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How to Curb Over-The-Counter Sales of Antibiotics? Evidence from a Field Experiment in Ethiopia

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Abstract

In a randomized controlled trial among Addis Ababa's community pharmacies, we implement informational interventions to curb over-the-counter (OTC) antibiotic sales, which, especially in developing countries, contribute to the development of antimicrobial resistance (AMR). Our results show that one-time letters to pharmacists and a poster placed within the pharmacy premises significantly reduce OTC antibiotic sales in the short-run, with the poster's effect persisting five months later. We observe no significant impact on antibiotic prices. These findings highlight the potential of targeted informational interventions to tackle OTC antibiotic dispensing and mitigate the growing AMR threat.

Keywords: Antimicrobial resistance, OTC antibiotics, Field experiment, Community pharmacies, Simulated patients

JEL classification: C93, I12, I18, C21

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> The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant.
>
> – Alexander Fleming, Nobel Lecture (December 11, 1945)

1 Introduction

The discovery of antibiotics was one of the major breakthroughs in medicine in the 20th century. Antibiotics proved to be so effective that they quickly acquired the status of miracle drugs capable of reducing morbidity and mortality caused by bacterial infections. However, as suggested by Fleming's quote, it soon became apparent that their success is limited by antimicrobial or antibiotic resistance (AMR hereafter), which refers to the ability of microorganisms, often bacteria, to evolve and develop protective mechanisms against the drug that once would have killed them.

While initially found mostly in hospitals and other healthcare institutions, antibiotic resistant strains of bacteria that cause common infections (such as tuberculosis and syphilis) are now spreading rapidly and are an increasingly worrying presence in many communities all over the world. This proliferation of AMR has dramatic economic and humanitarian consequences, with the most alarming concern being that, without intervention, we may enter a 'post-antibiotic era,' where normal infections and minor injuries can once again become life-threatening (Reardon, 2014; Kwon and Powderly, 2021). AMR adversely affects the productive capacity of the economy by, e.g., reducing the quantity and quality of labor (due to illnesses and deaths), leading to higher production costs and a consequent fall in output, profits, employment, and welfare. Estimates of the economic impact of AMR from a World Bank Report (2017) suggest that by 2050 the annual global GDP will fall by 1.1% in an optimistic low-AMR scenario and by 3.8% in a pessimistic high-AMR scenario. The humanitarian costs of AMR will also be dire, with up to 10 million worldwide annual deaths predicted by 2050, a figure bound to outpace the expected mortality from cancer (O'Neill, 2016). The impact of AMR is particularly pronounced among poor individuals who have limited access to costly second-line regimens, which are necessary when first-line treatments fail. Acknowledging this multi-faceted threat, an indicator for AMR has been incorporated into the United Nations Sustainable Development Goals.

Despite AMR being a naturally occurring process, its increasing spread has been ascribed to the overuse and abuse of antibiotics in both animal production (see, e.g., Van Boeckel et al., 2015; Tiseo et al., 2020) and, what we focus on here, humans (see, e.g., Giubilini, 2019; Malik and Bhattacharyya, 2019; Adda, 2020). According to a recent study involving 76 countries around the world, the defined daily doses of human antibiotic consumption increased by 65% between 2000 and 2015 and, in the absence of effective policies, are projected to increase by 200% by 2030 (Klein et al., 2018).[1]

Zooming further into the problem reveals that, even though antibiotics are normally regulated as prescription-only medicines, they can be easily obtained without a medical prescription, particularly in developing countries where community pharmacies play a major role in the provision of non-prescribed or 'over-the-counter' (OTC) antibiotics. Auta et al. (2019) conduct a meta-analysis of 38 studies from 24 countries and find that OTC antibiotics have a 62% chance of being dispensed by community pharmacies, despite this practice being illegal. In a review of published works from 1970 to 2009, Morgan et al. (2011) show that non-prescription use of antibiotics is associated with high rates of AMR. Behavioral change in relation to antibiotic dispensing and use is thus urgently called for, and the implementation of interventions expressly targeting community pharmacies can serve an important role in curbing the misuse of antibiotics in general and the OTC sale of antibiotics in particular.[2]

Against this backdrop, the main aim of the present study is to provide unambiguous empirical evidence about the effectiveness of a set of informational interventions in reducing OTC sales of antibiotics. The study site is Addis Ababa, the capital city of Ethiopia, where previous studies have documented a high prevalence of OTC antibiotic dispensing (Gebretekle and Serbessa, 2016; Erku et al., 2016; Koji et al., 2019). In partnership with the Addis Ababa Food, Medicine and Healthcare Administration and Control Authority (AAFMHACA), we conducted a randomized controlled trial in which 831 community pharmacies and drugstores (hereafter referred to as 'pharmacies' for the sake of brevity) were randomly assigned either to one of three experimental groups or to an untreated control group. Two treatments consisted of informational letters targeted at pharmacists and the third treatment was an informational poster on display in the pharmacy premises. One of the two letters included a message reminding pharmacists about the legal consequences of dispensing OTC antibiotics (we call this the 'Coercive' letter); the other letter drew pharmacists' attention to their key role in promoting the appropriate use of antibiotics (we call this the 'Appeal' letter).

To evaluate outcomes (namely OTC antibiotic dispensing), we utilized Simulated (or Standardized) Patients (SPs).[3] These SPs were kept unaware of the treatments and were trained to present symptoms of two common health conditions, i.e., Upper Respiratory Tract Infection (URTI) and Uri-

[1] The COVID-19 pandemic outbreak may have further exacerbated the already worrisome picture due to changes in health priorities and management of infections (Kwon and Powderly, 2021; Khojah, 2022).

[2] Reducing inappropriate antibiotic dispensing and use is, of course, not the only measure needed to contrast AMR. The discovery of new antibiotics by pharmaceutical companies and improved surveillance are equally essential.

[3] Successfully and widely used in the medical literature, SPs have recently been used in the health economics literature (e.g., Currie et al., 2011, 2014; Das et al., 2016; Sharma et al., 2018; Gottschalk et al., 2020). Advantages of the SP method are discussed by Das et al. (2016) and Collins et al. (2021).

nary Tract Infection (UTI), to pharmacists.[4] The URTI case mimicked pneumonia in a child who was not physically present at the site. The UTI case involved female SPs and was further divided into a product-based request and a symptom-based request to investigate whether actively requesting antibiotics influences OTC dispensing behavior. It is possible that pharmacists are more inclined to sell non-prescribed antibiotics to informed customers (see, e.g., Erku et al., 2016; Wang et al., 2021). The eleven SPs employed in this study made over 2,000 unannounced visits to pharmacies in three different waves: the first wave, which took place before the field interventions, gathered baseline data on the pharmacists' willingness to dispense OTC antibiotics; the second wave tested the effect of the field interventions three weeks after their delivery; the third wave was conducted five months later, allowing the examination of the persistent effect of the interventions.

Using a difference-in-difference estimation strategy, which exploits the panel nature of the data, we show that pharmacists significantly reduce the dispensing of OTC antibiotics three weeks after the interventions in all experimental treatments: in comparison to pre-intervention levels, where more than 50% of pharmacists are found to sell OTC antibiotics, the pharmacists who received either the Coercive or the Appeal letter decrease the likelihood of selling by about 24 percentage points and those treated with the poster decrease it by approximately 12 percentage points. Notably, we observe significant treatment effects even in the longer run (five months later), where the effect of the poster remains stable and the effect of both letters weakens by nearly 7 percentage points.

Our findings are robust across the pharmacist's gender, the type of drug retail outlet (community pharmacy vs drugstore), and the type of request (product-based vs symptom-based). In contrast, we observe heterogeneous treatment effects concerning the time of the visit. Specifically, both letters have a stronger effect before, rather than after, 5 pm (namely during instead of outside regular inspection hours), whereas the opposite holds true for the poster.

While our interventions successfully lead to a reduction in OTC antibiotic sales (extensive margin), it is possible that their implementation induces spillovers on the prices at which the antibiotics are sold (intensive margin).[5] Treated pharmacists who continue to sell OTC antibiotics may, for instance, price these medicines higher compared to pre-intervention levels to compensate for the lower quantity sold on average, to reflect a premium for the risk they assume in keeping selling antibiotics without a prescription, or simply due to selection where pharmacists charging higher prices are the ones

[4] The abuse of antibiotics for URTI and UTI, especially in developing countries, is reported in Godman et al. (2020) and Paul (2018), respectively. Additionally, there is little variation in the types of antibiotics commonly used to treat these conditions.

[5] The affordability of antibiotics is a critical issue in Ethiopia, as antibiotic prices are neither regulated nor monitored by the government. Imported drugs from various countries can exhibit substantial price variations, particularly in private community pharmacies (Gutema and Engidawork, 2018).

continuing the sales. On the other hand, selection may work in the opposite direction and induce a decrease in requested prices if pharmacists are motivated by the altruistic belief of providing a service to the community and are also the ones willing to take higher risk to follow this belief. Despite the possibility of such spillovers, we find that our interventions have no significant effect on prices.

Our paper makes several contributions to the literature. First, we add to an active body of research focused on changing behavior through inexpensive interventions that take the form of informational letters and posters. Letters with messages delivered and tailored to specific individuals are found to have a significant impact on behavior in various contexts, such as vaccination (Kiefe et al., 2001), energy consumption (Allcott, 2011), and tax compliance (Hallsworth et al., 2017; Bott et al., 2020). They have also been used to tackle AMR, primarily by reducing over-prescribing of antibiotics. For instance, Hallsworth et al. (2016) find that peer comparison letters sent to English general practitioners with high antibiotic prescription rates lead to a substantial decline in prescribing.[6] Previous field experiments have also shown the effectiveness of posters in improving behavior. Examples include Chakravarty and Mishra (2019), who successfully induce workers in offices around New Delhi to use less paper, Köbis et al. (2022), who reduce people's willingness to bribe in a southern African town, Becchetti et al. (2020), who promote environmentally responsible behavior in an Italian region, and Mussio and de Oliveira (2022), who increase the percentage of students receiving a flu vaccine at a US University. In the context of antibiotic over-prescribing, Meeker et al. (2014) analyze the effect of a poster hung in Los Angeles community clinics and indicating the clinicians' commitment to reduce inappropriate antibiotic use. Their findings show that the commitment poster decreases inappropriate prescribing. To our knowledge, we are the first to address the challenge of AMR by evaluating whether informational letters targeted at pharmacists and a poster hung in the pharmacy premises are effective tools to curb the malpractice of OTC antibiotic dispensing. In doing so, we contribute to the strand of literature that examines compliance with rules, particularly when enforcement is weak and sanctions are not severe.

Second, we study the persistent and sustained effects of the interventions. While many researchers recognize the importance of assessing the extent to which the behavioral change induced by an intervention persists, the existing evidence on long-run effects is relatively scant. Beshears and Kosowsky (2020), in their review of treatment effects, observe that only 17 out of 174 surveyed articles collect

[6] Meeker et al. (2016) report that clinicians in Boston and Los Angeles reduce their unnecessary antibiotic prescribing after receiving peer comparison emails and alerts via electronic health records. A recent economic literature examines the effect of informational letters on over-prescription of opioids, reporting mixed evidence (e.g., Sacarny et al., 2016, 2017; Doctor et al., 2018; Ahomäki et al., 2020). See the review paper by Wang and Groene (2020) for a list of experimental studies involving physicians.

follow-up data to estimate the effect of at least one treatment in the longer run. It is not uncommon in the behavioral literature to find cases where individuals' behavior returns to, or decays rapidly toward, pre-intervention levels once the intervention is removed (see, e.g., Meier, 2007; Charness and Gneezy, 2009; Royer et al., 2015). Past work has identified interventions that need to be repeated over time to have a sustained impact (e.g., Beshears et al., 2013; Allcott and Rogers, 2014). In the realm of AMR, Linder et al. (2017) find that peer comparison emails sent monthly to clinicians have a significant, though declining, effect on prescription rates 12 months after withdrawal of the intervention. We contribute to this literature by showing that the effect of letters and posters on OTC antibiotic sales persists well into the fifth month, despite some waning of the effect of the letters.

Third, our paper provides careful estimates of the prevalence of OTC antibiotics in an urban setting of a developing country. Assessing the misuse of antibiotics in developing countries is of paramount importance because these countries are the most adversely affected by AMR mainly due to high burden of infectious diseases, low quality of healthcare services, and limited or costly access to medical counseling. Additionally, they present systemic weaknesses in AMR surveillance systems and regulatory enforcement mechanisms (Pearson et al., 2018). Among developing countries, Ethiopia is of particular interest given the high incidence of multidrug-resistant bacterial strains (Muhie, 2019; Berhe et al., 2021) and the widespread malpractice of selling OTC antibiotics (Gebretekle and Serbessa, 2016; Erku et al., 2016; Koji et al., 2019).[7]

Finally, our study is an example of successful and cost-effective collaboration between government and academic researchers that benefits both parties in the spirit of Sacarny et al. (2017). These types of partnerships provide a win-win framework where policy makers can access scientific expertise and achieve specific goals (here, finding effective ways to curtail antibiotic malpractices) and academics have the chance to gain insights into important issues (here, OTC antibiotic dispensing) through fieldwork and data collection.

The remainder of the paper is structured as follows. Section 2 offers a conceptual framework for the decision to dispense OTC antibiotics in developing countries. Section 3 describes the experimental design. Section 4 presents the results and Section 5 discusses them. Section 6 provides concluding remarks.

[7] Using a sample of 58 pharmacies, Erku et al. (2016) report that antibiotics are obtained 75.9% of the times for visits involving presentations of URTI symptoms. Koji et al. (2019) focus on pediatric illnesses and find that out of the 262 pharmacies included in their sample, 63.4% dispense OTC antibiotics.

2 Background: reasons for selling OTC antibiotics in developing countries

In this section, we draw on research from both the social sciences and medicine to provide an intuitive explanation of the factors that influence the pharmacists' decision to sell OTC antibiotics in developing countries like Ethiopia. As documented by Servia-Dopazo and Figueiras (2018) in their review on the topic, these determinants are multifaceted and intricate. We will focus on those that underpin our interventions. Pharmacies in developing countries are not only health support locations, that dispense medications and offer counseling and advice, but also profit-driven businesses. Hence, a pharmacist's choice to sell OTC antibiotics is influenced both by the desire to heal the patient and by commercial interests.

Starting from the latter motivating factor, harmful OTC dispensing may occur because pharmacists place a high weight on their expected economic incentives, which reward the volume of sold medicines. For this to be true, pharmacists must perceive the probability of detection and/or the penalties conditional on detection as low. Gebretekle and Serbessa (2016) find that pharmacists in Addis Ababa are well aware that OTC sale of antibiotics is illegal and unethical. Yet, as they expect a weak regulatory enforcement system, it is in their best interest to sell as many drugs as possible. Regulatory bodies in developing countries audit a few pharmacies periodically, but enforcement of the law in case of detection is considered weak and often 'bypassable' through bribes (Pearson et al., 2018).[8] Changing the pharmacists' perception of incentives—by reminding that they can be audited and fined if caught misbehaving—may reduce OTC dispensing.

Unlike other healthcare professionals who either are not physically part of the community that they serve or are socially distant from the customers, pharmacists are well integrated into society. This may motivate them to develop an image as a health—rather than a medicine–provider (Goel et al., 1996). Taking a pro-patient perspective, they may fail to understand their prescribing skills and rather believe that they possess the knowledge to diagnose and treat infections. When deciding to sell OTC antibiotics, pharmacists may either not perceive or underestimate the true costs of their actions. In this case, pharmacists are short-sighted as they value the short-run benefits of the antibiotic to the customer above and beyond the long-run costs for both the individual and the society. Most pharmacy

[8] To exacerbate the malpractice of OTC sales due to financial reasons there is the fear of losing customers, especially regular ones: if a pharmacist does not dispense OTC antibiotics, he believes that the customers can easily get them from any nearby pharmacy (Servia-Dopazo and Figueiras, 2018). Note that this kind of "bandwagon effect" may be a motive for selling OTC antibiotics by its own: if it is widely believed that all pharmacies dispense antibiotics without a prescription, then following this behavior may be acceptable because of, e.g., social pressure or replacement logic (Bartling and Özdemir, 2023).

staff members have an information deficit in AMR and poor understanding of the problem.[9] If OTC antibiotic sales are due to the failure to understand one's own prescribing skills and/or unawareness of the benefits and harms of antibiotics, it may be helpful to remind pharmacists about the side effects of improper antibiotic consumption and the prominent role they play in preserving antibiotic effectiveness.

Pharmacists frequently agree to sell OTC antibiotics after the insistence of customers, who often cannot afford to consult a physician in developing countries and/or believe that consulting a physician is time-consuming (Gebretekle and Serbessa, 2016; Sakeena et al., 2018). If pharmacists do not concede to the requests, customers tend to react negatively. Additionally, there is still confusion among customers about the pharmacists' role in developing countries: most customers believe that pharmacists are knowledgeable and can provide the proper medication. It becomes therefore difficult for the pharmacists to refuse dispensing OTC antibiotics as they run the risk of being seen as incompetent and not suitable for their role. From this perspective, a clearly visible poster on the pharmacy wall, which points out that antibiotics cannot be sold without a medical prescription, may reduce the pressure and insistence of the customers and make it easier for the pharmacists to refuse dispensing OTC antibiotics. Additionally, the presence of the poster may raise the reputation costs that pharmacists incur towards customers in openly violating the law. Empirical evidence suggests, indeed, that the awareness of being observed while misbehaving can impact decision-making (Gneezy et al., 2018; Khalmetski and Sliwka, 2019).

3 The field experiment

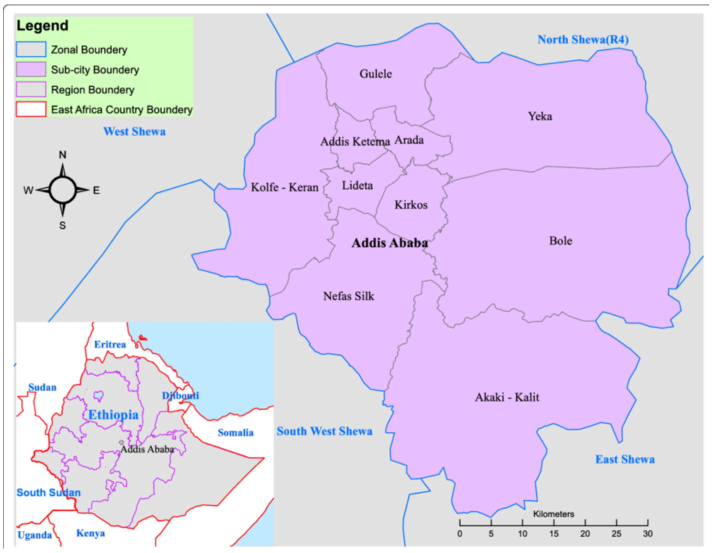
The field study was carried out in Addis Ababa in collaboration with AAFMHACA between May and December 2019. It was preregistered on the AsPredicted platform (ID #23159, available at `https://aspredicted.org/blind.php?x=bv6fb9`) and registered in the AEA RCT Registry with identifier AEARCTR−0012199. Ethical approval was obtained by the Economics & Business Ethics Committee at the University of Amsterdam.

3.1 Study site

Addis Ababa is the capital and largest city of Ethiopia and the seat of the African Union. It has an area of 540 square kilometers and the projected population size is approximately 3.5 million (Central

[9] As Goel et al. (1996) and, more recently, Sakeena et al. (2018) point out, pharmaceutical company salesmen are the main source of educational training of pharmacy personnel in many developing countries.

Figure 1: Addis Ababa sub-city map.



Notes: Map showing Addis Ababa sub-cities in 2019 (Source: Shapefile from Ethiopian Karta Agency).

Statistical Agency, 2011). Despite accounting for only 4% of the total population, the city hosts 21% of the major specialized hospitals in the country and nearly 43% of the total medical doctors. At the time of the study, Addis Ababa was divided into ten boroughs, called sub-cities (see the map in Figure 1).[10]

AAFMHACA is the main body that regulates the workings of community pharmacies, hospitals, and clinics in the city, but day-to-day operations of health facilities and healthcare providers are overseen by the sub-cities' health bureaus. Addis Ababa has three types of community drug retail outlets: pharmacies, drugstores, and rural drug vendors. The difference in name reflects differences in the kind of medications they can dispense as well as the qualification of the dispensers. Pharmacies are run only by holders of a university degree or above, drugstores by holders of a diploma in pharmacy, and rural drug vendors by health assistants.[11] Even though Addis Ababa has better-quality health facilities than other parts of the country, the prevalence of OTC antibiotic sales is markedly high.

3.2 Measuring OTC sales of antibiotics

To collect data on the pharmacists' willingness to sell OTC antibiotics, we made use of eleven Simulated Patients (SPs), aged between twenty-five and fifty years and recruited from Addis Ababa. The SPs

[10] In October 2020, the Addis Ababa City Council established an eleventh sub-city.

[11] There is only one rural drug vendor in Addis Ababa and it is not considered in this study.

were "fake" patients who, being undistinguishable from authentic patients and blind to the treatments, visited pharmacists and enacted a predetermined scenario.

Medical officers from health centers and AAFMHACA trained the SPs to present, in an accurate and consistent manner, one of two cases: a pediatric Upper Respiratory Tract Infection (URTI) and a female Urinary Tract Infection (UTI). The SPs trained for the URTI scenario presented themselves to the pharmacists as caregivers of a 2-year-old child with pneumonia and mentioned that they were hoping to purchase medicines from the pharmacy. The SPs trained for the female UTI scenario presented either a symptom-based request or a product-based request. A patient that asks for a specific antibiotic may signal knowledge of the disease and affect the pharmacist's willingness to sell the requested OTC product. We chose the URTI and UTI cases for two reasons. Firstly, they represent conditions with high incidence in Addis Ababa. Pediatric pneumonia is one of the most common childhood diseases in Ethiopia and represents a typical situation where antibiotics have been grossly abused in both clinical and pharmacy settings (Godman et al., 2020). Likewise, female UTI is prevalent among women and has become challenging to treat due to the emergence of AMR (Paul, 2018). Secondly, the antibiotics used for these diseases are quite specific and exhibit limited variation. For instance, amoxicillin is the most frequently dispensed antibiotic for treating pediatric URTI (Belachew et al., 2021). The standardized scripts for each scenario (presented in Appendix A) as well as predetermined answers to specific questions that the pharmacists could ask were pilot-tested and developed together with the health center and AAFMHACA officers.

The SPs were told to purchase the antibiotic when offered unless it was expensive, more than 160 Ethiopian birr (equivalent to 3 US dollars).[12] If no antibiotic was offered, the SPs politely greeted the pharmacist and left the pharmacy. Soon after having exited the pharmacy, the SPs filled in a questionnaire to record the type of visited drug retail outlet (community pharmacy or drugstore), the day and time of the visit, the pharmacist's gender, whether an antibiotic was offered, the requested price if offered, and any comments or advice given by the pharmacist.

Since the presented cases were the same across treatments and extensive training was provided to the SPs to ensure that they would behave in a similar manner, our study has sound internal validity and is thus able to effectively assess the impact of the treatments on OTC antibiotic sales. Additionally, since the SP method is covert, the visited pharmacists were unaware of being observed, which minimizes the Hawthorne (or experimenter demand) effect. Relevant in this respect is also the fact that the SPs were blind to the treatments.

[12] The antibiotics purchased in the first two waves were donated to a health center. However, the antibiotics acquired in the third wave could not be delivered due to the COVID-19 outbreak and had to be discarded.

3.3 Experimental treatments

To curb OTC antibiotic dispensing and to examine the heterogeneity of motives that underlie the pharmacists' decision of selling OTC antibiotics, we designed three treatments: the delivery of a so-called Appeal letter, the delivery of a so-called Coercive letter, and the display of a poster within the pharmacy premises. The letters and the message on the poster were written in the local official language, Amharic, and bore the letterhead, logo, and stamp of AAFMHACA. Personnel from AAFMHACA hand-delivered the letters and hung the poster on the pharmacy wall.

Upon receiving the letter (which was personalized, i.e., addressed with the name of the respective pharmacy/drugstore), the recipient had to sign a copy of the same letter as proof of receipt. This was intended as a form of soft commitment for the pharmacy to adhere to the message in the letter. The two letters had a similar introduction explaining the general emergence of AMR and the associated burden to the country and clarified that the misuse of antibiotics is a key driver of AMR.[13] To reduce the cognitive load of the recipient, the letters were written to be easily readable and understandable. Care was taken to ensure that they were of an appropriate length to capture the recipients' attention.

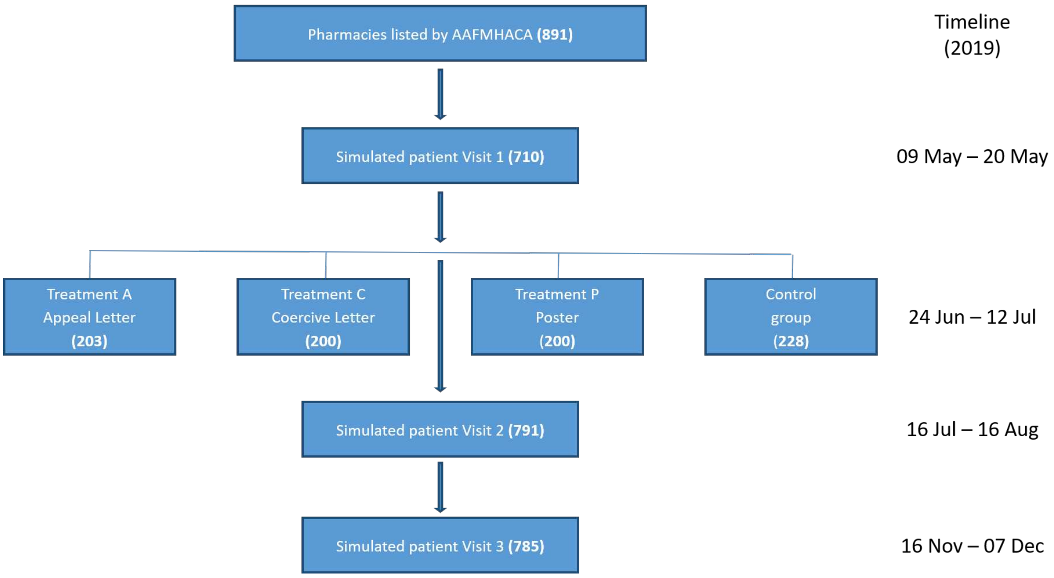
The Coercive letter was a hard-tone message that reminded the pharmacists about the possibility of unannounced audits by the authority and the ensuing applicable penalties in case of law infringement. The letter was intended to highlight the pharmacists' expected financial incentives by making it clear that the sale of OTC antibiotics is illegal and that breaking the law has serious legal and pecuniary consequences, which can amount to suspension or revocation of the license.

The Appeal letter appealed to the pharmacists' duty of care. It praised the pharmacists for their crucial role in encouraging the appropriate use of antibiotics and further reminded them to advise customers wishing to acquire OTC antibiotics to go to the nearest health center for a proper diagnosis. This soft-tone message was intended to influence the pharmacists' intrinsic motivations to limit AMR and to correct potential misconceptions about the pharmacists' role in the healthcare system.

Our third treatment required the compulsory placement of a poster in a prominent location within the pharmacy premises, such that it would be clearly visible by the customers entering the pharmacy. The poster included a simple text message reminding the readers that antibiotics cannot be sold without a prescription and encouraging them to help fighting AMR.[14] Since the poster could be read by customers, its presence in the pharmacy granted more leverage to the pharmacists to refuse OTC antibiotic requests and might raise the reputation costs of openly violating the law.

[13] An English translation of the letters is provided in Appendix B.
[14] See Appendix C for the exact content of the poster.

Figure 2: Timeline of the experiment.



3.4 Data collection

The sampling frame was constructed using the list of pharmacies provided by AAFMHACA. At the time of the experiment, the total number of pharmacies (including both community pharmacies and drugstores) was 891. The pharmacies situated within general hospitals were excluded from the study, as these pharmacies exclusively cater to registered in-patients and out-patients of the hospitals.

Figure 2 shows the timeline of our experimental protocol. We used the AAFMHACA list to randomly assign pharmacies to treatments and SPs, ensuring that no SP visited the same pharmacy more than once. From the 9th to the 20th of May 2019, we ran the first wave of data collection and gathered pre-treatment baseline data. In this wave, the SPs visited 710 pharmacies. Afterward (between June 24 and July 12), we administered our treatments, with a total of 831 pharmacies being randomized into three experimental groups and one control group. Two to three weeks after the intervention (from July 16 to August 16), we conducted the second wave during which the SPs made 791 visits. The third wave (counting 785 SPs' visits) was implemented from November 16 to December 7, 2019.

4 Results

4.1 Dataset description and randomization check

Our dataset comprises 831 distinct pharmacies—70.9% community pharmacies and 29.1% drugstores—that were randomly assigned to one of four groups, three experimental and one control. Chi-square tests, assessing the quality of the random assignment, provide support for a successful randomization of the pharmacy type—community pharmacies vs drugstores—across the four groups ($\chi^2(3) = 2.218$; p-value=0.528) and of the four groups across the ten sub-cities ($\chi^2(27) = 14.79$; p-value=0.972).[15]

Our SPs performed a total of 2286 visits over the three waves. The upper panel of Table 1 provides summary statistics on key variables of the visits. Chi-square tests, reported in the last column of the table, reveal that visits are uniformly distributed over waves and treatments as well as that most of the visit characteristics (namely, the time and day when the visit occurred, and the case presented by the SPs) do not differ significantly across treatments. The only significant difference is the distribution of the pharmacists' gender across treatments, as we observe a slightly higher fraction of female pharmacists in the poster treatment.

4.2 Frequency of OTC sales of antibiotics

We first describe the raw rates of OTC antibiotic sales before turning to a regression analysis that allows us to control for time trends in sales and for characteristics of the pharmacies, so as to thoroughly assess the effectiveness of our interventions. Figure 3 displays the frequencies of OTC sales of antibiotics across waves and treatments. As illustrated also in the bottom panel of Table 1, OTC antibiotic dispensing was a common practice among pharmacists in Addis Ababa before our interventions. We find indeed that one in two pharmacists are willing to dispense antibiotics without prescription in wave 1. The Chi-square test and the F-statistic in the bottom panel of Table 1 indicate that pre-intervention OTC dispensing rates as well as pre-intervention prices do not differ significantly across treatments, which confirms successful randomization.

Moving to the rates just after the interventions (wave 2), we observe a sizable drop in OTC antibiotic dispensing in all three experimental treatments but not in the control. More precisely, both letters halve the OTC dispensing rates compared to pre-treatment levels; the poster has a slightly weaker short-run effect as it reduces OTC antibiotic sales by one third.

The dispensing rates in wave 3 indicate that the effect of our informational interventions does not

[15] See Table D.1 in Appendix D for a detailed overview of the distribution of the pharmacies across sub-cities and treatments.

Table 1: Treatment randomization of visits

Variable	Treatments: Coercive	Appeal	Poster	Control	Overall	Test statistic
Wave						
Wave 1	31.08%	31.00%	31.99%	30.17%	31.06%	$\chi^2(6) = 0.714$
Wave 2	34.99%	34.68%	34.44%	34.31%	34.60%	
Wave 3	33.93%	34.33%	33.57%	35.52%	34.34%	
Pharmacist's gender						
Female	54.45%	56.39%	62.41%	58.28%	57.9%	$\chi^2(3) = 8.091^*$
Male	45.55%	43.61%	37.59%	41.72%	42.1%	
Time of visit						
Before 5pm	74.07%	77.58%	77.62%	78.1%	76.86%	$\chi^2(3) = 3.327$
After 5pm	25.93%	22.42%	22.38%	21.9%	23.14%	
Day of visit						
weekday	80.64%	82.49%	81.12%	82.24%	81.63%	$\chi^2(3) = 0.892$
weekend	19.36%	17.51%	18.88%	17.76%	18.37%	
Presented case						
URTI	45.12%	46.94%	45.28%	44.66%	45.49%	$\chi^2(6) = 9.496$
UTI-Product based	27.71%	26.44%	30.24%	24.14%	27.12%	
UTI-Symptom based	27.18%	26.62%	24.48%	31.21%	27.38%	
No. of visited pharmacies	563	571	572	580	2286	
Wave 1						
OTC Sales	53.14%	59.32%	50.82%	53.71%	54.23%	$\chi^2(3) = 2.808$
Mean of asked price (Birr)	65.344	69.293	74.854	71.462	70.206	$F(3, 365) = 0.504$
SD of asked price	52.143	49.232	59.148	52.077	53.052	

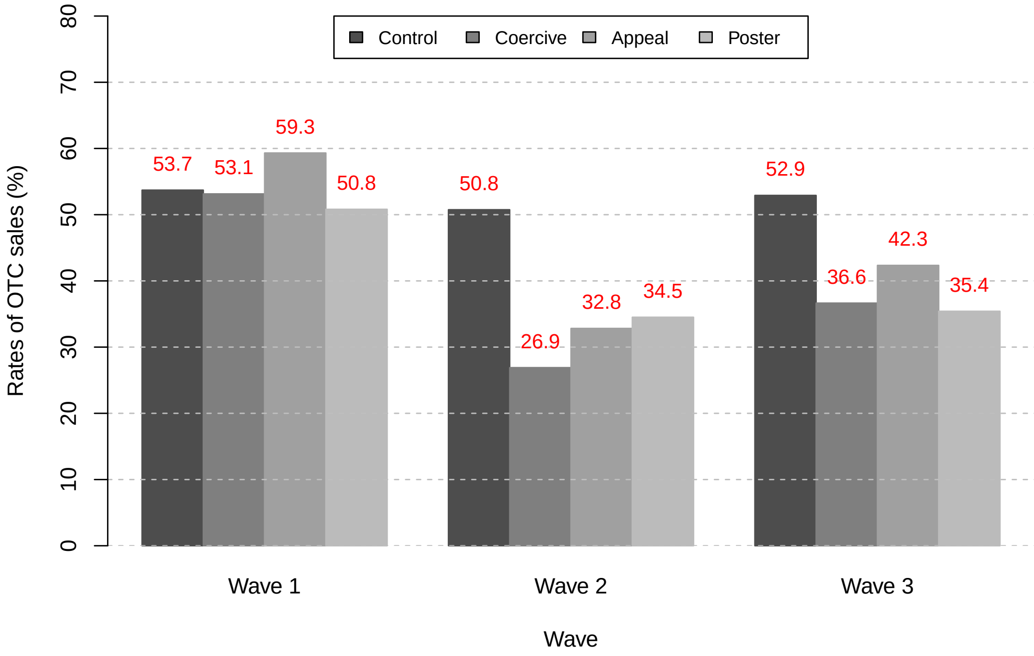
Notes: * p-value < 0.05.

vanish 5 months after their implementation. Specifically, while the letters seem to lose some power over time, with an increase of about 10 percentage points in the selling rates compared to wave 2, the effect of the poster remains stable. It is worth noting that the OTC dispensing behavior of the pharmacies in the control group remains constant over time, which is suggestive of weak spillover effects of the treatments on the untreated pharmacies.

4.3 Difference-in-difference treatment effects

To fully exploit the panel structure of our data and accurately measure the effect of our interventions, we estimate difference-in-difference (DiD) treatment effects using the following specification:

Figure 3: Frequency of OTC sales of antibiotics by wave and treatment.



Notes: The figure illustrates the dispensing rates of OTC antibiotics by pharmacists over the three waves and the four treatments. Wave 1 shows the pre-intervention rates, wave 2 displays the rates 3 weeks after the interventions, and wave 3 shows the rates 5 months after the interventions.

$$
\begin{aligned}
Y_{it} = \alpha + \alpha_C dC_i + \alpha_A dA_i + \alpha_P dP_i + \alpha_2 w2 + \alpha_3 w3 + \\
+ \boldsymbol{\beta_{C2}}(dC_i \times w2) + \boldsymbol{\beta_{A2}}(dA_i \times w2) + \boldsymbol{\beta_{P2}}(dP_i \times w2) + \\
+ \boldsymbol{\beta_{C3}}(dC_i \times w3) + \boldsymbol{\beta_{A3}}(dA_i \times w3) + \boldsymbol{\beta_{P3}}(dP_i \times w3) + \\
+ \gamma X_{it} + \delta Z_i + \epsilon_{it} \quad (1)
\end{aligned}
$$

where i indicates the pharmacy and t the wave. Depending on the analysis, the dependent variable Y_{it} is either a dummy variable taking the value 1 if pharmacy i decides to sell OTC antibiotics at wave t or the price charged by pharmacy i when selling at wave t. The explanatory variables include three treatment dummies indicating whether pharmacy i receives the Coercive letter (dC_i), the Appeal letter (dA_i), or the poster (dP_i); two wave dummy variables $w2$ and $w3$ that assume value 1 when the visit happened in wave 2 and wave 3, respectively; a set of control variables X_{it} that vary across pharmacies and over waves (e.g., the gender of the pharmacist, the case presented by the SP, the time of the visit); a set of control variables Z_i that remain constant over waves but vary across pharmacies (e.g., the dummies indicating the sub-city of pharmacy i). The coefficients on the interactions between the treatment and wave dummies—reported in bold in Equation (1)—are our primary outcomes of interest. For instance, $\boldsymbol{\beta_{C2}}$ identifies the average treatment effect of the Coercive letter in wave 2 (compared to wave 1) and $\boldsymbol{\beta_{P3}}$ identifies the effect of the poster in wave 3 (compared to wave 1).

Table 2 presents the estimated models. Columns (1) and (3) include as explanatory variables treatment and wave dummies; columns (2) and (4) include additional controls for characteristics of the pharmacists and the visits. Figure 4 provides a graphical representation of the DiD treatment effects, as estimated in the full models. Starting from the decision to sell OTC antibiotics (see columns (1) and (2) in Table 2 and Figure 4a), in both model specifications, the estimated coefficients of the interaction terms between the treatment dummies and $w2$ are negative and statistically significant, which confirms the patterns discussed above for Figure 3, namely that the likelihood of dispensing OTC antibiotics decreases significantly in the short-run: the decrease is of about 24 percentage points for the pharmacists receiving either the Coercive or the Appeal letter and of about 12 percentage points for the pharmacists receiving the poster. Consistent with the graphical results discussed above, we observe significant treatment effects also after 5 months, as shown by the estimated coefficients of the interaction terms between the treatment dummies and $w3$. There are, however, some differences across interventions in wave 3. Specifically, while the effect of the poster remains robust over time, the effect of both letters declines by about 7 percentage points compared to the short-run. Overall, the comparison between column (1) and column (2) shows that the estimated effects are robust to the introduction of different control variables.

Turning to the effect of the interventions on the price requested for the antibiotics, the estimated coefficients in column (3) of Table 2 indicate that prices are not affected by the interventions in either wave 2 or wave 3. This result does not change when we control for the pharmacist's gender, the type of drug outlet, the time and day of the visit, and the presented case (see column (4) and Figure 4b).

Some interesting results emerge when considering the estimated effect of the control variables. As compared to females, male pharmacists are significantly more likely to sell OTC antibiotics and ask for higher prices. Drugstores have a significantly higher likelihood of selling OTC antibiotics than community pharmacies, but they ask for lower prices. The likelihood to dispense OTC antibiotics increases significantly after 5 pm, when the authority is less likely to inspect the pharmacy. Lastly, we observe that a specific antibiotic request increases the likelihood of OTC dispensing by 6 percentage points across waves and treatments.[16]

[16] If we focus solely on wave 1 and compare OTC antibiotic dispensing in the two UTI cases, we find that

Table 2: Regression results on DiD treatment effects

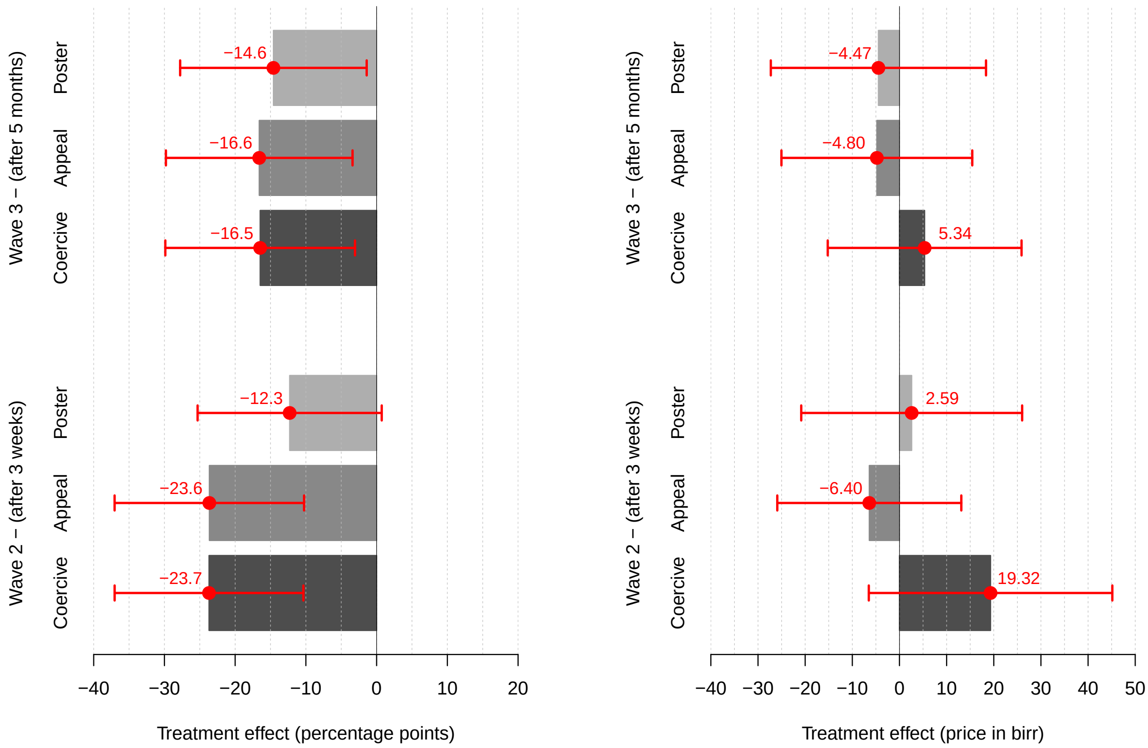
	d(sell OTC)$_{it}$		Price (Birr)	
	(1)	(2)	(3)	(4)
dC_i	0.001	−0.003	−7.466	−9.363
	(0.055)	(0.054)	(8.043)	(7.981)
dA_i	0.058	0.056	−3.006	−4.341
	(0.054)	(0.054)	(7.656)	(7.618)
dP_i	−0.030	−0.028	0.332	0.868
	(0.052)	(0.052)	(8.619)	(8.411)
$w2$	−0.032	−0.053	−6.794	−5.910
	(0.048)	(0.048)	(7.560)	(7.468)
$w3$	−0.007	−0.021	2.445	3.217
	(0.048)	(0.048)	(7.581)	(7.476)
$dC_i \times w2$	−0.239***	−0.237***	16.864	19.319
	(0.068)	(0.068)	(13.071)	(13.174)
$dA_i \times w2$	−0.237***	−0.236***	−8.245	−6.399
	(0.068)	(0.068)	(10.011)	(9.956)
$dP_i \times w2$	−0.131*	−0.123°	4.004	2.592
	(0.066)	(0.066)	(12.107)	(11.951)
$dC_i \times w3$	−0.167*	−0.165*	4.492	5.339
	(0.069)	(0.068)	(10.521)	(10.486)
$dA_i \times w3$	−0.164*	−0.166*	−4.970	−4.797
	(0.068)	(0.067)	(10.366)	(10.324)
$dP_i \times w3$	−0.150*	−0.146*	−3.237	−4.465
	(0.068)	(0.067)	(11.730)	(11.644)
d(male)$_{it}$		0.090***		7.496*
		(0.022)		(3.277)
d(drug outlet)$_i$		0.095***		−10.851**
		(0.026)		(3.531)
d(before5pm)$_{it}$		−0.082***		4.858
		(0.023)		(3.745)
d(wknd)$_{it}$		−0.001		−7.168°
		(0.028)		(3.925)
d(UTI-P)$_{it}$	−0.020	−0.019	12.601**	11.866*
	(0.024)	(0.024)	(4.675)	(4.625)
d(UTI-S)$_{it}$	−0.062*	−0.065**	12.102**	11.565**
	(0.025)	(0.025)	(3.880)	(3.894)
Constant	0.526***	0.550***	67.803***	63.649***
	(0.061)	(0.067)	(9.962)	(10.645)
No. of Observations	2,286	2,285	981	980
No. of Pharmacies	831	831	587	586
Robust S.E.	✓	✓	✓	✓
Sub-city dummies	✓	✓	✓	✓
R^2	0.050	0.071	0.047	0.063
F Statistic	5.441***	6.646***	2.157**	2.481***
F Statistic df	(22; 2263)	(26; 2258)	(22; 958)	(26; 953)

Notes: In columns (1) and (2), the dependent variable is a dummy taking the value 1 if the pharmacist sells the antibiotic OTC. In columns (3) and (4), the dependent variable is the requested price in Birr (the unit of currency in Ethiopia). Control variables: $d(\text{male})_{it} = 1$ for male pharmacists; $d(\text{drug outlet})_i = 1$ for drugstores; $d(\text{before5pm})_{it} = 1$ for visits before 5 pm; $d(\text{wknd})_{it} = 1$ for visits over the weekend; $d(\text{UTI-P})_{it} = 1$ and $d(\text{UTI-S})_{it} = 1$ for the UTI cases with and without specific antibiotic request, respectively. Robust standard errors clustered at the pharmacy level are in parentheses. Sub-city dummies are included in the analysis, with sub-city 1 as the reference category.
*** p-value ≤ 0.001, ** p-value < 0.01, * p-value < 0.05, $^{\circ}$ p-value < 0.10.

Figure 4: Estimated DiD treatment effects on the decision to sell OTC antibiotics and on the asked price (compared to the pre-intervention levels).

(a) Decision to sell

(b) Price in Birr



Notes: Panel (a) presents the DiD treatment effects as estimated in column (2) of Table 2. Panel (b) displays the DiD treatment effects as estimated in column (4) of Table 2. The error bars show the 95% confidence interval. In each panel, the three bottom bars correspond to the short-run treatment effects (measured 3 weeks after the interventions) and the three top bars represent the long-run treatment effects (measured 5 months after the interventions).

4.4 Heterogeneous treatment effects

As the average treatment effects of a particular intervention can conceal substantial variations in how specific subgroups respond to the intervention (Ferraro and Miranda, 2013), we conclude our analysis by exploring the presence of heterogeneous treatment effects. We select observable covariates that could be important modifiers of the effects. Specifically, we select two visit characteristics (i.e., the time/day of the visit and the case presented by the SPs), the pharmacist's gender, and the type of drug outlet (community pharmacy or drugstore).

Standard working hours in Ethiopia are Monday-Friday, from 8 am to 5 pm (as confirmed also

actively requesting antibiotics increases the likelihood of selling non-prescribed antibiotics by about 18% (see Table D.2 in Appendix D).

by AAFMHACA). Random inspections of the pharmacies by the regulatory authority are thus more likely to take place within this time frame, which we refer to as the 'normal inspection time'. If pharmacists expect this, our interventions (especially the Coercive letter) may be less effective after 5 pm on weekdays and over weekends, i.e., outside the normal inspection time.

The pharmacist's gender may also affect treatment responses. It has been shown that women are generally more prosocial than men (Brañas-Garza et al., 2018; Bilén et al., 2021), as well as more honest and rule-abiding (Dreber and Johannesson, 2008; Houser et al., 2012). Therefore, female pharmacists may be more responsive to our interventions that emphasize the pharmacist's key role in limiting the AMR phenomenon or the illegality of dispensing OTC antibiotics.

Druggists, as compared to pharmacists, have fewer years of education and less up-to-date professional training, and may therefore lack adequate knowledge about the causes and consequences of AMR. Belachew et al. (2022) find that druggists in northwestern Ethiopia (Amhara region) report to dispense OTC antibiotics more frequently than pharmacists do. The type of drug retail outlet may thus moderate treatment effects in our experiment.

Finally, we consider heterogeneity based on whether the SPs explicitly ask for an antibiotic or not. As said above in Section 3.2, a specific antibiotic request may indicate knowledgeable and informed customers, which can influence the pharmacists' willingness to sell OTC antibiotics.

To estimate heterogeneous treatment effects along these four dimensions, we augment Equation (1) allowing for triple interactions between the treatment dummies, the wave dummies, and a heterogeneity dummy for one of the covariates listed above. We thus run independent regressions for each covariate. Table 3 presents the results. Model 1 shows heterogeneous effects for the time of the visit. Model 2 considers heterogeneity in the pharmacist's gender. Model 3 looks at heterogeneity in the type of drug outlet. Model 4, finally, assesses heterogeneous effects for explicit antibiotic requests. Each model reports two columns of treatment effects, one for each possible level of the investigated covariate. The results of Wald statistics comparing the estimated coefficients for the two levels of each covariate are reported in the last two rows of the table.

Starting with the effects of the interventions within and outside the normal inspection time (Model 1), the Wald test rejects the null hypothesis that the coefficients are the same. The estimations indicate that the letters have strong and significant effects during rather than outside normal inspection times, while the contrary holds for the poster, which has significant effects outside, but not within, normal inspection times. We discuss potential explanations for this surprising result in Section 5.

Table 3: Heterogeneous treatment effects

	Dependent variable: $d(\text{sell OTC})_{it}$							
	Model 1		Model 2		Model 3		Model 4	
	Normal insp. time		Gender		Drug outlet type		Explicit antibiotic request	
	Yes	No	Female	Male	Pharmacy	Drugstore	Yes	No
$dC_i \times w2$	-0.373^{***}	-0.073	-0.232^{*}	-0.253^{*}	-0.232^{**}	-0.249°	-0.320^{*}	-0.204
	(0.086)	(0.125)	(0.090)	(0.109)	(0.081)	(0.132)	(0.137)	(0.126)
$dA_i \times w2$	-0.289^{**}	-0.158	-0.263^{**}	-0.204°	-0.204^{*}	-0.301^{*}	-0.421^{**}	-0.121
	(0.088)	(0.122)	(0.090)	(0.107)	(0.082)	(0.124)	(0.137)	(0.130)
$dP_i \times w2$	-0.051	-0.237^{*}	-0.131	-0.111	-0.107	-0.131	-0.303^{*}	-0.168
	(0.086)	(0.114)	(0.083)	(0.113)	(0.078)	(0.133)	(0.136)	(0.131)
$dC_i \times w3$	-0.157°	-0.166	-0.173°	-0.165	-0.136°	-0.231	-0.307^{*}	-0.239°
	(0.089)	(0.126)	(0.090)	(0.113)	(0.079)	(0.142)	(0.138)	(0.124)
$dA_i \times w3$	-0.163°	-0.158	-0.186^{*}	-0.143	-0.158^{*}	-0.187	-0.397^{**}	-0.056
	(0.084)	(0.122)	(0.090)	(0.106)	(0.078)	(0.131)	(0.139)	(0.128)
$dP_i \times w3$	-0.121	-0.162	-0.152°	-0.123	-0.141°	-0.113	-0.422^{***}	-0.074
	(0.087)	(0.120)	(0.085)	(0.116)	(0.075)	(0.148)	(0.128)	(0.135)
No. of Observations	2,285		2,285		2,285		1,246	
No. of Pharmacies	831		831		831		713	
Robust S.E.	✓		✓		✓		✓	
Sub-city dummies	✓		✓		✓		✓	
R^2	0.077		0.071		0.075		0.093	
F Statistic	5.233^{***}		4.794^{***}		5.048^{***}		3.529^{***}	
F Statistic df	(36; 2248)		(36; 2248)		(36; 2248)		(35; 1210)	
Wald test F Stat	2.830^{**}		0.067		0.254		1.126	
Wald test F df	(6; 2248)		(6; 2248)		(6; 2248)		(6; 1210)	

Notes: The table reports the heterogeneous treatment effects for 4 different factors: (1) whether the visit was within or outside the normal inspection time; (2) whether the gender of the pharmacist was female or male; (3) whether the visited drug outlet was a pharmacy or a drugstore; and (4) whether the SP explicitly requested an antibiotic. The dependent variable in all models is a dummy equal to 1 when the pharmacy offers the antibiotic. The effects are estimated using linear probability models that include a triple interaction between the treatment dummies, the wave dummies, and the dummy capturing the heterogeneous effect. Robust standard errors clustered at the pharmacy level are in parentheses. The "Wald test" row presents a test of the null hypothesis that the estimated coefficients are the same for the two levels of the heterogeneity dummy. Sub-city dummies are included, with sub-city 1 as the reference category.

*** p-value ≤ 0.001, ** p-value < 0.01, * p-value < 0.05, $^{\circ}$ p-value < 0.10.

As to the heterogeneous effects of the interventions for male and female pharmacists (Model 2), the two types of drug outlet (Model 3), and whether a specific antibiotic is requested or not (Model 4), we observe similar reactions to the interventions in the different subgroups. The signs and the statistical significance of the estimated coefficients suggest a longer persistence of the effect of the interventions for females than for males and a stronger effect when an antibiotic is expressly requested. However, the Wald test comparing the treatment effects of the subgroups fails to reject the null hypothesis of homogeneity for the coefficients of all three models.

5 Discussion

As a first empirical investigation of three distinct informational interventions targeted at community pharmacists and druggists in Addis Ababa, our study provides valuable insights into the OTC sales of antibiotics in an urban setting of a developing country. First, in line with previous research (Erku et al., 2016; Koji et al., 2019), our findings indicate a markedly high prevalence of OTC antibiotic sales in Addis Ababa. Indeed, a bit more than 50 percent of the untreated pharmacies are willing to dispense antibiotics without a medical prescription. Second, the OTC antibiotic dispensing rate declines significantly for treated pharmacies in both the short-run (three weeks after the interventions) and the long-run (five months after the interventions). Importantly, the effect of the poster remains stable over time, whereas the impact of the one-time letters is stronger in the short-run than in the long-run. On the one hand, this shows that pharmacists do not become accustomed to a continuous stimulus like the poster and continue to react to it even after 5 months. On the other hand, the attenuation of the effect of the letters suggests that their impact may fade away over time. Although it is tempting to conclude—in a vein similar to the home energy reports studied by Allcott and Rogers (2014)—that further deliveries can be necessary to prevent the decline, the effect of repeated reminders is not unambiguous, as repeated reminders may lose credibility and salience (e.g., if the pharmacists realize that random audits by the authority do not rise upon receipt of the letters, especially the Coercive one). However, if the waning effect of the letters is due to memory decay or removal of the "cue" (as suggested by Allcott and Rogers, 2014), additional deliveries may be helpful.

A further remarkable result is that a direct request for an antibiotic has a modest effect on the pharmacists' likelihood to sell OTC antibiotics, compared to an otherwise identical situation where the SPs did not ask for a specific antibiotic (41.6% vs 58.5%). Previous SP studies report that requests for specific antibiotics are fulfilled OTC by more than two-thirds of the visited pharmacies (Erku et al., 2016), and actively requesting antibiotics nearly doubles community pharmacists' OTC dispensing rates (Wang et al., 2021). We find, to the contrary, that in wave 1, for the UTI scenario, an explicit antibiotic request increases OTC antibiotic sales by approximately 18 percentage points. The heterogeneity analysis additionally reveals that all the experimental treatments reduce the likelihood of OTC antibiotic dispensing in a similar manner, independently of asking or not asking for a specific antibiotic.

While no significant treatment heterogeneity is detected for the pharmacist's gender and the type of visited drug outlet, we observe statistically significant heterogeneous treatment effects related to the time of visit. Specifically, the letters are found to have a stronger effect within, rather than outside, normal inspection time (i.e., before 5 pm on weekdays), whereas the poster is more effective after 5 pm and on weekends. This suggests that pharmacists update their beliefs about the likelihood of inspection in response to the letters (even to the Appeal one) but not in response to the poster. Although both the letters and the poster were hand-delivered by AAFMHACA personnel, the presence within the pharmacy of the authority may be more strongly related to a sense of auditing and checking upon receipt of the letters, which targeted specifically at pharmacists and had also to be signed, than upon receipt of the poster, which may have been perceived as addressing not only the pharmacist but also the customers. Anecdotal reports from the health officials that delivered the interventions speak in favor of this interpretation. According to such officials, the pharmacists treated with the poster welcomed it and expressly said that it would save them wrangling with the customers, particularly regular ones. As to the pharmacists receiving the Coercive letter, they became defensive and claimed that they do not sell antibiotics without prescription. Recipients of the Appeal letter diligently agreed with the message in the letter.

Although our preferred interpretation of the significant effect of the Appeal letter is that this letter made the pharmacist's key role in fighting AMR salient, we cannot rule out that the effect operates through a different channel. The observed significant treatment heterogeneity with respect to the time of visit hints at the possibility that the Appeal and Coercive letters work in a similar way, which differs from that of the poster. In particular, both letters may affect the pharmacists' expected economic incentives via an update of their beliefs about the probability of being audited and fined.

A final noteworthy feature of our study is that the interventions have no impact on the intensive margin, i.e., on the price charged by the pharmacists in case of antibiotic sales. In Ethiopia, as in most developing countries, prices for pharmaceutical products are often not displayed to the public and, since antibiotic prices are not controlled or regulated by the government, price variations for antibiotics can be quite large (Gutema and Engidawork, 2018). Had the treated pharmacists perceived their OTC antibiotic sales as risky and, as such, warranting a premium, they could well have charged a higher price for selling the antibiotics without a prescription. A high price would also have allowed the pharmacists to offset the potential loss of revenue due to a decrease in the quantity sold. However, notwithstanding the possibility of spillovers of the experimental treatments on antibiotic prices, our difference-in-difference analysis reveals that prices are not significantly affected by the interventions.

To measure OTC antibiotic dispensing we made use of SPs. Previous research argues in favor of the use of SPs when the risks and burdens imposed on those under scrutiny are minimal compared to the benefits and knowledge to be gained by the society (Rhodes and Miller, 2012). We claim that our experiment meets this requirement for three reasons. First, asking for OTC antibiotics is the norm in Ethiopia and thus our SPs would cause minor psychological harm to the pharmacists when requesting medicines. Second, the SPs were instructed not to push their requests but to accept the pharmacist's decision. Finally, finding an effective way to curb the sale of OTC antibiotics has extremely important implications for the global economy, especially for developing countries.

Some limitations of this study are worth outlining. We observe the effect of the interventions on the pharmacists' likelihood of dispensing OTC antibiotics, but we do not provide evidence on the total amount of antibiotic sales. Specifically, we did not assess whether patients, who were refused OTC antibiotics by one pharmacist, sought them from another pharmacist or visited a physician to obtain a prescription.

A second drawback of our interventions is that they may not be welfare enhancing if truly needy patients, who cannot afford to visit health centers, were refused antibiotics. In many developing countries, there is a need to balance excessive antibiotic use and access to antibiotics. This is of particular importance in Ethiopia, where health centers and physicians are expensive, scarce, or difficult to reach. Hence, it may be useful to complement our interventions with a policy that gives patients easy access to physicians and healthcare in general. For example, community pharmacies could provide patients with free vouchers to visit the nearest health center.

6 Conclusions

Our simulated patient study indicates that low-cost informational interventions—consisting of two types of letters and a poster, all hand-delivered to community pharmacists and druggists by the health authority—help reduce non-prescription sales of antibiotics in Addis Ababa, the capital city of Ethiopia, where OTC antibiotic dispensing is a common practice. Health regulators and policymakers wishing to curtail the problem may thus consider including the proposed interventions in their toolbox to optimize antibiotic dispensing.

Curbing OTC antibiotic sales, although undoubtedly relevant, is only one component of a more comprehensive strategy to tackle AMR. The effectiveness of antibiotics and the aggravation of AMR spread are also influenced by physicians' prescribing behavior and patients' compliance with antibiotic therapy. Nonetheless, our results provide the first evidence that letters highlighting either the legal consequences of OTC antibiotic dispensing or the pharmacists' role in the health system, as well as a poster reminding readers that antibiotics cannot be sold without a prescription, have desirable effects on pharmacists, one of the three main actors involved in the process of antibiotic consumption.

Regarding the Appeal letter, there are different channels through which it may operate. Disentangling whether this letter works because it makes the moral argument salient or because it changes the pharmacists' expected economic incentives may be a fruitful avenue for future research. For example, the recipients may not perceive the Appeal letter as a threat or pressure from the authority if it were hand-delivered by ordinary citizens rather than by AAFMHACA personnel.

Our study site is the capital and largest city of Ethiopia. It will be interesting to implement a nationwide scale-up of the interventions to understand whether they maintain efficacy at scale. The results gathered herein thus represent a first step towards designing further informational interventions aimed at encouraging pharmacists to adhere to appropriate antibiotic dispensing behavior.

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A Details on scripts for SPs

Case	Script	Ideal management
Pediatric URTI	The two-year-old son has been coughing for the past five days. He has a slight fever and has been crying and whiny. Requesting for anti-cough medicines. If asked about the type of cough, the SP answers that the cough has sputum.	Advise to visit the nearest health center. Provide anti-fever medicine for immediate relief.
UTI (symptom-based)	A female SP complains of burning sensation while urinating, chills, and a slight fever. Requesting for pain relief medicines. The SP explains that this has been repeated and that she had a similar experience before.	Advice to visit the nearest health center for diagnosis.
UTI (product-based)	An informed female SP complains of burning sensation while urinating, chills, and a slight fever. Requesting for Cipro/Ciprofloxacin. The SP explains that this has been repeated and that she had a similar experience before.	Advice to visit the nearest health center for diagnosis.

B Text of the Letters (originally in Amharic)

በአዲስ አበባ ከተማ አስተዳደር የምግብ፣ የመድኃኒት፣ የጤና ክብካቤ
አስተዳደርና ቁጥጥር ባለስልጣን
Addis Ababa City Administration Food, Medicine, Health Care Administration and Control Authority

Date:

To: *XYZ* Pharmacy/Drugstore

Addis Ababa

Object: Over the Counter Sales of Antibiotics

As you are aware, bacterial infection diseases like pneumonia, tuberculosis and diarrhoea are a major cause of death in Ethiopia. The emergence of antimicrobial resistance threatens the management of bacterial infections. Antimicrobial resistance is a result of inappropriate or unnecessary antibiotic use. In Ethiopia, there are indications of antibiotic misuse by healthcare providers, unskilled practitioners, and drug consumers. One common channel of abuse is the sale of non-prescribed antibiotics for diseases like sore throat, common cold, and diarrhoea. In a recent audit of pharmacies by experts, the Addis Ababa Food, Medicine and Healthcare Administration and Control Authority (AAFMHACA) found numerous counts of noncompliance with the regulations of the pharmaceutical sector.

[*Pharmacists in the Coercive letter treatment read*:

The authority reminds you that according to the Ethiopian FMHACA, Council of Ministers Regulation No. 299/2013, and the AAFMHACA, Council of Ministers Regulation No. 30/2012, it is illegal to dispense prescription-only medicines like antibiotics over the counter. The authority can undertake random audits of health facilities as needed. If misconduct is found, the authority will investigate and propose appropriate administrative measure as per the law, which can amount to suspension of license or certificate of competence.
Given these consequences, the authority advises you against non-prescription sales of antibiotics.]

[*Pharmacists in the Appeal letter treatment read*:

The authority believes that you as a pharmacist have a key role in encouraging appropriate use of medicines and curtailing antimicrobial resistance. In the pursuit of the same, the authority reminds you to politely turn away patients looking to purchase an antibiotic without prescription and further advise them to visit the nearest health centre for proper diagnosis. In addition, you can contribute to safeguarding antibiotics by counselling patients on appropriate antibiotic use when prescribed and on antimicrobial resistance.
Given the pharmacist's unique position in the health system, the authority advises you to take a lead role in combating antimicrobial resistance.]

Regards

መልስ ሲፅፉልን የኛን ደብዳቤ ቁጥርና ቀን ይጥቀሱ።
In replying Please Mention our reference number and date
Location : Kirkos Sub city ,Bole,Flamingo Tommy Tower Bulding Tel. 251- 118284079/0115586437 FAX: 251-372-43-99
E-mail: aahb@ethionet.et P.O.BOX 15286 Addis Ababa, Ethiopia

C Poster hung on the pharmacy wall (originally in Amharic)

Antibiotics medicines cannot be **sold** without doctor's prescription!

Help us combat antimicrobial resistance!

Addis Ababa Food, Medicine and Health Care Administration and Control Authority

D Additional tables

Table D.1: Pharmacy type per treatment and number of pharmacies per sub-city and treatment

		Treatments				
Variable	Value	Coercive	Appeal	Sticker	Control	Test
Pharmacy type	Comm. pharmacy	148	139	145	157	$\chi^2(3) = 2.218$
	Drugstore	52	64	55	71	
Sub-city	1	9	13	14	15	$\chi^2(27) = 14.79$
	2	15	17	18	14	
	3	11	10	12	8	
	4	43	42	39	46	
	5	10	6	8	17	
	6	12	15	7	14	
	7	36	39	40	43	
	8	11	8	9	10	
	9	29	30	35	33	
	10	24	23	18	28	

Table D.2: Effect of an explicit antibiotic request on the decision to sell OTC antibiotics in wave 1, UTI scenario

	Dependent variable: $d(\text{sell OTC})_{i1}$
$d(\text{UTI-S})_{i1}$	-0.178^{**}
	(0.067)
$d(\text{male})_{i1}$	0.128^{**}
	(0.047)
$d(\text{drug outlet})_{i1}$	0.103°
	(0.057)
$d(\text{before5pm})_{i1}$	0.007
	(0.065)
$d(\text{wknd})_{i1}$	-0.078
	(0.096)
Constant	0.574^{***}
	(0.121)
No. of Observations	450
No. of Pharmacies	450
Robust S.E.	✓
Sub-city dummies	✓
R^2	0.069
F Statistic	2.296^{**}
F Statistic df	(14, 435)

Notes: Linear probability model where the dependent variable is a dummy taking the value 1 if the pharmacist, when presented with the UTI scenario, sells OTC antibiotics in wave 1. Control variables: $d(\text{UTI-S})_{i1} = 1$ for the UTI cases without specific antibiotic request; $d(\text{male})_{i1} = 1$ for male pharmacists; $d(\text{drug outlet})_{i1} = 1$ for drugstores; $d(\text{before5pm})_{i1} = 1$ for visits before 5 pm; $d(\text{wknd})_{i1} = 1$ for visits over the weekend. Robust standard errors clustered at the pharmacy level are in parentheses. Sub-city dummies are included in the analysis, with sub-city 1 as the reference category.
*** p-value ≤ 0.001, ** p-value < 0.01, * p-value < 0.05, $^{\circ}$ p-value < 0.10.