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Elisabeth KEMPTER, Neha Bhardwaj UPADHAYAY

Faculty of Economics and Social Sciences
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Uncovering the Role of Education in the Uptake of Preventive Measures against Malaria in the African Population

Elisabeth KEMPTER[1], Neha Bhardwaj UPADHAYAY[2]

Abstract

In many African countries where malaria is endemic, this life-threatening disease is a leading cause of death. What role does education, in particular numeracy and literacy, play in malaria prevention and treatment-seeking? In this study we apply a birth cohort approach, which allows us to cover a time span of 60 years, and therefore, to provide a comprehensive view on the evolution of malaria prevention and treatment-seeking attitudes adapted among sub-Saharan African cohorts born during the 20th century. We use three different indicators to measure malaria control behavior: the share of respondents using insecticide-treated bednets (ITNs), the share of pregnant women taking antimalarial drugs, and the share of respondents taking their child to a medical facility when suffering from malaria symptoms like fever and cough. Our descriptive results suggest that younger birth cohorts are more likely to adapt malaria control measures than older ones.

Based on a sample of 33 African countries, 407 regions, and a total of 1,960 observations, we perform multiple regressions using the pooled OLS estimator. We find that being numerate as well as being literate is positively associated with malaria protection and health-seeking behavior, though the numeracy coefficients are of larger magnitudes indicating that numeracy is at least as important as literacy. While malaria prevention and treatment-seeking behavior is complex and influenced by unobservables, we cannot control for, we account for the most relevant factors like gender, socio-economic status, topology, and urban-rural settings. Our findings show that in addition to education, the involvement of women in health-care decision-making, as well as the exposure to media, is positively correlated with malaria control. On the other hand, we find that a low socio-economic status makes the adaption of adequate malaria prevention and treatment-seeking behavior more difficult. In highly elevated regions and regions with lower precipitation, where malaria is less prevalent, people seem to pay less attention to protection measures. Finally, while malaria is more acute in rural regions, in urban areas antimalarial drugs are also commonly used for protection.

Keywords- malaria, sub-Saharan Africa, insecticide-treated bednets (ITNs), numeracy, literacy

JEL Classification- H75, I12, I15, I18,

[1] Eberhard Karls University Tübingen, Germany *(elisabeth.kempter@uni-tuebingen.de)*

[2] ERUDITE, Université Paris Est Créteil, France *(neha-bhardwaj.upadhayay@u-pec.fr)*

Introduction

In many countries where malaria is endemic, this life-threatening disease, caused by Plasmodium parasites and transmitted to the human body through the bites of female infected Anopheles mosquitoes, is a leading cause of death. The latest WHO reports (2020, 2021) suggest that in 2020 there were 241 million cases of malaria in 85 countries worldwide and over 620 thousand deaths related to the preventable disease. Ninety-five percent of these malaria cases and deaths occurred in the African continent.[3] The most vulnerable groups, which are at high risk of being infected with malaria, are pregnant women and children aged under five. In 2020, infants and young children accounted for 80 percent of all malaria death in sub-Saharan Africa.

Before the 1970s, the global approach to fight malaria was designated to implement vertical top-down malaria elimination programs, without paying any attention to the belief systems, traditions, and behavior of local communities. Interventions took place in the absence of integrating the affected populations. Many of these programs, however, failed to achieve their objectives, which is why during the global conference on primary health care in Alma Ata in 1978 it was decided to end the period of vertical disease control programs and instead focus on horizontal community-based strategies for malaria eradication. While medical know-how is certainly essential, the successful accomplishment of such strategies does also rely on comprehending malaria-related beliefs as well as socio-economic, cultural, political, and environmental factors that shape malaria prevention and treatment-seeking attitudes of individuals and entire communities. The dismissal or ignorance of these aspects has led to public health efforts being delinquent in the past (Heggenhougen et al. 2003). With human behavior playing an important role in malaria control, advances in applied malaria research should therefore not only be made in the medical field but contributions in socio-economic science may equally be helpful in filling malaria research gaps.

In this paper, we aim to address the role of education in malaria prevention and treatment-seeking behavior focusing on sub-Saharan Africa, a highly malaria-endemic region. We argue that basic numeracy and literacy skills may mitigate existing misconceptions about

[3] While a total of twenty-nine countries accounted for 96 percent of malaria cases globally, only six African countries including Nigeria (27 percent), the Democratic Republic of Congo (12 percent), Uganda (5 percent), Mozambique (4 percent), Angola (3 percent) and Burkina Faso (3 percent) were responsible for just over half of all malaria cases. In terms of deaths, in 2020 infants and young children accounted for 80 percent of all malaria deaths in sub-Saharan Africa.

malaria (i.e., the disease is caused by excessive heat and overwork, Gessler et al. 1995; Ahorlu et al. 1997; De la Cruz et al. 2006) and this way positively contribute to the adaption of malaria control measures. While there exist several options to measure malaria prevention and treatment-seeking behavior, we use the following three proxy variables: The share of respondents sleeping under insecticide-treated mosquito nets, the share of pregnant women taking antimalarials, and the share of respondents seeking medical treatment in case their child shows malaria symptoms.

Studies that have investigated the link between education, and malaria-related knowledge as well as treatment-seeking behavior (e.g., Kaona et al. 2000; Tarimo et al. 2000; Fawole and Onadeko 2001), frequently comprise cross-sectional country and region-specific analyses based on primary data. Our aim is to provide a more holistic but detailed view on malaria prevention and treatment-seeking behavior in sub-Saharan Africa, which is why we base our study on a sample including 33 countries, which are divided into 407 African regions. Considering a time span of six birth decades including the 1940s to the 1990s our dataset contains a total of 1,960 observations.

Most results obtained by existing studies, covering this research area, are solely based on descriptive evaluations, probably due to the usage of rather small sample sizes. In this respect, we apply an econometric approach, which allows us to attribute causality to our findings. Moreover, while previous research considers more the quantity aspect of education and relies on input measures as a proxy (i.e., years of schooling attained), we employ numeracy and literacy indicators, which allow us to capture the quality aspect of education and to uncover to what extent education actually has been absorbed by the individuals. Our findings show that while both factors exert a positive influence on malaria prevention and treatment-seeking behavior, being numerate is at least as important in terms of magnitude as being literate.

The remainder of this paper is structured as follows. In the subsequent section, the progress made in global malaria control is discussed. Section 3 provides an overview of the literature looking at the relationship between human capital and malaria knowledge as well as prevention behavior. Section 4 describes the data sources and the various variables used in the analyses. Section 5 discusses the methods applied. Section 6 provides a summary of our results followed by a discussion in section 7. Section 8 concludes.

Progress made in global malaria control

In a worldwide effort to control malaria, around 1.9 billion rapid diagnostic tests and almost 2.3 billion insecticide-treated mosquito nets were distributed during the last two decades of which over 80 percent were delivered to Africa. At the same time (2000-2020), there was a decline in an estimated 1.7 billion cases and 10.6 million deaths related to malaria.

The rise in global attention towards malaria elimination has put forth global alliances of organizations such as the Multilateral Initiative on Malaria (MIM) and global partnerships like the Roll Back Malaria (RBM). These involve different actors committed to combat malaria including community health workers, researchers and academic institutions, malaria-endemic and donor countries, private sector, non-governmental, and international donor agencies, which have contributed millions of dollars to malaria research.

The Global Technical Strategy for malaria (GTS) 2016-2030, which was introduced by the World Health Assembly in 2015, aims at guiding countries in their progress towards malaria eradication. It sets out estimates of funding to achieve milestones related to the reduction in case incidence and mortality rate for the years 2020, 2025, and 2030. Total funding for malaria control and elimination was valued at US$ 3.3 billion in 2020, which was marginally higher than the 2019 figure of US$ 3.0 billion. Nevertheless, the money invested in 2020 fell short by US$ 3.5 billion since a global amount of US$ 6.8 billion was estimated to be required to stay on course towards the GTS milestones. The gap in funding needed and awarded funds has been progressively widening (from US$ 1.3 billion in 2017 to US$ 2.3 billion in 2018 to US$ 2.6 billion in 2019, and to US$ 3.5 billion in 2020). The funding remains concentrated in the area of drug development (36 percent of malaria funding between 2007-2018), followed by basic research (26 percent) and vaccine development (25 percent). Investments in vector control products and diagnostics were notably lower at 6.2 percent and 2.5 percent respectively (WHO 2020, 2021). The recently developed and first approved malaria vaccine by the World Health Organization is inter alia a successful outcome of the pooled funding invested in malaria control and elimination efforts.

Literature review

There is consensus amongst researchers that the human response to malaria and control programs is crucial to the success of malaria control strategies. This is also particularly relevant since a better grasp of health-seeking and treatment behaviour can lead to more effective health communication strategies for malaria and the promotion of early and effective treatment of clinical cases, especially among young children and pregnant women, who are most at risk of being infected with malaria.

There have been few systematic studies of how episodes of malaria are recognized and treated both, at the household and individual level. It is crucial to know how people, especially mothers and caretakers of young children, make decisions about whether to administer home remedies, consult traditional healers, or go to a clinic or hospital. Without information on health-seeking behavior, it would be difficult to develop an integrated strategy for reducing malaria infection and mortality.

The beliefs about the cause and transmission of malaria vary across societies according to educational, cultural, and economic factors, exerting influence on both preventive and treatment-seeking behavior. It is essential to take these perceptions into account and to address them since beliefs, deviating from correct scientific knowledge concerning the cause and transmission of malaria may hinder or delay appropriate treatment-seeking. In the worst-case scenario, they may lead to no actions being taken at all, which in turn can have serious consequences. For instance, research has shown that in some cases young children are deprived of insecticide-treated bednets due to the misconception that insecticides could also have toxic effects on children since they kill insects (Winch et al. 1997). Another example refers to the ingestion of bitter substances such as chloroquine, an antimalarial drug, which should be avoided during pregnancy on the grounds that bitter substances would cause miscarriage (Ndyomugyenyi et al. 1998; Launiala 2007).

While cultural traditions and beliefs should be respected, the provision of education and the development of numerical skills, including critical thinking ability, may contribute to the mitigation or even eradication of such misconceptions about malaria and therefore foster proper malaria prevention and treatment-seeking behavior. There is some evidence showing that education is positively associated with the acquisition of malaria-related knowledge (Kaona et al. 2000; Fawole and Onadeko 2001). In Africa, mothers are perceived as primary caregivers in the household and often first recognize when children fall sick by interpreting bodily and behavioral changes (Kidane 2000). They also believe to know when it is urgent to seek medical treatment and in which cases home remedies are effective (Mwenesi et al. 1995a). Evidence, however, shows that home treatment can result in taking inappropriate dosages of medication or prevent from getting patients to health facilities in time, in case their condition worsens (McCombie 1996). Besides, those who decide to “self-treat” tend to buy drugs from poorly informed sellers (Massele et al. 1993), sometimes even from primary school children who work as “shopkeepers” (Geissler et al. 2000). This indeed raises concerns about provided misinformation on appropriate treatment. Hence, to improve the effectiveness and success of malaria control strategies, primary attention should be paid to the behavior of mothers and caregivers when it comes to malaria prevention and treatment.

Literature on the relationship between education and malaria prevention attitudes or practices is inconclusive. De La Cruz et al. (2006) carried out a study about the use of mosquito nets in Ghana in which participants were asked questions about the cause and consequences of malaria, symptoms of the disease, risk groups, and ways of protection and treatment. Results show that survey respondents who protected themselves from malaria by using insecticide-treated bednets (ITNs) were not more knowledgeable about the disease than respondents who did not. In some cases, non-users of mosquito nets showed even more knowledge about malaria and its prevention than users, revealing that more education does not necessarily increase the usage of bednets. Dupas (2009) investigates what factors make rural households in Kenya invest in malaria prevention and finds no significant correlation between the educational level of household members and the take-up of malaria control devices. Koram et al. (1995) conduct a study in a peri-urban area of the Gambia exposed to seasonal malaria transmission. Based on a sample of 350 Gambian children they find no association between malaria in children and the overall education level of the children’s parents or guardians. In Gabon, Kun et al. (1998) analyze a sample of 100 children suffering from severe malaria who were matched to 100 children with mild malaria symptoms, based on sex, age, and provenance. These children were tracked and the time until the first reinfection was documented. The authors were unable to detect a significant correlation between neither the severity of the disease nor the time to first reinfection and socio-economic factors including the mother’s level of education.

On the other hand, some researchers find evidence of education being important for malaria prevention and treatment. Tarimo et al. (2000) examine the perceptions and knowledge of mothers on childhood malaria in Tanzania, focusing on the Kibaha district. They conducted a cross-sectional survey in which the respondents were asked about potential symptoms they associate with malaria. Their results show a significant and positive correlation between the recognition of fever, some other malaria symptoms, and having at least completed primary education. 81.3 percent of mothers were aware of the fact that high fever is likely to cause convulsions and deteriorate the child’s condition. In addition, Tarimo et al. (2000) investigate the treatment-seeking behavior of caretakers. While mothers are at first inclined to cure their children with home remedies (e.g., bathing, giving paracetamol or aspirin, etc.), the study finds that in a second step 92.9 percent of mothers would seek medical treatment in a health facility. Further 98.3 percent claimed that laboratory tests were useful to confirm the diagnosis of their child being sick. Another 89.4 percent stated that laboratory tests were important in order to first recognize what kind of disease or parasites their child suffers from and second to be able to take appropriate and effective treatment measures. The perceived necessity by mothers of performing laboratory tests, resulting from the described reasons above, is positively associated with having completed primary or higher education. Fawole and Onadeko (2001) focus on Nigeria's urban areas and analyze the treatment-seeking behavior of poor mothers and caregivers of children with fever. They find the education level to be a significant determinant of first aid sought. While 40.2 percent of mothers and caregivers with secondary education sought immediate treatment in a health facility, only 28.8 percent of those with no formal education visited a medical center. The majority of mothers with no education at all (52.6 percent) sought help from a traditional healer. Moreover, more educated mothers (41 percent) claimed to obtain drugs from patent medicine sellers (PMS) as compared to illiterate caregivers (25 percent). Kaona et al. (2000) carry out a KAP (Knowledge, Attitudes, and Practices) survey in the districts of Choma and Mporokoso, belonging respectively to the southern and northern provinces of Zambia. Based on data from 392 male and 415 female participants, the objective of this survey was to assess the respondents' knowledge regarding the cause of malaria as well as their preventive actions taken against the disease. While the authors do not find a correlation between education and awareness of malaria transmission, the level of education is positively associated with the intake of chloroquine (as compared to traditional or no medicine) and other preventive measures taken. Schultz et al. (1994) conduct another KAP survey in Malawi to gather information on women's use of antenatal clinic (ANC) services comprising malaria prevention and treatment during pregnancy. Using a sample of 809 pregnant women out of which 43 percent had no formal education and 70 percent had achieved below five years of schooling, the authors find education to be the only significant determinant of starting and pursuing ANC and giving birth in hospital.

Tobin-West and Kanu (2016) conduct a cross-sectional study, analyzing malaria prevention methods and their determinants among women of reproductive age (15-49) in Nigeria. While 89 percent out of 797 respondents showed a sound knowledge of malaria, which was significantly correlated with their educational level, the usage of mosquito nets was not at its full potential. Approximately half of the respondents (49.3 percent) owned a bednet out of which 88.3 percent were insecticide-treated (ITNs). However, only 18 percent of ITN owners used them consistently. Choonara et al. (2015) investigate, based on the Demographic and Health survey (2008-2009), factors determining the usage of ITN's among 622 pregnant women in Kenya. They apply a multivariate regression analysis and while their results show no effects of education on intermittent preventive therapy (IPTp), which can be employed as a malaria preventive measure during pregnancy, educational achievement exerts, besides other factors, a positive influence on ITN usage.

Safeukui-Noubissi et al. (2004) review in a matched case-control study the risk factors for severe malaria in Bamako, a district of Mali. Mothers of a total of 390 children participated in the survey. While 130 children were severely affected by malaria (cases), the remaining 260 children served as a control group. In contrast to Koram et al. (1995) and Kun et al. (1998), the findings of this study reveal that maternal education, as well as mothers' malaria-related expertise, are associated with a substantial decrease in the risk of children being infected with malaria. Yakum et al. (2020) carry out a study at the household level in the Northwest Region of Cameroon and look at the socio-economic determinants of behavioral adaptions to malaria control. Based on data from 400 households in ten districts with high malaria prevalence, the authors estimate a behavioral logit model of malaria prevention demand, whereby demand is defined as the likelihood of adapting various kinds of malaria prevention practices. Their findings show that inter alia the educational attainment of household heads has a positive influence on the number as well as the type of prevention measures adopted. Households, whose head has secondary or tertiary education, adapt with a higher probability more malaria prevention options and choose with a higher likelihood more holistic prevention options than those whose household head has completed only primary education.

Similarly, some researchers find that education matters by observing a significant negative correlation between low or no education and malaria-related behavior. A study in Brazzaville, the capital and region situated in the Democratic Republic of Congo, concludes that the odds of cerebral malaria were 90 percent higher among children whose mothers have not completed primary education (Carme et al. 1994). Evidence from Malawi shows that children and women in rural areas and with low education levels were more likely to suffer from fever than children from urban places and higher educated women (Ndawala et al. 2000). Another study, based on a sample of 672 households from the Blantyre district in Malawi, finds that households whose head has not obtained primary education were less likely to own mosquito nets (Holtz et al. 2002). Lastly, evidence from studies in different countries shows that lower education levels are associated with lacking knowledge about malaria, fewer prenatal check-ups, and hospital deliveries as well as fewer clinic visits (Carme et al. 1994; Macheso et al. 1994; Schultz et al. 1994; Slutsker et al. 1994; Mwenesi et al.1995a).

This comprehensive body of literature on the association between education and human behavior in malaria control shows that existing works restrict their analyses to individual countries, sometimes even single districts. As mentioned beforehand the goal of this paper is to obtain a bigger picture of malaria prevention and treatment-seeking behavior in sub-Saharan Africa, allowing for a cross-country comparison. We also want to highlight that, while previous research measures education with years of schooling completed or the overall level of education achieved, we provide a somewhat more nuanced distinction using numeracy and literacy measures. These output measures allow us to look at the particular implication of cognitive skills and critical thinking as well as being literate on human behavior related to malaria. Both, the capacity to read as well as numerical abilities are essential to understand health-related information, allowing to make smart healthcare choices and to take responsibility for one's own and family's health. In a medical context, the capacity to deal with words and numbers but also the capacity to read and act upon given information as well as being able to communicate health problems to medical providers and understand their health instructions is referred to as health literacy (Sørensen et al. 2012). We further elaborate on the importance of numeracy and literacy for malaria prevention and treatment-seeking practices in the discussion section. Finally, most studies we have come across during our research are correlational and therefore do not address simultaneity issues, which, however, cannot be ruled out in this case. It is indeed very likely that malaria control has a positive influence on education and cognitive skills. An adequate malaria protection and treatment behavior may reduce the likelihood of getting infected or if so, impede a severe course of the disease, which is often responsible for cognitive disorders and school absenteeism (Clarke et. al. 2008; Thuilliez et al. 2010; Nankabirwa et al. 2013). Consequently, if the burden of malaria decreases through active malaria control a positive influence on human capital accumulation can be expected. In this study, we attempt to establish a causal pathway and account for endogeneity by using the instrumental variable approach. The following section provides an overview of the data and variables used in our analysis.

Data and variables

To construct the database for our study we make use of four different types of surveys including the Demographic and Health Survey (DHS, years 1999-2020), the Malaria Indicator Survey

(MIS, years 2006-2019), the Integrated Public Use Microdata Series (IPUMS, years 1969-2016) and Afrobarometer data (AFB, years 1999-2020).

The DHS together with the MIS data constitute our main data sources for variable construction, providing detailed information on malaria prevention and treatment-seeking behavior of respondents, the socio-economic background of individuals and households, demographics as well as relevant information on education, literacy in particular. The MIS surveys developed by the Monitoring and Evaluation Working Group (MERG) with the initiative to coordinate the worldwide fight for malaria control, are carried out during the high malaria transmission season and comprise questions and guidelines that are derived from DHS materials, with a particular focus on malaria-related questions. The DHS surveys can be divided into two types: The Standard- and the Interim DHS surveys. While the Standard DHS surveys are typically carried out every five years and are based on large sample sizes including between 5000 and 30,000 households, the Interim DHS surveys usually have smaller samples and shorter questionnaires than the standard DHS surveys since they only focus on key performance monitoring indicators. These surveys are distributed in various recode formats that allow for different units of analysis including women, children, households, etc., and come with geocoded information. We choose the Individual Recode (IR) that exclusively provides individual women's data since this is the only recode providing malaria-related information. We employ these surveys, which come in waves, for 33 sub-Saharan African countries. In total, there are eight waves available. We use them from wave four onwards since questionnaires from earlier waves do not include malaria-related questions, which are of interest for the construction of our dependent variables. For each country, survey data from one or more waves are accessible. Table 11 and Table 12 in the Appendix provide an overview of data availability per wave for the DHS and MIS surveys, respectively.

We use data on numeracy and literacy to measure education, our primary explanatory factor. While DHS also provides us with data on literacy, we cannot rely on this data source to calculate age heaping-based numeracy estimates. The reason behind this is that enumerators carrying out DHS surveys do not rely on the respondents' estimates but countercheck whether the age stated by the individuals is correct since DHS is particularly interested in the accurateness of demographic data. Except for minor variations, age data that were double-checked during the survey usually fail to reflect any age heaping, which is essential for our method applied and therefore become unusable for our purposes. Hence, we obtain age data from IPUMS and Afrobarometer, two data sources, which are not prone to verify the individuals' declared age. IPUMS provides 77 census samples on 26 sub-Saharan African countries between 1960 and 2016, covering around 10 percent of the countries' population. In addition, IPUMS offers large sample sizes of individuals within each country allowing for a more precise aggregation at the sub-national level. For countries for which no age data are available on IPUMS, we use additional data from Afrobarometer whose surveys, being conducted since the late 1990s, provide broad coverage of 37 countries but at the same time are based on smaller samples. Table 13 in the Appendix presents IPUMS data availability per country and decade and Table 14 gives us an overview on the countries' coverage by wave from the Afrobarometer surveys. Additional data sources, which we use for added controls include Kiszewski et al. (2004) who constructed a Malaria Ecology Index (MEI), Nunn and Puga (2012) from whom we obtain data on terrain ruggedness, McKee et al. (1993) who developed the Standardized Precipitation Index (SPI), Africapolis, (OECD/SWAC 2020) providing us with data on the urban dummy and the History Database of the Global Environment (HYDE 3.2), developed by Klein Goldewijk et al. (2017), from where we obtain data on pasture and cropland. Detailed information on all variables used in the analysis including their definition and construction is provided in Table 1 and the summary statistics are displayed in Table 2. Considering a minimum threshold of 30 individuals, we aggregate our individual data on 1,311,750 women by region and decade. Our final dataset is an unbalanced panel including 33 African countries, 407 regions at the first administrative level[4], six birth decades and a total of 1,960 observations.

Measuring malaria prevention and treatment-seeking behavior

Our dependent variable aims at assessing malaria prevention practices and treatment-seeking behavior across sub-Saharan African regions and birth cohorts. Therefore, we use three different proxies. The share of respondents who use insecticide-treated bednets is our main proxy. However, since especially young children aged under five and pregnant women are at high risk of contracting malaria (WHO 2020, 2021) we use two additional measures, namely the share of pregnant women taking antimalarial drugs and the share of respondents taking their child to a medical facility (public or private) in case it shows symptoms of malaria including fever and cough. Figure 1 displays the average of these three shares per country across all birth cohorts considered. Comparing them, we observe that the most commonly used method to protect against malaria in the majority of countries included in our sample is the usage of

[4] Countries are divided into various administrative levels, whereby the first administrative division corresponds to the largest sub-national administrative unit of a country.

bednets (attaining slightly above 70 percent in Comoros). This finding is confirmed in existing literature (see Heggenhougen et al. 2003). Our descriptive statistics reveal that bednet usage is followed by the intake of antimalarial drugs (reaching around 40 percent in the Gambia). The share of respondents who take their child to a medical facility when it is sick and shows malaria symptoms such as fever and cough is shockingly low in all countries considered. It reaches at the most 10 percent in Burundi and Uganda.

Figure 2 compares malaria prevention and treatment-seeking behavior for the 1950s and 1990s birth cohorts at the regional level[5]. We observe that the share of bednet users was very low among the 1950s birth cohort as compared to the share of bednet users among the 1990s birth cohort[6.] When considering pregnant women taking antimalarials, we again note an increase across the birth cohorts. In line with what we discover from our cross-country findings, the share of respondents seeking treatment in a medical facility when their child shows malaria symptoms is very low among the 1950s birth cohort and remains more or less constant across younger birth cohorts, without showing much evolution.

In addition, we would like to highlight that our sample includes countries where malaria is less endemic. We therefore also account for malaria suitability, which includes geographic and climatic characteristics making a country more or less suitable for malaria transmission. Figure 3 gives an overview of malaria suitability across African regions and Figure 4 depicts the correlation between malaria preventive behavior and malaria suitability. We observe that in countries, where malaria transmission risk is low (i.e., South Africa, Eswatini, Lesotho, Namibia, Ethiopia, and Lesotho), people are less eager to protect themselves from malaria.

In our analysis, we capture exclusively women's behavior related to malaria since malaria specific questions are only treated in the Individual Recode files, the woman's questionnaire. Literature shows, as previously mentioned, that children aged under five and women, in particular, pregnant women are the most vulnerable groups (WHO 2020, 2021). Malaria in pregnant women may not only profoundly affect the mother's and the developing foetus's health, often resulting in low birth weight of the newborn, but also increase the risk of malaria during infancy (McGregor et al. 1983). While women belong to the high-risk group, they also play a dominant role as mothers and caretakers being responsible for their family

[5] The maps corresponding to malaria prevention behavior (bednet usage, antimalarial drug intake, medical treatment-seeking) of respondents among the 1940, 1960, 1970, and 1980 birth cohorts are provided in the Appendix Figures 8, 9, and 10.

[6] We find that there is a monotonic increase in bednet usage across birth cohorts (1940s to 1990s).

members' health (Rathgeber and Vlassoff 1993). Thus, we do not regard missing men in our sample as a major caveat.

Measuring numeracy and literacy

Numeracy

We rely on the age heaping method to measure the numeracy component of human capital. To some extent, we are able to determine a person's cognitive ability, quantitative reasoning, or "numeracy" by looking at its ability to state his or her exact age. Individuals who lack basic numerical skills frequently struggle to correctly indicate their age and have a systematic tendency of rounding their ages to numbers ending in zero and five, known as age heaping. For instance, an individual may indicate to be 45 years old when in fact it is 43. This heaping phenomenon becomes visible when analyzing self-reported age data. Figure 11 in the Appendix shows the example of two countries, South Africa where age heaping is low indicating that the society is highly numerate, and Nigeria where people have a higher tendency to heap their ages implying that the country's population has lower numeracy skills. Already back in the 1950s, Bachi (1951) and Myers (1954) used age heaping for influential demographic studies, demonstrating the inverse correlation between age heaping and education levels. In the economic history literature Mokyr (1983) was one of the first to apply age heaping, which later became a popular and widespread method used in various studies (Crayen and Baten 2010; Manzel et al. 2012; Hippe and Baten 2012; Stolz et al. 2013; Baten and Fourie 2015; Cappelli and Baten 2021). One major advantage of age heaping is that basic numerical abilities can be estimated even for early time periods where data on human capital are scarce or not available at all.

The age heaping method we employ in this study is based on the Whipple's index, which was initially introduced by George Whipple (1866-1924). For the calculation of the Whipple index, we first restrict the age range of individuals from 23 to 72. We exclude elderly people since they tend to overstate their age, which will bias our estimates. In addition, we drop individuals aged below 23, because younger individuals usually are more aware of their age since they have to report it more often on occasions like military service or marriage and therefore tend to heap less (Tollnek and Baten 2016). Moreover, in the case of children and adolescents, we do not know for sure whether they reported their ages themselves or whether their parents responded in their place (Manzel and Baten 2009). Second, we create age groups, starting respectively with the second digit 3 and ending with the second digit 2, such as 23-32[7]; 33-42 etc. We do not use common age ranges such as 20-29, 30-39 to avoid bias from people dying over time since there will be, for example, always fewer people who are 69 than 60 in a population. Third, we calculate the Whipple Index as the ratio of the sum of people reporting ages that end in a multiple of five to a uniform distribution assuming that one-fifth of the population actually does have an age ending in either 0 or 5. The resulting ratio is then multiplied by 100. The Whipple index is denoted as follows:

$$W = \frac{\sum(n_{25} + n_{30} + n_{35} + \cdots + n_{70})}{\frac{1}{5}\sum_{i=23}^{72} n_i} * 100$$

where i refers to the age of the individual. The yielded index ranges from 0 to 500.

While 0 indicates that no ages end in a multiple of five, 500 implies that all individuals reported an age ending in either zero or five. A value of 100 assumes no heaping and therefore reflects the “true”, even age distribution, where one-fifth of all stated ages actually is a multiple of five. This infers that a five-point rise in the Whipple Index is equivalent to a one percentage point increase in the share of heaped ages. To allow for a more intuitive interpretation we make a linear transformation of the Whipple Index and calculate the ABCC Index, which denotes the proportion of numerate individuals in the population.

$$ABCC = 1 - \frac{(W - 100)}{400} * 100 \; if \; W \geq 100 \, ; else \; ABCC = 100$$

The ABCC Index allows us to obtain numeracy scores ranging between 0 and 100, where 100 implies being fully numerate. Since we are interested in comparing the evolution of numerical abilities across regions and birth cohorts, we aggregate the obtained ABCC values by administrative region and birth decade[8], ranging from 1940 to 1990.[9] Figure 5 shows the

[7] Individuals that belong to the age group 23-32 show a somewhat different heaping pattern than older individuals, tending to heap on even numbers (Crayen and Baten 2010). We, therefore, make an adjustment for this age group.

[8] We calculate the birth decades of the individuals by subtracting the age groups from the census years. Since we name the age groups from their lowest value (i.e., ages 23-32 are named age group 23) we add +5, which gives us the middle of each age group.

[9] If we obtain more than one ABCC value per region and birth decade, resulting from the fact that we have more than one census year per country available, we calculate the average weighted by the respective sample size.

spatial distribution of numeracy across African regions and time. We observe little evolution of numeracy over the birth cohorts. Numerical abilities have remained fairly constant, displaying a path-dependent pattern. We observe that numeracy levels in the southern part of Africa are very high, attaining scores between 90 and 100 already for the 1940s birth cohort whereas the Sahel region, Sudan and Ethiopia show lower numeracy levels.

While the age heaping method is commonly used, it is not free from potential caveats that need to be discussed. When using survey data one major concern is that the respondents, especially women, actually reported their age themselves and were not asked about their age in different ways to verify the accuracy of their answers, which would make data unusable for our purpose. To mitigate this issue, we rely on IPUMS census and Afrobarometer data, two data sources, which first of all are not gender-specific and secondly only ask for the respondents' age and not in addition for their birth year, which decreases the likelihood of counterchecking the individuals' correct age.

Another aspect that has led to some concern in the estimation of numeracy is that individuals may heap more as they advance in years. In other words, the same cohort of people may more likely heap their ages when they are in their sixties than in their twenties. Consequently, older birth cohorts would tend to have lower numeracy scores. To verify whether we observe this trend in our sample we compare numeracy scores for individuals that were born in the same decade but belong to various age groups[10]. Our results are displayed in Table 3. While we obtain some significant coefficients, our results are not systematic and do not confirm that older age groups tend to heap more than younger ones. In other words, we can exclude the existence of an age bias in our sample.

Moreover, Földvári et al. (2012), Perrin (2020), and A'Hearn et al. (2022) question whether the marital status of women may bias numeracy scores. Their results show that age heaping is less common among married women than single women since they tend to orient themselves at their husbands' responses and adapt their age accordingly. This concern, however, is mitigated by Baten et al. (2022) who base their analysis on a large census data collection from Italy and find that the age heaping difference between married and single women is not systematic. Ferber and Baten (2021) look for the existence of a marriage bias in IPUMS samples including 26 sub-Saharan African countries but do not find any statistically

[10] Respondents who were born in the 1950s for example were in their twenties when the census took place in the 1970s and in their sixties when the census took place in the 2010s.

significant results.

Finally, one of the concerns was brought up by A 'Hearn et al. (2021), namely that age heaping does not only occur in multiples of five and ten. Based on an Italian sample from the 19th century their results show that while individuals do heap on multiples of ten, they rather tend to heap on numbers ending in six than in five. This finding, however, seems to be specific to this particular sample. Ferber and Baten (2021) verify whether this heaping pattern also holds for African countries. Based on age data obtained from IPUMS, Afrobarometer, and MICS surveys, they verify the distribution of stated ages by individuals for each country and test whether there is any heaping evidence other than on multiples of five and ten. Their results show that this is not the case, except for younger individuals who tend to heap on multiples of two. Since we make use of the same data sources, this is thus not a concern we have to worry about and as mentioned beforehand, we correct for the youngest age group who tends to heap on even numbers.

Literacy

In addition to numeracy, we also investigate the role of literacy in malaria prevention and treatment-seeking behavior. We obtain data from the DHS surveys and define an individual as being literate if it is able to read entire as well as parts of sentences. We consequently construct our literacy share per region and birth decade. Figure 6 shows the evolution of literacy in African regions across the birth cohorts considered. Similar to the numeracy levels, we observe that the share of individuals being able to read was already very high among the 1950s birth cohort in the southern part of Africa, ranging between 0.7 and 1.0, and remained at these high levels across subsequent cohorts. In the remaining African regions though we observe that the literacy rate was comparatively lower than the numeracy levels among the 1940s and 1950s cohorts and saw a more pronounced increase until the 1990s birth cohort. This measure certainly comes with its potential caveats. For example, the literacy rate does not tell us much about the distribution of literate individuals - whether they are highly concentrated and apart from the analphabetic population or rather evenly distributed across households. Therefore, we advise caution in its interpretation.

We find a very strong correlation between our numeracy measure and the literacy share as shown in Figure 7. Additionally, it is important to investigate the relationship between malaria control and education indicators. Therefore, we provide a visualization of the correlation between the malaria prevention variables and numeracy as well as literacy

(Appendix, Figure 12). It is pertinent to highlight that these correlation graphs are not conditioned on malaria suitability, which might be an explanation for the outliers that we observe in these scatter plots.

Controls

We account for factors commonly found in the literature. Evidence shows that the socio-economic status as well as gender matters for correct treatment-seeking behavior. Caregivers who are often mothers and women in general are frequently the first to perceive symptoms of childhood malaria and are in charge of disease management in the household (Molyneux et al. 1999; Hausmann-Muela et al. 2000). Since our sample contains exclusively female individuals, we do not control for gender, but we account for the share of women who are involved in the household's healthcare decision-making. We further control for media usage in our regression framework. Findings in the literature indicate that the lack of knowledge and awareness of malaria is a major factor hindering prevention and treatment practices, which can be addressed to a large extent by using media communication tools (Ibidapo 2005; Mozumder et al. 2007; Ankomah et al. 2014). In many developing countries print and electronic media are popular means of behavior change communications. Especially among pregnant women who are most at risk of contracting malaria, mass media is used to address the benefits of the regular usage of bednets (Ankomah et al. 2014). While many studies conclude that knowledge is an essential predictor of prevention and treatment-seeking behavior, others find that socio-economic issues such as poverty play a more important role (e.g., Heggenhougen et al. 2003). Worrall et al. (2005) refer to malaria as the disease of the poor and find that the cost of treatment was one of the main obstacles in terms of accessing treatment. They conclude that the treatment expenses hit the poorest households the hardest and that they tend to seek care outside the modern sector (e.g., advice from friends, traditional healers) while wealthier households show a higher intake of antimalarial drugs and prefer to opt for modern sector treatment including public and private health care facilities. Hence, we account in addition for the poverty share. Finally, we control for seasonality by using rainfall data. We also add some geographic-related controls including the Malaria Ecology Index[11] to account for the severity of malaria across the different regions, terrain ruggedness measuring the altitude of a region since malaria is hardly or not at all

[11] The Malaria Ecology Index from Kiszewski et al. (2004) measures malaria suitability at the first-level administrative divisions of African countries and examines potential transmission stability. It represents the contribution of regionally dominant vector mosquitos to the force of transmission and depicts a region's resiliency to malaria perpetuation.

prevalent in higher elevated regions and an urban dummy because urban areas have better housing facilities and provide limited options for the parasites to breed.

Methodology

Main regression analysis

To estimate our results, we apply a pooled regression model of the following form:

$$SAM_{itr} = \beta_0 + \beta_1 HumCap_{it} + X_{it}\Gamma + \mathrm{Z}_i \Upsilon + \mu_r + \upsilon_t + \varepsilon_{it}$$

where SAM_{itr} denotes the share of respondents adopting the respective malaria prevention or treatment-seeking measure (i.e., usage of insecticide-treated bednets, antimalarial intake, seeking of medical care) in an administrative region *i* during decade *t*. β_0 indicates the constant term and β_1 measures respectively the impact of numeracy or literacy on the usage of malaria control measures. X_{it} comprises all time-variant controls (i.e., share of women in health care, media exposure, poverty rate, rainfall) whereas $\mathrm{Z}_i\Upsilon$ is a vector of time-invariant controls (i.e., Malaria Ecology Index, terrain ruggedness, city dummy). We account for regional fixed effects (μ_r)[12] and decadal fixed effects (υ_t). ε_{it} denotes the error term.

Instrumental variable approach

While we account for a number of important factors, which are likely to influence behavioral aspects of malaria, we are also aware that there remain important potential determinants, especially cultural factors (e.g., communities' perceptions and beliefs about malaria causation and prevention, preference for traditional healers) we are unable to control for. These unobservables may lead to a potential omitted variable bias and hence be the source of endogeneity. At the same time, a simultaneity bias may be present. As discussed previously, it is likely that our human capital variables are jointly determined with our dependent variable. Put differently, literacy and numeracy may not only influence malaria prevention and treatment-seeking behavior, but improved malaria protection may also lead to better educational outcomes and a decline in cognitive impairment. In order to mitigate both a simultaneous causality and

[12] For the regional fixed effects, we use the regional classification of Africa as suggested by the United Nations.

omitted variable bias, we apply the instrumental variable (IV) approach using the log-ratio of pasture to cropland as an instrument. We argue that in regions, which benefit from a relative abundance of grazing, cattle farming is more prevalent (Boserup 1970) leading to a higher protein intake in pasture areas. In sub-Saharan Africa, animal source foods (ASF) are an important source of proteins enhancing nutritional adequacy (De Bruyn et al. 2016). An optimal protein supply plays a key role in early neural development. It boosts memory, optimizes brain health and cognitive functions, and is essential for learning (Giese et al. 2013). Our IV hence directly influences the learning capacity of basic numeracy and literacy and only affects our dependent variable (i.e., the share of people adopting malaria preventive behavior) by running through these human capital measures. Indeed, we cannot find any argument supporting the idea that the log-ratio of pasture to cropland has a direct effect on malaria prevention and treatment-seeking behavior. Unfortunately, research that has investigated the association between land cover classification and larval Anopheles habitats is rather scarce. Findings of some field studies in the Kenyan highlands reveal that the larvae of malaria mosquitos have been found more frequently in breeding sites on farm and pastureland than in forested areas (Minakawa et al. 2005; Munga et al. 2009; Mutuku et al. 2009). However, cropland covers were not found to have lower mosquito habitat suitability than pasture areas (Acheson et al. 2015). As aforementioned we use the Malaria Ecology Index to account for differences in transmission risk across regions. On the assumption that the exclusion restriction holds in our model and with the first stage F-statistics being way above 10, we consider this variable to be a valid instrument. Using the two-stage least-squares (2SLS) estimator we run an instrumental variable regression, with the first stage estimation being as follows:

$$HumCap_{itr} = \beta_0 + \beta_1 \, ln \, (\frac{pasture}{cropland})_{it} + X_{it}\Gamma + Z_i\Upsilon + \mu_r + \upsilon_t + \varepsilon_{it}$$

where $ln \, (\frac{pasture}{cropland})_{it}$ denotes the grazing area of a region *i* relative to its cropland, varying across decades *t*.

Regression results

Our pooled OLS estimation results show clear evidence for a positive correlation between human capital, measured by numeracy and literacy, and malaria prevention and treatment-seeking behavior. We observe this positive relationship between education and malaria control in the case of all three proxy measures including the share of insecticide-treated bednet users, the share of pregnant women taking antimalarial drugs, and the share of respondents seeking medical care when their child suffers from malaria symptoms. Tables 4, 5, and 6 display the regression results using respectively the various shares as the dependent variable. Starting with the share of bednet users, we obtain positive correlation coefficients of 0.26 in the case of numeracy and 0.23 in the case of literacy. In terms of antimalarial medication, a one percent increase in numeracy and literacy is associated with a respective increase of 34.5 and 9.7 percentage points in the share of pregnant women taking antimalarial drugs. Looking at treatment-seeking behavior we observe that a one percent rise in numeracy and literacy predicts respectively a 3.4 and a 0.7 percentage point higher share of respondents taking their child to a medical facility in case of fever and cough. Table 7 displays the standardized numeracy and literacy coefficients. Considering all three dependent variables, numeracy shows, relatively to literacy, higher correlation coefficients, indicating a somewhat stronger relationship with malaria prevention and treatment-seeking behavior[13]. Our control variables are much in line with what is found in the literature. It seems that a higher share of women involved in health care decision-making is positively associated with malaria control behavior. This finding is significant at a 1 percent level and valid for all our malaria control measures. We further observe to some extent a positive correlation between the exposure to media (newspaper, radio, television, and internet) and malaria prevention behavior. In contrast, looking at the poverty share, we find evidence for a strong negative correlation between having a low socio-economic status and the behavioral aspects of malaria control, significant at a 1 percent level across all specifications. Urbanization does not show a clear pattern in relation to malaria prevention and treatment-seeking behavior. While in urban sites the share of pregnant respondents taking antimalarial drugs seems to be higher than in rural areas, we observe at the same time a negative correlation between the usage of bednets and living in the city. Finally, we control for potential factors determining the severity of malaria across sub-Saharan African regions including rainfall, the altitude of regions, and malaria suitability. Our results show that rainfall and malaria suitability are positively associated with prevention and treatment-seeking behavior. This means that in areas with higher rainfall and where malaria is more prevalent, the share of respondents using insecticide-impregnated bednets, taking antimalarial drugs, and seeking medical treatment tends to be higher. Similarly, we find a negative association between higher

[13] See Appendix Figure 13 for a visual representation.

located regions, where malaria is less common or even non-existent, and protective behavior in response to malaria.

From the results of the instrumental variable approach, we infer that the direction, however not the size of the effect between our main variables of interest, measuring human capital, and our various dependent variables is causal. Findings of our instrumental variable regressions, which are displayed in the Tables 8, 9, and 10, suggest a positive influence of both numeracy and literacy on all three measures of malaria prevention and treatment-seeking behavior considered, including the share of insecticide-treated bednet users, the share of antimalarial takers as well as the share of medical treatment seekers.

Discussion

Our regression results, which show positive effects of human capital on malaria prevention and treatment-seeking behavior, are in line with the findings of

Choonara et al. (2015) who conclude that education is positively associated with the usage of insecticide-treated mosquito nets. In addition, we can also confirm the results of Kaona et al. (2000) who show that there is a positive relationship between the level of education and the adaption of malaria preventive measures including the intake of antimalarial drugs. Concerning treatment-seeking outcomes, we find in accord with Tarimo et al. (2000) and Fawole and Onadeko (2001), that education, more precisely numeracy and literacy, positively influences the caretakers' decision to take their children to a medical facility when they suffer from fever and cough. While our regression results show that education plays an essential role in malaria prevention and treatment-seeking behavior, we also observe, that the magnitude of the standardized numeracy and literacy coefficients differs substantially. Being numerate seems to be relatively more important in economic terms than being literate.

Why might this be the case? In the healthcare environment, the ability to understand and use numbers is essential since many tasks (e.g., understanding dates and timing of medication dosage, measuring medications, refilling prescriptions) are numeracy-related. A closer look at how numeracy is defined in the literature shows that it involves, besides the ability to perform basic arithmetic calculations, a wide range of other skills including the understanding of risks and probability (Woloshin et al. 2001; Schwartz et al. 2005), the understanding of time, money and measurement (Rothman et al. 2008), cognitive abilities and quantitative reasoning

(A'Hearn et al. 2022) as well as the capacity to apply mathematical skills in a particular situation, in other words, contextual oriented numeracy (Montori and Rothman 2005; Golbeck et al. 2005). How does this apply to malaria prevention behavior? With regards to the intake of antimalarial medication, it is certainly important to be able to understand medical directions containing numerical information concerning for example the dosage of drugs. Similarly, these abilities, especially the understanding of risk and time are essential when it comes to the recognition of malaria symptoms, the course and severity of the disease, and eventually the decision-making of seeking medical treatment. Indeed, it is important that caretakers recognize the risk children face once they show symptoms and are infected with malaria and that they also have a good sense of time when it comes to determining for instance the duration of convulsions or the time span in between. The correct usage of mosquito nets requires cognitive skills, in particular logical reasoning. Users have to understand how malaria is transmitted and why they actually should sleep under the bednets and keep them closed at all times. While this seems to be obvious, studies find that misconceptions about the cause of malaria, remain. In Tanzania and Ghana, for example, malaria is believed to be the result of overworking and heat (Gessler et al. 1995; Ahorlu et al. 1997; De la Cruz et al. 2006). In Uganda, poor diet and environmental conditions are among the perceived causes of malaria (Kengeya-Kayondo et al. 1994). In the Gambia and in Kenya malaria is associated with the possession of an evil spirit or the devil (Aikins et al. 1993; Mwenesi et al. 1995b). These mistaken beliefs may inter alia also explain the misuse of bednets, for example, for fishing (Minakawa et al. 2008; McLean et al. 2014) or playing football (Ntonifor and Veyufambom 2016). From another perspective, one could also argue that the understanding of probability as a component of numeracy is helpful to adopt correct preventive actions against malaria. The ability to think in probabilistic terms is notably important after contracting malaria in spite of the use of malaria prevention measures since it helps to comprehend that malaria prophylaxis and the use of mosquito nets remain important measures of protection, reducing the overall likelihood of getting infected with malaria.

While we cannot make causal claims with respect to our control variables, we can still discuss their correlations with malaria prevention and treatment-seeking behavior. Our results reveal a positive association between the share of women being involved in health care decision-making and malaria control behavior and are in line with the findings of Damaris Matoke-Muhia, a scientist focusing on malaria research at the Kenyan Medical Research Institute (KEMRI). According to her, it is the women, who do not only take care that high-quality mosquito nets are provided at the community level, but also make sure that they are used efficiently. In addition, as primary caregivers, they ensure that children who are infected with malaria receive and complete medical treatment. In some cases, however, women still may be prevented from taking the necessary health measures since they are often financially dependent and the ultimate decision-making power is not in their hands (Oberlaender et al. 2000; Heggenhougen et al. 2003). Instead, they have to get the permission from their husbands before being able to access malaria treatment (Molyneux et al. 2002). Under these circumstances, the price of insecticide-impregnated bednets and antimalarial medicine, such as chloroquine, frequently constitutes a major obstacle hindering women from buying malaria prevention products (Rashed et al. 1999).

We further find some evidence that the exposure to media (i.e., newspaper, radio, television, internet) is positively correlated with the share of pregnant women taking malaria prophylaxis and the share of respondents seeking medical treatment, which is in line with the findings of Bowen (2013), Ankomah et al. (2014), and Yaya et al. (2018). Media coverage can indeed be an excellent means of broadcasting health information and promoting various malaria prevention measures. In Nigeria, for example, mass media campaigns were initiated to raise awareness, particularly among pregnant women, on the effectiveness and long-term benefits of sleeping under insecticide-treated bednets during pregnancy (Ankomah et al. 2014).

Moreover, we observe that poverty and malaria control behavior are negatively interdependent, significant at a 1 percent level throughout all specifications. Despite massive efforts of achieving universal coverage of insecticide-treated bednet distributions, lower socio-economic status has been found to discourage the adaption of malaria prevention behavior. Berthélemy et al. (2013) provide evidence for the existence of a malaria trap, meaning that malaria reinforces poverty, which in turn makes it more difficult for the poor to deal with the disease and to seek protection and treatment.

In addition, Berthélemy et al. (2013) conclude that in areas where malaria is more prevalent, malaria protection behavior increases, which is in line with our findings. Indeed, in areas of high mosquito biting, people tend to protect themselves better using bednets, which in turn leads to lower malaria rates while in areas with a low mosquito biting nuisance, precaution and consequently the use of bednets decline, resulting in a higher rate of malaria (Thomson et al. 1996).

Lastly, we find an unambiguous correlation between urbanization and malaria control behavior. On the one hand, the share of bednet users seems to be lower in urban than in rural areas. This might be explained by the fact that malaria is, in general, more prevalent in rural areas where natural breeding sites, especially areas with stagnant waters, offer optimal conditions for mosquito vectors to proliferate. On the other hand, however, we observe that the share of pregnant women taking antimalarial drugs is higher in urban places. Although urbanization is supposed to reduce malaria transmission, the disease still persists in African cities, sometimes at more severe levels than in the countryside (Mattah et al. 2017) because containers or water tanks serve as breeding grounds (Heggenhougen et al. 2003). And while mosquito nets are commonly distributed in rural areas through free mass campaigns, antimalarial drugs are usually available in health facilities, pharmacies, and retail shops, which are more likely to be situated in urban sites.

The empirical findings discussed herein should be interpreted with caution in light of some limitations. First of all, the dataset we use for this study includes only women since both the DHS and the MIS surveys provide exclusively children's and women's data on malaria. Although most studies in this field base their analyses on female data because of various reasons (i.e., lack of sex-disaggregated malaria data, women are primary caretakers and more at risk), missing men in our sample hinder us from having a closer look at the underlying role of gender in malaria prevention and treatment outcomes. Pertaining our dataset, we also want to address the irregularities and frequency of the conducted surveys we employ. While the number of surveys carried out as well as the time interval between the individual surveys differ across countries, we consider the survey years together with the age of the women surveyed, to calculate six successive 10-year birth cohorts. Even though our cohort data, ranging from the 1940s to the 1990s, do unfortunately not allow us to consider the latest progress made in malaria prevention and treatment-seeking behavior, the time span of almost 60 years still makes it possible to look at the evolution of behavioral adaptions to malaria control across African regions.

Further limitations that need to be acknowledged concern our human capital variables, which are both generic indicators, measuring only very basic numerical and reading skills. Data availability does not allow us to distinguish between different performance categories such as basic, intermediate, or advanced literacy and numeracy. Despite the literacy rate being a commonly used method to measure reading and writing skills, concerns have been raised regarding its deficiency to account for different scenarios of distribution and therefore its potential failure to recognize the aggregate benefit of literacy if evenly distributed. A more even distribution of literate individuals across households, in contrast to fully literate or fully illiterate households, may indeed lead to greater effective literacy since illiterates benefit from living in a household where at least one person is literate (Basu and Foster 1998). The same is valid for numeracy. We employ the age heaping method to measure numerical skills, which is considered to be a reasonable indicator function for education. While the age heaping indicator, like other indicators of empirical research, certainly is subject to measurement errors, age heaping-based estimates are well suited for comparison with other educational estimates including literacy as we have seen in this study. We also acknowledge that not all samples are suited for age heaping analyses (Baten et al. 2022), notably due to substantial counterchecking of ages or the occurrence of sampling biases. Consequently, it is essential to thoroughly study the sample and carefully consider the sources where age data come from in terms of who collected data, who were the respondents, and how age data were obtained (i.e., questions asked).

Despite these limitations, we are able to ameliorate the scant literature on the relationship between human capital and the behavioral aspects of malaria prevention and control. Our study highlights the importance of collecting more robust and detailed data on human capital indicators that can be mapped to each household for a better understanding of factors that encourage malaria prevention and treatment-seeking practices. We provide further recommendations on malaria control in the following section.

Conclusion

Although there is no clear consensus, the role of human capital in this matter has been highlighted by several researchers (e.g., Tarimo et al. 2000; Fawole and Onadeko 2001; Choonara et al. 2015; Yakum et al. 2020). Hence, our paper studies the effect of numeracy and literacy on malaria prevention and treatment-seeking behavior. While literacy is essential for people's inspiration and capacity to access, comprehend and utilize information in manners, which advance and maintain health and wellbeing, numeracy is critical to a better understanding of healthcare-related tasks including for instance the measurement of fever, the dosage of medication and the frequency of administering drugs.

We use information from four different types of surveys including the Demographic and Health Survey (DHS), the Malaria Indicator Survey (MIS), the Integrated Public Use Microdata Series (IPUMS), and Afrobarometer data. Using a panel dataset including 407 African regions at the first administrative level, six decades, and a total of 1,960 observations, we find that education plays an essential role in malaria prevention and treatment-seeking behavior. Nevertheless, we also find that numeracy and literacy have different magnitude effects on malaria prevention and treatment-seeking behavior.

We also employ the Instrumental Variable approach to address any concerns regarding potential endogeneity arising due to simultaneity between our dependent variables and the education measures as well as unobservables like cultural factors. Our instrument is the log-ratio of pasture to cropland as it is believed to have a direct influence on learning capacities and affects our dependent variable (the share of people adopting malaria preventive behavior) only through the independent variables measuring human capital.

Our results highlight the importance of human capital attributes in the way malaria is prevented and treated in the African region. Despite our findings, however, we have to be aware of the fact that "correct knowledge" does not automatically imply that people change their perceptions or adopt a behavior, which would be considered by public health professionals to be in their self-interest. Human behavior is complex and sometimes tied to benefits related to other aspects than health. It is indeed not simply a consequence of knowledge and belief. We, therefore, have to be very cautious when we talk about education as "the solution" to improved malaria prevention behavior and as Good and Good (1993) pointed out, avoid thinking that we have to impart knowledge to people who "lack knowledge". However, we still believe that the development of human capital and cognitive skills may contribute to a substantial decrease in prevailing misconceptions about malaria.

We also report several findings of the control variables we include in our empirical analysis. We find that a higher share of women being involved in health care decision-making as well as exposure to media is critical for correct treatment-seeking behavior. On the other hand, a poor socio-economic status makes seeking protection and treatment difficult. We also find that while malaria is more prevalent in rural areas, urban areas also exhibit a high malaria persistence.

With the aforesaid findings, our paper has the following policy considerations: first, this study has highlighted the urgent need to focus on socio-economic and communication challenges associated with malaria and its prevention. The global work-stream on malaria needs to focus on avoiding conflicting advice and misinformation so that the response against not only malaria but also new diseases like the coronavirus is appropriate and effective amidst transmission in malaria-endemic settings.

Second, the enlistment and sustaining of political commitment (including for financial resources) for raising human capital levels to counter malaria are required. Therefore, investment in human resources should be given major attention. Malaria often occurs in villages and communities where health workers manage the disease at sub-center level. Therefore, the presence of a trained public health specialist in every district could play a vital role in malaria elimination and programs targeted at raising the local communities' education, awareness, and knowledge related to malaria.

Finally, health messages regarding malaria prevention and care should be conveyed from early stages in schools. This can be done by using, for example, audio and visual communication tools that educate children and through them also reach their caregivers. These public health intervention messages should be prepared with full engagement, including the participation of local communities. Keeping in mind that notably, numerical skills play an important role in malaria prevention and treatment-seeking behavior, schools should promote interest and achievement in learning mathematics and consequently rethink their curricula, placing a renewed focus on calculus. Over and above this, greater emphasis should be laid on linking theory to practice so that children learn how to apply numeracy skills in real-life situations.

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Tables and figures

Tables

Table 1: Variable description and sources

Variable	Description	Comments	Data source
Share bednet (ITN) users	Share of respondents using insecticide-treated bednets (ITN's)	admin 1 level; time-variant	DHS and MIS surveys
Share antimalarial takers	Share of pregnant women taking antimalarial drugs	admin 1 level; time-variant; combination of variables denoting the intake of various antimalarial drugs	DHS and MIS surveys
Share treatment seekers	Share of respondents seeking treatment in a medical facility (public or private) when their children show malaria symptoms (fever, cough)	admin 1 level; time-variant; combination of variables	DHS and MIS surveys
Numeracy	Numeracy scores ranging from 0 to 100, whereby 100 implies being "fully" numerate	based on Abcc Index, admin 1 level, time-variant	IPUMS & Afrobarometer
Literacy	Share of people being literate	admin 1 level, time-variant	DHS and MIS surveys
Women in healthcare	Share of women being involved in health care decision	admin 1 level, time-variant	DHS and MIS surveys
Media exposure	Share of people being regularly exposed to media	admin 1 level; time-variant; combination of variables including exposure to the internet, newspaper, radio and television	DHS and MIS surveys
Share poor	Poverty share at admin 1 level	admin 1 level; time-variant	DHS and MIS surveys
Urban dummy	Dummy equals 1 if a region contains at least one city, 0 otherwise	admin 1 level; time-invariant; we consider towns with more than 10,000 habitants	(Africapolis, OECD 2020)
Malaria Ecology Index	Malaria suitability	average value at admin 1 level, time-invariant	Kiszewski et al. (2004)
Altitude (log)	Average value of terrain ruggedness	admin 1 level, time-invariant	Nunn and Puga (2012)
Rainfall	Average decadal rainfall	admin 1 level; time-variant	McKee et al. (1993)
Pasture / Cropland (log)	Log-ratio of pasture to cropland at admin 1 level	admin 1 level; time-variant	HYDE 3.2; Klein Goldewijk et al. (2017)

Table 2: Summary statistics of variables

Variables	Obs.	Mean	SD	Min	Max
Share bednet users	1,960	0 .314	0.228	0	1
Share antimalarial takers	1,960	0 .222	0 .184	0	1
Share treatment seekers	1,960	0 .059	0 .047	0	0 .310
Numeracy	1,117	81.338	14.740	29	100
Literacy	1,960	0.445	0.300	0	1
Women in healthcare	1,960	0.245	0.219	0	1
Media exposure	1,960	0.107	0.121	0	1
Share poor	1,960	0.362	0.227	0	1
Urban dummy	1,960	0.322	0.468	0	1
Malaria Ecology Index	1,960	13.045	9.465	0	34.314
Altitude (log)	1,960	7.075	1.146	3.883	9.994
Rainfall	1,960	9.332	4.734	0	30.756
Pasture / Cropland (log)	1,941	4.473	8.944	0	94.076

Table 3: Verification of age bias: numeracy scores by birth decade and age group

Birth Decade	ABCC					Differences														
	23-32 (1)	33-42 (2)	43-52 (3)	53-62 (4)	63-72 (5)	(1)- (2)	(1)-(3)	(1)-(4)	(1)-(5)	(2)-(3)	(2)-(4)	(2)-(5)	(3)-(4)	(3)-(5)	(4)-(5)
1940	82.693	79.411	80.697	76.977	66.801	3.282	1.996	5.715	15.892***	-1.286	2.433	12.610***	3.720 **	13.896***	10.177***
	(2.241)	(1.595)	(1.427)	(1.234)	(1.392)	(2.951)	(3.702)	(3.812)	(4.274)	(2.426)	(2.440)	(2.711)	(1.901)	(2.051)	(1.860)
1950	81.131	84.817	78.116	78.619	94.288	-3.687 *	3.015	2.512	-13.157	6.702**	6.199 ***	-9.470	-0.503	-16.172	-15.668
	(1.685)	(1.197)	(1.180)	(1.181)	(3.492)	(2.141)	(2.372)	(2.381)	(8.042)	(1.737)	(1.740)	(8.725)	(1.669)	(10.381)	(10.434)
1960	86.318	82.378	78.962	85.025		3.941**	7.357***	1.293		3.416**	-2.647		-6.063		
	(1.088)	(0.980)	(1.050)	(2.612)		(1.501)	(1.580)	(3.628)		(1.438)	(4.010)		(4.340)		
1970	82.847	82.834	79.857			0.0129	2.989			2.977					
	(0.936)	(0.867)	(2.423)			(1.274)	(2.405)			(0.203)					

Table 4: Pooled OLS regression

DV: Share bednet (ITN) users	(1) pooled OLS	(2) pooled OLS	(3) pooled OLS	(4) pooled OLS
Numeracy	0.294*** (0.042)	0.256*** (0.040)		
Literacy			0.131*** (0.020)	0.232*** (0.023)
Women in healthcare		0.228*** (0.034)		0.170*** (0.030)
Media exposure		-0.151 (0.101)		0.040 (0.063)
Share poor		-0.159*** (0.022)		-0.164*** (0.025)
Urban dummy		0.003 (0.010)		-0.050*** (0.009)
Malaria Ecology Index		-0.0003 (0.001)		0.002** (0.001)
Altitude (log)		-0.056*** (0.006)		-0.032*** (0.005)
Rainfall		0.003*** (0.001)		0.003*** (0.001)
Constant	-0.003 (0.040)	0.103 (0.063)	0.239*** (0.013)	0.344*** (0.045)
Observations	1,117	1,117	1,960	1,960
R-squared	0.222	0.509	0.200	0.274
Region FE	No	Yes	No	Yes
Decade FE	No	Yes	No	Yes

Note: Robust standard errors in parentheses. Asterisks denote significance levels
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Pooled OLS regression (cont.)

DV: Share antimalarial drug takers	(1) pooled OLS	(2) pooled OLS	(3) pooled OLS	(4) pooled OLS
Numeracy	0.406*** (0.033)	0.345*** (0.029)		
Literacy			0.053*** (0.013)	0.097*** (0.015)
Women in healthcare		0.193*** (0.023)		0.102*** (0.028)
Media exposure		-0.021 (0.083)		0.254*** (0.046)
Share poor		-0.124*** (0.015)		-0.043*** (0.016)
Urban dummy		0.030*** (0.007)		0.037*** (0.008)
Malaria Ecology Index		0.002*** (0.00042)		0.003*** (0.001)
Altitude (log)		-0.020*** (0.004)		-0.019*** (0.004)
Rainfall		0.003*** (0.001)		0.002** (0.001)
Constant	-0.060* (0.034)	-0.112*** (0.041)	0.208*** (0.009)	0.217*** (0.032)
Observations	1,117	1,117	1,960	1,960
R-squared	0.321	0.709	0.282	0.327
Region FE	No	Yes	No	Yes
Decade FE	No	Yes	No	Yes

Note: Robust standard errors in parentheses. Asterisks denote significance levels

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Pooled OLS regression (cont.)

DV: Share medical treatment seekers	(1) pooled OLS	(2) pooled OLS	(3) pooled OLS	(4) pooled OLS
Numeracy	0.045*** (0.010)	0.034*** (0.008)		
Literacy			0.023*** (0.004)	0.007* (0.004)
Women in healthcare		0.038*** (0.007)		0.009 (0.006)
Media exposure		0.0003 (0.0340)		0.092*** (0.018)
Share poor		-0.038*** (0.004)		-0.037*** (0.004)
Urban dummy		0.001 (0.002)		-0.001 (0.002)
Malaria Ecology Index		0.0001 (0.0002)		-0.0002 (0.0002)
Altitude (log)		-0.004*** (0.001)		-0.003*** (0.001)
Rainfall		0.002*** (0.000)		0.001*** (0.000)
Constant	0.015 (0.009)	-0.027* (0.014)	0.051*** (0.003)	0.018** (0.009)
Observations	1,117	1,117	1,960	1,960
R-squared	0.021	0.428	0.023	0.375
Region FE	No	Yes	No	Yes
Decade FE	No	Yes	No	Yes

Note: Robust standard errors in parentheses. Asterisks denote significance levels
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Standardized coefficients of numeracy and literacy

Dependent Variable	Numeracy	Literacy
Share bednet users	0.180	0.163
Share antimalarial drug takers	0.266	0.157
Share medical treatment seekers	0.120	0.043

Table 8: Instrumental variable regression

DV: Share bednet (ITN) users	(1) IV	(2) IV
FIRST STAGE		
Pasture / Cropland (log)	0.007** (0.003)	0.007** (0.003)
SECOND STAGE		
Numeracy	0.122* (0.068)	
Literacy		0.990*** (0.098)
Women in healthcare	-0.086 (0.356)	0.520*** (0.073)
Media exposure	-2.268 (1.836)	-0.176 (0.113)
Share poor	-0.801 (0.766)	-0.259*** (0.094)
Urban dummy	-2.327 (2.486)	-0.491** (0.234)
Malaria Ecology Index	-0.224 (0.172)	0.028** (0.012)
Altitude (log)	-1.199 (1.183)	-0.104 (0.143)
Rainfall	-0.525 (0.563)	-0.036 (0.072)
Constant	9.139 (12.81)	1.447 (2.219)
Observations	1,111	1,941
R-squared		0.711
Region FE	Yes	Yes
Decade FE	Yes	Yes
F-Stat	75.92	88.1

Note: Robust standard errors in parentheses. Asterisks denote significance levels
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Instrumental variable regression (cont.)

DV: Share antimalarial drug takers	(1) IV	(2) IV
FIRST STAGE		
Pasture / Cropland (log)	0.007**	0.008**
	(0.003)	(0.003)
SECOND STAGE		
Numeracy	0.151*	
	(0.088)	
Literacy		0.016***
		(0.002)
Women in healthcare	-0.102	1.337***
	(0.445)	(0.116)
Media exposure	-2.570	0.594***
	(2.365)	(0.211)
Share poor	-1.187	-0.750***
	(0.985)	(0.143)
Urban dummy	-3.239	-0.490*
	(3.231)	(0.291)
Malaria Ecology Index	-0.291	0.012
	(0.219)	(0.012)
Altitude (log)	-1.436	-0.205
	(1.521)	(0.174)
Rainfall	-0.631	-0.099
	(0.734)	(0.094)
Constant	11.13	3.001
	(16.50)	(2.739)
Observations	1,111	1,889
R-squared		0.149
Region FE	Yes	Yes
Decade FE	Yes	Yes
F-Stat	75.92	84.3

Note: Robust standard errors in parentheses. Asterisks denote significance levels
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Instrumental variable regression (cont.)

DV: Share medical treatment seekers	(1) IV	(2) IV
FIRST STAGE		
Pasture / Cropland (log)	0.007**	0.007**
	(0.003)	(0.003)
SECOND STAGE		
Numeracy	0.026*	
	(0.015)	
Literacy		0.308***
		(0.031)
Women in healthcare	-0.038	0.195***
	(0.076)	(0.020)
Media exposure	-0.401	0.010
	(0.416)	(0.038)
Share poor	-0.223	-0.159***
	(0.170)	(0.026)
Urban dummy	-0.371	0.019
	(0.617)	(0.139)
Malaria Ecology Index	-0.042	0.012*
	(0.037)	(0.006)
Altitude (log)	-0.230	-0.023
	(0.266)	(0.087)
Rainfall	-0.098	-0.005
	(0.132)	(0.047)
Constant	1.482	0.161
	(2.860)	(1.389)
Observations	1,111	1,941
R-squared		0.281
Region FE	Yes	Yes
Decade FE	Yes	Yes
F-Stat	75.92	88.1

Note: Robust standard errors in parentheses. Asterisks denote significance levels
*** p<0.01, ** p<0.05, * p<0.1

Figures

Figure 1: Share of people using bednets, taking antimalarial drugs and seeking medical treatment (average over 1940s to 1990s)

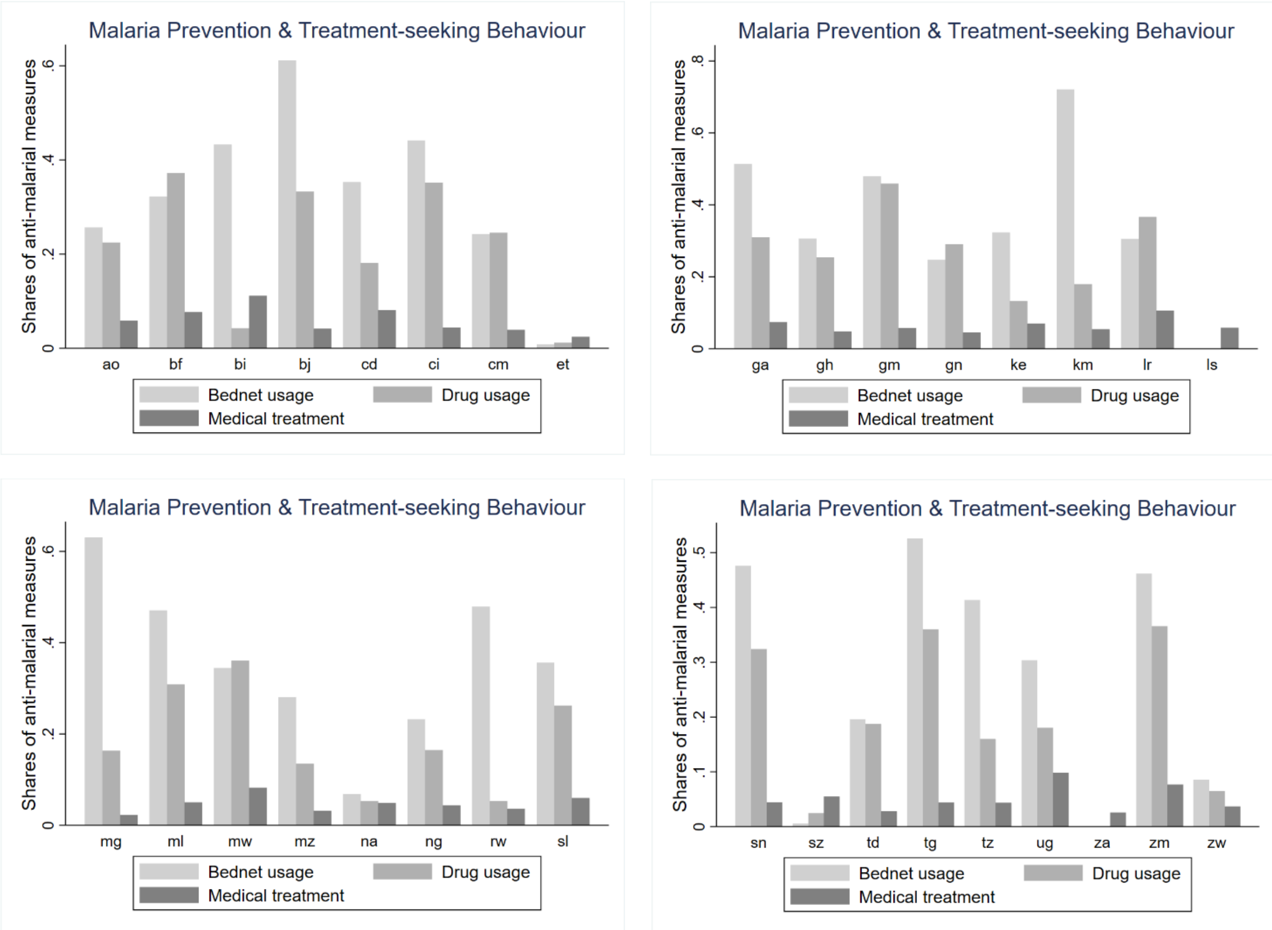


Figure 2: Prevention and treatment-seeking behavior among the 1950s and 1990s birth cohorts at the sub-national level

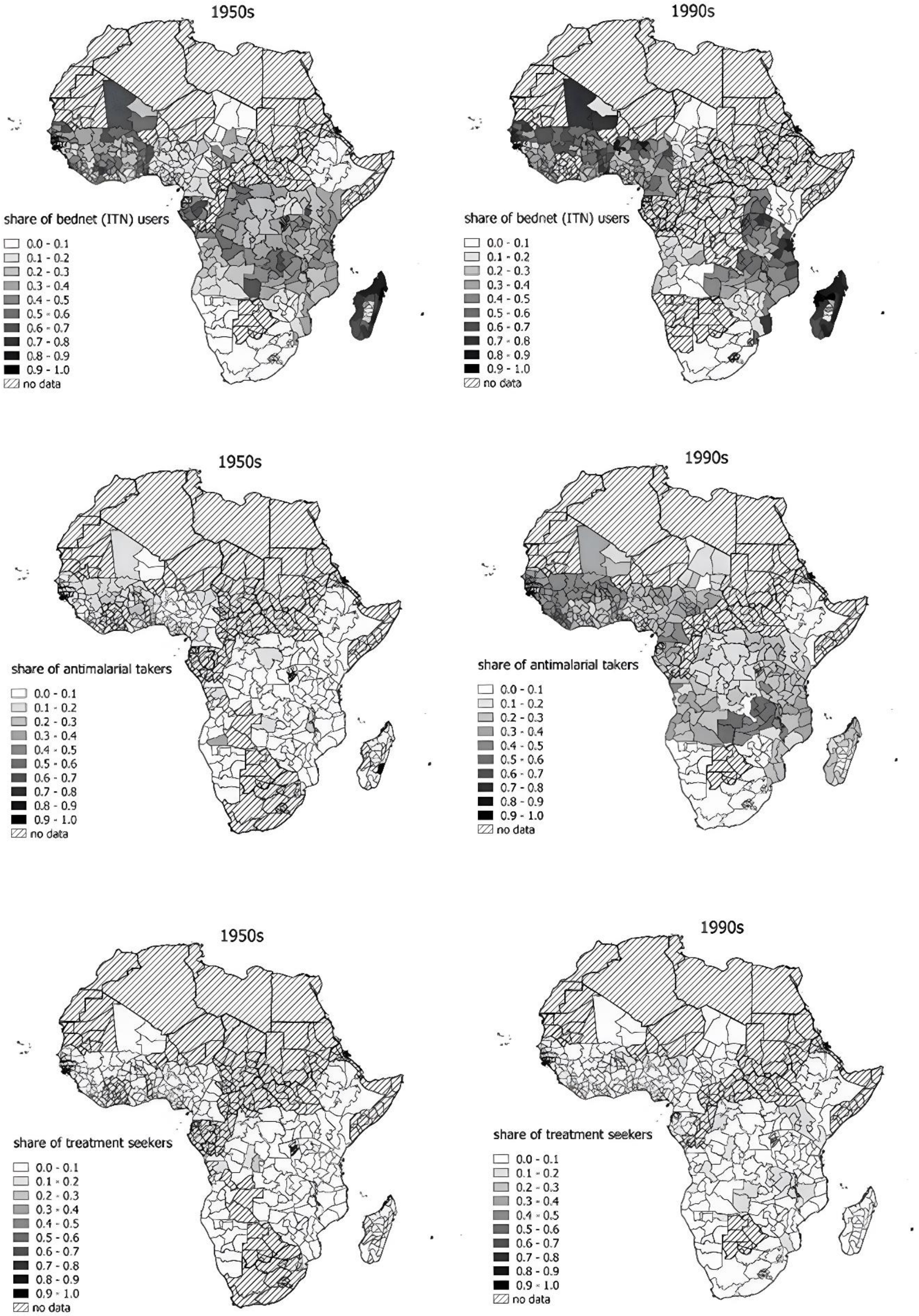


Figure 3: Malaria suitability (ecology based) across African regions

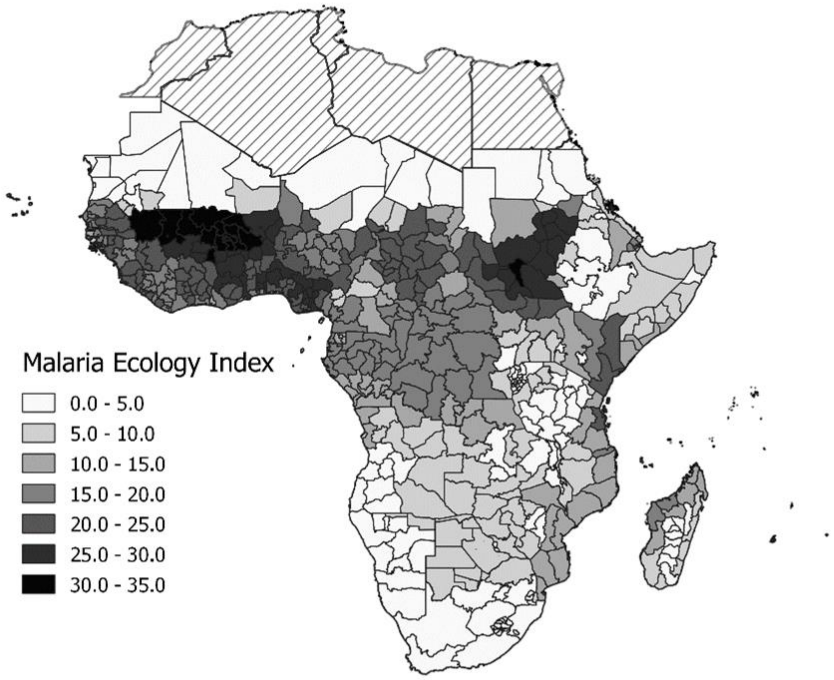


Figure 4: Correlation between malaria prevention behavior and malaria suitability (average over 1940s to 1990s)

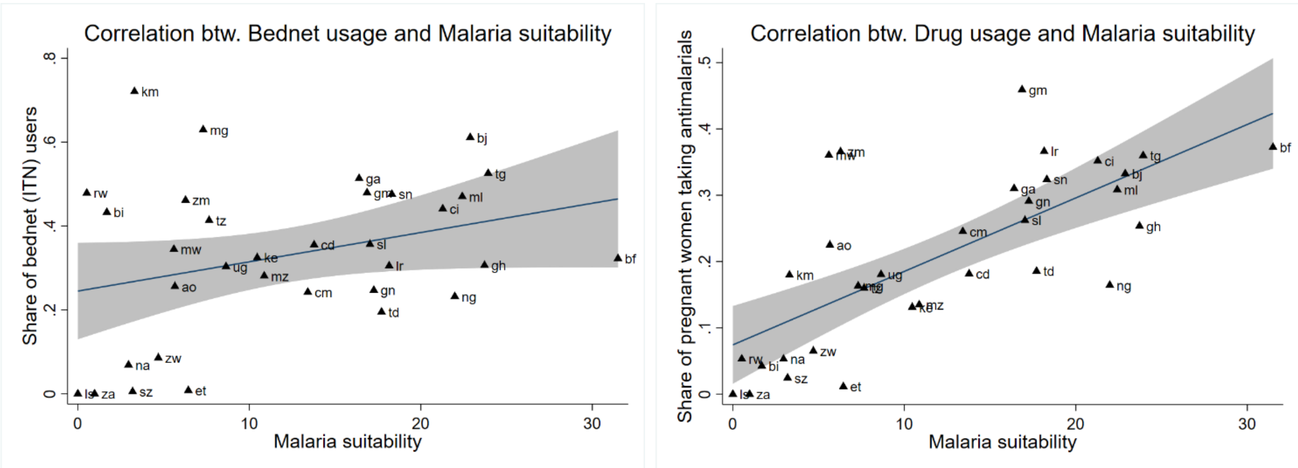


Figure 5: Evolution of numeracy over birth cohorts (1940s to 1990s)

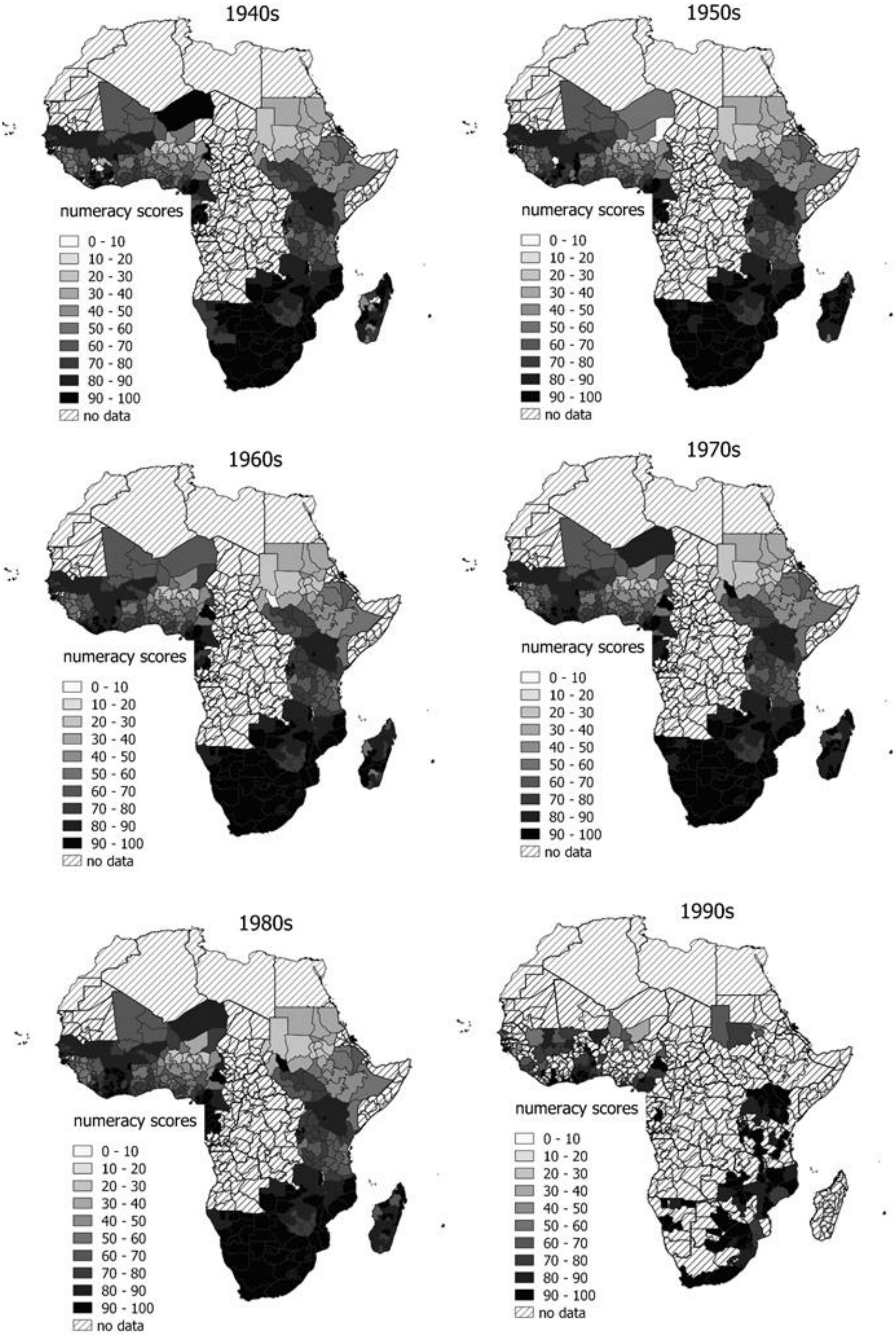


Figure 6: Evolution of literacy over birth cohorts (1940s to 1990s)

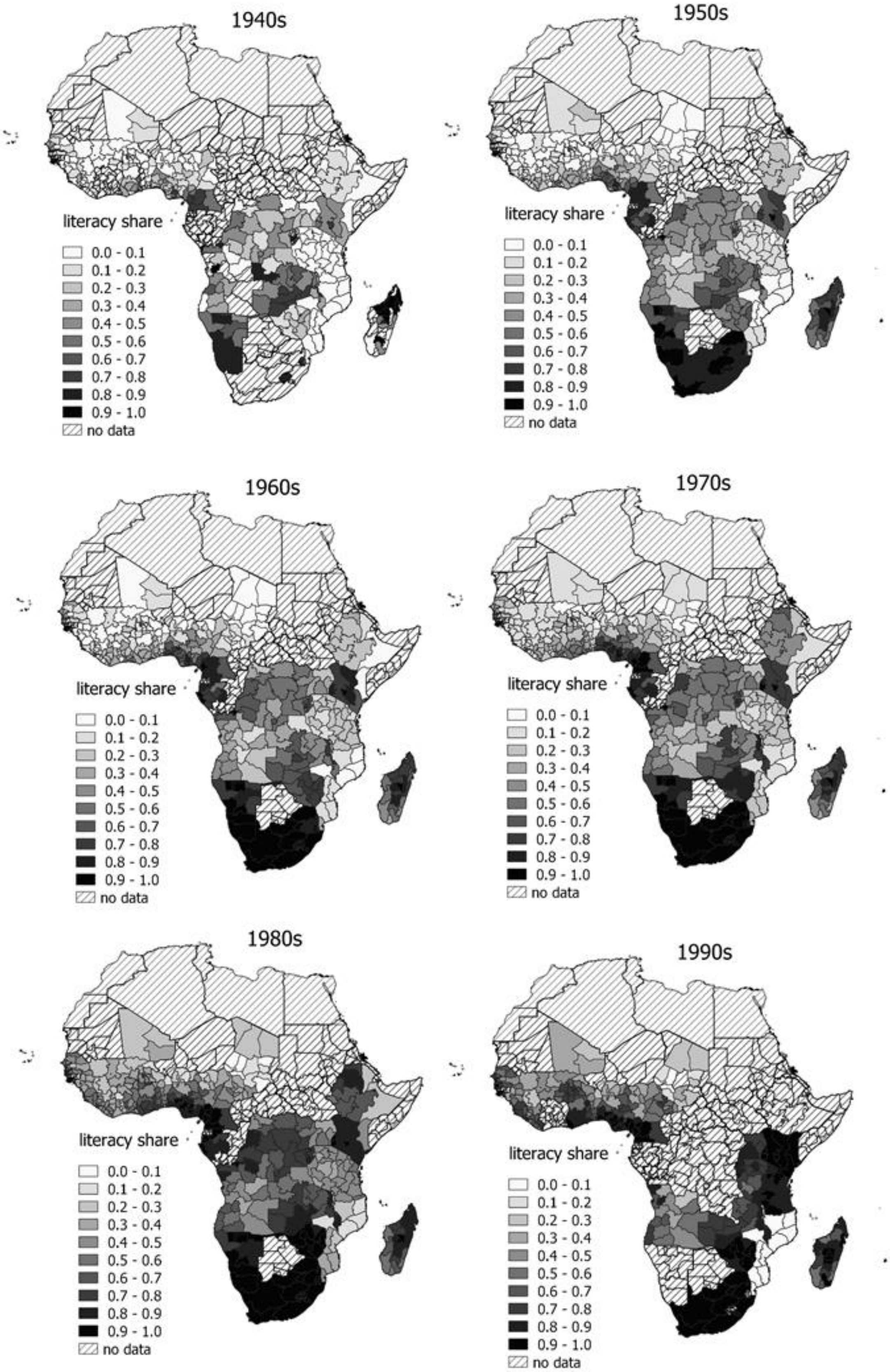
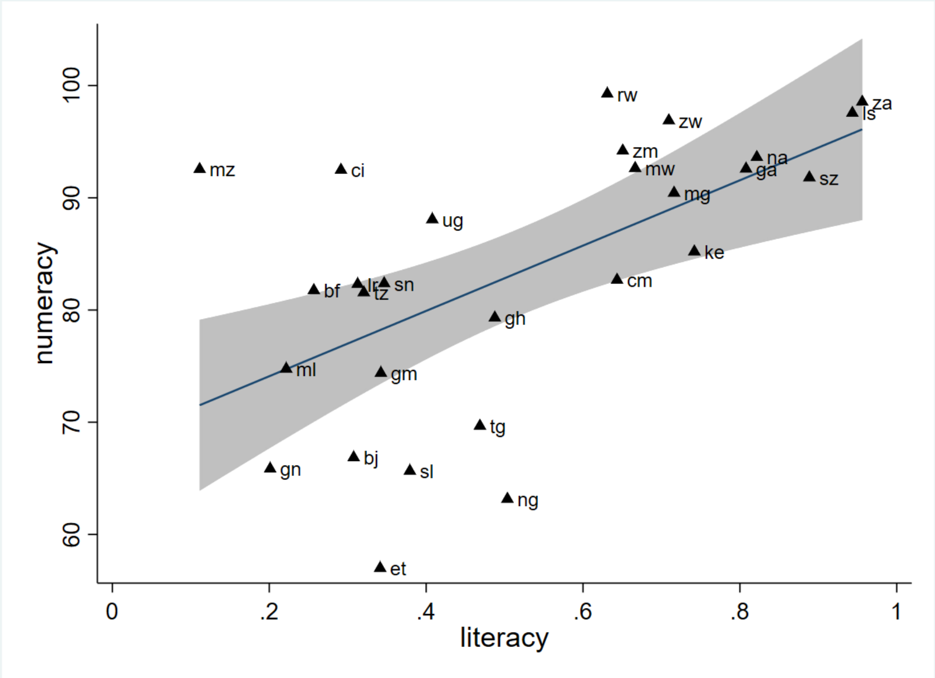


Figure 7: Correlation between numeracy and literacy (average over 1940s to 1990s)



Appendix

Data availability

Table 11: DHS data availability per wave

Wave 4	Wave 5	Wave 6	Wave 7	Wave 8
Benin	DR Congo	Benin	Angola	Ethiopia
Burkina Faso	Eswatini	Burkina Faso	Benin	Gambia
Cameroon	Ethiopia	Burundi	Burundi	Senegal
Ethiopia	Ghana	Cameroon	Cameroon	
Ghana	Guinea	Comoros	Chad	
Kenya	Kenya	Cote d'Ivoire	Ethiopia	
Lesotho	Liberia	DR Congo	Ghana	
Malawi	Madagascar	Ethiopia	Guinea	
Mali	Mali	Gabon	Kenya	
Namibia	Mozambique	Guinea	Lesotho	
Nigeria	Namibia	Lesotho	Liberia	
Senegal	Nigeria	Liberia	Malawi	
Tanzania	Rwanda	Malawi	Mali	
Uganda	Sierra Leone	Mali	Mozambique	
Zimbabwe	Tanzania	Mozambique	Nigeria	
	Uganda	Namibia	Rwanda	
	Zambia	Nigeria	Senegal	
	Zimbabwe	Rwanda	Sierra Leone	
		Senegal	South Africa	
		Sierra Leone	Tanzania	
		Tanzania	Uganda	
		Togo	Zambia	
		Uganda	Zimbabwe	
		Zambia		
		Zimbabwe		

Table 12: MIS data availability per wave

Wave 4	Wave 5	Wave 6	Wave 7	Wave 8
N.A.	Angola	Angola	Burkina Faso	Ghana
	Liberia	Burundi	Ghana	
	Senegal	Liberia	Kenya	
	Uganda	Madagascar	Liberia	
		Malawi	Madagascar	
		Nigeria	Malawi	
			Mali	
			Mozambique	
			Nigeria	
			Sierra Leone	
			Tanzania	
			Togo	
			Uganda	

Table 13: IPUMS data availability per decade

1940	1950	1960	1970	1980	1990
Benin	Benin	Benin	Benin	Benin	Benin
Botswana	Botswana	Botswana	Botswana	Botswana	Botswana
Burkina Faso	Burkina Faso	Burkina Faso	Burkina Faso	Burkina Faso	Burkina Faso
Cameroon	Cameroon	Cameroon	Burundi	Burundi	Cameroon
Estwatini	Estwatini	Côte d'Ivoire	Cameroon	Cameroon	Côte d'Ivoire
Ethiopia	Ethiopia	Estwatini	Côte d'Ivoire	Côte d'Ivoire	Estwatini
Ghana	Gabon	Ethiopia	Estwatini	Estwatini	Ethiopia
Guinea	Ghana	Gabon	Ethiopia	Ethiopia	Gabon
Kenya	Guinea	Ghana	Gabon	Gabon	Ghana
Lesotho	Kenya	Gambia	Ghana	Ghana	Gambia
Liberia	Lesotho	Guinea	Gambia	Gambia	Guinea
Malawi	Liberia	Kenya	Guinea	Guinea	Kenya
Mali	Madagascar	Lesotho	Kenya	Kenya	Lesotho
Mozambique	Malawi	Liberia	Lesotho	Lesotho	Liberia
Nigeria	Mali	Madagascar	Liberia	Liberia	Malawi
Rwanda	Mozambique	Malawi	Madagascar	Madagascar	Mali
Senegal	Nigeria	Mali	Malawi	Malawi	Mozambique
Sierra Leone	Rwanda	Mozambique	Mali	Mali	Namibia
South Africa	Senegal	Namibia	Mozambique	Mozambique	Nigeria
Tanzania	Sierra Leone	Nigeria	Namibia	Namibia	Senegal
Togo	South Africa	Rwanda	Nigeria	Nigeria	Sierra Leone
Uganda	Tanzania	Senegal	Rwanda	Senegal	South Africa
Zambia	Togo	Sierra Leone	Senegal	Sierra Leone	Tanzania
Zimbabwe	Uganda	South Africa	Sierra Leone	South Africa	Togo
	Zambia	Tanzania	South Africa	Tanzania	Uganda
	Zimbabwe	Togo	Tanzania	Togo	Zambia
		Uganda	Togo	Uganda	Zimabwe
		Zambia	Uganda	Zambia	
		Zimbabwe	Zambia	Zimabwe	
			Zimabwe		

Table 14: Afrobarometer data availability per wave

Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7
Botswana	Botswana	Benin	Benin	Benin	Benin	Benin
Ghana	Ghana	Botswana	Botswana	Botswana	Botswana	Botswana
Lesotho	Kenya	Ghana	Burkina Faso	Burkina Faso	Burkina Faso	Burkina Faso
Malawi	Lesotho	Kenya	Ghana	Burundi	Burundi	Cameroon
Mali	Malawi	Lesotho	Kenya	Cameroon	Cameroon	Côte d’Ivoire
Namibia	Mali	Madagascar	Lesotho	Côte d‘Ivoire	Côte d‘Ivoire	Eswatini
Nigeria	Mozambique	Malawi	Liberia	Eswatini	Eswatini	Gabon
South Africa	Namibia	Mali	Madagascar	Ghana	Gabon	Gambia
Tanzania	Nigeria	Mozambique	Malawi	Guinea	Ghana	Ghana
Uganda	Senegal	Namibia	Mali	Kenya	Guinea	Guinea
Zambia	South Africa	Nigeria	Mozambique	Lesotho	Kenya	Kenya
Zimbabwe	Tanzania	Senegal	Namibia	Liberia	Lesotho	Lesotho
	Uganda	South Africa	Nigeria	Madagascar	Liberia	Liberia
	Zambia	Tanzania	Senegal	Malawi	Madagascar	Madagascar
	Zimbabwe	Uganda	South Africa	Mali	Malawi	Malawi
		Zambia	Tanzania	Mozambique	Mali	Mali
		Zimbabwe	Uganda	Namibia	Mozambique	Mozambique
			Zambia	Nigeria	Namibia	Namibia
			Zimbabwe	Senegal	Nigeria	Nigeria
				Sierra Leone	Senegal	Senegal
				South Africa	Sierra Leone	Sierra Leone
				Tanzania	South Africa	South Africa
				Togo	Tanzania	Tanzania
				Uganda	Togo	Togo
				Zambia	Uganda	Uganda
				Zimbabwe	Zambia	Zambia
					Zimbabwe	Zimbabwe

Prevention and treatment-seeking behavior

Figure 8: Prevention and treatment-seeking behavior (usage of bednets) for the birth cohorts at the sub-national level

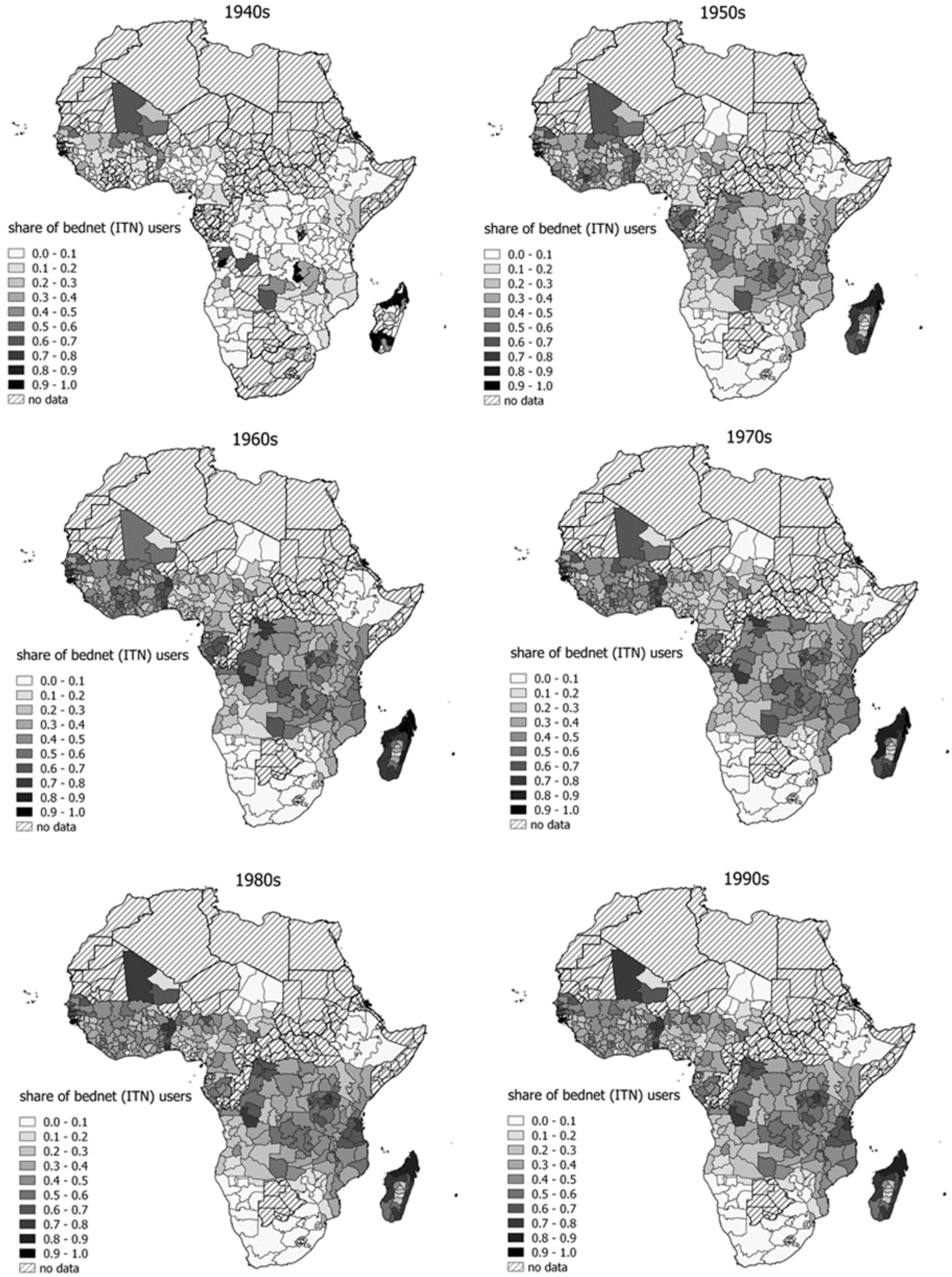


Figure 9: Prevention and treatment-seeking behavior (intake of antimalarial drugs) for the birth cohorts at the sub-national level

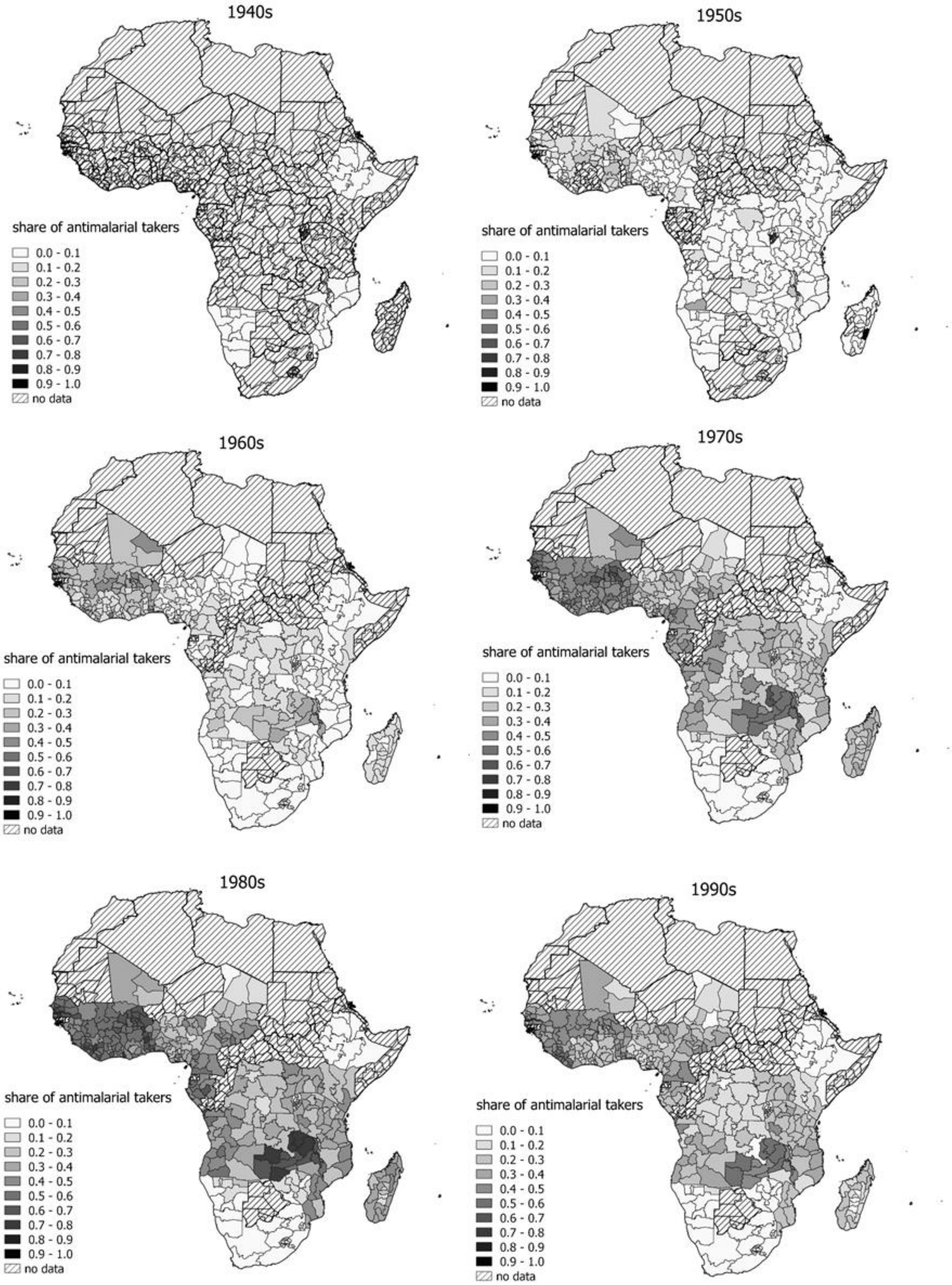
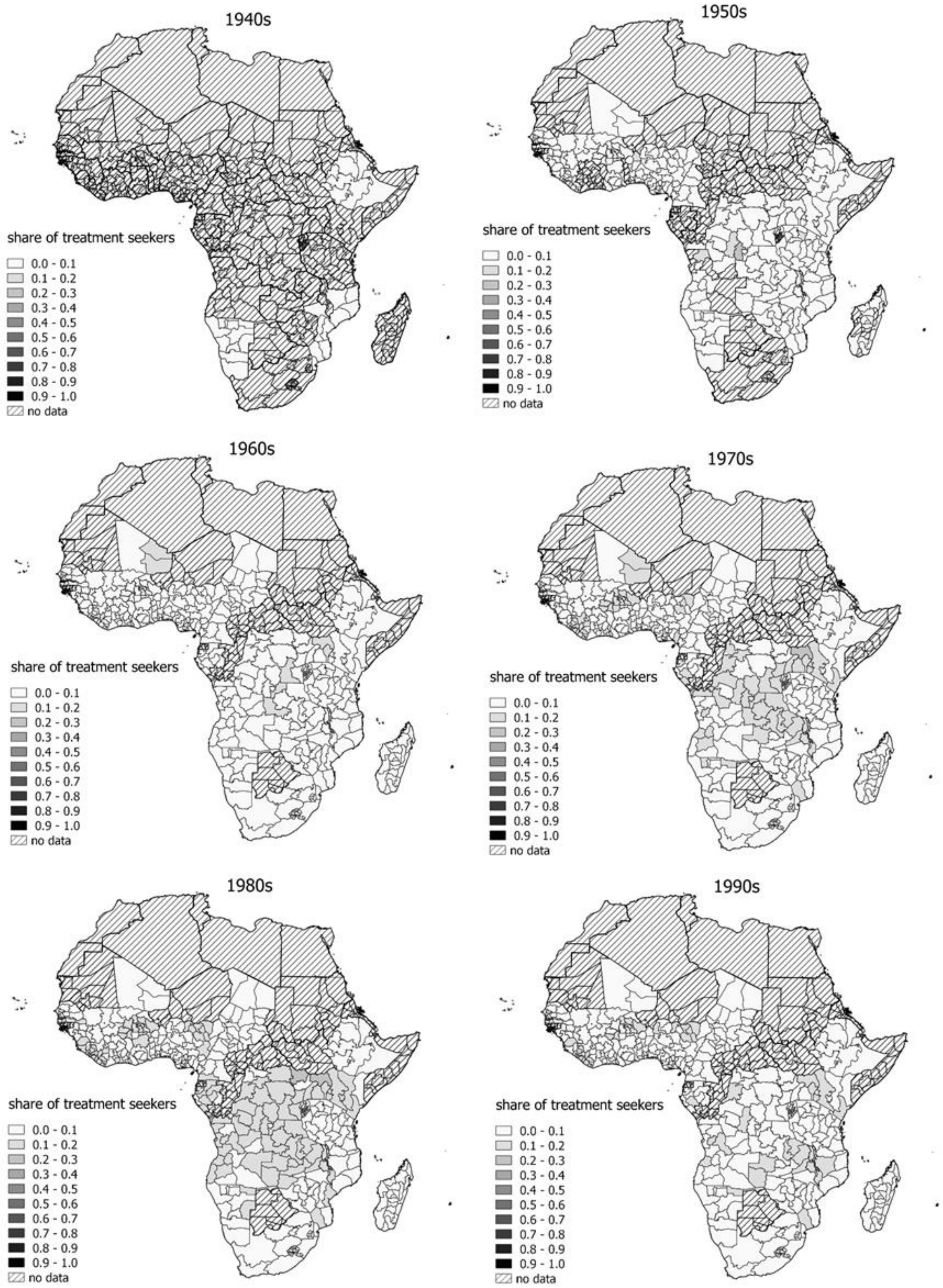
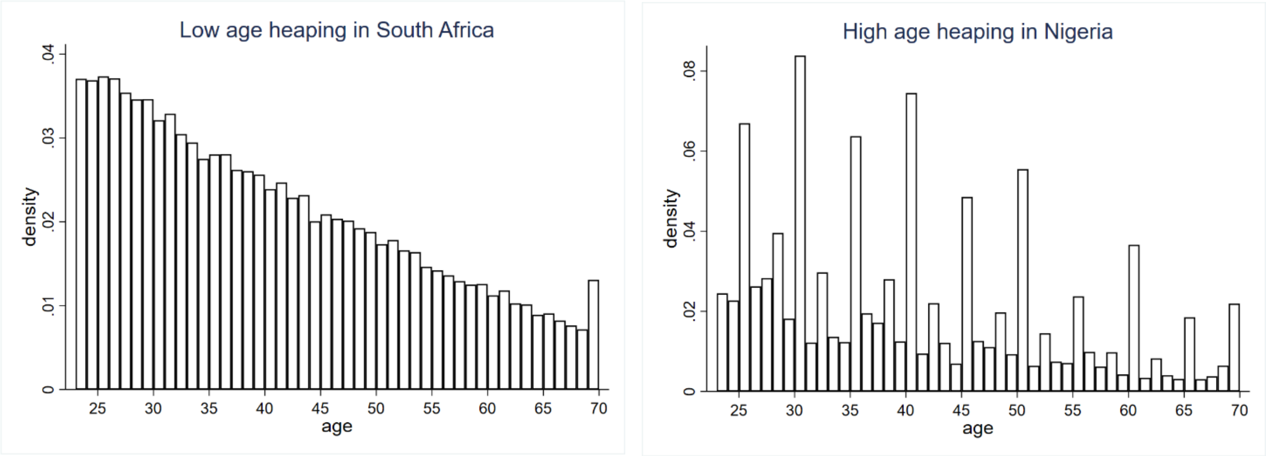


Figure 10: Prevention and treatment-seeking behavior (medical treatment) for the birth cohorts at the sub-national level



Age heaping patterns

Figure 11: Countries with low and high degrees of age heaping



Numeracy and literacy

Figure 12: Correlation between treatment-seeking behavior and human capital variables

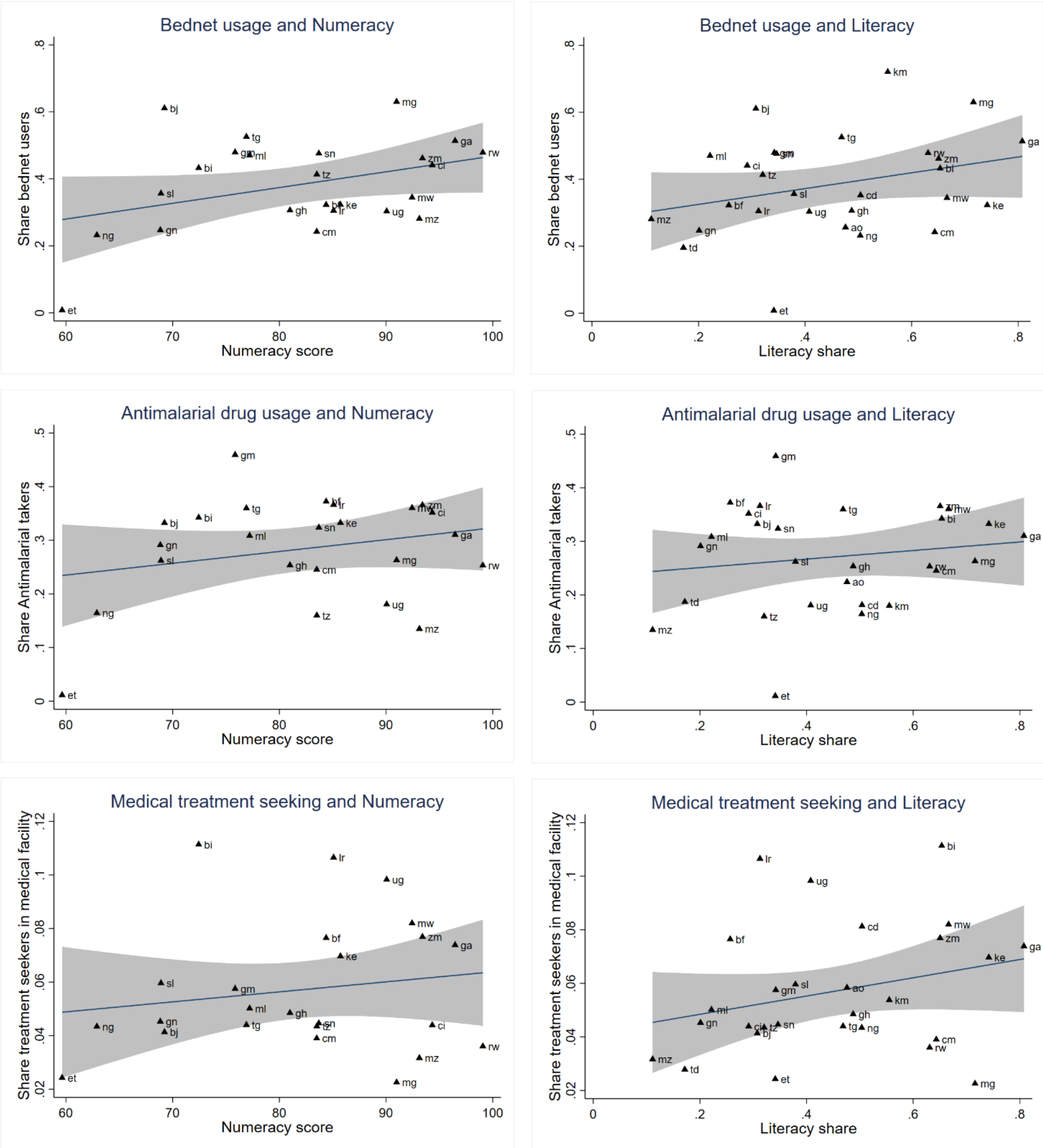


Figure 13: Correlation coefficients between numeracy and literacy