature of the methods selected is guided by the researcher's ontological and epistemological orientation (Ritchie et al., 2013). Thus, I declare an idealist ontological orientation, whereby reality is socially constructed, and multiple realities might exist (Hiller, 2016). AMR experts painted the world in 2050 and offered many realities uniquely shaped by their own personal and professional experiences within their field of expertise and interactions. Thus, I took an interpretivist epistemological stance, which states that individuals attribute meaning based on their interactions with the world (Hesse-Biber & Leavy, 2011), and the various personal and professional interactions these AMR experts had played an important role in the views they hold and the possible realities that can exist within the context of AMR.

3.4 Data Analysis

Thematic analysis was used to uncover patterns, themes, or topics emerging from the data that coincide with selected frameworks (Braun & Clarke, 2006; Lester et al., 2020). The protocol for thematic analysis initially described by Braun & Clarke (2006) was used to analyze data used in this thesis. NVivo 12 (Released March 2020) software was used to code and analyze the data.

3.4.1 Coding

Line-by-line coding was used to organize the data into themes, which consisted of the different areas and domains of the Anderson governance model (Appendix A) and the SCT model (Appendix B).

Using the governance framework (Anderson et al., 2019), which contains 3 governance areas and 18 domains, I coded each area as a node for a total of three nodes: monitoring and evaluation, implementation tools, and policy design (Appendix A). I created 18 sub-nodes within these three nodes, one for each domain in Andersons' model (Appendix B). For example, four

subnodes were created under monitoring the evaluation node: reporting, feedback mechanisms, effectiveness and AMR research. When coding these 18 subnodes, I coded all relevant quotes that discussed said domain, using the adapted definitions found in Table 1. For the SCT model (Appendix B), I coded each of the six components as a node: self-efficacy, sociocultural facilitators, sociocultural impediments, goals, behaviour, and outcome expectancies.

To identify context-specific challenges regarding governance and public engagement in AMR, instances where AMR experts described facilitators or hindrances specific to Sweden or Malaysia were analyzed. Two nodes were created for each Swedish and Malaysian workshop, where facilitators and hindrances represented two independent nodes. Hence, a total of four nodes across the two workshops were created. These four nodes aimed to capture nuances and context-specific challenges and opportunities that lay outside the parameters of the governance and SCT models.

Open coding was used to code quotes that did not belong to the different nodes specified by either the Anderson's framework or the SCT (Williams & Moser et al., 2019). This open coding allowed me to capture governance and public engagement-related themes that Anderson's framework and SCT did not address and establish gaps in the two frameworks used (Williams & Moser et al., 2019).

3.4.2 Coding Phases

Coding was completed in four phases. The first phase included coding relevant quotes under Anderson's governance framework and creating new themes or nodes for governance-related concepts that did not fall under the framework. The second phase included coding relevant quotes under the SCT as well as establishing new themes that the SCT did not address.

Before I began coding, a miscellaneous category was created, and this node allowed me to place quotes whose relevance I was uncertain of. With each new coding phase, these miscellaneous quotes were either moved to the list of nodes already existing (part of the two frameworks) or became independent nodes that represented important governance or public engagement components not addressed by the two selected frameworks. The two frameworks were adapted based on how well the data aligned (or not) with the pre-established frameworks.

The third phase of coding involved identifying relevant context-dependent opportunities and challenges of governance and public engagement in Sweden and Malaysia. The fourth and last stage of coding consisted of going back and checking whether all the quotes coded under a specific category were relevant and if there were any intersections between the different nodes or frameworks. Given the methodology guiding the collection of data through the two workshops, which is based on scenario analysis and hypothesizing alternative scenarios for the future (Lambraki et al., 2021), it was inevitable that AMR experts described public engagement or governance differently. Some nodes contained conflicting interpretations/solutions to AMR, but they were all presented to preserve and keep data representative of the varying opinions.

3.4.3 Revisiting Transcript Audio and Video

An additional data analysis component was revisiting the original audios for the two different workshops held with AMR experts from Malaysia and Sweden to capture any tones or emphasis throughout the workshops. This step was used to identify the context-dependent facilitators or impediments emergent from AMR experts' conversations regarding governance and public engagement. The videos were analyzed for changes in tone, pauses, pitch etc.

3.4.4 Organization of Data Based on Time Frame and Agent

Given the scenario planning design of the workshops, participants spoke about AMR in different time frames. Thus, two separate tables were used to organize quotes in terms of time frame (present vs future) for Sweden and Malaysia separately (Tables 2 and 3). Specifically, these tables captured what participants said about governance and public engagement in terms of what we have presently or lack and what we need to do in the future. These tables also organized the quotes based on agents, where agents were the individuals to whom the quote was directed: citizens, policymakers, pharmaceutical companies, researchers, farmers, supermarkets, etc. While the agent category was not included in Tables 2 and 3, it was discussed within the context of each domain. Tables 2 and 3 contain summaries of what Swedish and Malaysian AMR experts said about governance and public engagement across the different time frames, respectively.

3.4.5 Linking Governance and Public Engagement

Lucid chart software (Luc Software Inc) was used to generate a node connection diagram for each of Sweden and Malaysia, to help identify the connections between the different components of governance, SCT, and their interactions. This was a post hoc decision made post analysis to help visualize how governance and SCT interacted and, ultimately, which components were central to both frameworks. Each circle and diamond represented an element of governance or public engagement, respectively. Centrality represented high frequency of coding as well as intersectionality with other elements of governance or SCT, hence the largest circle in each diagram represented the node that was discussed the most as well as interacted with other elements the most. Specifically, centrality was determined through the number of quotes coded under each node and quotes that fell under multiple nodes denoted interactions with other nodes. The size of the circles or diamonds (denoting governance and public

engagement, respectively) was determined through a tally of the number of quotes coded under each node, with the biggest nodes having the greatest number of quotes coded under it. The size of other peripheral nodes was determined quantitively as well and was constructed with relative quote frequency in mind.

3.4.6 Ensuring Rigour

It is important to ensure rigour throughout the research process to establish trust and confidence in the results (McAlister et al., 2017). One of the strategies commonly used to confirm the trustworthiness of data and its interpretation is confirmability (Ahmed, 2024). Confirmability can include strategies such as peer-debriefing, checking with study participants, or active reflectivity (Ahmed, 2024). In this study, I ensured confirmability through peer-debriefing with my colleagues Dr. Irene Lambraki and Dr. Melanie Cousins. While inter-coder reliability was not possible as I performed all the coding myself, I used a common method to ensure rigour and that my interpretation of the results aligns with my colleagues. 10% of the codes were separately reviewed by Dr. Irene Lambraki and Dr. Melanie Cousins as per O'Connor & Joffe, H. (2020), and any discrepancies were discussed. Two Excel sheets, one for the Swedish workshop and one for the Malaysian workshop, were created; these sheets each contained 10% of the overall quotes coded in each workshop. My research colleagues were assigned an Excel sheet each, and they were responsible for placing the quotes selected under the relevant codes (the 18 governance domains and six public engagement elements). Adapted definitions of the governance nodes were provided to IL and MC to ensure consistency and understanding of the nodes. An agreement of 89% and above was established across IL and MC.

Chapter 4: Results

4.1 Elements of Governance Emerging from Sweden

AMR experts from Sweden discussed all 18 domains of Anderson's governance framework that fall under the three governance areas: implementation tools, policy design, and monitoring and evaluation.

Antimicrobial Stewardship

Antimicrobial stewardship was a component of governance consistently discussed by Swedish AMR experts. Specifically, stewardship behaviours discussed were taxation (or incentives to regulate behaviour), requiring diagnostics tests for any antimicrobial prescription, enforced trade standards, transparent messaging and collaborative stewardship efforts, and effective surveillance mechanisms to ensure successful AMR stewardship.

AMR experts from the Swedish workshop discussed taxation as an intervention to tackle AMR in 2030 and 2050. Various elements of antimicrobial stewardship described by Anderson's governance framework emerged from these conversations. Firstly, Swedish AMR experts expressed the importance of following up with farmers about their annual antibiotic use. Farmers who use antibiotics responsibly are incentivized by monetary expenses that help them with their farms. As stated by an AMR expert:

> "As long as I would say, all the agriculture policies are based on the public aids and suspensions and so on, and maybe one of the points for this success could have been the fact that the government in Sweden has a made a follow up of the use of antibiotics by farmers. And once the year is finished, if they have done a good job, they will get an extra amount of aid to his farm."

An AMR expert explained further that this follow-up ensures responsible antimicrobial use, that is, "using antibiotics in the right way and in the right doses." To summarize, AMR

experts highlighted the need for incentivizing farmers so that positive AMR behaviours, such as proper dose usage and responsible behaviours at the farm level, can be followed.

An AMR expert discussed that for taxation to be a successful tool in 2030 and 2050 in combatting AMR, proper diagnostic tests are needed to ensure that all antimicrobials prescribed are appropriate and necessary. The expert mentioned "having in place a rapid diagnostic test for every antimicrobial prescription so that no antimicrobial is prescribed without a test, and that would negate the need for over-the-counter medicines."

AMR experts across the focus groups also discussed antimicrobial stewardship in terms of standards and regulations set by countries with tighter AMR regulations. Participants discussed that trade relationships between countries with tighter and looser AMR regulations have played a role in some countries with loose AMR countries to change and abide by tighter standards. An example given by an AMR expert is "…Vietnam exports to the UK, and they increased a lot of their standards and the government invested in the improved facilities, the processing, the farming and so on." An expert further expressed that many farmers who export to countries with tighter AMR regulations cannot afford to lose that source of income; hence, abiding by these tighter regulations is important for their livelihood. As said by an AMR expert:

"…In China, you know, they have problems with antibiotic residues, and their solution was to shut everybody down and only give people permits to be able to farm if you were one of the preferred farmers to export because you know you cannot afford export to be stopped at customs, it destroys the whole sector."

Participants emphasized that trade plays an important role in countries' economies and is an essential regulatory point whereby quality control and standards can be enforced. AMR experts discussed that, for antimicrobial stewardship to be effective, accurate and transparent messaging around AMR should be transmitted. An AMR expert stated, "The talent we have to communicate about what is the risks with antibiotics. When should you avoid them? And when

you actually should take them." An AMR expert acknowledged that antimicrobials are important drugs for some people to have. Therefore, "we need to have good stewardship around antibiotics, but it is a lifesaver, so we do not want to scare people from taking antibiotics when they should."

AMR experts also discussed the importance of antimicrobial stewardship efforts to be collaborative and span the international scene. For example, an AMR expert stated that there must be "room for international corporation in order to avoid all unintended consequences." The expert further expressed their concern, "we see a lot of the international collaboration being dismantled." These worries arose in conversations surrounding AMR, global warming, COVID-19, and the achievement of SDGs. An expert also mentioned that it is "as important from a very Swedish context to think about what we're going to do here in Sweden, we need to address it also on a global scale. Otherwise, we are lost." Participants expressed worry about a future that is fragmented and disjointed whereby countries work in solos, making it difficult to unite efforts to tackle AMR.

AMR experts also emphasized that, for effective antimicrobial stewardship, appropriate and accurate surveillance is required. An AMR expert stated, "How are we going to count antibiotic usage? A lot of the data that we have comes from sales, but we know that that's very different from actual usage." AMR experts also stated that on top of not capturing usage, there are issues with the disposal of antimicrobials. An expert stated, "...in a fish farm in Scotland, you can only buy a certain antibiotic in 1K tubs, and you never use one kilogram, you'll use, you know, use much smaller amounts and dispose the rest." An AMR expert also worried that "across the world there is this lack of uniformity when it comes to gathering data around antibiotic use that is another aspect that needs to be considered. You know, if we're going to deal with this problem globally is about how we are doing the counting." In summary, AMR experts

defined a future surveillance system that is effective in curbing AMR as one that is consumption-based, accurate, and uniform. While AMR experts did not pinpoint where the responsibility of implementing this surveillance system lies, they discussed how currently the "new EU policy on combating AMR is to improve the surveillance and monitoring system and look no longer at the sales ... but look at the use data based on the veterinary surgeons at the veterinarian's prescription to specific species of animals." Hence, the EU seems to play an important role in standardizing data collection methods for antimicrobials in Europe but experts also mentioned the need to relay those reports at the international level as well.

Education

The second component of governance discussed by Swedish AMR experts was education. Three different aspects of education were discussed by Swedish experts as important in order to combat AMR in 2030 and 2050 successfully. These included the importance of educating farmers, the general public and the involvement of social scientists in AMR campaigns.

AMR experts discussed the significance of educating farmers on the appropriate use of antibiotics and using innovative technologies that can reduce the inappropriate use of antibiotics. An AMR expert stated, "…farming has become a very complex issue and more and more and they need to be aware of new technologies, very rapid changes in the business." This awareness, an AMR expert further explained, can be achieved through "education and training, and in order to give the tools to farmers on how to better use antibiotics is a very important part because this will be also important in terms of value of the production."

AMR experts also emphasized the need to engage and educate the public and children on antibiotics, increasing awareness on the topic and educating them on preventative methods to combat AMR. An AMR expert stated, "I mean education of children and broader education of

the public in terms of awareness of the benefits and harms that antibiotics bring. And linked into that the wider education piece on public health, diet, activity, so not necessarily exercise, but activity." Education on the aspects mentioned by AMR experts was thought to "lead to healthier lifestyles and hopefully better quality of life and the reduction in long-term conditions."

A huge component of education is the need for the participation of social scientists and communication experts. An AMR expert stated, "So, we think that again, more efforts in education and information campaigns are really important, and the right professionals should be doing these, meaning more involvement of social scientists, communication experts etc." They further explained that "traditionally, we scientists have been trying to do this, and perhaps not doing it in the right way or at least with the expected success."

Fostering R&D and Facilitating Market Access to Novel Products

The third component of governance emerging from Swedish AMR experts was fostering research and development and facilitating market access to novel products. Experts specifically addressed two important aspects of Fostering R&D: the need to invest in research, alternatives to antimicrobials, and vaccines, as well as the political setbacks in the face of innovation.

AMR experts discussed the importance of investing in research on antimicrobials, alternatives, vaccines, and new technologies to ensure that AMR can be combatted in 2030 and 2050. An AMR expert stated:

> "I think something that Sweden would need to have in 2050 to make this success would be also a much more agile regulatory context, meaning that a lot more investment into research, for example, on alternatives would need to be there and on better parts for industry interested in developing new products or new feeding strategies, feed additives, don't know bacteriophages and new vaccines."

New technology such as clustered regularly interspaced short palindromic repeats (CRISPR) and genetically modified organisms (GMOs) were also discussed as important

technologies as stated by an expert, "...innovation when we talk about GMO, CRISPR, genetics and so on, this is for me part of the innovation and innovation is key in order to reach this 2050 finish in a better way."

AMR experts also identified challenges in the face of innovation and research aimed at combating AMR. An AMR expert mentioned, "If we deny innovation, we are lost. And this is the real situation. I mean, we are lacking behind United States, Canada, Argentina, China, India, and it is because about politics, and that is it." Part of the problems mentioned by AMR experts is getting policymakers interested in combatting AMR and dedicating budgets towards research on it, which remains a challenge.

Infection Prevention and Control

IPC was also identified as an important component of governance discussed by AMR experts. The two themes identified were IPC lessons from the COVID-19 pandemic and fulfilling and SDGs.

AMR experts emphasized the role the COVID-19 pandemic has had on the lessons learned on IPC measures. One expert stated, "When we talk about preventive measures to take, I would like us to have a discussion on lessons learned from the pandemic. Now a lot of hygiene, sanitation, type of intervention has taken place, a lot of good results from that, at least on the preventing the spread of COVID-19."

While AMR experts highlighted the key role IPC measures played in preventing the transmission of the COVID-19 virus, they were concerned about the possible negative impacts of over-cleanliness. An expert stated, "Kids at the caretaking centers... but what they use nowadays, they use a lot of disinfectant on their hands and that it could be harmful to other

bacteria that they really need." While IPC measures were discussed positively, AMR experts warned of excessive sanitation and its influence on people's immunity.

AMR experts stated that individuals need to practice hygienic practices and have access to the basic necessities of life. One expert stated, "We need to see that people wash their hands, good hygiene and that we have access to toilets, proper toilets across the globe." They have highlighted how IPC measures are aligned with the SDGs as stated by an expert, "If there is no access to clean water and healthy nutritious food across the globe and hygiene, sanitation and access to food and water... which also took us back to the sustainable development goals of the, really basics one like no hunger and access to water." AMR experts consistently discussed IPC practices as the common factor linking AMR and SDGs.

Medicines Regulation

Medicines Regulation was another component of governance discussed by AMR experts. Three prominent themes emerged: regulation of veterinarians, dispense of antibiotics, and food regulations across borders.

AMR experts stated that in Sweden, veterinarians do not get paid for using or selling more antibiotics, which acts as a regulatory mechanism. One expert stated that "...the veterinary does not get paid for the antibiotics. I know it is that case in many other countries that they have, that they get paid if they sell more, they get more paid and I think that is a very important thing that all countries should apply too." This regulatory behaviour was identified as important to implement in other countries as well to limit the unnecessary use of antibiotics and serve as a hindrance.

Similarly, AMR experts identified that it is important to ensure all antibiotics are obtained on a prescription basis. One expert stated, "Yeah, I mean, it is not buying; it is about resources, isn't it? You know, in this country, you cannot use an antibiotic if you haven't got a prescription."

According to AMR experts, this regulatory checkpoint aimed to limit unnecessary consumption of antimicrobials.

AMR experts also discussed how food transported across borders could be a regulatory checkpoint where countries that have tight regulations can enforce certain AMR policies on imported food. One expert provided an example, "... A good case example would be the Pangasius, the fish market that Vietnam exports to the UK and they increased a lot of their standards and the government invested in the improved facilities, the processing, the farming and so on." AMR experts expressed that not only did regulating imported products act as a regulatory mechanism but it pushed countries with looser AMR policies to invest in resources that aimed to minimize AMR.

Public Awareness

AMR experts frequently discussed elements of public awareness, a governance component. The themes discussed include the inclusion of social scientists and experts in public awareness campaigns, showcasing scary examples to deter inappropriate antimicrobial use behaviours and the construction of effective messaging.

AMR experts discussed the need for AMR public awareness campaigns to include a variety of experts from the humanities. One expert stated:

"We think that again, more efforts in education and information campaigns are really important, and the right professionals should be doing these, meaning more involvement of social scientists, communication experts etc… Traditionally, we scientists have been trying to do this, and perhaps not doing it in the right way or at least with the expected success."

AMR experts mentioned that the inclusion of these professionals aimed to gather more understanding of human behaviour and how to better design public awareness campaigns.

AMR experts also discussed the need to show scary examples with public awareness campaigns; these are examples where individuals have been affected by AMR. One expert stated, "...make some examples to show some people that actually got caught with AMR and to show how bad it can be and so on. So, a little bit to scare people, to make them aware about the problems." Experts believed that showing this crude reality to people will create more awareness and hopefully deter them from behaviours that propagate AMR.

AMR experts discussed that within public awareness campaigns and efforts, it is important to have transparent and effective messages that not only focus on the risks but also highlight the benefits of using antimicrobials, especially in cases where it is needed the most. An AMR expert stated, "We need to have good stewardship around antibiotics, but it is a lifesaver, so we do not want to scare people from taking antibiotics when they should." This highlighted the need to communicate transparently about antimicrobials. Expert further stated, "...We have to communicate about what is the risks with antibiotics. When should you avoid them? And when you actually should take them."

Surveillance

Surveillance was an important governance component discussed by AMR experts. AMR experts mainly discussed what effective surveillance entailed. The three aspects discussed were: actual consumption, specificity, and uniformity.

An effective surveillance system described by AMR experts is one that monitors actual usage of antimicrobials, not merely the sales, as stated "...What we are doing is counting the sales and across the world there is this lack of uniformity when it comes to gathering data around antibiotic use that is another aspect that needs to be considered." AMR expert further expressed

concern around the disposal of antimicrobials when currently monitoring antibiotic use and stated:

"How are we going to count antibiotic usage? A lot of the data that we have comes from sales, but we know that that is very different from actual usage. So, in a fish farm in Scotland, you can only buy a certain antibiotic in 1K tubs and you never use one kilogram; you will use, you know, use much smaller amounts and that and dispose the rest."

Another aspect of surveillance discussed by AMR experts was the specificity and uniformity of an effective surveillance system. An AMR expert stated:

"It's about getting together and agreeing on standards." They further stated, "...A lot of metrics based on per kilogram of an animal, you know overall per kilogram of beef compared to poultry. How much active antibiotic are we using? But then you're still tied with this difference in potency so, you still need quiet fine granularity on that data as well. You know which antibiotics are being used, not only the overall amount that's being used but which antibiotics are being used?"

Therefore, AMR experts expressed the importance of having a uniform method of monitoring antimicrobial use, for example, the metrics used and the potency level of antimicrobials used.

AMR Research

AMR experts frequently discussed the need for more AMR research to understand AMR and its drivers further so that certain policies can be in place to limit it. Experts discussed the need for research that not only spans newer technologies but also human behaviour research.

An AMR expert stated, "...A lot more investment into research, for example, on alternatives would need to be there and on better parts for industry interested in developing new products or new feeding strategies, feed additives, don't know bacteriophages and new vaccines." AMR experts not only highlighted the need for AMR research and technologies that can curb AMR but also preventative mechanisms that can help prevent or limit the need for antimicrobial use.

AMR experts also emphasized the importance of conducting research on human behaviours in order to be able to promote positive behaviours that can collectively reduce AMR. An AMR expert stated:

"I think we will understand so much more about how humans behave and how we make our choices, though we will be able to influence people without them necessarily knowing, you know, the kind of nudging type of approaches. That may be part of this, delivering the, you know, the solution to AMR as well as other problems."

Research on AMR and newer technologies alongside human behaviour research were identified by AMR experts as important to ensure success in curbing AMR in 2050.

Effectiveness

Effectiveness was another important governance component discussed by AMR experts. The experts discussed effectiveness through lesson learning from the COVID-19 pandemic and the Swedish context.

One area where learning can be achieved, as mentioned by AMR experts, was the COVID-19 pandemic and the various IPC measures implemented to limit the spread of infection. An AMR expert stated, "I like us to have a discussion on lessons learned from the pandemic. Now a lot of hygiene, sanitation, type of intervention has taken place, a lot of good results from that, at least on the preventing the spread of COVID-19." Experts stated that through these lessons, we are able to recognize the value of IPC measures in effectively fighting against COVID-19, and these same lessons can be applied in the context of AMR.

AMR experts also discussed the need for drawing lessons from countries like Sweden, which effectively minimized AMR rates by introducing and enforcing certain policies. An AMR expert stated:

"Sweden is the country in the EU that uses the lowest, that has the lowest use of antibiotics to farm animals. So we are, I think we could be a good example for other European and other

countries around the world because we already use a lot less antibiotics compared to other EU countries."

Experts emphasized frequently that sharing these lessons and policies used to achieve success in reducing antimicrobials will be crucial moving forward.

Feedback Mechanisms

Feedback mechanisms was another governance component discussed by AMR experts. An AMR expert gave an example: "Let's say they, well, they call it the lack of accuracy in the risk analysis that we have had. I mean, we all governments, companies, etc, will try to make it sort of mapping of the risks that we are exposed to, and the failure has been brutal, I would say." AMR experts discussed the importance of conducting accurate risk analysis to assess the effectiveness of the policies we have so far and the ones we would like to implement.

Reporting

AMR experts often discussed the governance element 'reporting'. AMR experts discussed the need for uniform data collection and transparent reporting, as mentioned under the surveillance component above, whether it is by the farmer, veterinarian, etc. However, there were concerns regarding countries reporting their use of antimicrobials as stated by an AMR expert:

"If countries vow away to reduce their overall tonnage, kilograms of antibiotics being used actually they may, they may advise their farmers and their clinicians to use more potent antibiotics and therefore give that appearance, that total tonnage is being reduced in actual fact you might be using, you know more of a of an active substance and creating more of a problem and this comes down to actually, you know, uniformity of data collection."

AMR experts stated that there is fear that countries may appear to have used fewer antimicrobials but, in fact, maybe using much more potent ones, making AMR a bigger problem.

Accountability

Accountability was an important component of governance discussed by AMR experts. AMR experts only spoke about the accountability issue in terms of the SDGs; there were questions raised about what happens if we do not meet the goals by 2030. An AMR expert raised questions such as “Do we just start the conversation all over again? Who is responsible for overseeing the progress? Is it the UN?” another expert, in response, stated:

> “The sustainable development goals should be met by 2030. So, the question for me is, what happens when these aren't met? What then? Do we start the conversation again in 2030?...This is a very difficult situation for the United Nations and who else is there but the United Nations to bring this together.”

Coordination

Coordination was another governance component discussed by AMR experts. They talked about coordination at a country level and across sectors, which was frequently mentioned as part of the One Health approach needed to fight AMR. The themes emerging included global coordination, collaboration to improve infrastructure, and political challenges in the face of coordination.

AMR experts focused on coordination at the global level as AMR is a global problem, and for it to be solved, countries need to be at the same wavelength. An AMR expert stated, “...while you are looking at Sweden at the moment, antimicrobial resistance is a global problem.” Swedish AMR experts recognized the globality of AMR and that working in silos hinders the global effort to curb AMR.

Coordination was also discussed in the sense that higher-income countries should pitch in and help some LMICs build infrastructure. An example given by an expert was, “The EU has been involved in building infrastructure, but you know, you need the governments on board for

those countries or much more sector-level collaboration in the countries that are producing the food to build that infrastructure to improve all the farming standards." Swedish AMR experts expressed the need to invest in building capacity in LMICs but even more so, getting governments and policymakers on board with AMR policies.

A major challenge to coordination discussed by AMR experts is the rise of nationalism and protectionism, where people undermine the efforts of big orchestrators such as the UN, so some countries just flat out do not follow their recommendations. One expert stated:

> "The increase of nationalism around the world and almost we are seeing less collaboration that we did 5 years ago, and there is a whole change of world order there, in terms of US leading and contributing to a lot for the global institutions, you know they drew back from that and the impact that that is going to have on global collaborations and undermining United Nations and so on."

Equity

Equity was the most frequently mentioned governance component among AMR experts. The two major aspects of equity discussed by AMR experts were the lack of financial capital to enforce policies and train individuals as well as the inequity created by moving into consolidated sectors.

AMR experts focused on societal welfare and how LMICs are not well-equipped to handle future scenarios of global warming and antimicrobial resistance. So, access to antimicrobials was of grave concern to AMR experts. In addition, LMICs may not have the finances to use any tools that may be available; there is also the training and education aspect that requires sharing experiences between countries. An AMR expert stated:

> "Like you know, you go to Africa, Nigeria or Egypt which are massive fish producers, you cannot get any diagnostics done! I mean, they test water quality by testing the water and they go 'Yeah, water quality is okay'. It's just not the people that are trained, there is just not, they just don't even have the finances, even if those people did exist, they just haven't got the money and resources to be able to use any tools that are made available."

AMR experts further discussed that, since a lot of food is coming from LMICS, making sure to invest in these parts of the world so that the quality of food does not suffer is paramount.

AMR experts expressed concern that while one of the solutions to AMR is moving towards much more consolidated sectors, this will result in many individuals becoming unemployed. Hence, AMR experts discussed that it would be a challenge to balance trying to reduce AMR while simultaneously ensuring social welfare is intact. An AMR expert stated:

> "In many ways, the solution to antibiotic resistance or usage already exists in terms of, if we move towards much more consolidated sectors i.e., far fewer numbers of players producing the food ... But the real question is what do those people then do? What do the millions of people put out of work and losing their livelihoods?"

Participation

AMR experts often discussed participation. They discussed it in terms of emphasizing that antimicrobial resistance needs to be addressed from a One Health perspective. An AMR expert specifically talked about the EU's role in improving infrastructure in other countries, "The EU has been involved in building infrastructure, but you know, you need the governments on board for those countries or much more sector-level collaboration in the countries that are producing the food to build that infrastructure to improve all the farming standard."

Strategic Vision

AMR experts discussed strategic vision often when speaking about the future. They mentioned the need to be ambitious when it comes to getting AMR under control; the time frame needs to be ambitious. An AMR expert stated, "We need to be much more ambitious in terms of time frame in how to get AMR under control and more ambitious timeframe." Also, with all climate change conditions in the future, part of the strategic vision was to recognize how important it is to see HICs as providing guidance and help to LMICs in terms of resource

allocations to ensure people can stay where they are while providing them with the capacity to do so. AMR experts raised a point about the need to re-evaluate how we have been raising and grazing animals. An AMR expert stated:

"There's rapid intensification going on right now. You know we are moving from extensive systems to more intensification. So you are getting bigger farms growing at higher volumes with greater sophistication and so on. But actually, I take [Name of participant]'s point. It may be that some of these species we actually say no, we have pushed these too far. We need to step back, we need to deintensify because these animals are going to fall over and we were just we just pushing it too hard and it's not sustainable."

Hence, AMR experts emphasized the need to evaluate current practices in the animal and food sector, given expected trends.

Sustainability

Sustainability was an important governance component discussed by AMR experts. AMR experts stated that we need to think about the future with sustainability in mind; there is also the aspect of keeping policymakers on board with AMR policies and plans; we need to ensure the plans follow through and are maintained. For example, an AMR expert said:

"If you go back five years, politicians were absolutely, and policymakers absolutely on board with the antimicrobial resistance problem. They, you know, all of them were talking about it, you know, and what we were going to do about it. The question is, how do you maintain that? that level of interest when you know it has been swamped by other events that are going on?"

The fear that other events may deprioritize AMR was often discussed by AMR experts within the context of the COVID-19 pandemic.

A positive effort towards sustainability that AMR experts discussed was that some governments, with the future in mind, are reassessing their food production systems. An AMR expert stated, "Governments are reassessing, at least many of our country governments are reassessing strategic industries and what they are classifying in strategic industries with a view to going away from the more efficient global chains to local value chains with a view to ensuring

the security of supply." Within these discussions, AMR experts posited questions surrounding the reassessment of how countries produce food, specifically, whether domestic food production or international exportation is more sustainable.

Transparency

Transparency was another component of governance discussed by AMR experts within the context of AMR data reporting and messaging. As discussed previously, AMR experts primarily discussed the importance of transparency in reporting AMR data within countries and relaying that information internationally. In addition, transparency was discussed in terms of AMR messaging and the importance of relaying transparent and accurate messages about AMR. An AMR expert stated:

> "We are now talking about antibiotics and microbials that everyone understands that actually is a lifesaver. Yeah, it is something that society needs; it dramatically changed healthcare. It saves millions and millions of people's lives and so we cannot just go out there saying it is something bad."

AMR experts emphasized that we need to ensure that the messages we relay to individuals accurately depict the reality of antimicrobial use.

4.2 Elements of Governance Emerging from Malaysia

AMR experts from Malaysia also discussed all 18 domains of Anderson's governance framework that fall under the three governance areas: Implementation tools, policy design, and monitoring and evaluation.

Antimicrobial Stewardship

Antimicrobial stewardship was often discussed by Malaysian AMR experts. Antimicrobial stewardship discussions involved futuristic thinking, fostering research and development through taxation, a One Health surveillance system, diagnostic tests, and global collaboration.

With the future in mind, AMR experts from the Malaysian workshops discussed the need to think ahead and prepare for future scenarios of AMR and its close link with global warming. One expert stated that "climate change itself could also change the shape of antimicrobials we need to use because disease profiles may change. Weather is also a factor, flooding maybe there, etc, and therefore the kind of bacterial kind of diseases all may change in 2050." Malaysian AMR experts further discussed that a futuristic line of thinking necessitates the development of new antibiotics and new technologies to curb AMR, funnelled by a taxation system. Hence, one expert further explained, "We would need to plow some of this tax money back into R&D for newer antibiotics, considering the disease profile and proper diagnostics."

AMR experts also discussed the need for a One Health approach to surveillance, which includes monitoring antimicrobial use among the different sectors and being able to pinpoint where interventions are needed. An AMR expert stated:

> "In terms of classes of use across the different sectors or, say, human sector, different animal sectors, even different animal sectors, different industries again, that is interesting to record between the different sectors because that enables targeting different sectors to pinpoint where the problems are."

Beyond the data obtained from a One Health surveillance system, AMR experts in Malaysia viewed surveillance as a mechanism to identify gaps in different sectors.

AMR experts also mentioned the importance of diagnostic facilities at the point of care, as they can help focus IPC activities where they are most needed. One expert stated:

> "I think what Malaysia would have done in the next 30 years is to invest significantly in that sort of education and hospital infection prevention control team production takes a lot of investment. More broadly, there needs to be a huge amount of investment in rapid diagnostics and in microbiology facilities."

An Expert highlighted the need for investment in LMIC in terms of microbiology facilities and rapid diagnostics, especially because "much of the LMIC world does not have access to

good microbiology facilities, so antibiotics get used indiscriminately without backup evidence for their use."

AMR experts also frequently discussed the need for antimicrobial stewardship to be improved globally, not nations improving in silos. An AMR expert stated:

"If you are considering One Health approach and a global approach solution towards the One Health infection prevention measures. I think we need to consider all the emerging discussions very strongly around One Health, One World, One Planet. I think and only when we bring those three things into perspective, then it will be easy to follow up on some other things which the group first told, for example, what tools and mechanisms we use to detect climate-sensitive diseases. What tools and mechanisms will be used to monitor climate-sensitive production systems? How would we manage different trends changing with respect to the endemic pathogens? exotic pathogens? Emerging pathogens?"

AMR experts stated the need for collaborative efforts within and across nations.

Education

AMR experts discussed education within the context of training and raising awareness, and the need for training on IPC measures. An AMR expert stated:

"It is expensive to introduce full-blown infection control practices and procedures, including policies and all the training that's required. And it is not just training a few people; it's training, ultimately, everybody who works in a hospital or an institution or a population that might be. From a hospital perspective, yes, it's expensive, but it is very cost-effective, and that's where you need to come from."

While AMR experts recognized the expensiveness of training, they deemed it cost-effective since it reduced the number of expensive infections that need to be treated and reduced days of work lost and quality of life lost; hence, investment is key.

AMR experts also discussed that there needs to be more awareness and education about the relationship between the microbiome and the antibiotics we use. For example, An AMR expert mentioned that

"the microbiome is a great signature of how healthy we are and the moment we are taking antibiotics, you are wiping out commensal flora and allowing us for more infection, so this message has not, unfortunately, there is enough studies to show that if you take an antibiotic,

especially broad-spectrum antibiotic, it takes six months almost for the microbiome to get back to normal, which six months worth of susceptibility to infections for example. So this messaging is not coming out into the open as much as I would like it to the public so that they understand that taking an antibiotic is not without its risks."

AMR experts emphasized the need for greater awareness on antibiotics and their risks to human health.

Fostering R&D and Facilitating Market Access to Novel Drugs

AMR experts discussed the urgent need to invest a lot of tax money in the research and development of novel antibiotics, efficient diagnostic tests, vaccines, and real-time (RT) technologies.

AMR experts expressed a need to invest in the development of new antimicrobial drugs since the ones we have now may become obsolete. They specifically discussed how climate change provides a greater reason to invest in research and development, "The climate change itself could also change the shape of antimicrobials we need to use because disease profiles may change. Weather is also a factor, flooding maybe there, etc, and therefore the kind of bacterial kind of diseases all may change in 2050, and therefore we would need to plow some of this tax money back into R&D for newer antibiotics." An AMR expert further explained the need for "putting the money into environmental issues like you know, making sure no floods, IPC, biosecurity for farms, and research for solutions on trying to decrease AMR."

AMR experts discussed the need for rapid and efficient diagnostic tests to replace current traditional testing methods. An AMR expert stated that "just to do a simple listeria testing will take about seven days after confirmation, and let's say for things like salmonella is five days, depending on what method test, method that you follow. But generally, it will take about a week to two weeks sometimes." Experts painted a future where rapid and efficient diagnostic tools are developed, which can only occur through investment in technology and research. One expert

stated, “With the advance of the technology, 2050 will look more into what I mentioned, more digitalized, more rapid methods.”

AMR experts discussed the need to invest in vaccines as well and address drivers of vaccine hesitancy. An AMR expert stated, "We need to be investing in new vaccines and thinking about which ones we want to invest in because that is a definite strategy going forward.” Experts further discussed that

> “around the vaccine hesitancy. I think there needs to be quite a lot of research and understanding what the drivers are that are and what tools are for countering it because I do think we are going to be increasingly reliant on vaccination strategies. So some investment there as well would be helpful.”

AMR experts also discussed using real-time (RT) technologies that can generate data immediately and how we can use that data to track and trace information, and this would ultimately be used by policymakers. An AMR expert stated that this

> “real-time system... including the block [chain] technology... ultimately allowed onto the same thing, like how we can really track, trace, and generate data.” In describing the future, AMR experts also stated that “I think we may have to take advantage of the technology and the advantage of the very rapid molecular or state of the art tools to be more sort of predictive, so can we predict disease emergence.”

Experts emphasized the need for research and development in predicting disease emergence patterns through molecular tools to curb AMR.

Infection Prevention and Control

AMR experts discussed IPC measures in the context of adopting healthy behaviours in everyday life and waste management to prevent infection in the first place. AMR experts highlighted that people need to be aware of IPC practices in their day-to-day lives and it is not limited to hospitals or farms but everyone at all levels of society. An AMR expert stated:

> “Everybody should be able, should be aware about IPC and how we can apply IPC into our day-to-day practices. It is not only hospitals and farms, but everywhere I mean in public and

private life. We should be able to apply IPC practices. Uh. And at least 80% of IPC is practiced everywhere in day-to-day life, so that is what we thought we should achieve in 2050."

As mentioned earlier, AMR experts also discussed the need for diagnostic facilities, as identifying pathogens will assist in focusing IPC activities where they are most needed.

AMR experts also discussed waste management as an important intervention that needs to be coupled with IPC practices, simultaneously preventing the spread of infection. An AMR expert stated:

"I think waste management systems will also have to be put in because ultimately a lot of the infection is often because the way we pollute systems or river systems and with not just with chemicals but also other domestic products and hand hygiene. So, the basic hygiene has to come in, and waste-based management also has to be thought about, and that would be key to an overall holistic concept of IPC."

An AMR expert also raised their concerns regarding waste management in LMICs:

" hospitals use a lot of antimicrobials and disinfected liquids, and there are lots of multiple pathogens connected to the wastewater hospital, wastewater treatments, and in many countries, especially in developing countries, there is no proper regulations or treatment technologies in hospitals to control this pathogen coming into the environment."

Medicines Regulation

Malaysian AMR experts discussed medicines regulation in terms of surveillance and certifications and current business models of dispensing antimicrobials. AMR experts emphasized the need for the supply chain to be monitored. An AMR expert stated:

"Many countries have regulations, but enforcement capacity needs to be there, and we also need to improve advocacy side-by-side. Otherwise, people will still try and avoid testing facilities, farmer registration. Restrict access, restriction to only those who registered, active surveillance, and separating the antimicrobial classes and then taxing on the different tax slabs may need to be there."

AMR experts expressed that while taxation and the requirement for registration to purchase antimicrobials may introduce avoidant behaviours from farmers and other consumers, advocacy and enforcement capacity need to be there.

A challenge to regulating antimicrobials, as discussed by AMR experts, is that in LMICs, people are able to get over-the-counter antimicrobials without a prescription in comparison to HICs. An AMR expert stated:

> "The reality is that it will continue to exist because the problem is the business model and people's behaviour; it's a combination of both. So, for example, you, in many places, [there] is not enough doctors or there's no access to doctors. So invariably, you tend to either go to a clerk or you go straight to a pharmacy shop and say your symptoms, and they will somehow get you the antibiotic for various things, including the fact that they also make a profit."

Experts stated that regulations can sometimes be difficult because business models are not uniform; in distant villages and under-resourced areas, people are able to just go to a clerk or pharmacy shop and obtain their antimicrobials without any test or diagnosis.

Public Awareness

AMR experts also discussed public awareness but focused on the fact that regulatory mechanisms play as much of a role in directing societal behaviours. An AMR expert stated:

> "If people's awareness is good, there are no excuses, and then it is a question of making sure there's enough drug inspectors, there is enough regulatory enforcement if I can put it that way and implementation to catch the few people who probably are still selling over the counter thing... people will have excuses, and the system will continue to do what it is doing in not just in the right way, but also in the wrong ways."

As mentioned previously, AMR experts also discussed public awareness regarding creating awareness about IPC measures and practicing them daily, as well as having increased awareness about the microbiome and household and personal care products influencing us.

Surveillance

AMR experts discussed a future surveillance system where the government is able to tell you exactly how many tons of antimicrobials were used, what classes, for which purposes and in what sector. AMR experts specifically discussed blockchain technology as a tool to ensure

proper tracking and transparency in antimicrobial use. A thorough description of this surveillance system was given by an AMR expert:

> "Blockchain is quite common, have really started to implement for food safety, so I'm thinking why we can't implement the blockchains for antibiotic or antimicrobial as well. So, blockchain actually is perhaps can start from the product registration. So perhaps the government can ask the people to register the antimicrobial or register the drug first before they really impose taxation system. So, for example, if we want to implement that blockchain so the farmer or the producer should have a reporting system. They should report the daily usage, the type of antibiotic along the, along the supply chain. So, with the incorporating of the active surveillance so the authority can easily trace back whether the detail is tally with what they claim."

Alongside a strong surveillance system, an AMR expert emphasized the need for "strong diagnostic systems and strong epidemiology." AMR experts also described this surveillance system as one that is digital whereby data is being stored in real-time, as discussed previously. One expert stated that we need to, "have access to online real-time data systems that help to create big data on production, distribution and uses of any antimicrobial on farm and elsewhere." Experts explained that data on antimicrobial usage that is specific will help regulators make more informed decisions.

AMR Research

AMR experts discussed the importance of investing in AMR research with regards to vaccines and technologies that are crucial to tackling AMR in the future. An AMR expert stated:

> "Some of the vaccines which are existing which might not work for the new resistant strains in 2050, so for that we need to increase research funding for vaccine development by 2030 and also some investment should be increasing in technology which might lead to some solutions for infectious diseases and other thing is pathogens from different sectors."

Hence, AMR experts painted a future where there is more development and research on new tools that help predict what type of pathogens we will see in the future and which animals may have these pathogens, in an effort to prepare us for the future and finding plausible ways to minimize harm.

Effectiveness

AMR experts discussed effectiveness within the context of COVID-19-related policies around hygiene as well as a mechanism to assess progress towards AMR goals. Experts mentioned that the COVID-19 pandemic created an opportunity to test whether behavioural changes such as increased IPC measures practiced by individuals hindered transmission. An AMR expert stated:

"A behavior change takes a long time, especially when it comes to infection prevention. Of course, we've got a nice little behavior change precipitation factor with COVID and suddenly everybody knows the word hygiene at least, but things can easily slip, so I think if we need to aim towards 2050, we need a really active phase for awareness and insight and understanding, if I can put it that way to the real role of hygiene insiders and around us when I say that, I mean including the microbiome and around us, including the environment around us, so that has to start right now with the intermediate course correction at 2030."

AMR experts further emphasized the need to reassess progress and make correction where needed as " behavior change takes time to show, so whatever plans we have and strategies we have. If it really needs to work, we need to assess it around 2030 and do some course correction if necessary and then work towards 2050."

Feedback Mechanisms

AMR experts discussed feedback mechanisms such as the block chain technology that can offer feedback to regulators regarding antimicrobial use. An AMR expert stated:

"Let's say if they notice that the amount, for example, the antibiotic residue is not tally or for example, the type of antimicrobial is haven't registered, but they detected from their food product before this can help the governments to trace back whether the farmer is getting from the black market or what other sources, where are the sources to obtain this kind of antibiotic drugs? So, so the authority is easily to trace back or discount information along the food supply chain through the blockchain because anyone will not be able to modify or to delete discount message. So, I believe this will help the government to monitor the usage and eventually to reduce the issue of misuse or overuse."

AMR experts further mentioned the need for an oversight body that is external to the government monitoring the situation and providing feedback.

Reporting

Although AMR experts discussed the need for a very good surveillance system for tracing and documenting the purchase and sale of antimicrobials, the importance of reporting by all sectors was discussed. In an incentivized-tax approach painted by AMR experts in 2050, they discussed that those across the One Health system who report low antimicrobial use would be taxed less. However, for this taxation system, "users would demonstrate by reporting, which is then reinforced via annual national government surveillance for antimicrobial use. In other words, outcomes in food farms, hospitals in the environment, plus ideally antimicrobial sales figures reported." Therefore, AMR experts highlighted the need for congruency between government surveillance and personal reporting as a mechanism to curb AMR through taxation.

Accountability

AMR experts discussed the element of accountability in terms of who owns the problem and the solution to AMR as well as having an external body that holds countries accountable for unmet objectives. One of the problems with solving AMR that was discussed is the lack of accountability or responsibility felt by the different sectors towards the AMR issue. An AMR expert stated:

"… When we go to the countries usually, I mean it's a problem who owns this AMR problem? Is it the problem of public health? or is it the problem of animal health? or whether animal health people are creating problems in public health? or something like that? So, actually, initially, there's a big issue, I mean. Who owns this problem? Who owns the solution?"

Also, AMR experts discussed the need for creating an external body that holds countries accountable, as stated:

"I think it's important for all these things, whether it's IPC or AMR itself to have oversight bodies external to the government, external to populations, which continue to monitor the situation of how far countries have gone or regions have gone, or in individual groups have gone with any of the things that we are proposing so that we reach 2030 or 2050 appropriately."

Coordination

AMR experts spoke of the importance of all sectors' involvement in fighting AMR, having a shared regulatory body, and sharing AMR data. AMR experts discussed the importance of collaborative efforts among countries and sectors but "still most of the countries, different sectors are working in their own silos, they do not want to, I mean give access to their own data to other sectors, so it is a kind of issue at country level."

AMR experts also discussed the importance of having a governing body like ASEAN oversee and enforce certain Southeast Asian policies to unify efforts. An AMR expert stated, "I think it is inevitable that [there] needs to be cross border cooperation to try and control these things, and it can be a very different level that can be at government level. It could be within something like ASEAN or the EU or even trade agreements."

Lastly, AMR experts spoke about the importance of having in place a One Health surveillance system to share data on antimicrobial usage across different sectors instead of industries working in silos. An AMR expert stated:

"Now it is all done in silos. You know, I do my fish somebody does their shrimp. Somebody does the poultry, but there is no platform to share the information across that clearly. But once countries see the value of this approach, I am sure in 20 years so we will have One Health surveillance systems with a long list of key patterns of concern of the zoonotic nature and all that coming together."

Equity

AMR experts discussed equity in terms of policies we put in place to fight AMR that should be sensitive to the poorer populations and countries, especially with an intervention like

the taxation of antimicrobials. Also, it is important to recognize the financial capabilities and infrastructure capacity needed to implement AMR policies, especially in LMICs. The first issue discussed by AMR experts was the antimicrobials' access issues when introducing taxation, people still need to access antimicrobials in different parts of the world. An AMR expert stated:

"…Access is an issue and therefore, rebates or discounts for those who really have an affordability issue should be there, and there should be a mechanism for it. Otherwise, you know there could be problems for humans and the animal industry, especially those who are not in a bigger set up or those who are on the poorer side."

Experts also discussed equity when stating the importance of HICs in helping LMICs improve their enforcement capacity to ensure that AMR targets can be met. An expert stated that:

"there is a plan for European Union to invest some money in Asian region, nine countries to support, improve this AMR surveillance capacity and different AMR prevention activities, I mean it is it will not be like Fleming Fund, but there would be a reasonable amount of money will be spending on nine countries in this region to improve the capacity and sharing of experience on AMR surveillance and prevention of AMR. So, this, this we can consider that investing tax money on providing solutions for the issue."

This was discussed by AMR experts as a positive way to refunnel taxation and help LMICs build capacity to fight AMR.

Participation

AMR experts discussed the importance of involving stakeholders in developing capacity in countries needing assistance fulfilling AMR objectives. Specifically, an AMR expert spoke about how "The World Organisation for Animal Health and WHO are working together to actually enhance a lot of capacity inside the country [Malaysia], particularly to implement the international standards, I mean related to animal health and welfare as well as international health regulations."

AMR experts expressed concern that tackling AMR requires dedicated budgets that some LMICs lack; hence, organizations like The World Organisation for Animal Health and WHO

have spearheaded such efforts. AMR experts also raised the issue of compliance which can sometimes be driven by differing priorities. An AMR expert stated that "some countries are not compliant. So the problem is the priority, what is the priority for the country? The priority for the countries just to secure food for some people?"

Strategic Vision

AMR experts discussed strategic vision when envisioning the future of AMR. They discussed using taxation to relocate individuals in highly dense regions and the importance of setting short-term targets for AMR. An important preventative strategy proposed by AMR experts was to use taxation money in the future to relocate individuals from highly dense areas to less dense areas, as highly dense areas are characterized by increased infections due to ease of transmission. An AMR expert stated that

> "high population density leading to many infections and reduced sanitary conditions and all. I mean, my suggestion was that maybe we put some tax on this amount, kind of resettlement or moving to certain places so that money can be invested back on improving the situation they are in, evenly distributed population, improved sanitary conditions etc and health facilities."

AMR experts discussed that strategic vision also involves having uniform targets and setting objectives for shorter periods to achieve them. An AMR expert stated that

> "shorter periods give you more push rather than longer periods where people tend to... human behaviour... tend to wait for, you know we have enough time, so I think we target 2030 rather than 2050, and that would give us a much more impetus, especially policymakers, international agencies and stakeholders, to push things through and then hopefully, you know, by 2050 will be 70% more than we were then if you wait to that period."

With the future in mind, AMR experts specifically discussed the importance of having water management systems as well as advanced technologies that will help with curbing AMR in the future.

Sustainability

AMR experts discussed the difficulty in maintaining efforts to curb AMR currently and in the future. They were curious about a mechanism to finance policies for a long time. AMR experts specifically touched on how LMICs are especially challenged as financial resources for AMR are scarce. An AMR expert stated:

"If you look at the implementation of NAPS across the board, especially in lower-income countries, there is hardly any money in it, if at all any implementation in any sector often, it is because of some project money or from either international agencies or even the government, and that is about it."

Hence, AMR experts were worried about the sustainability of AMR efforts. Thinking about the future, AMR further experts spoke about the importance of implementing waste management systems in LMICs, as many of their governments may not have the financial capital and interest to invest in AMR policies. AMR experts discussed that a challenge facing the sustainability of AMR efforts is the changing political landscape in different countries, where different politicians have different interests, and the issues immediately dealt with tend to be more pressing. An AMR expert stated:

"because of various factors in who is becoming leaders or who are forming governments and what their priorities are. Many other things which are collective and societal in nature, the government is moving away from and only anything which sort of is a crisis or is a public health or a big issue in the eyes of the public then they move on and this is probably the cause of lack of willpower, political power or even money."

With such shifting priorities, AMR experts mentioned the difficulty in maintaining efforts toward curbing AMR at a global level.

Transparency

AMR experts discussed transparency in the context of reporting antimicrobial usage. They mentioned the importance of having a comprehensive system of documentation that allows one

to track usage, the prescriptions dispensed, use purposes etc. This type of transparency was identified by AMR experts as an important step in tackling misuse and abuse of antimicrobials.

An AMR expert stated, “a very good system for tracing documentation, purchase, sale, everything, quality. So, in the process this would have promoted more responsible buying, more responsible usage because there is documentation.” This documentation system was suggested by AMR experts to improve the behaviour of individuals towards antimicrobials as well as the different sectors that contribute to the issue of AMR.

4.3 Comparing Governance Elements Emerging from Sweden and Malaysia

AMR experts from the Swedish and Malaysian workshops addressed all 18 components of governance constructed by Anderson et al. (2019). While they addressed the 18 components of governance, there were variations in the type of issues spoken about regarding each component and the range of topics discussed under the 18 components.

Regarding antimicrobial stewardship, Swedish and Malaysian AMR experts both addressed the necessity for proper diagnostics and collaboration on antimicrobial stewardship across countries and sectors. Both experts addressed the need for better farming practices but differed in how those practices were brought about. The Swedish AMR experts proposed incentivizing farmers through rebates or monetary rewards for following appropriate farming practices that are intended to hinder the propagation of antimicrobial resistance in the farming sectors. In contrast, Malaysian experts focused on the need to improve biosecurity measures at the farm.

Regarding the education component of governance, both AMR experts from Sweden and Malaysia mentioned the need to educate not just farmers and hospitals but society at large. Swedish experts, however, touched on the importance of not just raising awareness and proper

training but also the importance of teaching people how to live lifestyles that are conducive to good health and prevent AMR. The Swedish AMR experts also touched on the importance of involving social scientists in the making of campaigns hindering the spread of AMR. This involvement, according to Swedish AMR experts, ensures the appropriateness and effectiveness of said campaigns. Malaysian AMR experts specifically spoke about increasing public awareness about the interaction between antibiotics and the microbiome, along with the short and long-term issues associated with using antimicrobials.

In addressing the component of 'fostering R&D and facilitating market access to novel drugs', Swedish and Malaysian AMR experts discussed the need for investment and extensive research on newer antimicrobials, alternatives, vaccines, and technologies to combat AMR in the future. However, Malaysian experts heavily focused on the need to keep climate conditions in mind when constructing newer technologies to combat AMR, these technologies include disease prediction technologies to ensure preparedness when necessary. The Swedish experts emphasized the need to tackle setbacks facing innovation, drug development and technological advancements, mainly stating the need to keep policymakers and regulators involved and interested so that investment in R&D can be sustained.

Swedish and Malaysian AMR experts both addressed the need for IPC practices to be applied among different sectors and at the individual level to the point where IPC practices become common practice for everyone. Experts from both workshops acknowledged the role that the COVID-19 pandemic has played in teaching us lessons regarding IPC and the effectiveness of certain IPC measures in curbing disease propagation. IPC measures were acknowledged as important indicators for health and as necessities to lead a good life by both experts, but their link to SDGs was highlighted by Swedish experts. Swedish experts highlighted

that SDGs, such as access to clean water and toilets, are closely interlinked with the AMR issue. The Malaysian AMR experts specifically touched on the importance of waste management practices as they are often neglected but represent an important component of IPC measures.

Regarding the medicines regulation component of governance, Swedish and Malaysian AMR experts addressed the need to necessitate a prescription for every antimicrobial drug dispensed, which was aimed at reducing the unnecessary use of antimicrobials. More specifically, Malaysian AMR experts spoke about the need for advocacy and improving enforcement capacity alongside the regulation of antimicrobials. Malaysian AMR experts also discussed the need to improve business models in LMICs because they represent a challenge towards implementing proper regulations on antimicrobials, as most people can obtain antimicrobials over the counter, generating a profit for pharmacists. The Swedish AMR experts mentioned the need to regulate veterinarians in other parts of the world as some veterinarians in countries other than Sweden still get paid to write prescriptions for antimicrobials. Finally, the Swedish AMR experts spoke about the importance of enforcing tighter regulations across borders so that countries have increased standards in terms of food and farming practices. Swedish experts discussed that these regulations of practices across borders forced more countries to comply with appropriate standards for raising their animals and food. AMR experts expressed that these regulations also promoted the economic advancement of these countries as trade is an important avenue through which some countries flourish.

Regarding the public awareness component of governance, Swedish and Malaysian AMR experts both spoke about raising awareness of IPC practices and enhancing our knowledge of antimicrobial use and its influence on us. The Malaysian AMR experts mentioned that while people's awareness is good, it really comes down to enforcement capacity by regulators and drug

inspectors. The Swedish AMR experts focused on the logistics of what public awareness would look like. They mentioned that social scientists need to be involved in constructing AMR awareness campaigns, using scary examples to deter people from AMR-conducive practices, and implementing effective and transparent messaging that conveys the benefits and harms clearly.

Regarding surveillance, Swedish and Malaysian AMR experts both spoke about the importance of having a surveillance system that is uniform across sectors and countries, specific, and technologically advanced to relay data in real-time. AMR experts discussed that this surveillance system will assist in tracking and monitoring the sales and, most importantly, capture actual usage of antimicrobials.

Regarding AMR research, Swedish and Malaysian AMR experts spoke about the importance of investing in research involving antimicrobials, alternatives to them, new vaccines, AMR drivers, and technologies that can help us curb antimicrobial resistance. Malaysian experts spoke about predictive technologies that will help us anticipate the types of diseases and bugs we will likely encounter. Swedish AMR experts spoke about the need to understand human behaviour so that we are able to positively influence people's attitudes and behaviours and improve efforts aimed at tackling AMR.

Effectiveness was another governance component discussed by Swedish and Malaysian AMR experts. Effectiveness was discussed in the context of harvesting lessons from COVID-19 regarding IPC practices and their effectiveness in curbing disease. Swedish AMR experts additionally spoke about the need for other countries to take examples from countries like Sweden that successfully reduced AMR rates through specific policies and adjust and adapt them within their context. Malaysian experts emphasized the need for re-assessing how our current strategies pan out by 2030 and adjust accordingly.

Regarding the feedback mechanisms component of governance, Swedish and Malaysian AMR experts spoke about the importance of having an external body of government that can oversee progress and provide feedback for improvement. Swedish AMR experts emphasized the significance of conducting a risk analysis that considers future conditions to ensure current policies can accommodate future conditions and the likelihood that said policies will be effective. On the other hand, Malaysian AMR experts discussed the importance of having a system of data monitored by a third party that can relay feedback at different levels to ensure that misuse of antimicrobials can be identified and minimized.

With the reporting component of governance, Swedish and Malaysian AMR experts discussed the importance of transparent reporting of antimicrobials, which relies on a well-designed and uniform data collection and surveillance system. Swedish AMR experts discussed the importance of a surveillance system that accurately reports the usage of antimicrobials and uses common metrics. In contrast, Malaysian experts spoke about the importance of conducting blockchain technology to convey real-time data on the usage of antimicrobials and identify any incongruences in reporting.

With regard to accountability, Swedish and Malaysian AMR experts discussed the importance of delegating an external body to oversee and hold countries or sectors accountable when objectives are not met. Swedish AMR experts spoke about the challenge of assigning a body to be responsible for overseeing the SDGs and tracking progress. Malaysian AMR experts discussed the challenges associated with solving AMR, such as identifying the person, sector, or country responsible for the AMR problem and in what hands the solution lies. Hence, Swedish and Malaysian AMR experts expressed that everybody needs to feel a sense of responsibility as everyone's actions influence the AMR problem.

AMR experts from Sweden and Malaysia equally discussed the importance of coordination within and across countries in fighting AMR. Both experts also spoke about the significance of HICs in helping LMICs improve their enforcement capacity to fight AMR better. Swedish AMR experts mentioned the importance of lesson sharing and financial assistance to LMICs so that they are more equipped to fight AMR. Malaysian experts spoke about a governing body like ASEAN and its importance in executing certain policies and unifying efforts against AMR in Southeast Asia. Swedish AMR experts specifically discussed challenges related to reaching AMR targets, including protectionism and nationalism. Malaysian experts discussed a future One Health surveillance system that allows for the integration of AMR data in one location and allows sectors and industries to work together instead of silos.

AMR experts from Sweden and Malaysia also discussed the element of equity. Both experts spoke about the lack of financial capability in LMICs in enforcing AMR policies and training individuals across different sectors. Swedish experts voiced their concern regarding moving into consolidated sectors in the future as many individuals will lose their jobs in the process. Malaysian experts on the other hand suggested the use of taxation to funnel financial capital to support LMICs in building infrastructure capacity.

AMR experts from Sweden and Malaysia also discussed the element of participation. Participation for both experts was discussed in terms of stakeholders addressing AMR from a One Health perspective, that is involving all sectors. Swedish experts specifically spoke about the important role EU plays in supporting infrastructure in some countries but voiced their concern as individual governments need to be on board as well in order to improve things like farming standards. Malaysian experts on the other hand discussed the importance of organizations like OIE and WHO in enhancing capacity in the Southeast Asian region.

AMR experts from Sweden and Malaysia both discussed the need for strategic vision, one that plans with the future in mind. In their discussions, the Swedish experts emphasized the need for us to have ambitious time frame to fight AMR. Also, they spoke about the possible need to de-intensify farming, given current and future patterns of AMR. The Malaysian experts on the other hand spoke about the need to relocate people from densely populated areas to less populated area, as a mechanism to minimize infection transmission, facilitated through taxation. They also spoke about the need to set clear short-term goals that are achievable.

AMR experts from Sweden and Malaysia both discussed sustainability. Swedish AMR experts raised some concerns regarding keeping policymakers on board and interested in the AMR issue. They also raised the issue of food production and the direction it is heading towards, specifically whether domestic or locally sourced products will be more sustainable. Malaysian experts on the other hand worried about maintaining financial support for LMICs to support their AMR policies. The other concern they had was regarding the shifting political climate in each country, especially with differing priorities that may come in conflict with AMR efforts.

Lastly, Swedish and Malaysian AMR experts both discussed transparency. Both experts spoke about transparency in terms of data reporting facilitated through a future surveillance system that accurately depicts consumption to ensure antimicrobial use is minimized. The Swedish experts went further and discussed transparency in terms of messaging, that is, constructing messages that convey risk but also explain benefit.

4.4 Components of Public Engagement Emerging from Sweden

AMR experts in Sweden discussed the six different components of the SCT, namely: behaviour, goals, outcome expectancies, self-efficacy, sociocultural facilitators, and sociocultural impediments (Appendix B).

Behaviour

Regarding the behaviour component, Swedish AMR experts discussed current behaviours that may facilitate or hinder public engagement in AMR. Experts discussed society's willingness to pay and attitudes towards solutions.

People's willingness to pay for premium products was discussed by experts as a current and future facilitating behaviour to curb AMR. An AMR expert stated, "When I go to the stores here, you find products, particularly products that are raised based on animals that are antibiotic-free, and they have a premium price on those. And yet consumers are willing to pay that extra price. Low nitrate meat products, low antibiotics, or antibiotic-free meat products." They further stated, "...There is a market, their consumers are willing to pay but it still a minority market or niche market, but that may change over time and by 2030/2050 probably a much larger portion of the market are willing, consumers are willing to pay a higher price for higher and consistently higher quality food." Experts further explained that willingness to pay more for products raised free of antibiotics or chemicals will likely encourage more farmers to use less antibiotics.

Another behaviour discussed by AMR experts is society's attitude towards solutions, where individuals often look for fast solutions that are often short-lived and AMR is a long-term issue that requires sustainable efforts and consistent engagement. AMR experts stated, "One of my worries is that we have a society that always looks for quick fixes, which means that in some of these cases, where it will have no effect or a small effect, people are still wanting to go to that road for the simple reason that they believe it is a quick fix." Further, an expert stated that this "mentality in our society really doesn't help us when we are trying to target issues that are long term battles like AMR and climate change."

Goals

AMR experts also discussed the element of goals. They specifically discussed the need for short-term goals combatting AMR. They discussed that having plans to combat AMR in 2050 is insufficient to keep people engaged in positive behaviours against AMR as it is a long timeline. Experts stated, “That is part of the battle with a target for 2050 as well, isn't it? It is a long way away from people. It is a long horizon.” According to experts, people become more engaged when clear short-term goals are set. A challenge identified by AMR experts with regards to goals was keeping the public's interest when goals are not met and reassessing policies. They stated, “We have set these goals and we will unfortunately be far from them in 2030 I believe. How would we rebuild that engagement saying, will say agenda 2050 then? Pretty much the same type of goals, but and, that will be, that will be tough to get people to, we lose credibility.”

Outcome Expectancies

AMR experts also discussed outcome expectancies, especially when discussing the need for scary and deterring AMR examples. An AMR expert stated, “...You have to scare people and you have the examples from Denmark where the pig farmers, their children, they weren't very pleased when they came to school because they had such a big problem with AMR on the pig farms so and the people working there, they had resistant bacterial, So, I think some of those examples were quite scaring for a lot of people.” When provided with examples where AMR affected individuals or sectors, AMR experts mentioned that it can regulate the behaviour of individuals as they can understand the negative consequences of consuming unnecessary antimicrobials.

Self-efficacy

In a global sense, AMR experts also discussed self-efficacy, where countries can learn from countries that successfully combatted AMR and implemented effective policies. AMR experts stated:

> "All countries adopted national action plans to combat AMR, covering the three pillars: human health, animal health and environment. I think those action plans have been in place for 3, 4 or 5 years, and we are at a crossroads now where we can harvest a lot of good lessons from those plans and policies that have been successful in countries and can be brought more to the region or more globally."

Experts explained further that when one country sees another successful in their AMR national action plans, it provides a stronger case for implementing said policies.

Sociocultural facilitators

AMR experts also discussed a sociocultural facilitator that can further help fight AMR: the reliance and trust of Swedish citizens in the government. AMR experts stated:

> "We have for a long while really relied on the authorities in Sweden. We have a research project that pointed out that Sweden is far away from other countries, how we perceive this with the government, and we really rely on the government compared to other countries that rely more on private standards and so on."

This reliance on government and trust in their decisions, according to AMR experts, is what has created success in Sweden and is a driving force for continued action against AMR in Sweden.

Sociocultural impediments

Lastly, AMR experts discussed sociocultural impediments such as the individual's attitude towards immediate results and maintaining credibility. As mentioned previously, AMR experts expressed concern about society's general attitude toward quick fixes, which can hinder consistent efforts toward fighting AMR. Maintaining credibility was also discussed by AMR

experts as a challenge ahead since AMR goals may change over time, and unfulfilled goals may carry over from one year to another; hence, maintaining engagement on AMR can be difficult. An AMR expert further asked, “How do you communicate that without losing too much credibility and not losing people and getting them to switch off another set of targets?” Sustainability was identified as an important issue within the scope of AMR and maintaining public and policymakers' interests can be difficult.

4.5 Components of Public Engagement Emerging from Malaysia

AMR experts from Malaysia discussed only four elements of public engagement detailed by the SCT; goals and sociocultural facilitators were not discussed. AMR experts discussed the ‘outcome expectancies’ component of engagement more often than other components.

Behaviour

Malaysian AMR experts discussed numerous ways certain behaviours may influence the propagation of AMR. Most frequently discussed was the reliance on the black market for antimicrobials with the introduction of a taxation mechanism limiting antimicrobial use as well as avoidance issues.

An AMR expert stated, “I am very fearful of a counterfeit movement, fearful of access issues, fearful of the fact that the companies may try, and, you know, pressurize the government to avoid taxation for them in some of the countries, all that is very real and may happen.” Another problem with taxation discussed by AMR experts is the migration of individuals from countries with tighter regulations around antimicrobials and taxation to countries with looser regulations and substandard antimicrobials. An AMR expert stated:

“If all the countries don't do it [taxation], there is definitely going to be cross border, cross border, what is the right word, counterfeit not substandard. Even just normal drugs trying to get in so that people make a quick buck out of it, especially if let's say Malaysia introduces taxes and

the neighbouring countries don't introduce tax, cross-border migration of these products will be quite rampant, and I foresee that would be a big problem if one country does and one country does not."

AMR experts expressed their concern since mismatched regulations across neighbouring countries can create avoidance issues in addition to the issue of buying antimicrobials unnecessarily and without a prescription.

Outcome Expectancies

AMR experts frequently discussed outcome expectancies with regard to the taxation of antimicrobials. They spoke about how taxation can lead to decreased use of antimicrobials and provided positive incentives for farmers to appropriately use antimicrobials. An AMR expert stated, "Commonly used antimicrobials have more taxes compared to the ones which are rarely used because it is like used by, when it's very severe conditions. So it was, where the commonly used antimicrobials have more taxes because people tend to use more, also, for mild symptoms." Experts discussed that increased taxation of antimicrobials often creates a disincentive for individuals to receive them. Hence, people can become deterred from this behaviour by acknowledging the financial consequences of receiving such medications.

Self-efficacy

Self-efficacy through lesson learning from other countries that effectively managed to reduce AMR was discussed by AMR experts in Malaysia. This was discussed within the scope of COVID-19 and the lessons we have harvested regarding IPC measures and their effectiveness. Taking these lessons and applying them within the context of AMR was an important learning moment. An AMR expert mentioned the need for "continuing to share and apply lessons learned from global or regional level activities so that they can be implemented at the country level in Malaysia and in other countries, and how we can learn from one another."

Sociocultural impediments

Lastly, AMR experts in Malaysia also discussed sociocultural impediments. The primary impediment discussed by experts was the lack of social consciousness and a sense of collective responsibility. An AMR expert stated, “In many high-income countries, there is a sense of collective responsibility and social responsibility. So, when there is a law, people tend to follow it.” Experts explained that countries that may not share these sentiments may behave differently towards AMR policies, compounded with differing levels of governmental trust observed in different countries, which may also influence compliance.

4.6 Comparing Public Engagement Components Emerging from Sweden and Malaysia

AMR experts in Sweden discussed all six elements of public engagement, while Malaysian AMR experts discussed only four. The two elements of public engagement that Malaysian AMR experts did not discuss were goals and sociocultural facilitators.

Under the behaviour component, Swedish AMR experts spoke about Swedish peoples’ willingness to pay for premium antimicrobial-free products but voiced concern regarding societies’ general attitude towards solutions. Malaysian AMR experts discussed fears associated with black markets and avoidance issues due to the introduction of an intervention like taxation.

Only Swedish experts discussed goals. They emphasized the need for achievable short-term goals and maintaining engagement when these goals are unmet. For this, they discussed the importance of having an overseeing body that consistently reassesses goals.

Under the outcome expectancies component, Swedish AMR experts discussed the importance of providing scary examples to deter people from unnecessarily using antimicrobials. In contrast, Malaysian AMR experts discussed that increasing taxes on its own can act as a disincentive for buyers.

Under the self-efficacy component, Swedish and Malaysian AMR experts discussed the need to learn lessons from countries that successfully implemented AMR policies. Both experts also discussed the need to learn lessons from COVID-19 and apply those to future AMR policies.

Only Swedish experts discussed the component of 'sociocultural facilitators'. They mentioned that Swedish society places high trust in the government and public health officials. This trust was discussed as an important facilitator when applying AMR policies.

Finally, Swedish and Malaysian experts both discussed 'sociocultural impediments'. Swedish experts discussed the importance of maintaining credibility when objectives are unmet. Malaysian experts, in contrast, spoke about the lack of social consciousness in some countries, making it difficult to enforce AMR policies.

4.7 Existing and Future Governance and Public Engagement Elements Emerging from Sweden and Malaysia

AMR experts in Sweden and Malaysia discussed governance (Table 2) and public engagement (Table 3) elements as either currently being implemented (and lack thereof their implementation) or what would need to be in place by 2050 to successfully tackle AMR.

Table 2. Current and Future Elements of Governance Discussed by AMR Experts in Sweden and Malaysia

Governance Area	Country	Current	Future
Antimicrobial Stewardship	Sweden	➢ Trade policies regulate the type of products and number of manufacturers responsible for the quality of products that are moving across borders. ➢ European Union has limited enforcement capacity in interfering with AMR policies in respective European countries.	➢ Farmers will be incentivized through taxation if they follow appropriate antimicrobial use practices. ➢ A surveillance and reporting system that accurately depicts antimicrobial consumption will be in place. ➢ Changing political climates will present a challenge to AMR antimicrobial stewardship. ➢ Diagnostic tests will be required for the dispense of antimicrobials. ➢ Communication on AMR will be transparent and consistent. ➢ European Union will play a larger role in unifying AMR goals and policies.
	Malaysia	NA	➢ A futuristic mindset would have prepared societies and governments to tackle AMR and climate change. ➢ Subsidies and penalties will be applied to companies that properly use or misuse antimicrobials. ➢ Effective stewardship would have been achieved through uniform and detailed surveillance of antimicrobials across different sectors. ➢ Large investments will be made in advanced technologies and diagnostic facilities. ➢ Industries will move away from using antimicrobials in their food and animal. ➢ People's general awareness on AMR will be increased.

Education	Sweden	➢ There are many educational campaigns aiming to reduce AMR.	➢ Farmers will be well-trained and aware on technologies facilitating the fight against AMR. ➢ Society will have more awareness on AMR and preventative methods to help stay healthy longer. ➢ Social scientists will be more involved in the construction of AMR campaigns. ➢ Prescribers of antimicrobials will be trained appropriately on proper prescribing practices.
	Malaysia	➢ There is expertise to train and educate antimicrobials' prescribers and users but there is a lack of funding and investment to apply such training and educational campaigns in LMIC settings.	➢ Behaviours such as self-medication and prescribing without clinical diagnosis will be minimized through education. ➢ There will be investment in education and training on IPC measures. ➢ There will more awareness and education on the microbiome and its relationship with antimicrobial use and IPC measures.
Fostering R&D and Facilitating Market Access to Novel Drugs	Sweden	➢ There are technologies like CRISPR and genetically modified organisms (GMOs) currently used to curb AMR.	➢ There will be technological development in multiple areas, new feeding strategies, feed additives, bacteriophages etc… ➢ Personalized medicine will be used to create very specific technologies that are patient centered. ➢ There will be more investments in technologies that target climate change such as those that capture carbon dioxide in order to curb the implications of climate change on AMR.
	Malaysia	➢ There are effective technologies used in farms, hospitals, and industry, rapid testing and vaccines. ➢ There is research needed to advance and invent technologies as well as	➢ There will be more innovation and technological advancements in terms of AMR fighting technologies (i.e., IR, automated and digitized food safety, rapid microbiological testing). ➢ There will be increased investment in vaccines to curb

		understand human behaviour.	infectious diseases and research to understanding reasons for vaccine hesitancy.
Infection Prevention and Control	Sweden	➢ There are many countries aware of AMR in the animal and human sector and are adopting proper IPC preventative practices (through the COVID-19 pandemic).	➢ There is going to be increased awareness on the issue of AMR in the future as well as IPC practices. ➢ IPC practices will be more habitual because of the lessons COVID-19 taught society. There will be extensive research in this area. ➢ Sanitation will be a key driver of change and ensuring that everyone has access to toilets and clean water will be a challenge.
	Malaysia	➢ There are many lessons that can be learned from the COVID-19 pandemic, regarding sanitation and hygiene.	➢ People will take AMR more seriously and IPC measures, whether it is at the farm level, hospital level, or personal level will increase. ➢ Everyone in the future understands the significance of following hygienic practices and their implication with AMR.
Medicines Regulation	Sweden	➢ Veterinarians getting paid for selling more antimicrobials is a challenge to tackling AMR. ➢ In Sweden, there is a strong regulatory mechanism where patients are unable to obtain antimicrobials without a prescription.	➢ Antimicrobials will be used in smaller and precise doses, aided by advanced technologies. ➢ There will be a requirement for a prescription before the dispense of antimicrobials in all countries. ➢ The movement of goods will continue across borders based on standardized qualities and investment in LMICs will continue.
	Malaysia	➢ Some Asian countries allow for antimicrobial use without a prescription which represents a challenge in dealing with AMR. ➢ Business models and people's behaviour are difficult to regulate.	➢ The supply chain will be monitored and registration for buying antibiotics will be required. ➢ Enforcement capacity in LMICs will be enhanced as well as regulatory mechanisms.

Public Awareness	Sweden	➢ People are aware of how the climate is changing rapidly and understand the urgency to act, which might facilitate cooperation with AMR policies.	➢ There will be increased awareness across society on environmental issues like global warming and its connection with AMR. ➢ There will be a refined tax system that prompts changes in behaviour-with help of applied data science and psychology. ➢ Scary examples to deter people from using antimicrobials unnecessarily will be provided. ➢ Farmers, veterinarians, and other regulators will be far more engaged on antimicrobial use ands function as regulatory checkpoints. ➢ There will be increased awareness on the content of products, not just antimicrobials used but the carbon footprint associated with their production. ➢ Awareness campaigns will use transparent messaging.
	Malaysia	➢ COVID-19 presented a great opportunity for learning about things like hygiene, social distancing etc, hence people's awareness increased.	➢ People's awareness will be good which will facilitate adherence with AMR policies. There will be more scrutiny towards those who sell antimicrobials over the counter. ➢ People's awareness about the chemicals present in their household products will increase
Surveillance	Sweden	NA	➢ There will be an AMR surveillance system that is species/sector/usage specific.
	Malaysia	NA	➢ Surveillance will be effective in specific reporting of where antimicrobials are going, into which sectors. The system will be much more transparent and allows one to track not only sales but actual usage. ➢ The surveillance system will highlight areas of concern and specific microorganisms that are

			resistant within the different sectors. ➢ Block technology will be used to validate claims from farmers and other antimicrobial users. ➢ Environmental surveillance will track pollution from industries. ➢ The surveillance system will aid in tracking resistance patterns overtime.
AMR Research	Sweden	NA	➢ There will be more research on alternatives to antimicrobials, feed additives, bacteriophages, and vaccines. ➢ There will be greater understanding of human behaviour and how to manipulate and influence it positively.
	Malaysia	NA	➢ There will be more research needed on AMR and alternative methods to keep animals and people healthy.
Effectiveness	Sweden		➢ There will be assessment of how AMR National Action Plans have been adopted by different countries and those lessons will be shared globally.
	Malaysia	NA	➢ There will be behavioural changes in practices against AMR as we would have learned important lessons about behaviours that perpetuate AMR.
Feedback Mechanisms	Sweden	NA	➢ We will be conducting risk analysis to ensure proposed interventions accommodate for future climate conditions as well as assessing their effectiveness.
	Malaysia	NA	➢ There will be reassessment of how effective interventions have been and we would better understand if any necessary corrections are needed. ➢ There will be an external government body that oversees the AMR One Health surveillance system, to detect

			incongruencies in data reporting and identify if sectors or individuals consume antimicrobials from alternative sources (i.e., black market)
Reporting	Sweden	NA	➢ There will be a One Health surveillance system that is uniform in data collection and reports actual consumption of antimicrobials instead of sales.
	Malaysia	NA	➢ We will be using blockchain technology to track usage and hence increase transparent reporting of antimicrobial use.
Accountability	Sweden	NA	➢ There will be a designated external body that will be accountable for the fulfillment of the SDGs goals and re-assessment of further actions to be taken when objectives are unmet.
	Malaysia	➢ There is a challenge as to who owns the problem and solution to AMR, this need to be rectified moving forward.	➢ There will be an external body to oversee the progress in different countries towards AMR goals.
Coordination	Sweden	➢ The different trade standards, protectionism and rising nationalism represent challenges towards coordination of AMR efforts.	➢ There will be global collaboration in fighting AMR. ➢ There will be collaboration between HICs and LMICs to improve enforcement capacity and support necessary AMR efforts.
	Malaysia	NA	➢ There will be involvement of all sectors to fight AMR as well as the construction of a One Health surveillance system that minimizes silo work. ➢ The EU and ASEAN will coordinate with respective countries they oversee to unify AMR targets, goals and actions needed to reach identified goals.
Equity	Sweden	NA	➢ There will be concerns over the access of antimicrobials in certain parts of the world.

			➢ There will be movement towards more consolidated sectors, job loss is expected, and this presents a challenge to creating equity while fighting against AMR. ➢ There will be concerns over shifting the AMR problem to other countries instead of assisting other countries in reaching their goals.
	Malaysia	NA	➢ There will be access issues with an intervention like taxation as poor individuals still need to access antimicrobials. ➢ There will be increased enforcement capacity and countries' priorities will shift.
Participation	Sweden	NA	➢ The UN will be more responsible in improving the infrastructure in other countries as well as standards for farming. ➢ Clinicians, veterinarians and other regulators will be responsible and engaged to solve the AMR issue.
	Malaysia	➢ OIE & WHO are collaborating to improve capacity in certain countries. These efforts need to be supported and increased. ➢ There are compliance issues in certain countries as guidance resources are available but are unacted upon.	➢ There will be more investment in hospitals, farms etc. to train individuals on IPC measures as the participation of these individuals is necessary for the success against AMR.
Strategic Vision	Sweden	➢ An ambitious timeline is set to achieve AMR goals.	➢ The changing climate conditions will create urgency in investing in LMICs in terms of resource allocation and enforcement capacity. ➢ There will be deintensification efforts as sustainability and animal welfare become important.

	Malaysia	➢ Shorter periods provide society for more push towards action, hence current goals should be placed within a shorter time frame to allow for re-assessment.	➢ Some money from taxation will go towards relocation of people from high to low density areas for lower transmission of infections. ➢ Climate change will influence water availability, hence technologies such as water management systems will be developed.
Sustainability	Sweden	➢ There is a challenge of keeping policy makers interested in the AMR issue and this will present an issue in the future as well.	➢ Local and international food production will be an important part of the discussion on sustainability in the future.
	Malaysia	NA	➢ We will have a mechanism to finance AMR policies, whether through taxation or allocating some money from national budgets to ensure sustainability. ➢ Waste management systems will be financed in the future but are challenged by changing political interests in different countries.
Transparency	Sweden	NA	➢ Countries will transparently report their antimicrobial use data and relay this information from regional to international for accountability. ➢ There will be increased transparency in AMR campaign messaging.
	Malaysia	NA	➢ There will be a comprehensive system of documentation that allows for transparent reporting. ➢ This comprehensive system will allow governments to report exactly how much antimicrobials were used, in what species, sectors etc.

Note: given the scenario planning design of the original study, AMR experts were asked to discuss what the future looks like in 2050, hence more future elements were discussed and "NA" was placed under some current elements. In addition, experts were not specifically asked about these different elements, hence some are left as "NA".

Overall, Swedish and Malaysian AMR experts discussed future government elements more frequently than current elements. In Table 2, current governance elements discussed by Swedish and Malaysian AMR experts were either challenges or facilitators of governance. Swedish AMR experts discussed the following current challenges: the EU limited control in the European region, veterinarians getting paid for antimicrobials in some countries, ambitious timelines for reducing AMR rates, protectionism and nationalism, and lack of policymakers engagement on AMR. Swedish AMR experts discussed current governance facilitators as elements or policies that already exist but need further improvement in the future. The current governance facilitators discussed are the following: existing trade policies, AMR educational campaigns, technologies such as CRISPR and GMOs, and increased awareness on climate change and animal welfare. Future governance elements discussed by Swedish AMR experts included: incentivization of farmers for following appropriate antimicrobial use practices, a One-health surveillance system that is specific and transparent, requirement of diagnostic tests for antimicrobials, transparent AMR messaging, increased involvement of social scientists, greater technological advancements and increased sectoral/national/international collaboration to tackle AMR.

In Table 2, Malaysian AMR experts discussed the following current governance challenges: limited funding capacity to implement AMR policies, lack of understanding of human behaviour and innovation, OTC use of antimicrobials, non-compliance with AMR policies, and lack of an accountable body for the AMR issue. Future governance elements discussed by Malaysian AMR experts included: providing subsidies and penalties to control antimicrobial use, increased innovation, public awareness and technological advancements, increased monitoring of the supply chain, a One-Health surveillance system that is transparent,

the availability of an external body that oversees progress and increased collaboration between HICs and LMICs.

Table 3. Current and Future Elements of Public Engagement Discussed by AMR Experts in Sweden and Malaysia

SCT Component	**Country**	**Current**	**Future**
Behaviour	Sweden	➢ People are willing to pay for premium products and this willingness is predicted to increase as awareness on the importance of animal welfare heightens. ➢ AMR is a long-term issue, but people's attitudes and behaviours are mostly short-term. ➢ Adherence to prescription courses is low and needs to increase in the future. ➢ Some societies offer antimicrobials without prescription, so it is important to engage supermarkets in regulating/limiting the products they freely make available.	➢ A portion of taxes will be directed towards shifting farming practices (i.e., improved husbandry and vaccinations) ➢ Society will have greater understanding of human behaviour to influence people. ➢ World population will increase which will push for intensification practices which will compromise animal welfare. ➢ China will hold enormous economical power which will largely shift eating behaviours globally.
	Malaysia	➢ People in some countries are able to access antimicrobials over the counter or self-medicate and this needs to change in the future.	➢ Taxation will create responsible usage of antimicrobials because a system of documentation will be required ➢ Some people will go to black markets to evade paying taxes. ➢ Most commonly used antimicrobials will be taxed more, which will disincentivize unnecessary use. ➢ Some countries may appear compliant with taxation policy but employing taxes only on exported products

			and sharing profits with governments.
Goals	Sweden	➢ It is a challenge to tackle AMR long-term goals since it is a long horizon and people tend to view immediate problems as more important and may not have the patience to wait until 2050.	➢ NA
	Malaysia	➢ NA	➢ There will be systems in place to execute AMR goals and ensure that incentives are being provided to maintain these goals and systems.
Outcome Expectancies	Sweden	➢ Providing positive examples where AMR goals were successfully implemented provides more hope for success in parts of the world where certain policies aren't enacted. ➢ Engaging farmers in preventative practices to increase animal welfare is ought to reduce reliance on antimicrobials.	➢ Increased taxation of antimicrobials will hinder farmers from purchasing antimicrobials and encourage preventative practices. ➢ Future climate conditions will increase awareness of individuals and willingness to pay taxes on antimicrobials. ➢ Tackling AMR in the future will be challenged by the loss of jobs in the coal industry.
	Malaysia	➢ NA	➢ Incentive-based tax system in the future will encourage farmers and prescribers to use antimicrobials appropriately. ➢ Increased taxation of commonly used antimicrobials will more likely minimize their use.
Self-Efficacy	Sweden	➢ Sweden successfully reduced the use of antimicrobials, and this	➢ National action plans will be evaluated in different countries and important

		positive example is to be shared with other European countries and the world in general.	lessons will be shared with other countries.
	Malaysia	➢ The COVID-19 pandemic showcased how distancing and hygiene measures were effective in reducing transmission. We need to harvest these lessons to address AMR.	➢ NA
Sociocultural Facilitators	Sweden	➢ The current generation is concerned with animal welfare and are more willing than previous generations to pay for premium products containing less/no antimicrobials. ➢ The previous COVID-19 pandemic has made people more receptive to AMR messages. ➢ Swedish citizens rely on and trust their government and are more likely to follow rules and regulations in comparison to other nations.	➢ NA
	Malaysia	➢ While discussions about AMR are available, industries need to be shown alternatives to AMR so that shifts in behaviours and attitudes can be carried out. ➢ There are cultural and social differences where some societies possess more social responsibility and conscientiousness than others, influencing the uptake of policies.	➢ NA
Sociocultural Impediments	Sweden	➢ It is difficult to relay AMR messages as it is a complex ecological issue	➢ NA

		and people may not see the effects immediately. ➢ People look for quick fixes and hence, engagement on AMR may not be attractive. ➢ Different understandings of animal welfare and general standards across different countries make it difficult to unify efforts against AMR. ➢ Developing countries lack the capital to invest in the AMR problem and developed countries need to offer help and advice. ➢ Political shifts may influence the relevancy of the AMR problem.	
	Malaysia	➢ Some societies lack a sense of social responsibility and hence face difficulty in implementing AMR policies.	➢ Taxation may inspire counterfeit practices such as taxation avoidance.

Note: given the scenario planning design of the original study, AMR experts were asked to discuss what the future looks like in 2050, hence more future elements were discussed and "NA" was placed under some current elements. In addition, experts were not specifically asked about these different elements, hence some are left as "NA".

Similarly, in Table 3, Swedish and Malaysian AMR experts discussed current public engagement elements as either challenges or facilitators. Swedish AMR experts discussed the following current public engagement challenges: society's general attitudes towards quick fixes, non-adherence to antimicrobial regiments, difficulty in relaying AMR messages, and political shifts. Swedish AMR experts discussed the following current public engagement facilitators: people's willingness to pay for premium products, Swedish citizens' trust in their government, and increased public concern with animal welfare. Future public engagement elements discussed by Swedish AMR experts included: greater understanding of human behaviour, taxation may

drive people into black markets and important AMR lessons will be harvested and shared among countries

Malaysian AMR experts discussed the following current public engagement challenges: accessibility of antimicrobial OTC and cultural and societal differences making it difficult to implement certain AMR policies. Future public engagement element discussed by Malaysian AMR experts was the introduction of a taxation system that will regulate practices and provide incentives but simultaneously may lead to counterfeit practices.

4.8 Interaction Between Governance and Public Engagement Elements

Figures 1 and 2 illustrate the interactions between the different governance elements and public engagement elements. These connections represent interactions deduced from the conversations of AMR experts in Sweden and Malaysia. These figures also emphasize internal and external interactions within and between the varying elements of governance and public engagement. Elements of governance are denoted by a circle whereas elements of public engagement are denoted by a diamond shape. The size of the shape and font represents the relative frequency at which a specific element was discussed by AMR experts. The direction of the arrows represents the relationship between the various elements. The color of the arrow signifies whether an element interacts with other elements of the same framework or a different framework. Black arrows represent an interaction between the various governance elements, violet arrows indicate an interaction between public engagement elements, and amber arrows represent an external interaction between an element of governance and an element of public engagement.

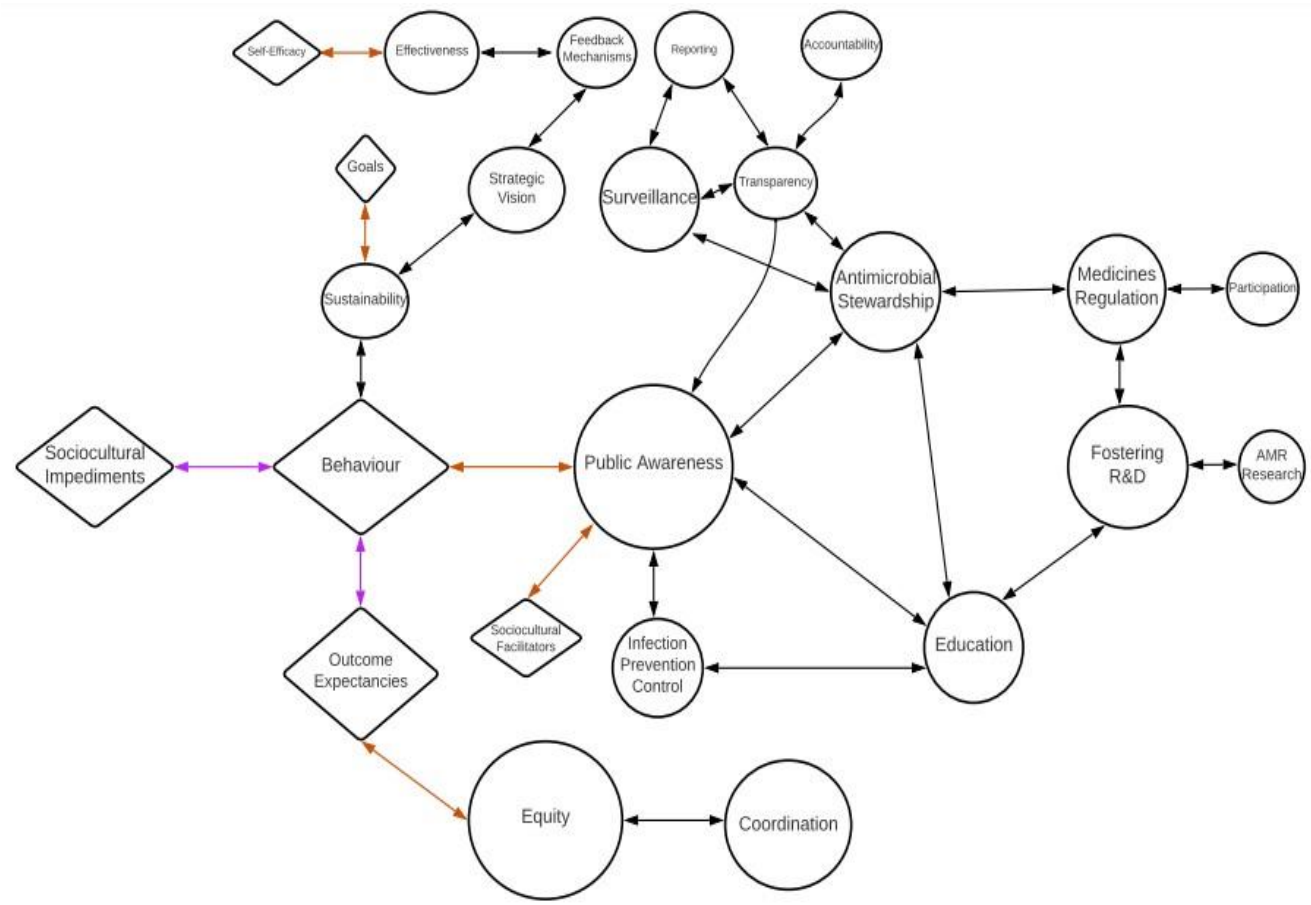


Figure 1. An Interaction Diagram Between Governance and Public Engagement Elements Constructed Through Swedish AMR Experts' Conversations During Two Workshops Held on September 10 and 11, 2020 About the Effectiveness of Taxation and Infection Prevention Control in Curbing AMR in 2050.

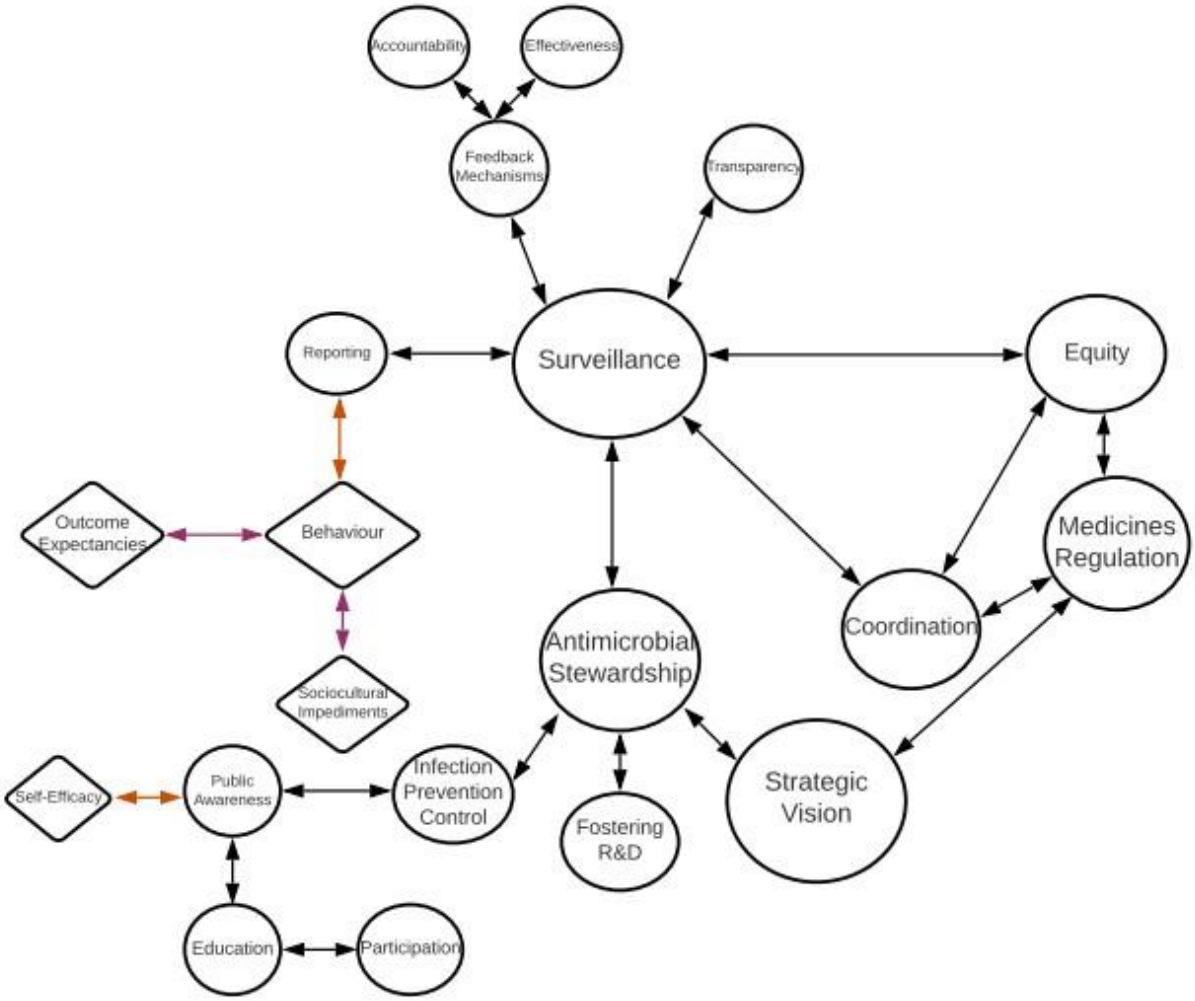


Figure 2. An Interaction Diagram Between Governance and Public Engagement Elements Constructed Through Malaysian AMR Experts' Conversations During Two Workshops Held on October 7 and 8, 2020 about the Effectiveness of Taxation and Infection Prevention Control in Curbing AMR in 2050.

Both Swedish (**Figure 1**) and Malaysian (**Figure 2**) AMR experts conversations about governance and public engagement generated similar interactions. Focusing on governance elements, Swedish and Malaysian experts discussed the interactions between antimicrobial stewardship and surveillance, surveillance with transparency and reporting, equity and coordination, as well as public awareness and education. Swedish and Malaysian experts connected 'antimicrobial stewardship' and 'surveillance' similarly. Also, the governance element of surveillance was similarly connected to two governance elements: 'reporting,' and 'transparency' in both contexts. Unique to the Swedish experts conversations (**Figure 1**), the element of 'antimicrobial stewardship' was connected to 'transparency'. Swedish and Malaysian AMR experts similarly connected 'equity' and 'coordination.' As well, elements of 'public awareness' and 'education' were consistently linked together by Swedish and Malaysian experts.

Numerous differences in the frequency and interactions of the different governance elements can also be observed between the Swedish and Malaysian diagrams. Most notably, public awareness was the most central node identified through Swedish AMR experts' conversations whereas Malaysian AMR experts' conversations generated surveillance as the most central. A unique interaction between equity and surveillance emerged from only Malaysian experts (**Figure 2**). This interaction was revealed through Malaysian AMR experts' discussions of a One Health surveillance system that requires funnelling taxation money to introduce blockchain technology; this system was said to require investments that many countries cannot provide; this was not mentioned in the Swedish workshops. There was also a larger focus on equity in the Malaysian diagram compared to the Swedish diagram, where equity was more frequently discussed and interacted with more governance elements.

A few observations can be drawn comparing the interaction between governance and public engagement elements in the Swedish and Malaysian diagrams (**Figures 1** & **2**). In the Swedish diagram, the two elements of governance, 'public awareness' and 'sustainability' independently interacted with the public engagement element: 'behaviour'. In the Malaysian diagram, the element of governance, 'public awareness', interacted with one public engagement element: 'self-efficacy."

4.9 Context-Specific Challenges and Opportunities Emerging from Sweden and Malaysia

AMR experts in Sweden and Malaysia shared similar challenges that were presented when tackling AMR. These shared challenges are related to equity and differing food standards. AMR experts from Malaysia and Sweden discussed the financial difficulty that would be faced by people living in LMICs upon the introduction of taxation. A Malaysian AMR expert stated:

> "We had a general consensus that we support such a tax on AMR, on antibiotics. We felt that it should be human and animal and other sectors but keeping in mind that access is an issue and therefore rebates or discounts for those who really have an affordability issue would be there, and there should be a mechanism for it."

Malaysian and Swedish experts also discussed the challenges associated with different food standards practiced by different countries. These conflicting standards indicate that food quality, safety, and antimicrobial levels vary from country to country, making it difficult to tackle AMR globally.

AMR experts in Malaysia specifically identified two major context-specific challenges; the first challenge described was the lack of infrastructure in LMICs like Malaysia, which requires investment. AMR experts expressed that many LMICs do not have the proper infrastructure to have lab tests and equipment to allow for the proper diagnosis of infections, making the use of antimicrobials less specific, perpetuating the existing problem of AMR. As stated by an AMR expert:

"I think what Malaysia would have done in the next 30 years is to invest significantly in that sort of education and hospital infection prevention control team production takes a lot of investment. More broadly, there needs to be a huge amount of investment in rapid diagnostics and microbiology facilities. Much of the LMIC world does not have access to good microbiology facilities, so antibiotics get used indiscriminately without backup evidence."

Furthermore, AMR experts predicted a challenge ahead regarding the investment in LMICs to help improve facilities and build the proper infrastructure to allow for effective AMR policies to be applied.

The second challenge described by Malaysian AMR experts was the wide availability of wet markets in SEA. Malaysian experts expressed concerns regarding the safety of foods prepared in wet markets. An AMR expert stated:

"We realized that it is very difficult to completely remove these wet markets, or I mean wild animal consumption from Southeast Asian practices because it's tradition and people still like it. So, we have been discussing about introducing some kind of good practices, for wet markets because it is going to be a challenge in the future as well, because we observed, I think about 70% of human diseases are coming from animal and this area, I mean particularly this Asia Pacific region has very high biodiversity and life of people with wet markets and wet life is very high, so that aspect we will have to strengthen in the future."

4.10 New Elements of Governance Emerging from Sweden

A new component of governance identified through AMR experts discussions in Sweden was the need to incentivize big pharmaceutical companies to be more interested and invested in discovering new antimicrobials. These pharmaceutical companies are said to play a large role in many countries when it comes to sponsoring changes, as they possess a lot of power. A Swedish AMR expert stated:

"Big pharmaceutical companies need to be incentivized. And I agree that there is a lot of recent need for incentives in areas that they could act as alternatives to antibiotics, but I just want to be very clear that do not believe that it's very profitable business day to be in antibiotics either. That's one of, of course, the really big reasons why there are very few big pharma companies still remaining in the in the antibiotic business because it's actually hard to make money on antibiotics."

Furthermore, AMR experts expressed that pharmaceutical companies need to be involved and invested in developing new antimicrobials.

The second component of governance discussed by AMR experts in Sweden was the need to get politicians on board with AMR policies and interventions. They identified it as important that politicians are constantly involved and invested in the fight against AMR. An AMR expert stated that the issue with tackling AMR is:

"... How to raise the profile among policy makers. I think that is the issue. How do we raise the urgency of the, to move forward with the plans and with the policies to deal with AMR? There was a number of years ago, probably 2015, 2016, AMR was one of the top priorities, one of the top three priorities in most of our countries. We had the UN assembly; we had a global action plan and then the National Action plans within the last two- or three-years things have, it's fallen down the priority list in all of our countries."

Therefore, experts emphasized that it is important to keep the politicians on board with AMR policies sustainably because future changes and shifting priorities may influence the urgency of addressing the AMR issue and delaying needed efforts.

4.11 New Elements of Public Engagement Emerging from Sweden

AMR experts from Sweden identified an additional component to consider regarding public engagement. They identified consistent messaging as important to improve public engagement on AMR policies and laws. The consistency of messages was discussed by AMR experts as important in increasing the public's trust in the government and lawmakers. An AMR expert stated:

"The public in general, expect experts to be all on the one page and to give the same information and the same advice and all. But what we've found from the pandemic is there are many different experts advises, many different expert opinion and practices and guidance on what to do. And I think this is caused a lot of confusion among the general public and then this confusion has led to a loss of confidence in expert opinion."

They highlighted the need for consistent messaging to regain public trust and consequently improve citizen engagement and compliance.

4.12 New Elements of Public Engagement Emerging from Malaysia

AMR experts from Malaysia identified two additional aspects of public engagement that fall outside the scope of the public engagement elements used. The first public engagement element discussed was the individual selected to deliver public health messaging. An AMR expert stated:

" …If the right people deliver the message and you get somebody the public can trust, often health professionals, I'm sure this is, I don't know whether it would apply to food industry, but I imagine similar principles apply in terms of public health. Yes, it's a matter of getting somebody trusted to deliver that message."

Further, selecting the appropriate individuals who are well-trusted in communities was seen as important by AMR experts to deliver effective AMR messages.

The second new element of public engagement discussed by Malaysian AMR experts was the need to overcome conflicts of interest, particularly with regard to implementing certain AMR behaviours and conflicts with pharmaceutical companies. An AMR expert stated:

"… Sometimes some countries have very large pharmaceutical industries, and they will particularly... are not interested in introducing some of these measures themselves. There would certainly be a conflict between the need to introduce those and the need to support their pharmaceutical manufacturers, some of which make very large profits. And for those countries. So, there is an inherent potential conflict there."

AMR experts further explained that the lack of novel antimicrobials perpetuated by the lack of development of new antimicrobials by pharmaceutical companies due to the associated costs needs to be reconciled to improve AMR outcomes further in the future. Thus, engagement with pharmaceutical companies was seen by experts as necessary to support proposed interventions to minimize AMR.

Chapter 5: Discussion

The overarching objective of this thesis was to investigate governance and public engagement elements that emerged from conversations by AMR experts in Sweden and Malaysia about the sustainability and effectiveness of taxation and IPC measures as strategies to mitigate AMR in 2030 and 2050. To achieve this, an analysis of secondary data from two independent workshops with Swedish and Malaysian AMR experts from various AMR-relevant professional backgrounds who are seldom involved in AMR discourses was conducted.

While Swedish and Malaysian AMR experts discussed 18 elements of governance, governance elements falling under 'implementation tools' were mentioned more often than elements falling under 'policy design' and 'monitoring and evaluation'. For example, there were more frequent discussions around surveillance, antimicrobial stewardship, IPC, medicine regulation, fostering research and development, and public awareness in comparison to discussions about coordination, accountability, and feedback mechanisms. Swedish AMR experts discussed six elements of public engagement, while Malaysian experts discussed four.

Looking at Figures 1 & 2, it is visually noticeable that governance and public engagement elements interacted differently in Sweden and Malaysia. Most notably, In Sweden, the governance element of 'equity' interacted with public engagement element of 'outcome expectancies'. Additionally, 'public awareness' interacted with two public engagement elements, 'sociocultural facilitators' and 'behaviour'. In Malaysia, the governance element of 'public awareness' interacted with public engagement element 'self-efficacy', whereas the element of 'reporting' interacted with 'behaviour'.

Two new governance elements were identified by Swedish experts: incentivizing big pharma and getting politicians on board. An additional public engagement element was

identified through Swedish AMR experts conversations: consistent messaging. There were no new governance elements discussed by Malaysian experts but their conversations revealed two additional public engagement elements: the person sending the messaging and conflict of interest issues.

5.1 Governance and AMR

With respect to antimicrobial stewardship, Swedish and Malaysian AMR experts discussed the need for proper diagnostics and facilities and collaboration efforts across countries and sectors. While experts addressed the need to promote positive farming practices, they differed in the method through which those practices were brought about. Swedish experts proposed incentivizing farmers to follow appropriate farming practices through rebates or monetary rewards, while Malaysian experts focused on improving biosecurity measures at the farm. Two studies assessing Swedish and other European pig farmers' perceptions and worries around AMR and their farming practices found that they were most worried about financial issues rather than resistance in their farms (Visschers et al., 2015; Alarcon et al., 2014). Given the relative significance of financial incentives or burdens to farmers, financial policies are key drivers of behaviours.

Two studies examined the importance of biosecurity measures at farms and found that farmers' characteristics played a greater role in determining antimicrobial use (Backhans et al., 2015 & 2016). General findings included that older and educated farmers, in tandem with good veterinarians' communication skills, played a greater role in farming practices than increasing biosecurity levels (Backhans et al., 2015 & 2016). The weak relationship between antimicrobial use and biosecurity measures at the European level can be attributed to good biosecurity measures; the modifying factor appears to be farmers' personal characteristics. Fraser et al. (2010) further conducted a study on pig farmers' attitudes toward biosecurity measures and

associated costs and found that the inclination toward performing a biosecurity measure decreases with increased costs. This highlighted the importance of providing incentives and penalties to improve the uptake of biosecurity measures.

Altogether, these studies collectively highlight the importance of incentivizing farmers and supporting biosecurity efforts to curb AMR. These findings also solidify the need for collaborative efforts across sectors, such as veterinarians and farmers, since multiple studies showed that some veterinarians feel pushed to prescribe antibiotics by farmers and suppliers and sometimes are not even consulted by farmers (Ortman & Svensson, 2004; Hockenhull et al., 2017). The theme of working collaboratively with other sectors was also identified by a study assessing Swedish poultry farmers' views on AMR (Björkman et al., 2021).

Swedish and Malaysian AMR experts discussed the importance of educating farmers, industries, hospitals, and society at large on AMR. Swedish experts specifically discussed educating people on preventative measures such as lifestyle changes conducive to good health, reducing reliance on antimicrobials, and involving social scientists in making AMR campaigns. Swedish AMR experts' conversations on education reflect Sweden's ongoing strategy against antibiotic resistance, building awareness and educating prescribers and the public, given that patients' beliefs and prescribers' knowledge impact prescribing practices (Mölstad et al., 2017). This educational piece is well-integrated into Swedish society, where hospitals, daycares, and any entity working with the public are offered information on AMR and best practices, which is disseminated using various methods and in six languages to ensure the inclusion of immigrants (Mölstad et al., 2017).

In Malaysia, the incongruency between patients and prescribers is evident; a study showed that 37% of patients expected an antibiotic prescription, although more than 20% of prescribers

deemed them unnecessary in said cases (Hassali et al., 2015). Hence, it is important to raise awareness among patients and prescribers equally. A Malaysian study assessing an AMR educational tool showed that only 26% of patients believed they played a role in fighting AMR, and post-intervention, this increased to 69% (Thong et al., 2021). This further shows that increased knowledge and awareness of AMR across society are critical in instilling agency and a sense of influence within individuals.

In addressing the component of 'fostering R&D and facilitating market access to novel drugs', Swedish and Malaysian AMR experts discussed the need for investment and extensive research on newer antimicrobials, alternatives, vaccines, and technologies as key to combating AMR in the future. While Malaysian experts focused on the need to keep climate conditions in mind when constructing newer technologies, Swedish experts discussed tackling innovation setbacks, such as keeping policymakers and regulators involved and interested so that investment in R&D can be sustained. There are many setbacks in discovering new antimicrobial drugs, such as funding issues, low commercial and therapeutic value, and a history of company failures that shun future companies from investing in developing novel antimicrobials (Piddock et al., 2022). Achaogen is an example of a company that declared bankruptcy a little less than a year post FDA approval for their antibiotic Zemdri (Piddock et al., 2022).

Incentivizing companies to increase research and development in the realm of AMR may necessitate a combination of push and pull incentives described by Bhavnani et al. (2020). Push incentives are applied early in the research and include funding opportunities but run the risk of researchers overlooking risks to maintain funding, whereas pull incentives may influence the time it takes for a regulatory review or provide incentives after the drug goes into the market (Bhavnani et al., 2020). In tandem with new R&D, Piddock et al. (2022) stated the importance of

providing access to existing antimicrobials and equalling the level-field so that antimicrobials are available when necessary.

In Sweden, the focus since 2020 has been on push incentives that prioritize access to critical pathogens through guaranteed annual funding for antimicrobial drug developers in exchange for a set volume of supply (Anderson et al., 2023). While Malaysians focused on the need for investment in new technologies and drugs, a major setback to innovation in Malaysia is the price control of pharmaceutical companies, where some companies can hike up their prices without limit (Hasan et al., 2019). Sweden and Malaysia represent very different scenarios regarding R&D and access to antimicrobials; while Sweden has access and funding, Malaysia does not. Tackling the issue in Malaysia requires tighter regulatory mechanisms around pharmaceutical companies and greater incentives to develop antimicrobial drugs, with financial capital representing a hurdle.

Swedish and Malaysian AMR experts addressed the need to apply IPC practices across all sectors and at the individual level to the point where IPC practices become common practice for everyone. Experts viewed the COVID-19 pandemic as a learning point regarding the effectiveness of IPC measures in curbing infections. A study conducted by Maugeri et al. (2022) reported that the COVID-19 pandemic played an important role in raising awareness of the importance of prevention measures like IPC. With increased hygienic practices, social distancing measures, and other IPC measures implemented through COVID-19, infection transmission was reduced; hence IPC measures are becoming more recognized as important (Rawson et al., 2020).

In Sweden, IPC policies vary depending on the region (21 regions), but IPC's main problem is the shortage of beds and nurses (Lytsy, 2018). This further led to crowded hospitals and understaffed health departments (Lytsy, 2018). The Malaysian AMR experts specifically

touched on the importance of waste management practices as they are often neglected but represent an important component of IPC measures. Waste generated by healthcare facilities contains many pathogenic microorganisms, and the negligence of proper waste treatment systems further perpetuates the AMR problem (Harhay, 2009). A Malaysian study showed that the prevalence of multiple pathogens that are the leading cause of multi-drug resistance is 80%, based on data from two hospitals using samples of hospital effluents (Bakon et al., 2023). Hence, Sweden and Malaysia have different challenges facing implementing IPC measures and efforts to curb AMR should address nurse and bed shortages in Sweden and hospital waste-disposal practices in Malaysia.

Regarding the medicines regulation component of governance, Swedish and Malaysian AMR experts addressed the need to necessitate a prescription for every antimicrobial drug dispensed, which is aimed at reducing the unnecessary use of antimicrobials. The challenge that the availability of OTC antimicrobial use in LMICs presents in fighting AMR has been well-documented and continues to be tackled through efforts to increase enforcement capacity (Sartelli et al., 2020). Swedish AMR experts mentioned the need to regulate veterinarians and enforce tighter regulations across country borders to ensure compliance with AMR reduction policies. This is a grave concern, given the rise in medical tourism worldwide (Hill, 2011).

Medical tourism represents a huge challenge to AMR, where many patients travel to foreign countries and purchase drugs at a cheaper cost under looser regulatory structures, amplifying the resistance of purchased drugs (Chen & Wilson, 2013). Many countries where individuals travel for medical purposes, harbour infectious diseases that these individuals can bring back to their home country, propagating the issue of resistance and changing the nature of endemic diseases in their country (Chen & Wilson, 2013). A study showed that 30-60% of

Norwegian travellers purchased an antibiotic without a prescription when travelling to Thailand, Turkey, and Spain (Gravningen et al., 2020). This shows that although Nordic countries have strict regulatory mechanisms for obtaining antimicrobial drugs, cross-border travel can perpetuate AMR due to looser regulations. Factors associated with medical tourism trends in Norway included low income and previous hospital admissions (Gravningen et al., 2020). A need for cross-border standards is evidently important in fighting AMR in the future. An Australian study involving 106 participants reported an increase in cases of antibiotic-resistant *Escherichia coli* following an international trip, from 8% to 49%, showcasing how travel can contribute to increased infections and perpetuating AMR (Kennedy & Collignon, 2010).

Regarding the public awareness component of governance, Swedish and Malaysian AMR experts spoke about raising awareness of IPC practices and appropriate antimicrobial use. While Swedish AMR experts discussed the logistics of public awareness campaigns, Malaysian AMR experts discussed the special need to engage with regulators. In essence, AMR is a social problem partly rooted in societal values prioritizing immediate issues and lacking foresight regarding the long-term consequences of antimicrobial prescribing behaviours (Broom et al., 2021). Furthermore, the participation of social scientists, communication experts, and psychologists is necessary to create appropriate campaigns built on current behaviour models and how to influence behaviour best (Broom et al., 2021). Although both experts expressed the need to involve social sciences in fighting AMR as it is a socially driven issue, it is concerning that social science research on AMR is lagging immensely (Frid-Nielsen et al., 2019). Out of 1000 academic papers on AMR, only three are in the social sciences (Frid-Nielsen et al., 2019). Researchers hypothesized that the reason for less social science in AMR research may be the non-collaborative nature of health departments given the epistemological differences social

scientists have from health experts (Frid-Nielsen et al., 2019). The separation between health and social disciplines needs to be broken so that more integration and knowledge can penetrate both disciplines (Frid-Nielsen et al., 2019). Hence, while it seems that the attention on AMR has increased over the years, the pool of social science research aiding in the understanding of how AMR is perpetuated remains minuscule. This shows the need to advocate for more social science to add to our understanding of AMR.

Malaysian experts, while acknowledging the need to raise awareness to the public, believed that regulatory bodies should be more engaged, as they represent a checkpoint for behaviour. Additionally, the bulk of the AMR problem requires shifting the focus to LMICs with high resistance and dense populations (Pokharel et al., 2019). The limited access to antimicrobials, substandard sanitation, poverty, and looser regulatory systems in some LMICs further complicate tackling AMR (Iskander et al., 2020). Investing in regulatory structures that can monitor the direct use of antimicrobials is important and ideally distributing the responsibility across multiple regulators (Porter et al., 2020). The varied perspectives of AMR experts from Sweden and Malaysia showcase that as much as AMR is a social problem, setting regulatory mechanisms must be considered key in cases where it is lacking.

Regarding surveillance, Swedish and Malaysian AMR experts both spoke about the importance of having a surveillance system that is uniform across sectors and countries, specific, and technologically advanced to relay data in real time. This system as described by experts will assist in tracking and monitoring the sales and, most importantly, usage of antimicrobials. Ten Oever (2021) discussed the importance of having a surveillance system that captures accurate and detailed information on antimicrobial use and that is accessible from the regional to

international levels. This accessibility will allow for tracking of consumption within all sectors and drawing attention to where interventions are necessary (Ten Oever, 2021).

Sweden's AMR surveillance system was strengthened by introducing svebar, an automated system that relays real-time reports on resistance pathogens and affected species (Vong et al., 2017). This surveillance system is connected to most laboratories in Sweden as it relies on the data funnelled from them to identify risk pathogens that need to be targeted (Vong et al., 2017). Sweden recently also adopted a real-time digital surveillance system used in intensive care units (ICU) to relay multiple data outcomes (Winroth et al., 2024). These outcomes include patient demographics, mortality, antimicrobial consumption, and exposure to antimicrobials by length of hospital stay (Winroth et al., 2024). Although this surveillance system is not perfect, as the metric used may not accurately capture consumption due to the changing nature of the ICU and the dosing fluctuations (Winroth et al., 2024), it is a huge step toward addressing gaps in existing AMR practices.

Malaysia established the National Surveillance of Antibiotic Resistance (NSAR) program in 1988 to track AMR in hospitals; tracking of AMR in animals and, specifically, aquaculture is rather limited (Ministry of Health Malaysia, 2017). In par with experts' conversations, conducting surveillance in LMIC settings represents a different challenge due to the lack of testing and diagnostic facilities and issues of training and data collection (Saeed et al., 2017; Hazim et al., 2018). Because of this, trust in these data is low as credible and accurate data represent the cornerstone of a good surveillance system.

Regarding AMR research, Swedish and Malaysian AMR experts spoke about the importance of investing in research involving antimicrobials, alternatives to them, new vaccines, AMR drivers, and technologies that can help us curb antimicrobial resistance. Malaysian experts

spoke about predictive technologies that will help us anticipate the types of diseases and pathogens we will likely encounter. Current technologies such as CRISPR, RNA-silencing, and other genetic engineering tools are being used to decrease reliance on antimicrobials, but gaps still remain in these technologies, and their further development will be an important step toward the fight against AMR (Murugaiyan et al., 2022).

The investment in these technologies and coordination between governments, policymakers and scientists will be pivotal to achieving further innovation. From 2017 to 2021, Sweden invested 122 million euros in AMR R&D, and across all European countries, some trends emerged (Fabbro et al., 2024). Investments in policies, therapies, vaccines, and capacity making have increased, while research on preventatives and AMR diagnostics has decreased (Fabbro et al., 2024). Therefore, investments in these areas are paramount to changing the current AMR climate in addition to collaborative efforts among European countries and the rest of the world. Swedish AMR experts also spoke about the need to research and understand human behaviour to positively influence people's attitudes and behaviours and improve efforts to tackle AMR. The role of sociologists and other researchers in the humanistic field is minute, as they contribute to 0.6% of all AMR research; this means that most of our understanding of AMR is based on biological and medical factors (Haenssgen et al., 2018). This highlights the need for a deeper social understanding of AMR.

Regarding the feedback mechanisms component of governance, Swedish and Malaysian AMR experts spoke about the importance of having an external body of government that can oversee progress and provide feedback for improvement. Swedish AMR experts emphasized the significance of conducting risk analysis that accounts for future conditions to ensure current policies can accommodate future conditions and the likelihood that said policies will be

effective. On the other hand, Malaysian AMR experts discussed the importance of having a system of data monitored by a third party that can relay feedback at different levels to ensure that misuse of antimicrobials can be identified and minimized. Currently, there are tools developed to predict the type of diseases and the likelihood of certain resistant genes appearing, in addition to the use of machine learning, all in efforts to avoid future catastrophes and to curb these new patterns of resistance (Wang et al., 2022).

The EU and ECDC play an important role in Europe directing AMR research priorities and AMR policies, especially in the veterinary section, as they have expanded into the public health realm (Carelli et al., 2023). Scandinavian countries and European countries that are managing AMR well prefer local expert direction for AMR, whereas Southeastern Europe, where many countries are suffering from AMR more, are in favour of a big regulatory body like EU and ECDC (Carelli et al., 2023). A qualitative study involving AMR experts from several Southeast Asian countries similarly reported that the lack of an Asian-centric regulatory body is a big problem facing SEA, as there is currently no body to orchestrate research efforts, standardize data collection and strategies appropriate for the region (Shrestha & Legido-Quigley, 2022). Not having a shared regulatory body overseeing the regions' AMR policies and efforts results in the detachment of interventions by various countries, and any collaboration will be difficult given the greater number of organizations that need to come together and share information.

Within the reporting component of governance, Swedish and Malaysian AMR experts discussed the importance of transparent reporting of antimicrobials, which relies on a well-designed and uniform data collection and surveillance system. Swedish AMR experts discussed the importance of a surveillance system that accurately reports the usage of antimicrobials and

uses common metrics, while Malaysian experts spoke about the importance of conducting blockchain technology to convey real-time data on the usage of antimicrobials and identify any incongruences in reporting. These findings echo existing discussions about challenges facing current AMR surveillance systems. Important challenges identified among current AMR surveillance systems include non-standardized methods of data collection, data incongruency and separate data systems (Do et al., 2023b). An additional challenge specific to the transparency of reporting is the lack of data representativeness in some contexts, where data reported may not highlight the current AMR patterns in a region (Do et al., 2023b). To improve current AMR surveillance systems, capacity building such as increasing training and access to diagnostic tools was viewed as paramount (Do et al., 2023b).

Transparency has been identified as an important component in an effective AMR surveillance system, this encapsulates the process of collecting the data, updating progress, funding, and outcomes/goals (Ruckert et al., 2024). AMR experts expressed that AMR reports being readily available is an important component of governance as it allows for the extraction and analysis of data for focused efforts; it also improves trust among sectors and countries. A study assessing the alignment of NAPs in 117 countries with GAPs showed that only half of the countries with NAPs made their data publicly available (Munkholm & Rubin, 2020). With data undisclosed, one is left to wonder whether the promises of AMR are actualized in person. Having a transparent system of reporting, whether for NAPs or AMR policies represents an important step towards increasing credibility and accountability.

AMR experts from Sweden and Malaysia equally discussed the importance of coordination within and across countries in fighting AMR. As well, they spoke about the significance of HICs in helping LMICs improve their enforcement capacity to fight AMR better. Swedish AMR

experts mentioned the importance of lesson sharing and financial assistance to LMICs so that they are better able to fight AMR. Malaysian experts spoke about a governing body like ASEAN and its importance in executing certain policies and unifying efforts against AMR in Southeast Asia. Swedish AMR experts specifically discussed challenges related to reaching AMR targets, including protectionism and nationalism. COVID-19 exacerbated existing notions of nationalism in the USA and many other countries as it created many divisions among people and made way for discriminatory behaviours (Boylan et al., 2021). Malaysian experts discussed a One Health surveillance system that allows for the integration of AMR data in one location and allows sectors and industries to work together instead of silos.

5.2 Public Engagement and AMR

Across the two contexts of Sweden and Malaysia, experts identified improving business models, society's sense of self-efficacy though model learning, as well as influencing behaviour to minimize reliance on black markets as key factors in tackling AMR.

Huttner et al. (2014) highlighted the multiple success stories from different countries like Sweden, France and China in tackling AMR and the various lessons to be learned from implemented policies. Huttner et al. (2014) further emphasized the importance of identifying success stories and failures since every policy may carry unintended consequences. STRAMA, a Swedish program aimed at promoting the reasonable use of antibiotics, is an example of a successful measure in reducing the use of antimicrobials at a country level (Mölstad et al., 2008). STRAMA works at a local and national level, and the existing local structures facilitate its implementation (Mölstad et al., 2008). Therefore, the replication of such a program in other countries requires knowledge and adaptation of policies across different contexts (Mölstad et al., 2008). Increased self-efficacy of countries in implementing AMR policies that proved successful in other countries improves public engagement and collaborative efforts against AMR.

According to experts, successful examples provide encouragement to other countries to follow the same path and may inspire new partnerships between countries.

While many countries prohibited the OTC use of antimicrobials, this does not always translate well into practice (Jacobs et al., 2019). This incongruency partly exists because the interests of private businesses are getting compromised with enforcement mechanisms aiming to regulate the use of antimicrobials (Porter et al., 2020). Hence, the engagement with pharmacies, clinicians and other prescribers of antimicrobials requires concurrent regulation to ensure that positive prescribing behaviours are practiced and maintained. This intersectionality between engagement and governance can be depicted in a term coined by Gunningham called 'smart regulation', which illuminates the need to engage with antimicrobial prescribers and regulatory bodies in the design of AMR policies (Porter et al., 2020).

5.3 New Governance Elements

Raising the priority of AMR among policymakers and incentivization of pharmaceutical companies to develop new antimicrobials were identified as new elements of governance that need to be considered. While studies have recognized the importance of incentivizing pharmaceutical companies, it is more important to understand the nuances of such a decision and the misconceptions we have about the development of new antimicrobials. It is important to introduce an optimal number of antimicrobials in the market as well as to consider different reimbursement systems used by different countries, as countries like the USA offer reimbursement systems for only cheap generic antimicrobials, which reduces the likelihood of introducing newer antimicrobials (Outterson, 2014). Even more important than the introduction of new antimicrobials, it is perhaps more effective to introduce preventative measures against antimicrobials than focusing on collecting capital to support the introduction of new antimicrobials (Outterson, 2014).

5.4 New Public Engagement Elements

The two new elements of public engagement highlighted through discussions of AMR experts in Sweden and Malaysia were consistent messaging as well as having a trusted medium through which information is disseminated. Study participants largely discussed messaging within the context of the COVID-19 pandemic and the COVID-19 messaging literature provides valuable background on the varying factors influencing messaging and adherence/non-adherence practices that are resultant. Sauer et al. (2021) discussed the Crisis and Emergency Risk Communication (CERC) manual constructed by the CDC that aims to improve communication between regulators and citizens. CERC states that credibility can be achieved by providing non-opposing information and ensuring no variance between healthcare and political leaders' stances. A study by Bekalu et al. (2021) showed that politically fueled media targeting different audiences plays a major role in generating inconsistent messaging, with the public being swayed in the middle and creating less stability. Furthermore, politically driven messaging about COVID-19 shifted trust from scientists to political networks that thrive on the loyalty of their members (Bekalu et al., 2021).

With being loyal to a political principle rather than scientific evidence, people can fall victim to ideologies that can cause harm. While AMR may not be as politically charged as COVID-19, Bekalu et al. (2021) highlighted the difference in adherence rates across multiple subgroups (e.g. gender, socioeconomic status, education, mainstream outlet), highlighting the importance of targeted messaging in improving adherence outcomes. A Swedish study reported that patients' trust in healthcare workers was linearly associated with compliance to postpone antibiotic therapy (Rönnerstrand & Sundell, 2015). Taking these relationships and reflecting on

the importance of sentiments like trust can be a large driver for change in societies where it is high.

5.5 Synergy between AMR Governance and Public Engagement

Given the complex multidisciplinary nature of AMR, the numerous factors influencing the propagation of AMR and context-specific considerations, a whole system approach is necessary to start unravelling the intersecting factors and their relationships to one another. The complexity of AMR necessitates system thinking and considering the multitude of variables involved in propagating AMR, hence the synergy between governance and public engagement was hypothesized and visualization diagrams helped illustrate those synergies. Governance methods such as surveillance and innovation and research, while important, current public knowledge on AMR is variable depending on the individual exposure to AMR-related information and hence, engagement with the public is equally important. Although the literature acknowledges the need for public engagement methods in tackling AMR, there is no consensus on how to approach the AMR problem best, from a social perspective (Charani et al., 2021). The interactional diagrams displayed in Figures 1 and 2 are a clear example of the complex nature of AMR as a governance and social issue and how HICs like Sweden and LMICs like Malaysia paint a different picture of the interaction between governance and social/cognitive factors. The interaction between different elements of governance and public engagement provides a contextual understanding that can further foster policy development. The different interactions between governance and public engagement help us contextualize the driving forces for AMR within Sweden or Malaysia. Further, these interactions can allow us to tackle AMR and understand the nuances within each context, which can become entry points through which we

can start to tackle AMR in Sweden and Malaysia, and within reason, extrapolate to HICs and LMICs that may share similar social and political values.

Chapter 6: Conclusions

AMR is a multi-layered issue that requires the involvement of numerous actors at the local and international scene due to the numerous factors involved in propagating it. The various governance and public engagement elements discussed highlighted that very complex nature of AMR. In a literature saturated in using the Health Belief Model to assess awareness among AMR consumers, this study was first to use the sociocognitive theory to assess public engagement elements that seldomly get discussed. Although the governance model used was only applied in the context of national action plans, this study investigated various topics such as IPC, taxation, biosecurity, trade relations, among others and how the model can be useful in thinking about AMR at a wider scope. This study is also unique as it combined two usually independent concepts, governance and public engagement to understand how they independently, and together influence AMR. This study also added new elements of governance that challenge and enhance existing governance and public engagement frameworks used in the AMR literature.

Although this study involved a secondary data analysis and a small sample size, the inclusion of AMR experts' various and unique professional backgrounds that are often not involved in policy making reveal wider and important discussions to be had about AMR that reflect different professional experiences. Another limitation of this study is the fact that AMR experts were not questioned specifically about governance and public engagement, hence Malaysian experts discussing only four aspects of engagement instead of six does not mean that some public engagement elements were not important to them.

There are also limitations that are apparent when using Anderosn's governance framework and the sociocognitive theory. Anderson's governance framework was developed to assess AMR

NAPs and given that secondary data was used for this thesis, the governance framework was adapted to fit the preexisting data. However, the interaction between the different governance elements showcased the dynamic nature of the framework and how one element can contribute to another. A common criticism of the Anderson governance framework is its limited applicability in LMICs with low resources but in this study, all 18 elements of governance were discussed as in HICs and LMICs settings. Although the 18 elements of governance were discussed by

Swedish and Malaysian AMR experts, these discussions don't necessarily translate to these 18 elements being implemented in said settings, rather their relative importance in wider discussions to be had about AMR. Regarding the sociocognitive theory, it is often a theory that is utilized in studies focusing on academic motivation, among other areas, in this thesis, it has been used as a marker for public engagement. While it hasn't been used as a marker for public engagement previously, it certainly aided in the understanding of human behaviour and modelling. Since AMR is a whole system problem that requires individual behavioural modifications, this theory brought to light the cognitive and social aspects that direct behaviour, which are often forgotten in the AMR literature.

Despite the listed limitations, this thesis provided in-depth explorations of governance and public engagement within the context of AMR. Although efforts to improve governance structures and public engagement exist, AMR remains and is projected to continue being a threat across the One Health system. Currently, the close interaction between governance and public engagement is understudied and needs further clarification. The identification and comparison of governance and public engagement elements discussed by Swedish and Malaysian AMR experts provided important insights into the current states of AMR governance and public engagement

within HICs and LMICs and what needs to be done to improve upon both. Further, these insights will highlight what needs to be done differently in Sweden and Malaysia and extrapolate these to HICs and LMICs. New elements of governance and public engagement were identified, thus, AMR discourses and frameworks in the future should include these important elements to enhance current systems. The findings of this study could assist stakeholders in providing AMR-specific mandates and policies and considering the behavioural influences certain policies may have on the public. The crosstalk between stakeholders, antimicrobial prescribers and users is key to tackling AMR now and in the future. Doing so will certainly take us one step further from a pre-antibiotic era.

Given the results of this study, future research should also seek to further understand the complex factors influencing AMR using an interdisciplinary approach that involves the biological, environmental, veterinary, political, and social sciences. As many of these disciplines currently work in silos, AMR experts discussions about collaboration echo the importance of bringing research together and encouraging other disciplines to form joint research efforts to paint a more comprehensive picture of AMR. Although this study provides a comparison and contrast between HICs and LMICs, the results from Sweden and Malaysia cannot be generalized to other HICs and LMICs. Hence, future research can shed light on the country-specific biological, social, and political factors as well as sector-specific drivers of AMR. The findings of this study also showcase that there is more focus on the human and animal side of AMR, deeper explorations of the environmental aspect are needed as current literature is lagging behind when it comes to understanding and addressing environmental drivers of AMR. Lastly, future research should aim to bring together social theories such as the health belief model and sociocognitive theory. Both theories add to our understanding of human behaviour, the health belief model

predicts behaviour based on perceived risks and benefits while the sociocognitive theory examines contextual and cognitive factors that are just as important to consider when thinking of a behaviour. Creating a hybrid of these two theories and getting professional opinions from various experts on the different elements of public engagement at play with regards to AMR may unlock new pathways through which we can start to understand the social and cognitive drivers that push people to behave in different ways.

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Appendices

Appendix A: Andersons' AMR Governance Framework (Anderson et al., 2019)

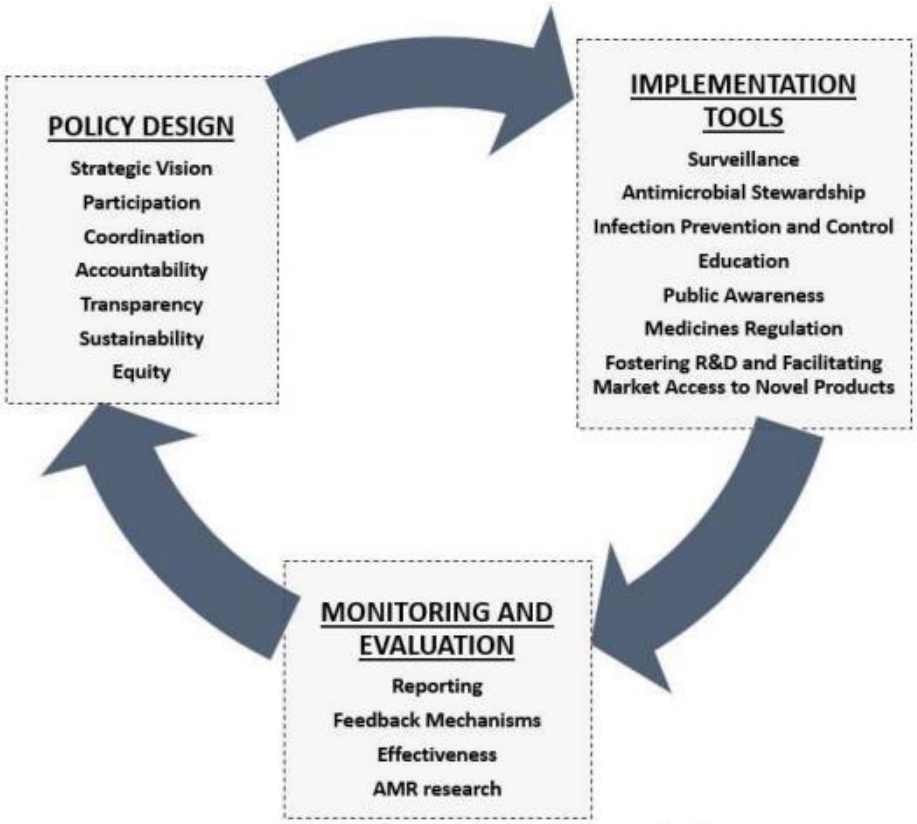


Figure 2 AMR governance framework: three areas and 18 domains.

Appendix B: Socio-Cognitive Theory (Luszczynska, A., & Schwarzer, R. 2015)

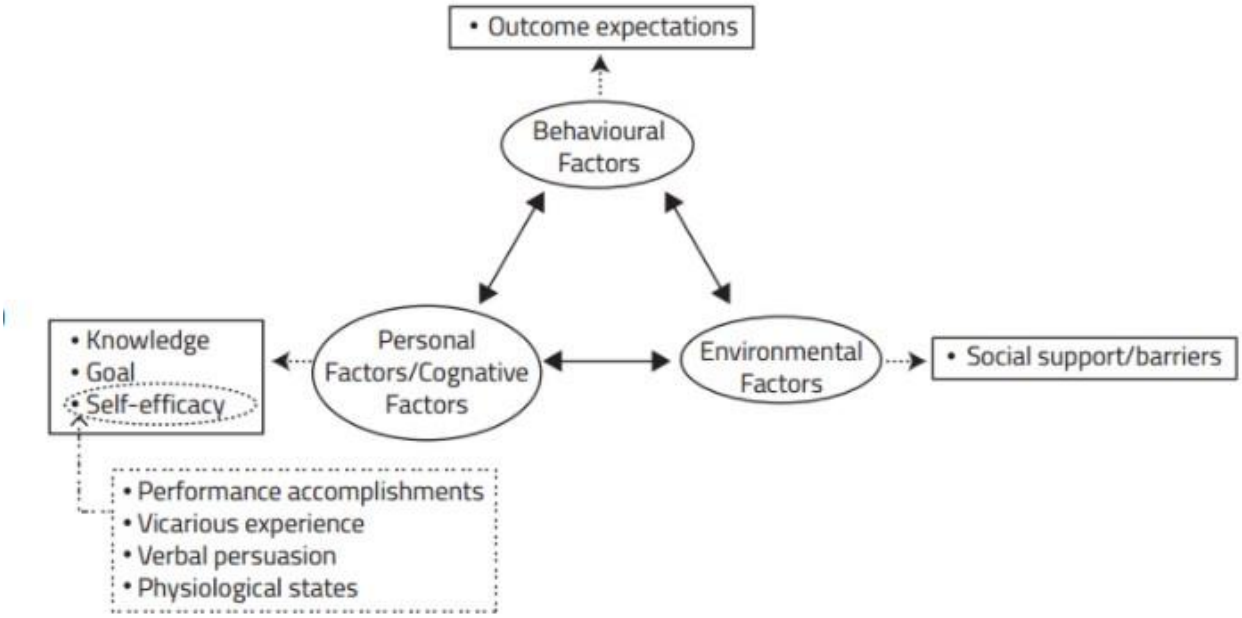


Table A1: Governance and Public Engagement Elements Node Connections and Explanations Emerging from Swedish AMR Experts Conversations About the Effectiveness of Taxation and Infection Prevention Control in curbing AMR in 2030 and 2050 That Resulted in The Construction of Figure 1.

Node 1	**Node 2**	**Connecting Quote**	**Explanation for Connection**
Antimicrobial stewardship	Medicines Regulation	"Having in place a rapid diagnostic test for every antimicrobial prescription so that no antimicrobial is prescribed without a test, and that would then negate the need for over-the-counter medicines."	AMR experts expressed the need for a rapid diagnostic test for every antimicrobial prescription, an important regulatory mechanism and an important stewardship task in the future.
Antimicrobial stewardship	Education	"We need to have good stewardship around antibiotic but it is a life saver so we do not want to scare people from taking antibiotics when they should. It is easier tobacco because we, everyone could just say stop smoking because it kills you and this, so there is a parallel to what was done by tobacco. But my point is that that took like 50 years at least. Yeah, and that was a simple chore. The talent we have to communicate about what is the risks with antibiotics. When should you avoid them? And when you actually should take them."	AMR experts emphasized that as important as it is to minimize use of antimicrobials, it is important to communicate and educate about the benefits of antimicrobials and that they are needed in certain cases.
Antimicrobial stewardship	Transparency	"We're now talking about antibiotics and microbials that everyone understands that actually is a lifesaver. Yeah, it is something that society needs, it dramatically changed healthcare. It Saves millions and millions of people's lives and so we cannot just go out there saying it's something bad."	AMR experts expressed that we need to be transparent in the messages we send about antimicrobials.
Antimicrobial stewardship	Surveillance	"How are we going to count antibiotic usage? A lot of the data that we have comes from sales, but we know that	AMR expressed that more uniform and specific data

		that's very different from actual usage. So, in a fish farm in Scotland, you can only buy a certain antibiotic in 1K tubs and you never use one kilogram, you'll use, you know, use much smaller amounts and that and dispose the rest. But it's, but you, and so we're not really counting usage in that case, what we're doing is counting the sales and across the world there is this lack of uniformity when it comes to gathering data around antibiotic use that is another aspect that needs to be considered. You know, if we're going to deal with this problem globally is about how we are doing the counting."	collection will likely increase the ability to track antimicrobial consumption, hence a future surveillance system is needed to accurately depict consumption, not just sales.
Antimicrobial stewardship	Public Awareness	"We need to have good stewardship around antibiotic but it is a life saver so we do not want to scare people from taking antibiotics when they should. It is easier tobacco because we, everyone could just say stop smoking because it kills you and this, so there is a parallel to what was done by tobacco. But my point is that that took like 50 years at least. Yeah, and that was a simple chore. The talent we have to communicate about what is the risks with antibiotics. When should you avoid them? And when you actually should take them."	Similarly to education, antimicrobial stewardship efforts discussed by AMR experts included the need to increase awareness among the public on the proper use of antibiotics and associated risks as well.
Medicines Regulation	Participation	"Yeah, for me it may be that actually, we don't need, you know the public do not need to be engaged so much as we are thinking right now. You know, there's other key controllers of antibiotic use within our societies, right? if clinicians and veterinarians are controlling antibiotic use it, then actually, you only really need to engage with those guys, or they are far more important to engage with."	While AMR experts expressed the importance of getting the public engaged on AMR, it was emphasized that the participation of stakeholders is just as important, because they are regulatory checkpoints for antimicrobials.
Medicines Regulation	Fostering R&D and Facilitating Market Access	"I think particularly in the animal production and there will be much smarter use of antibiotics, so we will move away from metaphylaxis. So, the	AMR experts discussed the need to develop rapid diagnostics and earlier

	to Novel Products	treatment of all animals in a group when an infection is discovered to much more targeted interventions on antibiotic use. So, reducing the number of doses that are being used, the number of animals that are being treated and that maybe through the development of early diagnostics and earlier markers of infection."	infection indicators since more targeted treatments and developed diagnostics will allow us to control AMR, as treatment will be specific and deemed necessary with these new tools.
Fostering R&D and Facilitating Market Access to Novel Products	AMR Research	"I think something that the Sweden would need to have in 2050 to make this success, would be also a much more agile regulatory context, meaning that a lot more investment into research, for example on alternatives would need to be there and on better parts for industry interested in developing new products or new feeding strategies, feed additives, don't know bacteriophages and new vaccines. I think a more agile context so that those companies really get interested into investing and developing themes that makes possible real reduction on the use of antimicrobials."	AMR experts discussed the need to invest into research on AMR and alternatives, as well as new products and technologies that can help curb AMR.
Fostering R&D and Facilitating Market Access to Novel Products	Education	"I would say that it is also important to keep in mind that the issue of Education and training to farmers. I mean farming has become very complex issue and more and more and they need to be aware of new technologies, very rapid changes in the business. So, education and training, and in order to give the tools to farmers on how to better use antibiotics is a very important part because this will be also important in terms of value of the production."	AMR experts emphasized the need to educate and train farmers, for example on newer technologies to aid at their farms, this will increase the quality of their productions and may lessen the need to use antimicrobials.
Education	Public Awareness	"So, we think that again, more efforts in education and information campaigns are really important, and the right professionals should be doing these, meaning more involvement of social scientists, communication experts etc. Traditionally, we scientists have been trying to do this, and perhaps not doing it	AMR experts not only discussed the need to educate the public but emphasized the need to involve the appropriate professionals in the making of awareness campaigns.

		in the right way or at least with the expected success."	
Education	Infection Prevention Control	"From what I see at the moment, and countries are becoming much more aware of it in the human side and on the animal side and more and more countries are adopting better practices, better biosecurity practice on the farm level, more selective use of vaccines and I think if we continue in this trend and in this direction by 2050, AMR or will not be a big problem."	AMR experts spoke about how there is heightened education and awareness on IPC measures at the farm level and within society.
Transparency	Public Awareness	"I just have a comment when we were talking about the use of antibiotics and the communication, and we talked about to have some scaring examples and so on. I think it's as important, even more important to really explain the correct use of antibiotics. For instance, if you have a sore throat that it won't help with antibiotics, if you have what you call in Swedish, [Swedish word] with the white stuff in your, in your throat because it is a virus and then it doesn't help. A lot of people, they think that they need antibiotics because to be, to be healthy again. But I think just to inform the society about those issues. It could be a good thing."	AMR experts discussed the need to have scary examples to deter improper use of antimicrobials, but at the same time raise awareness on how to use antimicrobials correctly. This sense of transparency in communicating was considered important in increasing messaging effectiveness.
Transparency	Reporting	"This comes down to big data gaps that we have in antibiotic usage around the world and how we count antibiotic usage and so [Name of participant] is quite right. If countries vow away to reduce their overall tonnage, kilograms of antibiotics being used actually they may, they may advise their farmers and their clinicians to use more potent antibiotics and therefore give that appearance, that total tonnage is being reduced in actual fact you might be using, you know more of a of an active substance and creating more of a problem and this comes down to actually, you know, uniformity of data collection."	AMR experts discussed the need to have accurate and specific reports on antimicrobial use, otherwise, inaccurate reports can deceive and paint a different picture from reality.

Transparency	Surveillance	"This comes down to big data gaps that we have in antibiotic usage around the world and how we count antibiotic usage and so [Name of participant] is quite right. If countries vow away to reduce their overall tonnage, kilograms of antibiotics being used actually they may, they may advise their farmers and their clinicians to use more potent antibiotics and therefore give that appearance, that total tonnage is being reduced in actual fact you might be using, you know more of a of an active substance and creating more of a problem and this comes down to actually, you know, uniformity of data collection."	AMR experts discussed that gaps in AMR surveillance data can allow for loopholes in the system, these loopholes and deceitful data can make tackling AMR more difficult.
Surveillance	Reporting	"The new EU policy on combating AMR is to improve the surveillance and monitoring system and look no longer at the sales data as you say, that's a very crude proxy of use data, but look at the use data based on the veterinary surgeons at the veterinarian's prescription to specific species of animals. Giving an aggregate use for cattle or dairy is not much, but we need, or for pigs, we need exact use by species and per stage of life cycle and I think once we have that much more detailed information and under several countries under the National Action plans on AMR ,they have built this in that by I think in the many of the EU countries between 2022 to 2027 they will have by 2027 this species-specific stage of life cycle, actual use of antibiotics."	AMR experts discussed that an important aspect of surveillance is having reports of specific data across species, and instead of aggregate data, there is a need for specifics and actual consumption instead of sales data.
Feedback Mechanisms	Effectiveness	"We are at cross-roads now where we can harvest a lot of good lessons from those plans and policies that have been successful in countries and can be brought more to the region or more globally. I think that maybe one way of moving forward more rapidly is drawing on that information that is already here and we need to pull it together and identify and prioritize which best	AMR experts discussed that we have garnered many lessons and seen many positive examples of countries curbing AMR, these lessons need to be applied globally, and these policies should be

		practices and which policies have worked the best in the last 3-5 years. That will help give us a kickstart to go forward."	assessed as we go to ensure their effectiveness in different contexts.
Feedback Mechanisms	Strategic Vision	"Let's say…they call it the lack of accuracy in the risk analysis that we have had. I mean, we, all governments, companies etc. will try to make [some] sort of mapping of the risks that we are exposed to and the failure has been brutal I would say…. the point is that the mapping of the risks in the near future, we need to absolutely change. We need to reorient the whole thing because we are exposed to so many black swans [Referring to Black Swan theory] that if we don't do that, we're gonna have problems."	AMR experts talked about the need to conduct risk analysis and understand the gravity of the AMR issue and learn from the many failures, including basic things like lack of masks during the COVID-19 pandemic. They expressed that we need to be prepared for future scenarios and learn from failures to avoid the worst-case scenario or at least be more prepared to handle it.
Strategic Vision	Sustainability	"Well…in terms of you know, my area of aquaculture. Actually, there's rapid intensification going on right now. You know we're moving from extensive systems to more intensification. So you're getting bigger farms growing at higher volumes with greater sophistication and so on. But actually, I take [Name of participant]'s point. It may be that some of these species we actually say no, we've pushed these too far. We need to step back; we need to de-intensify because these animals are going to fall over and we were just we just pushing it too hard and it's not sustainable."	AMR experts expressed the need to look into the future scenarios and understand the sustainability of certain practices such as farming intensification.
Coordination	Equity	"If we want to reduce migration or stop migration, we need to invest in those countries and help them develop their infrastructure. Their infrastructure for better human help, the infrastructure for animal health, but also their infrastructure in terms of creating employment and opportunities in those countries. I think	AMR experts expressed that while migration might become a big problem in the future, coordination efforts in some countries to invest in building

		it's basically back to the whole development paradigm. If we want, if we don't want to continue to have the same problem with migration that we've had for hundreds of years, and it seems to be getting worse, we have to do lower on the development side."	better infrastructure in some others can be part of the solution to reduce the rate of migration. Creating solutions for people so that they don't have to move was discussed as important as it provides them with the opportunity to thrive in their respective countries.
Equity	Outcome Expectancies	"We need to move away from fossil fuels to manage the threats of climate change. But of course, there is a strong lobby for like coal industry and the millions of people that will lose their jobs where we close down all the coaling district and everyone else knows that that's somehow the right thing to do. But how do you do that? What are they going to do instead."	AMR experts discussed the challenge of balancing equity and outcomes of moving away from fossil fuels. While moving away from fossil fuels is beneficial to the environment, many people will lose their livelihoods.
Public Awareness	Infection Prevention Control	"From what I see at the moment, and countries are becoming much more aware of it in the human side and on the animal side and more and more countries are adopting better practices, better biosecurity practice on the farm level, more selective use of vaccines and I think if we continue in this trend and in this direction by 2050, AMR or will not be a big problem."	AMR experts discussed the fact that people in 2050 will be much more aware of IPC in their day-to-day life and different sectors will uptake and maintain proper IPC practices.
Transparency	Accountability	"I really like this this concept of the antibiotic footprint as well. So, and that could be very interesting on food labeling. If you can get him off, you know I'm thinking of food again, but if you can get that on labels and you can get the supermarkets on board with that. That I mean, that could be a game changer. If you if you have to print your only biotic footprint on a product, supermarkets aren't gonna be stocking stuff on the	AMR experts discussed that labelling products and having that antibiotic footprint recorded can be a really good accountability mechanism. The sellers get to be honest about the content of their food and

		shelves. They have got an antibiotic footprint."	accountable, and the customer receives transparency and is accountable for the choices they make.
Public Awareness	Sociocultural Facilitators	“I think a lot of, especially the younger citizens nowadays, they are more concerned about the animal welfare and they are more willing to use to pay more for less meat so they eat less meat, but they they're willing to pay more for the product.”	AMR experts discussed that younger individuals are much more aware and concerned about animal welfare and quality of food they pay for, this increased awareness facilitates behaviours such as paying for premium products, less meat etc.
Public Awareness	Behaviour	“There's other societies where antibiotics are more freely available where you might have to engage more with the public so you know a good example in the food sector would be, you know, we think that consumers have got a lot of power and consumers have got a lot of power, but actually we can only buy what supermarkets have on their shelves and we have a lot less say over what's on the supermarket market shelf than we might think. Actually, our supermarket buyers are the ones that actually have the, you know, a lot of the influence about what we actually end up consuming. And so, you know they're real key gatekeepers for the food that we actually eat on a daily basis. So, it may be that we don't need to engage quite as well as widely as, it is just an alternative POV.”	AMR experts highlighted that while engaging with the public on AMR is important for shifting behaviours, gatekeepers of antimicrobials are just as important in regulating behaviour, as people can only get what these gatekeepers offer and provide.
Effectiveness	Self-Efficacy	“I was just thinking, how do we move forward more rapidly? I think that was the question coming across the board. I think we have got to take a stand back a little and look at what all other countries have been done and even countries more globally. All countries adopted national action plans to combat AMR, covering	AMR experts discussed the need to harvest all the lessons we learned from countries that succeeded in reducing antimicrobial use and apply those lessons in

		the three pillars: human health, animal health and environment. I think those action plans have been in place for 3, 4 or 5 years and we are at cross-roads now where we can harvest a lot of good lessons from those plans and policies that have been successful in countries and can be brought more to the region or more globally."	other contexts. The success stories will allow other countries to see that change is feasible and ways to sustain it.
Sustainability	Goals	"If you go back five years, politicians were absolutely, and policymakers absolutely on board with the antimicrobial resistance problem. They you know, all of them were talking about it, you know, and what we were going to do about it. The question is, how do you maintain that? That that level of interest when you know it's been swamped by other events that are going on? But the second thing is, how do you maintain that interest when actually, you know you are kind of stopping something…when you start talking about 2050. Do these people have the patience to see something through to 2050? They want to see instant rewards for what they're doing, so yeah, they'll put in a billion pounds for antimicrobial resistance research, because, it's you know that's, and that's what happened in 2015, 2016, there was a load of money going in. Politicians were chucking money and so you're getting research and projects, and its quite high profile, but. But actually then, how do you maintain that engagement when not much is changing? We're just kind of slowing down a problem."	AMR experts discussed how far-away goals like 2050 are much less tangible and garner less interest from policy makers because it is a huge timeframe and commitment. There was also a question of how to sustain interest.
Behaviour	Sociocultural Impediments	"One of my worries is that we have a society that always looks for quick fixes which means that in some of these cases, where it will have no effect or a small effect, people are still wanting to go to that road for the simple reason that they believe it is a quick fix. We know that people are regardless of whether we are talking about getting better bodies,	AMR experts expressed their worry that people's tendencies to look for quick fixes might hinder tackling issues like AMR as it is a long-term issue that requires intensive

		exercising, is there a quick fix? Just look at the market of diet, to get that fit body and instead of understanding that it is a long road, we look for a quick fix. That mentality in our society really doesn't help us when we are trying to target issues that are long term battles like AMR and climate change."	planning and that we might see its effects later in the future.
Behaviour	Outcome Expectancies	"For the farmer when they get this increased income, that perhaps there may be the temptation to use that money to buy antimicrobials. But since they would be more expensive, this would shift the use of these resources to alternative to antimicrobial. So, for example, they would be more willing to put improvements in husbandry, increase use of preventative measures like vaccination, like use of better feed etc. So, in general increase the welfare for the animals are far more so we would see this shift to the alternatives to make things better for the animal."	AMR experts discussed the fact that taxation will deter farmers from buying antimicrobials and funneling that taxation money into helping them with preventative AMR practices will incentivize them to use less antimicrobials but improve things like husbandry or biosecurity.

Table A2: Governance and Public Engagement Elements Node Connections and Explanations Emerging from Malaysian AMR Experts Conversations About the Effectiveness of Taxation and Infection Prevention Control in curbing AMR in 2030 and 2050 That Resulted in The Construction of Figure 2.

Node 1	**Node 2**	**Connecting Quote**	**Explanation for Connection**
Surveillance	Equity	"Actually, there's a plan for European Union to invest some money in Asian region, nine countries to support, improve this AMR surveillance capacity and different AMR prevention activities, I mean it is it will not be like Fleming Fund, but there would be a reasonable amount of money will be spending on nine countries in this region to improve the capacity and sharing of experience on AMR surveillance."	AMR experts expressed the significance of HICs coming together as part of the European Union to invest and support an AMR surveillance system in LMICs.
Surveillance	Transparency	"The government will be able to tell you exactly how many tons of antimicrobials, or what categories have gone into what purposes to which sectors. Because if you're collecting tags, everything is documented there. But now if you go, I don't think any of the countries which are using, we may be able to exactly tell how much antibiotics is used by the poultry or by the fish people or by the human sector that's what I think. My main thinking is taxation is brought about improved governance structure, which is more transparent."	AMR experts expressed that the future surveillance system will tell the exact amount of antibiotics used within different sectors, increasing its transparency.
Surveillance	Feedback Mechanisms	"Let's say if they notice that the amount, for example, the antibiotic residue is not tally or for example, the type of antimicrobial is haven't registered, but they detected from their food product before, this can help the governments to trace back whether the farmer is getting from the black market or what other sources? where are the sources to obtain	AMR experts expressed the need for a surveillance system that is trackable through blockchain technology. The traceability of this surveillance system is important in detecting

		this kind of antibiotic drugs? So, the authority is easily to trace back or discount information along the food supply chain through the blockchain because anyone will not be able to modify or to delete, discount message. So, I believe this will help the government to monitor the usage and eventually to reduce the issue of misuse or overuse."	compliance as well as ensuring nobody can change input data.
Surveillance	Reporting	"Users [of antimicrobials] would demonstrate by reporting, which is then reinforced via annual national government surveillance for antimicrobial use. In other words, outcomes in food farms, hospitals in the environment, plus ideally antimicrobial sales figures reported."	AMR experts discussed the close connection between surveillance and reporting where reporting of antimicrobial consumption is further reinforced by a national AMR surveillance system. While tracking and monitoring are important, reporting results and sharing them is important too.
Surveillance	Antimicrobial Stewardship	"In terms of classes of use across the different sectors or say, human sector, different animal sectors… different industries again, that is interesting to record between the different sectors because that enables targeting different sectors to pinpoint where the problems are, basically."	AMR experts discussed a surveillance system that is specific to sectors and can allow for identifying areas of improvement within the different sectors, where antimicrobial stewardship efforts can be focused.
Surveillance	Coordination	"It's actually the cross sectoral is very important because if you take a medicines like streptomycin recently is increasingly used in crops…there is an antiviral resistance developing in the crop that might be severe going into this, so there is a serious lack of cooperation between agriculture, health ministry so they're not aware of the situation…if you look at	AMR experts expressed the need for a future surveillance system that is across sectors but also across countries, as different sectors and countries are fragmented and do not share

		Mongolia has one of the highest daily doses for thousand inhabitants compared to any other country in the surveillance report and the other reports mentioned clearly, China is one of the top country per capita consumption rates, for animals, for the humans, so there need to be a serious overlaps between the, what type of antimicrobials that consuming [Participant lists 3 types of antimicrobials] so they need to be a pattern which type of an antibiotic is going into the sectors."	communication on resistance rates and areas of concern.
Equity	Coordination	"I think the issue is what defines success, and that is one point that we quickly wanted to discuss. The second point is that it needs to involve all sectors which are using antibiotics when you tax some product like that, but then the question is about raw material or is it about the end product? And then how much taxation? And would that taxation then cause a problem in terms of affordability, access and availability?"	AMR experts in discussing what success looks like with the taxation intervention mentioned the need to tax across all sectors but paying special attention to access and cost issues.
Equity	Medicines Regulation	"Many countries have regulations but enforcement capacity needs to be there and we also need to improve advocacy side-by-side, otherwise people will still try and avoid, so testing facilities, farmer registration. Restrict access, restriction to only those who registered, active surveillance, and separating the antimicrobial classes and then taxing on the different tax slabs may need to be there. Looking at the burden and affordability and the disease profile."	AMR experts expressed that while we need to have regulatory checkpoints and things like diagnostic facilities and farmer registration, these can cause access and financial issues in countries unable to enact them.
Medicines Regulation	Coordination	"Having for example across ASEAN and perhaps having more uniform targets or more uniform prohibitions like across the EU or regulations, for example, might be helpful. Even though member states, even in the EU have their own national targets on antimicrobial use."	AMR experts discussed the significance of having standard targets and AMR policies across a coordinating body such as ASEAN to help drive change in the region. They spoke about how the

			EU is a coordinating body in Europe.
Medicines Regulation	Strategic Vision	"Having for example across ASEAN and perhaps having more uniform targets or more uniform prohibitions like across the EU or regulations, for example, might be helpful. Even though member states, even in the EU have their own national targets on antimicrobial use."	Part of the strategic vision discussed by AMR experts is setting future targets by appointing a body across Southeast Asia that can regulate and standardize policies.
Strategic Vision	Antimicrobial Stewardship	"We are not talking about necessarily raised without antibiotics, because that is not always, that that could be a disincentive and incentive to treating animals that do need to be treated or are sick. And it sometimes a disincentive to resolving the underlying problems. But um, accepting that animals need to be treated when they're sick, but only treated with they're sick. And so really responsible use and rectifying the underlying problem so just and if that means some acceptance of increased prices for people that spread along the value chain, then that might need to be the case."	AMR experts expressed that increased responsible use of antibiotics [using them when necessary and animals are sick] is part of stewardship efforts in tackling AMR. For animals to be less sick, they discussed that in the future, there will be increases in prices to raise animals properly and awareness of individuals would have increased so that they are more willing to pay for it.
Antimicrobial Stewardship	Fostering R&D and Facilitating Market Access to Novel Products	"The climate change itself could also change the shape of antimicrobials we need to use because disease profiles may change. Weather is also a factor, flooding maybe there, etc., and therefore the kind of bacterial kind of diseases all my change in 2050, and therefore we would need to plow some of this tax money back into R&D for newer antibiotics, considering the disease profile, proper diagnostics etc. And so therefore for testing facilities, putting the money into environmental issues like you know, making sure no floods, IPC, biosecurity for farms, and	AMR experts discussed the need for more investment in AMR-reduction practices and the need to invest in research and development as well as having futuristic thinking and planning based on projected climatic conditions (part of strategic vision as well).

		research for solutions on trying to decrease AMR."	
Antimicrobial Stewardship	Infection Prevention Control	"We should know what are the infections which have which are involved with the resistant bacteria. So availability of diagnostic facilities at point of care and all this would be helpful to understand the profile of microorganisms engaged in AMR, I know I think it will help to focus IPC activities well on different aspects maybe at hospital level or farm level or maybe food safety issues because salmonella is one of the biggest issues."	AMR experts discussed how the availability of diagnostic facilities at point of care will help focus IPC activities where they are most needed.
Feedback Mechanisms	Effectiveness	"A behavior change takes a long time, especially when it comes to infection prevention. Of course, we've got a nice little behavior change precipitation factor with COVID and suddenly everybody knows the word hygiene at least, but things can easily slip, so I think if we need to aim towards 2050, we need a really active phase for awareness and insight and understanding, if I can put it that way to the real role of hygiene… I mean including the microbiome and around us, including the environment around us, so that has to start right now with the intermediate course correction in 2030, because let's say behavior change takes time to show, so whatever plans we have in strategies we have. If it really needs to work, we need to assess it around 2030 and do some course correction if necessary and then work towards 2050."	AMR experts discussed the need to take and learn the hygiene lessons from COVID-19 and apply it within the AMR context. We should have feedback mechanisms and entities in place to assess progress in 2030 so that modifications can be made as we approach 2050.
Feedback Mechanisms	Accountability	"I think it's important for all these things, whether it's IPC or AMR itself to have oversight bodies external to the government, external two populations, which continue to monitor the situation of how far countries have gone or regions have gone, or in individual groups have gone with any of the things that we're proposing so that we reach 2030 or 2050 appropriately."	AMR experts discussed that we need accountable external entities that can assess the AMR situation and provide feedback on how to improve.

Infection Prevention Control	Public Awareness	"We thought that by that time [2030/2050] everybody should know what is IPC very well and it should be a part of daily life. Everybody should be able, should be aware about IPC and how we can apply IPC into our day-to-day practices. It is not only hospitals but farms, but everywhere I mean in public and private life. We should be able to apply IPC practices. Uh. And at least 80% of IPC is practiced everywhere in day-to-day life, so that is what we thought we should achieve in 2050."	AMR experts discussed that part of success in 2030/2050 is heightened awareness of people on IPC measures and integration in day-to-day life.
Public Awareness	Education	"What extent self medication and self-diagnosis of diseases is based on clinical symptoms? So these are all the behavioral changes which may require in the long run. You know where we really give importance to public health…regional veterinary services, the livestock services… science or anything, evidence and science. So, the practices which we presently think or not really helpful from an antibiotic usage and AMR perspective needs to be changed and this is a slow process and that is where education awareness."	AMR experts discussed how people's awareness and education on the use of antimicrobials needs to increase, this requires shedding the light on public health and science in general.
Education	Participation	"It's a complicated issue! in terms of the costs, it is expensive to introduce full blown infection control practices and procedures, including policies and all the training that's required. And it's not just training a few people, it's training ultimately, everybody who works in a hospital or an institution, or a population that might be…Overall it is very cost effective, but it does require upfront investment and that might be on behalf of the hospital board which controls the budget to the hospital and might be driven by a national government."	AMR experts discussed the need to improve education on IPC measures across hospitals, institutions and populations but they recognized the need for the participation of governments and other stakeholders that can funnel the needed finances.
Reporting	Behaviour	"What we initially thought is assuming that the scenario of Malaysia in 2050 climate change, they successfully managed to handle the AMR issue by taxation. So is under that scenario. I think a, the system there they would have put in	AMR experts discussed that in the situation where taxation was successful in mitigating AMR, the

		place, a very good system for tracing documentation, purchase, sale, everything, quality.”	behaviour of AMR consumers and regulators would change and a surveillance system that accurately documents use will hold people more accountable and improve compliance, as taxation will deter unnecessary use.
Public Awareness	Self-Efficacy	“If the taxation money is used for this major social behavior change now in COVID days we are seeing so many advertisements and messages are coming. So, if learning from this exercise, if we're able to really create this existing material, which are universal in nature, which are really, you know, which can really stimulate the conscience of the users, then there could be some benefits like just seeing all the masking demasking discussions, the safe distancing discussions, the, and all these discussions are creating lot of hand washing discussions. None of these were new, but the way this is being discussed, the way this is being debated and promoted by the respective countries in the governments is bringing about a massive social behavior chain massive social behavior change which we may be noticing or may not be noticing.”	AMR experts discussed that COVID-19 messaging has brought about greater social awareness on things like safe-distancing or wearing masks, we can learn so much about how to make behavioural changes from COVID-19.
Behaviour	Sociocultural Impediments	“I'm very fearful of a counterfeit movement, fearful of access issues, fearful of the fact that the companies may try, and, you know, pressurize the government to avoid taxation for them in some of the countries, all that is very real and may happen.”	AMR experts discussed that while taxation can mitigate behaviours, there are concerns that in certain countries, tax evasion issues might rise, which is a challenge in fighting AMR using a taxation intervention.

Behaviour	Outcome Expectancies	“I said actually commonly used antimicrobials have more taxes compared to the ones which are rarely used because it is like used by, when it's very severe conditions. So it was, where the commonly used antimicrobials have more taxes because people tend to use more, also, for mild symptoms.”	AMR experts discussed that taxation policy should including taxing people more for medications used more regularly as other ones are needed for severe conditions. A tax will disincentivize unnecessary purchase of antimicrobials as people will expect to pay more for these drugs.