



The Economic Crisis–Antimicrobial Resistance Feedback Loop: Microbial Evolution in Fragile Health Systems

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Introduction

Many people still turn to antibiotics when they develop symptoms of the common cold, even though antibiotics are ineffective against viral infections and their misuse contributes to a growing global public health threat. Antimicrobial resistance (AMR) occurs when microorganisms acquire resistance genes or mutations that allow them to survive exposure to antimicrobial agents that would normally inhibit or terminate their growth. As unregulated antimicrobial use persists, resistant organisms continue to spread among people, animals, and agricultural systems. The effects are devastating, ranging from increased mortality rates to agricultural risk and nationwide productivity loss. This trend poses significant long-term global health and economic risks.

Because of the prevalent structural instability and limited resources in the Middle East and North Africa (MENA) region, countries like Lebanon, marked by economic fragility and political challenges, are uniquely susceptible to public health crises, including AMR. Increasing financial volatility removes access to formal healthcare, pushing many away from hospitals and physicians. Instead, self-medication and informal antibiotic use become coping strategies. Despite this vulnerability, such cases are underrepresented in the AMR literature, which focuses mostly on Western settings.

These socio-economic struggles do more than change health-seeking behaviour; they directly influence microbial evolution. As financial pressures intensify and improper self-medication continues, microbes are exposed to subtherapeutic drug levels that eliminate susceptible organisms while allowing resistant ones to survive and multiply. Over time, this leads to a population-wide spread of resistance genes, both interpersonally and agriculturally, further straining an already weakened healthcare system. This dynamic drives an economic crisis – AMR feedback loop, which illustrates how structural failures in governmental systems accelerate biological resistance at a population-wide scale.

This paper aims to examine how Lebanon's ongoing economic collapse has contributed to the spread of antimicrobial resistance through changes in antibiotic usage and availability. Drawing on peer-reviewed literature, WHO reports, and regional public health data, this paper asks: What are the socioeconomic mechanisms linking financial instability to microbial resistance? By focusing on the economic crisis – AMR feedback loop, this paper offers a framework applicable to fragile healthcare systems. The findings aim to aid in health policy strategies in Lebanon and similar countries across the MENA region.

Section 1: The Economic Crisis–Antimicrobial Resistance Feedback Loop

Unlike acute epidemics such as influenza or COVID-19, which can produce sharp “spikes” in infection over several weeks, antimicrobial resistance develops more

gradually as a chronic and cumulative phenomenon. However, it can accelerate rapidly when specific resistance genes spread through a population. Its growth is heavily tied to the socio-economic state of countries and accelerates upon severe economic collapse. Poor infrastructure and strained health systems resulting from economic recession create conditions that favour resistance evolution. As resistance increases, healthcare costs and institutional strain intensify, reinforcing financial instability. This dynamic reveals a clear economic crisis – AMR feedback loop in which each condition intensifies the other, creating a self-sustaining cycle.

Economic instability exacerbates the drivers of AMR through several mechanisms, especially by weakening the healthcare system. Due to financial restraints such as currency devaluation, individuals may be forced to delay seeking formal medical care and instead self-medicate with leftover antibiotics or use substandard medications, which foster resistance due to improper use. More importantly, economic pressure on health systems can lead to the breakdown of basic services like surveillance and infection control, which is particularly detrimental, as most resistant bacteria thrive in hospital environments.

Reduced reliance on formal healthcare increases the likelihood of subtherapeutic antibiotic exposure through missed doses, discontinuation, and unsupervised use. Such exposure creates a selection pressure that favours resistant phenotypes. Surviving strains may spread resistant genes through horizontal gene transfer, amplifying resistance in clinical and community settings.

In turn, AMR creates systemic vulnerabilities, making mundane tasks riskier and more complicated. Routine procedures such as C-sections, hip replacements, and organ transplants have become significantly more dangerous in settings where resistant infections are harder to treat. For example, surgical site infections that were once manageable may now require intense care and extended revision surgeries. As for cancer patients, who are often immunocompromised by chemotherapy, resistant infections are linked to significant treatment delays, longer hospital stays, and higher mortality rates. Consequently, AMR-related inpatient costs have increased dramatically and continue to do so. Additionally, fatalities and disabilities resulting from resistant pathogens directly lead to major productivity loss in the workforce, causing a decline in labour market output. The agricultural sector is similarly affected, where resistance in livestock reduces meat and poultry output, ultimately impacting productivity and trade, creating a major threat to global food security.

Ultimately, these interactions illustrate that antimicrobial resistance in economically fragile settings is not driven by isolated incidents of antibiotic misuse but by systemic shortcomings that continuously push selective pressure. Once resistance is established, it anchors itself not only in microbial populations but within the structures of the health system itself. Its burden reshapes healthcare priorities, reallocating

resources towards immediate treatment, rather than research, prevention, and regulation. This shift weakens regulatory capacity right where oversight is most necessary, allowing informal antibiotic markets and antibiotic misuse to persist. As a result, resistance becomes increasingly embedded within weakened healthcare systems. This dynamic defines the economic crisis – antimicrobial resistance feedback loop and provides the analytical framework through which Lebanon’s current situation can be examined.

Section 2: Lebanon’s Economic Collapse and Antibiotic Use Patterns

Lebanon has experienced a prolonged collapse, not a transient downturn. Indeed, Lebanon has faced what the World Bank describes as ‘overlapping financial, economic, and institutional crises’ (World Bank, 2025, p.ix). Its recent conflict with Israel generated an estimated US\$7.2 billion in economic losses, while recovery and reconstruction needs were estimated at US\$11 billion. By the end of 2024, Lebanon had experienced nearly a 40% cumulative GDP contraction since 2019, intensifying its already complex, multi-dimensional crisis (World Bank, 2025, p.1). The conflict and its aftermath have deepened poverty and vulnerability in Lebanon, which remains heavily cash-reliant following the earlier sovereign debt and banking crisis. All this, in addition to the thousands of wounded people in the aftermath of the conflict, has strained both formal healthcare capabilities and people’s access to it. These conditions are conducive to accelerated AMR emergence.

Across parts of the MENA region, AMR risks are intensified by the widespread misuse and weak regulation of anti-microbials. These effects are exacerbated by systemic issues, such as the “significant presence of low-quality generic antibiotics in the market” (Rahme et al, 2025, p.2). A study assessing the Lebanese population’s knowledge, attitudes, and practices regarding antibiotic use and AMR found that only 44.74% of the participants were unaware that antibiotics were not effective against viruses. Most concerning, “36% and 26.41% still believe antibiotics should be taken for fever or cough, respectively, regardless of cause” (Rahme et al, 2025, p.5). Additionally, awareness of AMR is particularly low, and even among those who had heard of it, many did not understand that unnecessary antibiotic use accelerates its spread. The study found that physician consultation costs were enough to discourage participants from seeking formal health advice, instead self-medicating with leftover antibiotics from a previous illness, seeking advice from family, and proceeding directly to pharmacists to receive medication (Rahme et al, 2025, p.10). This illustrates how, in the case of financial instability, economic survival overrides medical regulation in the community.

Moreover, the study found that “many participants (26.41%) believe it’s acceptable to miss a dose, and 37.41% think it’s okay to stop prescribed antibiotics for alternative remedies” (Rahme et al, 2025, p.6). In a separate study focusing on individuals with chronic illnesses, it was found that more than half of the participants

with diabetes mellitus (DM) were forced to make unsupervised medical decisions during the economic crisis in Lebanon, such as changing medications, dosages, and even discontinuing medication (Cherfane et al, 2024, p.5). All previously mentioned actions exacerbate AMR spread by intensifying selective pressure.

Suffice it to say, there is an obvious case of institutional strain occurring in Lebanon's healthcare system. Since the onset of the economic crisis, which was swiftly followed by the COVID-19 pandemic, the Ministry of Public Health has struggled to implement an effective response due to weak organization and inadequate infrastructure. It has faced financial hardships, cuts to public spending, and reductions in ministerial budgets, making it ultimately disengaged from its commitments and undermining its functions (Yamout et al, 2025, p.3). Ostensibly, this cultivates the weakening of the government's surveillance capacity, preventing it from properly handling the issue of antibiotic distribution and misuse, leading to reduced infection control. Moreover, a notable trend in the healthcare system is the massive exodus of doctors and nurses due to the deteriorating economic conditions. Nurses 'intent to leave' shows that hospitals are not meeting the requirement of sufficient and qualified personnel to provide quality care for patients (Houry et al, 2024, p.1). This contributes to the absence of antimicrobial stewardship programs (ASPs), as infectious disease specialists, pharmacists, and microbiologists are driven out of hospital settings by economic collapse, further weakening institutional capacity. These systemic failures and institutional pressures reinforce the economic crisis – AMR feedback loop. It is important to recognize that, here, Lebanon is not an independent case, but rather an illustration representing all crisis-affected, resource-constrained settings, such as countries in the MENA region. While these dynamics are structural in nature, their consequences manifest at the biological level, where resistance mechanisms are selected for and sustained.

Section 3: Selection Pressure and the Evolution of Antimicrobial Resistance

Selection pressure is an evolutionary force that favours the survival of specific genotypes in a population, effectively eliminating susceptible organisms while allowing those with advantageous traits to persist (Sijbom et al., 2023, p.1). In clinical settings, sub-MIC (sub-minimum inhibitory concentration) levels are a primary driver of this pressure (Drlica & Zhao, 2007, p.1). These suboptimal levels frequently arise from patient nonadherence, such as early discontinuation of treatment once symptoms subside, or missed doses. Additionally, the use of poor-quality or counterfeit antibiotics from unregulated black markets often results in insufficient active ingredient delivery (Salam et al., 2023, p.8-9). Unlike lethal doses that eradicate the entire bacterial population, subclinical doses create a “selective window” that allows susceptible bacteria to be

eliminated while resistant strains survive, creating evolutionary pressure that favours their proliferation.

Evolutionarily, bacteria adapt to resist antibiotics either through chromosomal gene mutations or the acquisition of external DNA through horizontal gene transfer coding for resistant traits (Salam et al., 2023, p.5). Once non-resistant bacteria are eliminated, resistant ones are free to expand to fill newly available ecological niches within patients and healthcare environments. Indeed, clinically significant resistant pathogens spread within and across healthcare facilities. Healthcare-associated infections (HAIs) are often linked to resistant bacteria that persist within healthcare environments. Reports have found that the cost of treating these infections is substantial and can reach up to \$5.6 billion annually (CDC, 2024). However, HAIs are usually avoidable if hospitals take necessary measures such as appropriate infection control, avoiding overcrowding, maintaining proper cleanliness, and isolating infected individuals.

Beyond hospital settings, AMR circulates through livestock, agriculture, and the environment, reinforcing its persistence and spread. Certainly, livestock farms represent a significant source of antibiotic-resistant bacteria. They can serve as reservoirs for pathogenic zoonotic bacteria, which can be transmitted to the environment through air and livestock manure slurry, leading to potential infection outbreaks and the spread of antibiotic-resistant genes. The source of such genes is primarily the overuse or misuse of antibiotics in agriculture and livestock, the administration of which is motivated by treating infections, preventing animals at risk from getting infections, or being used as feed additives to boost growth. Overall, resistance in food-related bacteria is indicative of the overall burden of environmental bacterial resistance. Moreover, several recent studies have reported antibiotic-resistant bacteria in various environmental samples, including soil, water, and wildlife. The detection of such bacteria in soil has been particularly documented, as it serves as a natural habitat for a diverse range of microorganisms and a natural reservoir of resistant genes. However, due to human activity, soil now serves as an accumulation site of acquired resistant genes. Additionally, natural water sources and even the air have also been affected by resistant bacteria contamination. Studies on urban air have shown a significant number of resistant bacteria in cities, raising various health concerns. Another major factor in AMR spread is the release of antibiotic residues into the environment through hospital waste, sewage, animal husbandry refuse, pharmaceutical production, and agricultural runoff (Pandey et al., 2024).

The mechanisms described above demonstrate how systemic factors translate directly into microbial evolution. Economic constraints, weak healthcare infrastructure, and widespread antibiotic misuse create repeated subclinical exposures and ecological opportunities for resistant strains to thrive. Once established, such strains persist and disseminate through hospitals, communities, agriculture, and the environment. The

emergence of antimicrobial resistance thus becomes a predictable consequence of these pressures. A self-reinforcing cycle, as identified above, shows that resistance is not exclusively a clinical issue but an interplay of complex socioeconomic, behavioural, and environmental factors. Understanding these pathways highlights why reversing resistance is challenging and sets the stage for examining its broader health, economic, and policy implications in the following sections.

Section 4: Regional Implications for Fragile Health Systems in MENA

The structural vulnerabilities driving antimicrobial resistance in Lebanon are not unique but are shared across many fragile health systems in the MENA region. Common weaknesses include economic instability, fragmented or informal healthcare systems, limited access to effective antibiotics, weak regulatory oversight, and the absence of coordinated AMR surveillance. Together, these conditions create environments in which antimicrobial misuse is widespread, and resistance can emerge and persist across national boundaries (Al Bakri et al., 2025).

As discussed previously, the spread of AMR across regions is driven by consistent biological pressures. The MENA region, characterized by instability similar to Lebanon's, therefore demonstrates parallel evolutionary pathways in the emergence and dissemination of antimicrobial resistance. Overreliance on over-the-counter antibiotics has been documented across parts of the region, promoting sustained selection pressure that favours resistant strains and facilitates the spread of resistance genes. In addition, ongoing conflict and population displacement increase opportunities for transmission through refugee mobility, overcrowded healthcare facilities, and disrupted antibiotic stewardship. Shared water systems, agricultural practices, and regional trade further contribute to environmental overlap, enabling resistant organisms and genes to circulate beyond local settings.

Ultimately, although national contexts differ, the evolutionary pressures shaping AMR remain consistent, resulting in convergent resistance patterns across the MENA region. Addressing antimicrobial resistance, therefore, requires coordinated regional strategies that extend beyond individual health systems and emphasize systemic regulation, surveillance, and stewardship.

Section 5 — Disrupting the AMR Feedback Loop

While existing literature often addresses specific biological drivers of AMR, this paper proposes broad, systems-level interventions designed to break the economic crisis – AMR feedback loop in fragile health systems and minimize the effect strained health systems have on the widespread escalation of AMR.

One possible intervention would be the creation of what this paper calls ‘Selective Pressure Dampening Zones,’ which targets selection pressure without resorting to measures such as attempting to eliminate antibiotic misuse instantly, a highly unrealistic method when dealing with areas of low surveillance and weak antibiotic oversight. According to the WHO (2015), reducing inappropriate antibiotic exposure has been identified as a core strategy for limiting selective pressure in resistant populations. However, when assessing vulnerable health systems, other factors must be considered. Designating “high-risk AMR zones” such as overcrowded hospitals and refugee camps, followed by enforcing temporary restricted antibiotic lists in these zones, aims to force the use of narrow-spectrum agents, as well as ensure supervised dosing of all antibiotics. This way, selective pressure is relieved, slowing the evolution of resistant strains and lessening the strain on the already fragile healthcare infrastructure in countries such as Lebanon and the MENA region, and weakening the economic crisis – AMR feedback loop.

Moreover, to prevent early treatment discontinuation, course-completion incentives can be provided to patients, motivating them to finish their antibiotic courses and thus disrupting the economic crisis – AMR feedback loop. Patients can receive food vouchers, transport credits, and pharmacy discounts only after recorded adherence to prescribed antibiotic regimens. Confirmation can be tracked via pharmacy stamps, SMS codes, or other low-tech options that fragile countries can adopt without issue. Economic barriers are a well-documented contributor to treatment non-adherence in low-resource settings, with non-adherence associated with greater healthcare costs and worse clinical outcomes across disease groups (Achterbosch et al., 2025). This way, adherence becomes an economic decision, rather than a moral one.

To further prevent dose skipping and the saving of antibiotics, this paper proposes introducing “lock-and-release” packaging to all antibiotic prescriptions. This way, they are dispensed in time-locked blister packs, ensuring that each dose becomes accessible only at the correct interval, which reduces the risk of skipping, sharing, or saving pills. This mechanism shifts stewardship from education to design-based compliance and prevents fluctuating drug levels, thus stabilizing selection environments.

To tackle environmental AMR reservoirs, hospitals can install antibiotic degradation filters to purify hospital wastewater. Environmental reservoirs, particularly hospital wastewater, are increasingly recognized as contributors to the persistence and spread of antimicrobial resistance (WHO, 2025). Targeting hospitals rather than entire systems is especially effective in urban centres where treating public locations is heavily limited. Reducing the environmental gene pool in such a way reduces the reintroduction of resistant bacteria to humans, thus disrupting the economic crisis – AMR feedback loop.

Another critical intervention point in disrupting this feedback loop is transforming traditional surveillance into an evolution-aware system that detects not only the presence of resistance, but also how resistance is emerging and spreading over time. Conventional surveillance largely tracks resistance levels after they have already become widespread, which limits the ability to intervene before the healthcare system is overloaded. A more evolution-oriented approach would integrate genomic data and trend analysis to monitor the rate of emergence, patterns of gene diversity, and early warning data from environmental or non-clinical reservoirs. Such surveillance can identify when specific resistance mechanisms or lineages are increasing rapidly, allowing public health authorities to respond earlier in the evolutionary cycle rather than reacting after high prevalence has already been established. Whole genome sequencing and integrated data platforms have already been shown to enhance understanding of AMR mechanisms and dissemination pathways, strengthening the evidence base for timely interventions (Djordjevic et al., 2024). This evolution-based approach helps break the economic crisis – AMR feedback loop by enabling proactive responses that preserve health system capacity and avoid the system collapse that drives further informal antibiotic use.

By targeting the feedback mechanisms that sustain antimicrobial resistance rather than addressing its symptoms in isolation, fragile health systems can shift from reactive containment to evolutionary control.

While these proposed interventions aim to address systemic drivers of resistance, their feasibility depends on political stability, funding availability, and institutional capacity. Data limitations in fragile settings may restrict real-time surveillance and implementation. A context-sensitive application would therefore be necessary.

Conclusion

Antimicrobial resistance in Lebanon cannot be understood as the result of isolated prescribing errors or individual noncompliance. Rather, it emerges from a self-reinforcing feedback loop in which economic collapse weakens health system regulation, promotes informal antibiotic use, and intensifies microbial selection pressure. These biological changes then feed back into the health system, increasing treatment costs, mortality, and institutional strain, further eroding regulatory capacity.

By framing AMR as an economic-evolutionary phenomenon, this paper demonstrates why conventional stewardship approaches designed for stable health systems are insufficient in fragile settings. Resistance in such contexts can be understood as a foreseeable evolutionary response to systemic instability. Lebanon may serve as a cautionary example for other crisis-affected health systems in the MENA

region. Addressing antimicrobial resistance under these conditions requires policies that recognize and interrupt the feedback mechanisms driving resistance evolution, rather than reacting after resistance has already become entrenched.

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