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National action on antimicrobial resistance and the political economy of health care

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ABSTRACT

Antimicrobial Resistance (AMR) is one of the biggest threats to human health in the twenty-first century. A key dimension of global governance in this domain consists of encouraging governments to create national action plans (NAPs) aimed at improving awareness of AMR, improving knowledge through surveillance and research, reducing infection, optimising the use of antimicrobial medicines, and investing in new drugs, vaccines and other interventions. The adoption and implementation of NAPs occur in the context of great political and institutional diversity across countries, and this article examines the consequences of different ways of financing health care. We expect the implementation of NAPs to be more successful in optimising antibiotics use when governments play a larger role in financing health care compared to private expenditure. An analysis of patterns of antibiotic consumption in 191 countries between 2000 and 2018 supports the hypothesis.

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KEYWORDS Political economy; antimicrobial resistance; national action plans; health expenditure

Introduction

Antimicrobial Resistance (AMR) is a critical threat to human health and wealth in the twenty-first century (Murray *et al.*, 2022; Review on Antimicrobial Resistance, 2016). Following decades of neglect, governments around the globe have acknowledged the urgency of the situation. In its landmark resolution on AMR of 2015, the World Health Assembly urged member states to have in place, within two years, national action plans (NAPs) on AMR that are aligned with the global action plan (GAP) that the WHO

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had just adopted (WHO, 2015b, p. 18). Most countries published such plans within a few years, raising hopes of coordinated action to counter this major threat to global health. However, real progress in tackling AMR depends on plans being put into practice and achieving the intended outcomes (Carelli *et al.*, 2023; Rubin *et al.*, 2023). While scholars have begun to gather evidence on the implementation and impact of NAPs, much remains to be learned.

A recent study shows that, on average, NAPs have improved antibiotic use (Heinzel & Koenig-Archibugi, 2023b). However, we know less about the conditions that make NAP implementation more or less effective. This article addresses a particular set of conditions that may influence the effectiveness of NAPs: the political economy of healthcare financing. It is well understood that how health care is paid for is one of the drivers of the speed and spread of AMR. Financial incentives play a role in the sale and consumption of antibiotics, a key cause of AMR. We argue that differences in healthcare financing systems affect the extent to which measures taken by governments to implement their NAPs are successful in achieving a central objective stated in the GAP: the reduction and optimisation of antibiotic use in human health care. Bringing the volume of antibiotic consumption to clinically justifiable levels is only one of the measures needed to mitigate the harm done by AMR, but it is widely considered an important ingredient of any viable solution.

After providing some background information on NAPs and their implementation, the article proceeds as follows. In a first step, we detail why we expect healthcare financing to matter for successful AMR policy implementation and specifically why we expect implementation to be more successful when government funding as a percentage of total health financing is higher. We provide three reasons for that conjecture. First, healthcare providers face greater incentives to prescribe and sell antibiotics when their income is linked to transactions involving individual patients, as it happens when patients pay for the service or medicine out of their own pocket. The effect on professionals' incomes creates an incentive to ignore, circumvent or resist government regulation of antibiotic prescriptions and sales. Second, healthcare providers are more likely to comply with government regulations when they are dependent on government financing. Governments can incorporate reporting, monitoring and auditing requirements relating to AMR into their financial arrangements with healthcare providers, and economic dependence provides an effective enforcement tool. In short, we argue that the extensive involvement of governments in healthcare financing reduces both the willingness and the ability of healthcare providers to behave in ways incompatible with the measures taken by governments. Third, patients are less likely to use antibiotics (including through self-medication) when they are reassured that the cost of medical and hospital care for possible complications from infections would not weigh exclusively on their limited household budgets.

The second step we take in the article is to present an empirical test of the hypothesis that implementation is more successful when the share of public funding relative to total health financing is higher. We conduct a cross-national analysis of the interaction between NAP implementation and the political economy of healthcare in 191 countries between 1990 and 2018. Our analysis provides substantial support for our theoretical expectation that the mode of funding health care influences the effectiveness of NAPs in addressing antimicrobial resistance.

National action plans on AMR

As noted in the introduction, the WHO directed two requests to its member states: to produce NAPs and to ensure that those NAPs are aligned with the GAP. The GAP encourages a set of actions that fall under five strategic objectives: improvements in awareness and understanding of AMR; improvements of knowledge and evidence through surveillance and research; reductions of infection through sanitation, hygiene, and infection prevention; optimising the use of antimicrobial medicines in human and animal health; and increased investment in new medicines, vaccines and other interventions (WHO, 2015a).

Most governments heeded the WHO's request and created NAPs before 2020. Louise Munkholm and Olivier Rubin have shown that NAPs mostly align with the GAP's five overarching objectives but only moderately with the corresponding recommended actions (Munkholm & Rubin, 2020; Rubin & Munkholm, 2022). They also find evidence of 'isomorphic mimicry', i.e., harmonisation that takes place primarily in form and not in function. Several countries issued national documents that closely resemble the GAP, but there is limited implementation of the actions they announced. A specific manifestation of this consists of One Health measures promoted by the 'Tripartite' formed by WHO, FAO, OIE: such measures receive more attention in the NAPs of low-income and lower-middle-income countries than in the NAPs of upper-middle-income and high-income countries (Munkholm *et al.*, 2021).

As Munkholm and Rubin note, the gap between NAP adoption and implementation is often related to capacity deficits in low-income and lower-middle-income countries. Lack of material and human resources in national bureaucracies and public health bodies is often mentioned in case studies on the development and implementation of NAPs in this group of countries, such as Bangladesh, Benin, Brazil, Burkina Faso, Ghana, Kenya, Mali, Pakistan, the Philippines, South Africa and Tanzania (Ahmed *et al.*, 2022; Corrêa *et al.*, 2023; Frumence *et al.*, 2021; Godman *et al.*, 2022; Hein *et al.*, 2022; Khan *et al.*, 2020; Lota *et al.*, 2022; Sariola *et al.*, 2022; Shabangu *et al.*, 2023; WHO, 2022a, 2022b). Studies on AMR policy making in high-income countries refer less to capacity problems (Carelli & Pierre, 2022; Hannah & Baekkeskov, 2020).

Despite these challenges, many countries that adopted NAPs have started implementing them. Currently, the main source of information on NAP implementation globally is the periodic Tracking Antimicrobial Resistance Country Self-Assessment Survey (TrACSS) managed by the Tripartite (WHO-FAO-OIE, 2022). The responses provided by governments to this survey indicate that 112 out of 159 countries with an adopted NAP were implementing it in 2021.[1]

Of course, neither adopting nor implementing a NAP guarantees that global or national goals have been reached. As noted earlier, the GAP sets five objectives, with a series of actions relating to each. As a measure of effectiveness in achieving two of those objectives, the GAP proposes the 'extent of reduction in global human consumption of antibiotics (with allowance for the need for improved access in some settings)' (WHO, 2015a, p. 13). In the remainder of this article, we focus on this measure of effectiveness and the conditions that may facilitate its achievement while acknowledging that an effective and fair solution to the AMR problem requires a broader range of interventions.

NAPs and the political economy of healthcare financing

The similarities and differences between healthcare systems have attracted much attention among health policy specialists and scholars from related disciplines (Beckfield *et al.*, 2013; Immergut, 1992, 2021; Lynch, 2023; Wendt, 2022). One strand of research has endeavoured to group national healthcare systems into a set of meaningful types (De Carvalho *et al.*, 2021; Doetter *et al.*, 2021; Mackintosh *et al.*, 2016; Reibling *et al.*, 2019; Wendt *et al.*, 2009; Wendt & Bambra, 2020). Virtually all health system typologies proposed in the literature consider the modality of financing health care (although there is no consensus on the weight to be given to this aspect compared to other dimensions of variation). Another strand of research examines whether and how the different types relate to a variety of outcomes, from clinically measurable health indicators to citizen satisfaction with healthcare provision (Beckfield *et al.*, 2015; Bergqvist *et al.*, 2013; Curran *et al.*, 2021; Jacques & Noël, 2022; Karim *et al.*, 2010; Missinne *et al.*, 2013; Rydland *et al.*, 2020; Widding-Havneraas & Pedersen, 2020). Some studies find a systematic association between health system type and outcomes, whereas others do not. This article contributes to the latter area of research by examining the relationship between healthcare financing as a specific (but important) component of health systems on the one hand and the ability of national AMR action plans to affect antibiotic use on the other hand.

The WHO classifies healthcare financing modes into six main categories: transfers from government domestic revenue (allocated to health purposes); contributions to social insurance schemes; compulsory prepayment, specifically mandatory private health insurance; voluntary prepayment, specifically non-mandatory private health insurance; out-of-pocket payments made by households at or after the time of healthcare delivery; and foreign sources of funding, which may or may not be distributed by the government (WHO, 2023). In the following, we discuss how these healthcare financing modes influence the ability of governments to implement their AMR policies. The discussion focuses on the differences between government funding on the one hand and out-of-pocket household expenditure on the other hand. At the end of the section, we discuss the potential implications of other health financing modes.

A general feature of antibiotic use is that it generates a collective action dilemma. From the perspective of the individual patient and the individual healthcare professional who interacts with the patient, using an antibiotic may be a rational choice even in situations where its clinical appropriateness is not established beyond doubt. However, excessive and inappropriate consumption of antibiotics accelerates AMR and thus generates collective harm (Krockow *et al.*, 2022; Rönnerstrand & Sundell, 2015). Even when fully informed about the collective impact of antibiotic overuse, patients and healthcare professionals must weigh the individual and immediate benefits of consumption and the diffuse and future benefits of abstention. Despite the general nature of this dilemma, there is substantial variation in antibiotic use decisions within and across countries. Some of the drivers of this variation are economic.

Researchers studying the drivers of AMR have long recognised the relevance of economic factors in influencing antibiotic use. Economic incentives are particularly evident in the use of antibiotics in animal husbandry, whether for growth promotion or prophylaxis. It is also well documented how agricultural interests have lobbied governments and legislators to prevent regulation that could negatively affect their economic returns (Begemann *et al.*, 2018; Kahn, 2016; Kirchhelle, 2018; Vogeler *et al.*, 2022). The role of economic drivers of antibiotic use in human health care tends to be more subtle. They affect both healthcare providers and patients, which we discuss in turn.

In a variety of contexts, the revenues of healthcare professionals and organisations – doctors, nurses, hospitals, pharmacists, informal health workers, and other roles – are affected by the volume of antibiotics that are prescribed and sold to patients. This link has been identified as influencing the decisions of healthcare professionals in a multiplicity of national settings. In many cases, the link between volume and revenue is immediate, as in the case of pharmacies and informal health providers selling antibiotics without prescription (Auta *et al.*, 2019; Bahta *et al.*, 2021; Batista *et al.*, 2020; Blaser *et al.*, 2021; Gautham *et al.*, 2021; Gebretekle & Serbessa, 2016; Kahn, 2016; Khan *et al.*, 2022; Khine Zaw *et al.*, 2022; Kotwani *et al.*, 2021; Lin *et al.*, 2020; Sakeena *et al.*, 2018; Servia-Dopazo & Figueiras, 2018). Retailers of medicines face individual consumers in on-the-spot transactions, and a pharmacy professional in Eritrea described a typical situation by noting that, 'If you try to teach the patient about antibiotic resistance and you told them they do not need antibiotics, they leave your pharmacy and get the medicine next door' (Bahta *et al.*, 2021, p. 4). In other cases, the link is less direct. For instance, from the 1980s onwards, Chinese hospitals derived a large and increasing fraction of their revenues from drug sales; in turn, doctors who work for hospitals receive a large percentage of their income in the form of bonuses linked to the revenues that they bring in, leading to high levels of overprescription of antibiotics and other medicines (Currie *et al.*, 2014). An audit experiment showed that hospital doctors were much more likely to prescribe antibiotics if they expected the prescription to be filled in the hospital pharmacy than if the patient indicated they would purchase the drugs elsewhere (Currie *et al.*, 2014). Similar effects have been observed in other national contexts, such as Austria (Stacherl *et al.*, 2023). Because they are more inclined to treat patients as consumers, private hospitals are less likely to limit antibiotic use than public hospitals in the same country. A doctor and department head of an Australian hospital explained:

> The private hospital has, as far as I can tell, no antimicrobial stewardship system whatsoever, and it's in the same building as the public hospital, with a lot of staff that are shared between, well, a lot of medical staff that are shared between the two facilities … I think I can totally do my own thing up there. I fling more broad-spectrum antibiotics around up there than I do here. (Broom *et al.*, 2021, p. 455)[2]

In some contexts, pharmaceutical companies provide general practitioners and other professionals with incentives for prescribing their products, such as money, goods, and sponsorships for attending professional conferences and leisure travel (Fickweiler *et al.*, 2017; Gul *et al.*, 2021; Noor, Liverani, *et al.*, 2023; Noor, Rahman-Shepherd, *et al.*, 2023).

Economic factors affect not only the supply of antibiotics by healthcare providers but also the demand from patients. Especially in low-income settings, antibiotics are often perceived as a more affordable alternative to expensive medical treatment. The ethnographic study by Nabirye *et al.* (2023) documents the extensive use of antibiotics among precariously employed urban day-wage workers living in an informal settlement in Kampala, Uganda. For instance, '[o]ne woman who experienced extensive headaches described how she would often use metronidazole as a pain relief medication because she rarely had the money – or time – to go to the clinic and see a health worker' (Nabirye *et al.*, 2023, p. 102; see also Afari-Asiedu *et al.*, 2020). A pharmacist in Hyderabad, India, noted that the poor

> are often driven by the needs to continue working and get wages which may be on daily basis, so they cannot afford to miss jobs or working hours, they may not have enough money to meet doctors too or buy adequate medications, so they may go to retail shops and buy antibiotics directly without advice. (Broom *et al.*, 2020, p. 21)

In the context of poverty and lack of effective public services, antibiotics can be perceived as a 'quick fix' (Denyer Willis & Chandler, 2019). An individual decision to abstain from antibiotics is much riskier in an economic context where complications from infections can lead to catastrophic financial consequences through costly hospitalisation and loss of vital income. In turn, the precarious economic situation of patients can affect how health professionals make prescribing or dispensing decisions: they may be less inclined to limit antibiotic use if they know that infection complications could have a devastating financial impact on their patients (Krockow *et al.*, 2022; Tarrant *et al.*, 2021).

Given the motivations and incentives we described, health systems that rely to a significant extent on out-of-pocket spending by patients pose a challenge to governments that aim to implement ambitious reforms to contain AMR. This challenge materialises for three reasons, which we label the incentive, control, and reassurance mechanisms, respectively.

The *incentive mechanism* stems from the fact that healthcare providers are more motivated to prescribe and sell antibiotics when their income is linked to transactions with individual patients, as it happens when patients pay for the service or medicine out of their own pocket. These economic consequences provide an incentive to ignore, circumvent or resist government regulation of antibiotic prescriptions and sales. Formal regulation is especially likely to be ignored in settings where public officials are unable or unwilling to enforce it. Inability often stems from a lack of resources and qualified personnel. For instance, a human health government official in Pakistan remarked that the Drug Regulatory Authority of Pakistan was expected to curb inappropriate marketing practices by pharmaceutical companies but 'are lacking in human resources. One person, one drug inspector in the whole district, maybe looking after two to three districts. How can he manage?' (Khan *et al.*, 2020, p. 979). But unwillingness can play a role, too. According to Gautham *et al.* (2021), in India 'regulators were reluctant to enforce heavy sanctions for illegal sales, fearing an adverse impact on rural healthcare'. Some studies note the problem of corruption among officials responsible for enforcing the rules (Broom *et al.*, 2020; Khan *et al.*, 2020; Khine Zaw *et al.*, 2022).[3] A systematic review of the literature found that '[n]otwithstanding the regulations implemented in most countries, there are hardly any penalties for dispensing antibiotics without prescription' (Servia-Dopazo & Figueiras, 2018, p. 3249). To be sure, the incentive mechanism could still operate with financing provided by the state under certain fee-for-service models. But it would be a contingent effect, compared to being an almost structural feature of a system relying on out-of-pocket payments.

The *control mechanism* stems from the fact that healthcare providers are more likely to comply with government regulation when they are dependent on government financing. As emphasised by Immergut (2021), national health service systems provide governments with greater leverage over various aspects of the healthcare system. Governments can incorporate reporting, monitoring and auditing requirements relating to AMR into their financial arrangements with healthcare providers, and economic dependence can provide options for positive and negative incentives. For instance, as part of the UK Five Year Antimicrobial Resistance Strategy, in 2015 the National Health Service of England included an antibiotic prescribing element to the national 'quality premium', which provides financial rewards to the bodies (the Clinical Commissioning Groups) that are responsible for planning and commissioning healthcare services in their local area. To qualify for such financial rewards, primary care prescribers were asked to meet reduction targets for all antibiotics, with more stringent targets applied to a set of broad-spectrum antibiotics. The introduction of this financial reward was associated with a significant reduction of antibiotics prescribed by general practitioners (GPs), especially in high-prescribing practices (Anyanwu *et al.*, 2020; Balinskaite *et al.*, 2019; Borek *et al.*, 2020; Bou-Antoun *et al.*, 2018).

The *reassurance mechanism* relates to the implications of healthcare financing modes for patients rather than providers. For the reasons noted earlier, abstaining from antibiotics entails larger risks in systems where the patients themselves bear the financial cost of treating complications, possibly through expensive hospitalisation. By contrast, healthcare systems based on substantial public financing can reassure patients (and their healthcare providers) that their choices regarding antibiotic use do not have major financial implications for them, and hence promote their acceptance of stewardship measures.

The discussion so far has focused on the differences between two funding modes that, in some respects, can be considered polar opposites: government vs. out-of-pocket payments for health care. As noted earlier, other funding modes exist, notably mandatory health insurance schemes, which can be public or private, voluntary health insurance, and company health schemes. The effect of these other modes on the effectiveness of antibiotic stewardship policies is less clear-cut than in the case of government and out-of-pocket spending.[4] Insofar as such schemes are prepaid and would cover the cost of potential infection complications, they can support such policies by activating the reassurance mechanism. On the other hand, the control mechanism is likely to be weaker when nongovernmental bodies make reimbursement decisions. The operation of the incentive mechanism is ambiguous and contingent on the context and specific financial arrangement. For instance, Broom *et al.* (2018) report that the reimbursement policies of private insurers have a major impact on antibiotic prescription decisions in a private hospital in Australia: by refusing to cover the costs generated by potential post-surgery infections, the insurers create a strong incentive for hospital staff to minimise financial risks and put all surgical patients on a full prophylactic or post-surgical antibiotics regime, even if much of it is clinically unnecessary. On the other hand, outbreaks of antibiotic-resistant infections in hospitals can generate substantial economic costs (Dik *et al*., 2016; Roberts *et al*., 2009). A social insurance scheme covering a substantial share of the population and expected to (partly) pay for those cumulative costs from AMR may have an economic incentive to support antibiotic stewardship measures. Thus, social insurance providers may be aligned with the policies of governments even if they are organisationally independent from them. Further research on the specific arrangements that make different kinds of health insurance providers more or less interested in backing efforts to reduce AMR seems warranted.

To summarise our discussion so far, we argue that the extensive involvement of governments in healthcare financing reduces both the willingness and the ability of healthcare providers to behave in ways incompatible with antibiotic stewardship policies while mitigating patients' incentives to circumvent restrictions imposed by those measures. While we distinguished three mechanisms for analytical purposes, we expect them to operate in close connection. For instance, even an individual pharmacist may find it difficult to clearly distinguish between the economic incentive to sell an antibiotic and the professional obligation to help a poor customer who would not be able to afford hospital treatment. Hence, the following analysis focuses on government funding relative to total health financing as a common factor that potentially activates each of the three mechanisms we discussed.

Research design

Our theoretical discussion implied that the implementation of NAPs would be more effective in countries where government funding makes up a larger share of health financing. We test this theoretical argument by utilising cross-national data on antibiotic consumption between 2000 and 2018.

We estimate Ordinary-Least-Squares regression (OLS) to test whether NAPs are more effective at reducing antibiotic consumption when public involvement in healthcare funding is greater. Our dependent variable is the defined daily doses of antibiotics consumed per 1000 people in each country-year (Browne *et al*., 2021). Our sample includes 191 WHO member states between 2000 and 2018. We estimate two sets of models. First, we use fixed effects regressions that include country fixed effects to control for time-invariant between-country differences and year fixed effects to account for common shocks. For these models, the standard errors are clustered at the country-level to adjust for unit-level correlation in the error term. Second, we estimate between-country differences using OLS regressions with year fixed effects and clustered standard errors at the year-level.

The primary independent variable in the models is an interaction between NAP implementation and public financing of health care. To determine whether a country has been implementing a NAP, we rely on the coding of TrACSS responses mentioned earlier (footnote 1). We interact this measure of NAP implementation with an indicator of the importance of public financing in countries' healthcare systems. Specifically, we draw on cross-national data generated by the Global Burden of Disease 2021 Health Financing Collaborator Network (GBD Collaborator Network) (Micah *et al.* 2023). The Institute for Health Metrics and Evaluation (IHME) – a research institute at the University of Washington, Seattle – coordinates this network of several hundred researchers based in numerous countries and makes the resulting dataset available (IHME, 2023). The dataset covers global health financing for 204 countries and territories between 1990 and 2019, drawing on the WHO's Global Health Expenditure Database (GHED) and national government sources. Given the uneven quality of the data included in the GHED, the GBD Collaborator Network used statistical modelling techniques to derive consistent and complete estimates, and converted them into inflation-adjusted 2021 US Dollars (Micah *et al.* 2023). The IHME-provided data are disaggregated into four categories: 'government' financing, which includes both government health budgets and social (non-risk-related) insurance schemes; private prepaid expenditure, which contains voluntary and mandatory private health insurance and company schemes; out-of-pocket expenditure by households; and development assistance for health (Micah *et al.* 2023). As discussed in the previous section, the effect of social insurance schemes can be expected to be similar to the impact of government financing in some but not necessarily every way. Specifically, social insurance is likely to activate the reassurance mechanism and, at least in the right circumstances, the incentive mechanism, but perhaps not the control mechanism. Given that the IHME-provided data do not enable us to assess the role of government funding separately from social insurance funding, we use their aggregate measure in our analysis. This approach creates a more demanding test for our hypothesis, because the aggregate measure is likely to dilute any evidence of the processes we expect (compared to a measure capturing exclusively government funding). Private health insurance remains excluded from the variable even if it is mandated by law.[5]

To prevent misunderstandings, we avoid the label used by the GBD Collaborator Network and IHME ('government health expenditure'), and instead use the label 'public financing' to describe the aggregate variable provided by IHME (consistent with OECD, 2020). We measure governments' involvement in the healthcare system by focusing on public funding as a percentage of total health financing.

We control for several additional potential confounders to minimise the risk of omitted variable bias. First, we control for countries' level of economic development through a measure of GDP per capita (World Bank, 2023). We also control for economic growth and population size (World Bank, 2023). Second, we adjust for differences in countries' bureaucratic quality to ensure that results are not entirely driven by bureaucracies with better implementation capacity (Chayes & Chayes, 1995; Pierre *et al.*, 2023). We control for bureaucratic capacity by using a variable from the V-Dem dataset that indicates the extent to which appointment decisions in the state administration are based on personal and political connections, as opposed to skills and merit (Coppedge *et al.*, 2021). The rationale is that lower-skilled officials will find it more challenging to perform the complex tasks of implementing NAPs (Anderson *et al.*, 2019). One downside of including the bureaucratic quality control variable is that it captures some of the capacity deficits and corruption that weaken regulation of antibiotic use in the private health sector, but the match is far from perfect, leaving enough variation in national action effectiveness for the financing mode variable to explain. Third, we control for the level of democracy since democracies tend to invest more in public goods, but also offer more opportunities for opponents of policy change to slow down the process (Bueno De Mesquita *et al.*, 2003). We use the electoral democracy index from V-Dem (Coppedge *et al.*, 2021). Fourth, we include measures of countries' membership in intergovernmental organisations focused on health to control for differences in countries' attention to international cooperation in health, as well as the number of health-focused international nongovernmental organisations with members in the

Table 1. descriptive statistics.

Variable name	*N*	Mean	SD	Min	Max
Antibiotic consumption (DDD per 100,000)	3629	12.574	7.044	2.800	45.900
Public share of total health financing	3428	0.500	0.216	0.023	0.947
Implementing NAP	3629	0.072	0.258	0.000	1.000
GDPpc (log)	3420	8.426	1.534	4.488	12.163
Economic Growth	3229	1.039	0.066	0.387	2.247
Population (log)	3428	15.496	2.205	9.151	21.067
Bureaucratic capacity	2984	0.417	1.200	−2.610	3.600
Democracy	3049	0.536	0.263	0.014	0.948
Health IOs (log)	3226	1.862	0.400	0.693	2.944
Health NGOs (log)	3240	3.391	1.148	0.000	5.493

country. Data are from Heinzel and Koenig-Archibugi (2023a). Table 1 presents descriptive statistics for these variables.

Empirical analysis

In the following, we evaluate our hypotheses that the association between NAP implementation and reduction in antibiotic consumption depends on share of health financing that comes from public sources. Before doing so, we evaluate whether public financing of health could cause NAP implementation to minimise the possibility of reverse causality. Figure 1 shows that the percentage of public funding does not appear to correlate with the status of countries' NAPs.

Table 2 displays the results from our fixed effects estimations. Model 1 is a simple OLS regression with country and year fixed effects and our main variables of interest (without interaction). In Model 2, we interact the two main independent variables. Model 3 further includes our control variables. Model 4 is an even more stringent estimation as it includes country-specific linear time trends to ensure that we do not simply pick up reductions in antibiotic consumption over time. Finally, Model 5 is a demanding specification that includes a lagged dependent variable.

The headline finding is consistent and strong throughout the presented models: NAP implementation substantially reduces antibiotic consumption when the national healthcare system is primarily financed from public sources. This finding implies that while the public share of healthcare

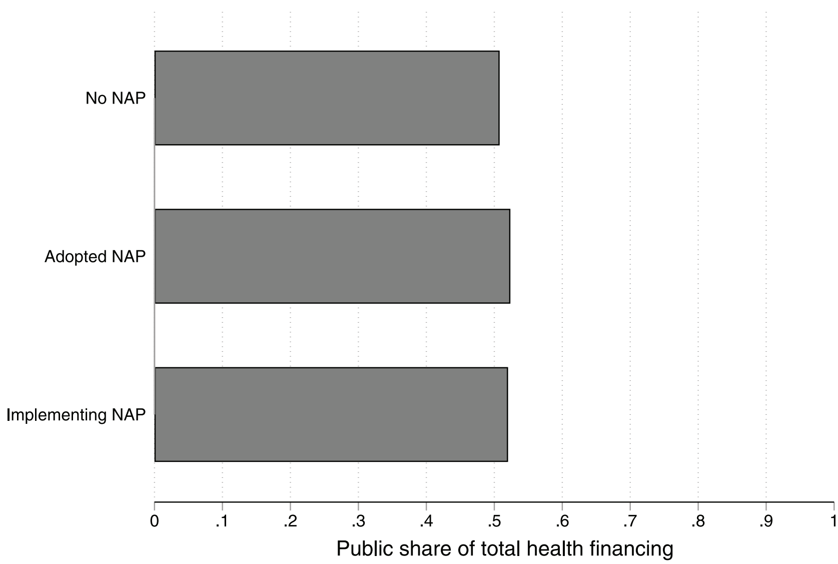

Figure 1. Public share of total health financing by NAP status in 2018.

Table 2. Within-country comparisons.

	(1)	(2)	(3)	(4)	(5)
Public share of total health financing	1.5023	1.5685	1.4467	1.2626	0.4709
	(1.3201)	(1.3284)	(1.6975)	(1.0374)	(0.5508)
Implementing NAP	−1.0736**	1.1556	0.0927	0.5474	0.3620*
	(0.4490)	(0.8228)	(0.6907)	(0.3919)	(0.1980)
Public share * Implementing NAP		−4.0833***	−2.2538**	−2.5956***	−1.2662**
		(1.2484)	(1.1107)	(0.8489)	(0.5031)
Economic growth			−0.0529	0.3957	0.4459*
			(0.6653)	(0.4254)	(0.2646)
Population (log)			3.1776	−4.4504	−2.1777
			(1.9470)	(3.5945)	(1.5145)
Bureaucratic quality			−0.7492	−0.1506	0.0202
			(0.5794)	(0.2229)	(0.1198)
Democracy			3.7882	0.3500	−0.2907
			(2.7201)	(0.8287)	(0.4134)
Health IOs (log)			−0.4855	−2.3638***	−1.1749***
			(1.1195)	(0.6407)	(0.3164)
Health NGOs (log)			0.7334	0.3454	0.2290
			(0.7963)	(0.3712)	(0.2109)
GDPpc (log)			0.9717	0.8809*	−0.0126
			(0.7387)	(0.4586)	(0.2308)
Lagged DV					0.6480***
					(0.0462)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Country-specific linear time trends	No	No	No	Yes	Yes
Year fixed effects	No	No	Yes	Yes	Yes
Countries	191	191	166	166	166
Years	19	19	18	18	18
Observations	3428	3428	2761	2727	2727
R^2	0.929	0.930	0.940	0.984	0.990

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

funding does not seem to affect whether governments implement NAPs (Figure 1), it does seem to shape how effectively they reduce antibiotic consumption through their NAPs (Table 2). The interaction is statistically significant ($p < 0.01$) at conventional thresholds and negative. Figure 2 visualises the interaction based on Model 3 for ease of interpretation. The figure shows that NAP implementation fails to attain statistical significance until the public share reaches around 55 per cent. In other words, implementing NAPs does not appear to reduce antibiotic consumption – on average – for countries below that threshold. However, for those country-years with a public share above 55 per cent, implementing NAPs appears to decrease antibiotic consumption in a statistically significant way ($p < 0.05$). This group includes approximately 44 per cent of country-years in the sample, as indicated by the grey bars in Figure 2. In other words, the effectiveness of NAPs at reducing antibiotic consumption is driven by the 44 per cent of countries with high public involvement in healthcare financing.

So far, our models have focused on within-country comparisons by employing country fixed effects. In a second step, we conduct between-

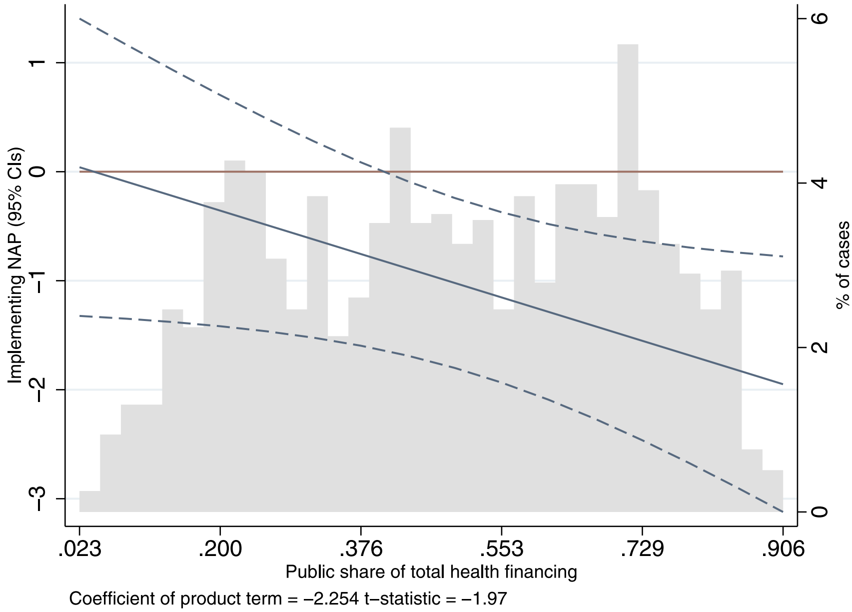

Figure 2. Marginal within-country effects of NAP implementation on antibiotic consumption at different levels of public involvement in healthcare financing.

Note: The Figure presents the estimated association between implementing an NAP and antibiotic consumption at different levels of public share in total health financing. The blue line displays how much consumption changes when a NAP is implemented, and the dotted blue lines show the 95 per cent confidence intervals. The grey bars visualise the percentage of country-years at each level of public share.

country comparisons to understand whether cross-national differences in healthcare financing also explain differences in the effectiveness of NAPs across countries in Table 3. Model 6 estimates simple OLS models with year fixed effects and our two main variables of interest. In Model 7, we interact those independent variables. In Model 8, we account for omitted variable bias by including our control variables. Finally, Model 9 controls for a lagged dependent variable.

The coefficients for both NAP implementation and the public share of health financing are positive and statistically significant in Model 6. The positive cross-national association between the public share and antibiotic use suggests that publicly funded systems promote broader access to medicines. Similarly, the positive sign of NAP implementation may reflect unobserved cross-national differences in health system strength that our control variables do not capture fully. However, our focus is on the role played by public financing when the government takes steps to regulate antibiotic use more stringently. The results presented in Models 7, 8 and 9 show that government action tends to be more effective in countries with a larger share of public funding. The coefficient of the interaction is negative and statistically

Table 3. Between-country comparisons.

	(6)	(7)	(8)	(9)
Public share of total health financing	14.9872***	15.7160***	6.6354***	0.0997
	(0.4440)	(0.4222)	(0.2886)	(0.1179)
Implementing NAP	4.0019***	10.3645***	6.5771**	0.1042
	(0.4612)	(3.3313)	(2.3567)	(0.1798)
Public share * Implementing NAP		−10.2117**	−10.4094***	−0.5990**
		(4.1165)	(2.8881)	(0.2355)
Economic growth			−0.6006	0.4744**
			(1.4853)	(0.1820)
Population (log)			0.3126***	0.0226
			(0.0232)	(0.0143)
Bureaucratic quality			−0.2222*	−0.0041
			(0.1086)	(0.0180)
Democracy			−0.3571*	−0.1928*
			(0.1762)	(0.1061)
Health IOs (log)			2.7155***	0.0342
			(0.5594)	(0.0621)
Health NGOs (log)			0.2105*	−0.0423
			(0.1008)	(0.0248)
GDPpc (log)			1.8567***	−0.0222
			(0.0272)	(0.0192)
Lagged DV				1.0093***
				(0.0074)
Year fixed effects	Yes	Yes	Yes	Yes
Countries	192	192	167	167
Years	19	19	18	18
Observations	3428	3428	2761	2761
R^2	0.302	0.308	0.443	0.986

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

significant in all three models. Figure 3 illustrates the marginal effects of the interaction based on Model 8. Thus, the analysis of differences between countries yields results consistent with our findings regarding changes within countries.

To summarise, our analyses imply that the political economy of healthcare systems mitigates the success of NAPs in addressing antimicrobial resistance as countries with a more limited role of public sources in health financing share make smaller dents in antibiotic consumption during NAP implementation than countries relying more on public funding.

Robustness checks

We estimate several robustness checks to ensure our results are consistent when employing alternative specification choices. First, we re-estimate models using pseudo-maximum likelihood estimation (Table A1). Second, we use Huber-White standard errors to correct for heteroscedastic errors (Table A2). Third, we employ government effectiveness, life expectancy and civil society participation as additional control variables (Table A3). Fourth, we use alternative measures of the public financing independent variable that account for the uncertainty in the estimates provided by IHME (Table

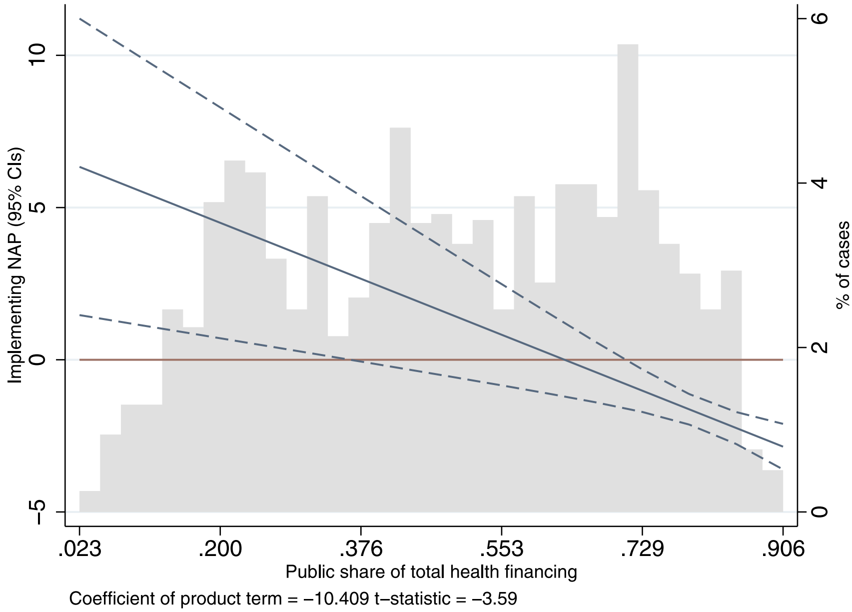

Figure 3. Marginal between-country effects of NAP implementation on antibiotic consumption at different levels of public involvement in healthcare financing.

Note: The Figure presents the estimated association between implementing an NAP and antibiotic consumption at different levels of the public share of health financing. The blue line displays how much consumption changes when a NAP is implemented, and the dotted blue lines show the 95 per cent confidence intervals. The grey bars visualise the percentage of country-years at each level of the public share.

A4). Fifth, we use total antibiotic consumption as an alternative dependent variable (Table A5). Sixth, we employ changes in antibiotic consumption as a further dependent variable (Table A6). Fifth, we re-estimate models using the upper and lower bound estimates of antibiotic consumption provided by Browne *et al.* (2021) (Table A7). Finally, to ensure that our results are not dependent on including any one region in our sample, we re-estimate the models while excluding one WHO region at a time. Our results are robust to these alternative specifications.

Discussion

We discuss some implications of our findings, some limitations of our study, and some directions for further research.

As noted earlier in this article, previous studies have examined the role of economic factors in enabling or – more often – hindering efforts to achieve a collectively more rational use of antibiotics. There is also some emerging evidence that the implementation of national action plans on AMR is helping address this serious threat to human health (Heinzel & Koenig-Archibugi, 2023b). Our study shows that these two dimensions are related: the effectiveness of government action in improving antibiotic use depends crucially on how health care is financed. On average, across the large sample we consider, national plans seem able to make a dent on antibiotic consumption only when more than half of health spending is financed by public sources – that is, either by the government directly or by social insurance schemes set up by law and where contributions are unrelated to individual risks. By contrast, government interventions are more likely to yield disappointing results when a large proportion of health care is paid for through private transactions, notably through the out-of-pocket spending by households that prevails in many countries, especially those with lower average incomes.

Some limitations of our findings highlight fruitful avenues for further research. First, our measure of public share of health financing combines government and social insurance funding. As we pointed out, this creates a more demanding test for our hypothesis because the beneficial impact we hypothesised may be less pronounced for social insurance than for government financing. Nevertheless, further progress in data availability could enable researchers to investigate whether and how much social insurance schemes help governments achieve ambitious antibiotic stewardship goals.

Second, we formulated three mechanisms (control, incentive and reassurance) that can link health financing to the effectiveness of national action plans, but we have not shown their relative importance empirically. Hence, their role is plausible rather than certain. It may be challenging to disentangle them at the micro-level – e.g., a pharmacist may dispense an antibiotic without a prescription at the same time because it brings revenue, because there is no oversight, and because they may worry that the patient cannot afford hospitalisation to treat a missed bacterial infection. Future research could attempt to gauge their relative importance by exploiting observational variation at local and national levels, and by operationalising the mechanisms as treatments in an experimental set-up.

Third, we rely on information about national implementation supplied by government agencies to the WHO. Such agencies may have an incentive to misrepresent the actual degree of implementation. While this is a valid concern, studies on NAP implementation conducted by scholars in various countries do not give us reasons to believe that the situation is systematically misrepresented in government reports to WHO (Ahmed *et al.*, 2022; Chan *et al.*, 2022; Corrêa *et al.*, 2023; Frumence *et al.*, 2021; Godman *et al.*, 2022; Hannah & Baekkeskov, 2020; Hein *et al.*, 2022; Khan *et al.*, 2020; Lota *et al.*, 2022; Sariola *et al.*, 2022; Song *et al.*, 2022; Thomas & Lo, 2020; WHO, 2022a, 2022b). Government reports may be more accurate than alternative sources such as expert surveys.[6] But, developing a robust multistakeholder system for validating government-provided information would also be desirable for researchers.

Finally, we studied the effect on total antibiotic consumption, in line with the measure of effectiveness stated in the WHO's global action plan (WHO, 2015a, p. 13). However, antibiotic medicines do not all involve the same risk of worsening AMR. Some antibiotics are safe to use widely, but others need to be carefully monitored, and a few need to be used only as a last resort (Sharland *et al.*, 2018). Further research is needed to determine whether public funding of health care improves the use not only of antibiotics in general but also of those for which careful stewardship is most urgent.

Conclusion

AMR is one of the most serious threats to human health in the twenty-first century (Murray *et al.*, 2022; Review on Antimicrobial Resistance, 2016). After decades of neglect, governments worldwide seem to have risen to the challenge, pledging to undertake various measures to counter the problem in their territories. We have argued that how health care is paid for in many countries is an obstacle to the effectiveness of national action plans. Implementing such plans tends to affect the extent of antibiotic use only when governments and social insurance schemes provide a substantial share of health spending.

Path dependency plays a big role in the development of healthcare systems (Wilsford, 1994). However, the role of the public sources in financing health remains a politically contested issue in many countries, occasionally leading to major shifts (Atun *et al.*, 2015; Harris, 2017; Immergut *et al.*, 2021; Reich *et al.*, 2016; Selway, 2015). In this sense, our findings confirm the insight that politics plays a central role both in creating and countering AMR (Baekkeskov *et al.*, 2020). Ensuring high levels of government involvement in healthcare financing has long been a demand of commentators concerned about health access and equity, also in relation to recent debates about Universal Health Coverage (McIntyre *et al.*, 2017). Our study provides further evidence of the importance of the political economy of health care for ensuring a safer future for all.

Notes

1. A question included in TrACSS concerns the country's progress with developing a national action plan on AMR. Possible responses are: (a) the country has no NAP, (b) a NAP is being developed, (c) a NAP has been adopted, (d) a NAP was approved, budgeted, is aligned with GAP objectives and has an operational plan, and (e) a NAP was approved, has funding, involves relevant sectors, and monitoring and evaluation is in place. We code governments as implementing their NAPs from when they answered either (d) or (e) for the first time.
2. Further evidence on differences between private and public hospitals is reported in Broom and Doron (2020). See also Tarrant et al. (2021).
3. Cf. also Collignon et al. (2015) and Rönnerstrand and Lapuente (2017).

4. We are grateful to the anonymous reviewers for encouraging us to discuss this aspect.
5. Micah et al. (2023) provide data on development assistance for health separately from government funding. As the former is partly routed through non-governmental channels, we do not merge it into the latter.
6. According to a survey of 352 experts from 118 low- and middle countries, 67 per cent of countries had a NAP in 2021, compared to 86 per cent declared to TrACSS in that year (Zay Ya et al., 2023). A count from the 'Library of AMR national action plans' maintained by the WHO, complemented by an online search, shows that for 19 of the 29 countries that the expert survey indicated not have a NAP, there is evidence that a NAP did exist. When correcting for these differences, the expert survey and the TrACSS indicate virtually the same percentage of countries that had a NAP 80 per cent versus 86 per cent. Therefore, the differences are likely due to lack of information among the experts rather than misreporting by country officials.

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Data availability statement

Appendices and data are available in the online supplementary information accompanying this article.

Disclosure statement

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