Charles University

Faculty of Social Sciences
Institute of Economic Studies

MASTER'S THESIS

The Effects of Different Malaria Prevention Measures: Panel Data Analysis

Author: **Bc. Adéla Pavelková**

Supervisor: **Mgr. Barbara Pertold-Gebická M.A., Ph.D.**

Academic Year: **2019/2020**

Declaration of Authorship

The author hereby declares that he compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

The author grants to Charles University permission to reproduce and to distribute copies of this thesis document in whole or in part.

Prague, May 7, 2020

Adéla Pavelková

Signature

Acknowledgments

I would like to express my sincere gratitude to my supervisor Mgr. Barbara Pertold-Gebická M.A., Ph.D. for her valuable support, guidance, motivation, patience, knowledge and useful advices.

I would like to also express my sincere thanks for guiding me when choosing the topic and compiling the content.

I am also grateful to my family and friends for constant support during the whole studies.

Abstract

The main aim of this diploma thesis was to explore the topic of malaria preventive measures. Concretely, to study which preventive measures are useful and to see how they are distributed around the world. For international organizations, this is very important as they need to know whether funds allocated for malaria aid are distributed effectively. This study is using manually compounded data from the World Health Organization for all countries threatened by malaria mostly from 2001 to 2018. For this purpose, panel data regression methods using robust standard errors, bootstrapping and cluster analysis were used. The results showed that generally, the most useful preventive measures are indoor-residual sprayings, a combination of sprayings and insecticide-treated nets and rapid diagnostic tests. Furthermore, the effect of the population living in rural areas is significant. Besides, gross domestic product is a very important factor for African countries. The stability analysis – bootstrapping – confirmed our results. However, we examined that insecticide-treated nets are still the most distributed measures. Doing the cluster analysis, we observed that countries on the same continent should not be treated similarly and we emphasized countries that should receive higher attention. Overall, the advantage of this study is external validity as our results can be generalized.

JEL Classification	C01, C13, C33, C38, I10, I11, I15, I19
Keywords	Malaria, Preventive Measures, Panel Data, Regression Analysis, Bootstrapping, Cluster Analysis

Abstrakt

Hlavním cílem této diplomové práce je prozkoumat téma preventivních opatření proti malárii. Konkrétně se tato práce snaží identifikovat, která preventivní opatření jsou účinná a jak jsou tato opatření rozdistribuována po světě. Vzhledem k omezenému počtu finančních prostředků je pro mezinárodní organizace důležité vědět, zda jsou tyto prostředky vynaloženy efektivně. Tato práce využívá manuálně sestavených dat ze Světové zdravotnické organizace pro všechny státy, které jsou ohroženy malárií během let 2001 až 2018. Pro účely práce jsou zde využité metody regresní analýzy pro panelová data včetně využití robustní standardní chyby, bootstrapová metoda a shluková analýza. Výsledky ukázaly, že obecně nejúčinnějším opatřením jsou insekticidní spreje, kombinace insekticidních sprejů a sítí impregnovaných insekticidem a rychlé imunochromatografické testy. Efekt populace žijící v zemědělských oblastech byl také signifikantní. Pro Africké země je navíc velmi důležitým faktorem hrubý domácí produkt. Bootstrapová analýza potvrdila naše výsledky. Obecně jsou však sítě impregnované insekticidem používané stále nejvíce. Pomocí shlukové analýzy jsme zjistili, že ne všechny státy na jednom kontinentu procházejí podobnou malarickou situací a v diplomové práci jsme zdůraznili několik států, na které by se organizace měli více zaměřit. Výhodou naší studie je možnost generalizovat výsledky, jelikož analýzy byly provedeny obecně pro všechny státy ohrožené malárií.

Klasifikace C01, C13, C33, C38, I10, I11, I15, I19

Klíčová slova Malárie, Preventivní Opatření, Panelová Data, Regresní Analýza, Bootstrapová Metoda, Shluková Analýza

Contents

List of Tables

List of Figures

Acronyms

ACT	Artemisinin – Based Combination Therapy
BLUE	Best Linear Unbiased Estimate
CDC	Center for Disease Control and Prevention
GDP	Gross Domestic Product
GPIRM	Global Plan for Insecticide Resistance Management
GPM	Generalized Pairwise Modeling
ITN	Insecticite-Treated Nets
IRS	Indoor Residual Spraying
LLIN	Long-Lasting Insecticide Treated Nets
PBO	Piperonyl Butoxide
RDT	Rapid Diagnostic Test
WHO	World Health Organization

Master's Thesis Proposal

Author:	**Bc. Adéla Pavelková**	Supervisor:	Mgr. Barbara Pertold-Gebická M.A., Ph.D.
E-mail:		E-mail:	
Phone:		Phone:	
Specialization:	ET&M	Defense Planned:	June 2020

Proposed Topic:

The Effects of Different Malaria Prevention Measures: Panel Data Analysis

Motivation:

Every year, the number of people dying on malaria is approaching 500 000. Therefore, malaria belongs to one of the greatest threats around the world affecting mainly emerging countries. In my diploma thesis, I would like to focus on preventive measures that help decrease the number of deaths caused by malaria. Many organizations (WHO, UNICEF) try to help malarial countries by providing them funds or different preventive commodities. I would like to study the impact of these preventive measures on occurrence of malaria. Furthermore, there exist only a few studies discovering the general problem of malaria prevention. Most of the existing studies are aimed only at one concrete preventive control or one concrete country, mostly African region (such as study by J. Gimnig, P.Otieno and V. Were (2016) focused on Western Kenya or study by T. Solomon, E. Loha, W. Deressa, T. Gari, H. Overgaard and B. Lindtjorn (2019) from Ethiopia). The research by K. Wangdi, L. Furuya-Kanamori and J. Clark (2018) studies malaria prevention as general. For that purpose, they used Bayesian approach. However, using old data, they did not consider modern measures such as long-lasting insecticide nets. Therefore, I would like to get new information about malaria prevention from the research in my diploma thesis.

Hypotheses:

1) The first hypotheses I will be testing is whether the greater availability of preventive measures helps to decrease the number of malaria deaths. My expectation is that they do help.

2) Another hypothesis is focused on the differences between continents. My question is whether there is a similar development in the countries belonging to the same continent.

3) Next hypothesis explores methodology, namely, whether the fixed effect model or random effect model is better for my analysis. I believe that fixed effect model works better as thanks to panel data structure, there exist country-specific characteristics that endogenously affect the relationship between preventive measures and number of deaths caused by malaria.

Methodology:

More concretely, I would like to study the effects of distribution of mosquito nets, distribution of indoor residual spraying, availability of preventive testing on malaria (including the availability of RDT – rapid diagnostic tests), availability of different drugs, the effect of participation in World Malaria Program and the effect of distributed funds intended to prevent malaria.

For the purpose of the analysis, I will collect the data from the World Health Organization and from the Demographic and Health Surveys Program. I will rely on panel data for countries, which are threatened by malaria (Africa, America, Eastern Mediterranean, South-East Asia and Western Pacific). The data are mostly available from 2005 to 2018.

Information on preventive measures and on the number of malaria-related deaths will be expresses in per capita terms to allow for comparison of differently sized countries.

The relation between preventive measures and malaria-related deaths might be endogenous. Mainly because aid is heavily concentrated on countries with the highest prevalence of malaria distributing mosquitos. To deal with this potential endogeneity I will rely on the panel structure of the data. I will use panel data regression techniques: fixed effect model and random effect model. I will conduct both techniques, test their validity and compare their result. As stated above, my hypothesis is that fixed effect model should work better, because of the endogeneity. To check the robustness, I will use simulation based method – bootstrapping. It will serve as control for the stability of my analysis. As malaria kills very rapidly, I will be able to see the development over time, which contrasts with other diseases with longer incubation period.

Another possibility of dealing with the endogeneity of aid is reliance on exogenous variation in the inflow of international aid (caused by such events as outbreak or end of war conflicts).

Additionally, taking advantage of having the data for countries all over the world, I will use the cluster analysis (k-means clustering and hierarchical clustering) to compare the results for different groups of countries to see whether countries from the same continent are in the same cluster and do have the same properties.

Finally, I will compare the accuracy of results obtained from different methods.

Expected Contribution:

The contribution of my thesis would be in studying the effects of different preventive measures, which should help various organizations as well as local governments to know what helps the most. I could observe how effective are these programs in preventing malaria as well as compare their usefulness in different regions and their development over time. I would use the most recent available data, which were still not used for such research. The main advantage in contrast to other studies will be in external validity. My results will be taken for the whole world with focus on different regions. The existing studies on this topic are often aimed only at one concrete country and therefore cannot be generalized. To my best knowledge, generalized studies about the effects of malaria prevention using the most recent data cannot be almost found.

Outline:

Introduction and motivation
Facts about malaria and its prevention around the world
Literature review
Description of data and methods
Panel data analysis
Cluster analysis
Results and discussion – globally and regionally
Conclusion

Core Bibliography:

K, Wangdi, Furuya-kanamori L, Clark J, et al. Comparative effectiveness of malaria prevention measures: a systematic review and network meta-analysis. Parasites [online]. 2018, 11(1), 210 [cit. 2019-05-01]. DOI: 10.1186/s13071-018-2783-y. ISSN 17563305.

G, Gachelin, Garner P, Ferroni E, Verhave JP a Opinel A. Evidence and strategies for malaria prevention and control: a historical analysis. Malaria Journal [online]. 2018, 17(1), 96 [cit. 2019-05-01]. DOI: 10.1186/s12936-018-2244-2. ISSN 14752875.

HAILU, Alemayehu, Bernt LINDTJØRN, Wakgari DERESSA, Taye GARI, Eskindir LOHA a Bjarne ROBBERSTAD. Cost-effectiveness of a combined intervention of long lasting insecticidal nets and indoor residual spraying compared with each intervention alone for malaria prevention in Ethiopia. Cost Effectiveness and Resource Allocation [online]. 2018, 16(1), 1-17 [cit. 2019-05-01]. DOI: 10.1186/s12962-018-0164-1. ISSN 14787547.

NYAVOR, Kunche delali, Margaret KWEKU, Isaac AGBEMAFLE, Wisdom TAKRAMAH, Ishmael NORMAN, Elvis TARKANG a Fred BINKA. Assessing the ownership, usage and knowledge of Insecticide Treated Nets (ITNs) in Malaria Prevention in the Hohoe Municipality, Ghana. Pan African Medical Journal [online]. 2017, 28, 1-8 [cit. 2019-05-01]. DOI: 10.11604/pamj.2017.28.67.9934. ISSN 19378688.

JN, Hogarh, Agyekum TP, Bempah CK, Owusu-ansah EDJ, Avicor SW, Awandare GA, Fobil JN a Obiri-danso K. Environmental health risks and benefits of the use of mosquito coils as malaria prevention and control strategy. Malaria Journal [online]. 2018, 17(1), 265 [cit. 2019-05-01]. DOI: 10.1186/s12936-018-2412-4. ISSN 14752875.

MANGENI, Judith nekesa, Diana MENYA, Andrew OBALA, Alyssa PLATT a Wendy prudhomme O'MEARA. Development and validation of a rapid assessment tool for malaria prevention. Malaria Journal [online]. 2016, 15, 1-12 [cit. 2019-05-01]. DOI: 10.1186/s12936-016-1575-0. ISSN 14752875.

Author **Supervisor**

1 Introduction

Worldwide, there exist many diseases threatening the population living on Earth. Many international organizations such as the World Health Organization are doing their best to protect people against these illnesses. Unfortunately, many life-threatening diseases persist and their mortality rates are enormous. One of the most serious diseases is malaria. In 2018, more than 400 000 deaths caused by malaria were reported by the World Health Organization (2019b). Furthermore, 272 000 deaths were estimated to happen by children under five years (WHO, 2019b). Therefore, to eliminate the disease, it is crucial to find preventive measures that would protect people from malaria and other mosquito-borne diseases. In 2018, 2,7 billion US dollars were invested in malaria prevention measures (WHO, 2019b). Therefore, it is of very high importance to understand in which preventive measures the international organizations and governments should invest. Many studies have tried to explore which preventive measures are the most useful ones. However, the results are very diversified. For example, a study by K. Wangdi *et al.* (2018) confirmes the statistical significance of insecticide-treated nets. On the other hand, a study by J. Gimnig *et al.* (2016) verified that insecticide-treated nets are not a useful preventive measure. Overall, it is still not clear which preventive measures should be favored. Besides, most of the studies focus just on one country or region such as the study by J. Gimnig *et al.* (2016), A. Hailu *et al*. (2018) or K. Nyavor *et al.* (2017) studying various African countries. Besides, some studies aim at only some malaria preventive measures such as the study by D. Asingizwe *et al.* (2019) focusing on long-lasting insecticide-treated nets and indoor residual spraying or study by J. Hogarh *et al.* (2018) examining mosquito coils. Therefore, there is a lack of general studies focusing on malaria preventive measures around the world using the most recent available data.

The main objective of this thesis is to explore how useful various preventive measures are, to see which countries experience the worst situation with regards to malaria and to observe the supplying of malaria preventive measures in various countries. This is very important as many international organizations need to explore which countries have a lack of preventive measures to supply them with useful preventive measures as the funds needed for malaria control are very scarce. The advantage of this study is having dataset for all countries around the world which are threatened with malaria mostly from 2001 to 2018. The dataset was collected from the World Health Organization using all available information. To measure the usefulness of the preventive measures, panel data regression techniques will be used. We will conduct a fixed-effect model and random-effect model, test their validity and compare their results. Furthermore, we will verify their stability using bootstrapping. Using this simulation-based method, we will examine the confidence intervals. The effects of malaria preventive measures will be studied in terms of malaria deaths in various countries. The explanatory variables will be insecticide-treated nets, long-lasting insecticide-treated nets, indoor residual spraying, funds, rapid diagnostic tests, artemisinin-based combination therapy, gross domestic product, the population living in rural areas and a dummy variable whether a country experienced a war. Therefore, we will see which preventive measures help to reduce malaria deaths. Using a clustering method, a division of countries into various groups will be done. Therefore, it will be visible which countries are similar with regards to malaria, observing average values of our variables of interest. This will be done for the whole panel data to see the alternation of countries among various clusters as well as for one selected year to analyze the current situation. Putting these results together, we will see whether countries with the highest number of malaria deaths are sufficiently supplied with useful preventive measures. We may explore that the most useful preventive measures are not delivered into regions that need the highest attention and organizations invest in wrong measures that are not so helpful. The main advantage of this thesis will be in external validity, as other studies are mostly focused only on one specific country and therefore, we cannot generalize them. Furthermore, using these techniques for the most recent data, we will enhance the overall knowledge about malaria preventive measures from a new methodological perspective. To my best knowledge, such recent data from the World Health Organization were still not used for such research. Besides, this methodological approach will also enlarge the knowledge about malaria prevention measures from a new viewpoint.

Looking at the structure of the thesis, chapter 2 describes the current malaria situation. Chapter 3 provides a brief overview of the history of malaria preventive measures. Chapter 4 looks at the literature review. Chapter 5 presents the malaria preventive measures. Chapter 6 covers the methodological description together with the description of our variables. Chapter 7 shows the results of our different techniques. In chapter 8, we will proceed with various modifications of our panel data regression models. We will deal with heteroscedasticity and autocorrelation using heteroscedasticity and autocorrelation-consistent standard errors and provide various results of different regressions to explore the usefulness of the preventive measures in detail. Also, we will discuss there some issues and limitations of this thesis, for example, the endogeneity. The conclusion of our thesis will be provided in chapter 9.

2 Current malaria situation

To fully understand the importance of malaria prevention, we need to look at the current situation of malaria all around the world. Almost 230 million incidents of malaria were reported in 2018 with over 400 000 deaths in the same year (WHO, 2019b). Fortunately, this number is slowly decreasing. Surprisingly, even with this extraordinarily high number of deaths, there is no visible worldwide panic. Most of these incidents were reported in Africa, South-East Asia, and the Eastern Mediterranean. Countries with the highest number of malaria deaths are Nigeria, Democratic Republic of Congo, United Republic of Tanzania, Angola, Mozambique and Niger (WHO, 2019b). Recently, the incidence rate is around 57 cases per one thousand people who are currently at risk of malaria. This rate has remained at the same level since 2014, before that year, it was higher (WHO, 2019b).

On malaria deaths, the most vulnerable group are small kids under 5 years. Another group facing high risk are pregnant women, who due to malaria illness have kids with small birth weights who are delivered much sooner than they should have been. Often, this leads to high infant mortality. This is a big problem with malaria as consequently many women die during their pregnancy or after a child has been delivered only because of the malaria infection. Therefore, WHO is highly monitoring pregnant women and promotes high attention to malaria prevention (WHO, 2019b).

On malaria elimination, many countries are strongly fighting with this illness and some of them have reached visible successes. In 2018 and 2019 countries like Paraguay, Uzbekistan, Algeria and Argentina have been reported by WHO as countries erasing malaria. Furthermore, some countries have reached a year without malaria cases. Among these countries are China, Iran, El Salvador, Timor- Leste and Malaysia (WHO, 2019b).

To understand the situation with malaria more properly and to observe the development of its elimination, a couple of graphs based on the data from the World Health Organization (2019b) is shown below. On the first graph (2.1), we can observe the total number of deaths in comparison to malaria deaths by children under 5 years.

It is clearly visible that small children are the most vulnerable group. Overall, the situation has been improving over time. However, we can see that the elimination has slowed down during the last years as the number of deaths has remained relatively stable.

Looking at the other two graphs, we can examine the situation on each continent. Africa is projected separately as the number of deaths is much higher there and it would not be well-arranged to put it in one graph. On Africa (graph 2.2), the same development as on the previous graph may be recognized. That is logical, as African countries are the most threatened ones, therefore the world situation is just an imitation of African development. Observing the graph (2.3), the situation is not so straightforward like on the previous two graphs. On South-East Asia, the situation is clearly improving, however having not so stable movement. The situation in the Eastern Mediterranean is slightly worsening during the last four years. America and the Western Pacific are relatively stable. However, looking at the axes, these countries have a markedly better position in malaria situation than Africa.

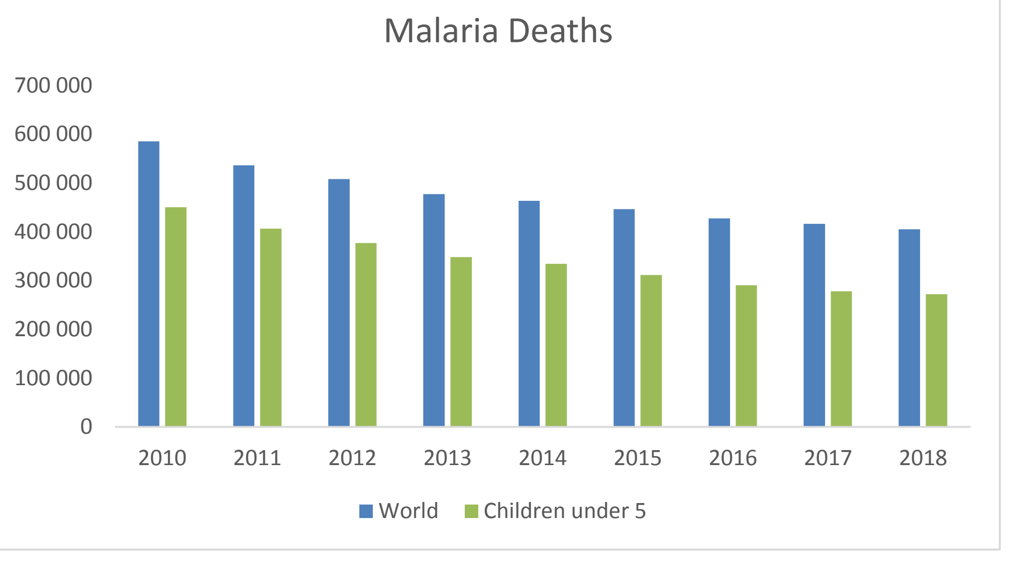

Figure 2.1: Malaria deaths – general

Source: WHO + author’s computations.

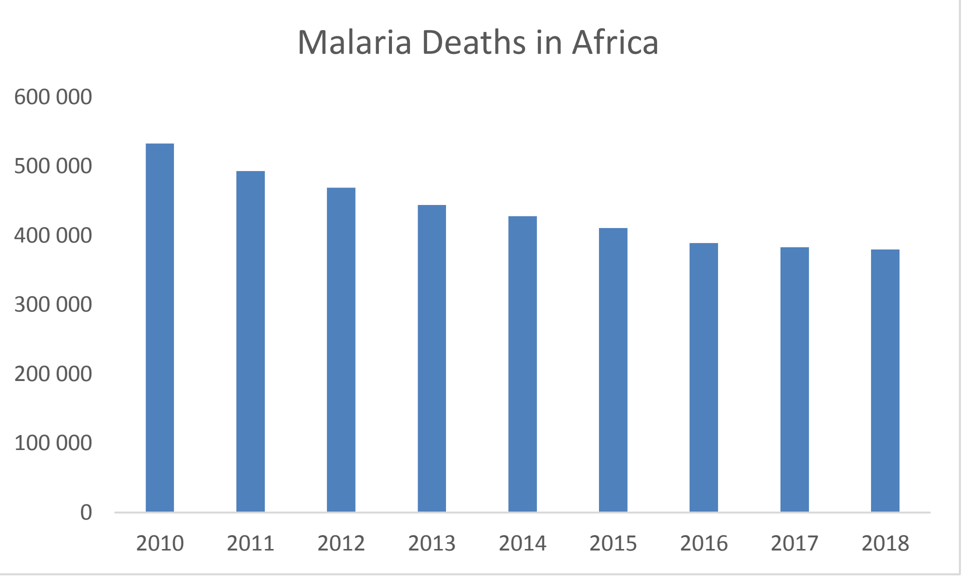

Figure 2.2: Malaria deaths – Africa

Source: WHO + author's computations.

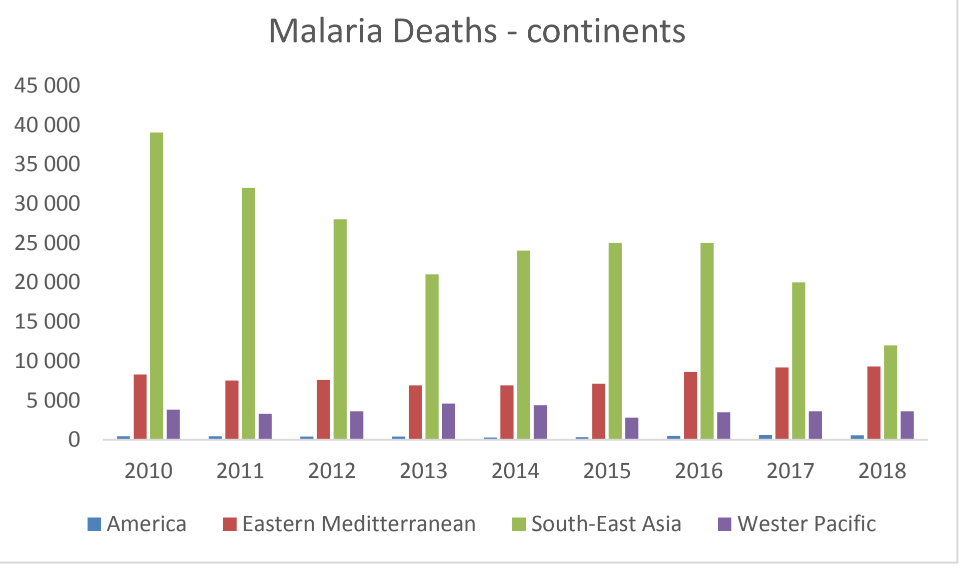

Figure 2.3: Malaria deaths – continents

Source: WHO + author's computations.

3 History of malaria prevention

The threat of malaria exists for a long time, therefore the attempts to prevent malaria started very early. In the study by G. Gachelin *et al.* (2018), the authors state that malaria prevention has been defined before the year 1930 and after that year it was only adjusted. They also add that even though the prevention has been defined for such a long time, it is still not possible to state which preventive measure is the most useful one.

The first attention given to malaria prevention is dated to the end of the nineteenth century. Among the first substances that were used to prevent malaria was quinine, which was later seen as not that effective. Around the year 1900, there was a new perspective on how to prevent malaria. Concretely, mosquito larvae should be reduced. This method started to be used widely in Brazil, India or at the location of the Panama Canal. The problem with this new method was the inability to use it on a large scale. Therefore, in 1925, at the First International Congress of Malaria, this prevention was also declared as ineffective. Also, there was discussed that malaria has not been reduced but only transferred to new places such as the region around the Panama Canal or other construction areas, where the dispersion was very rapid. Not only malaria but also yellow fewer expanded largely and therefore higher attention was desperately needed. Since 1925, the attention to malaria prevention was higher and the topic started to be of very high importance. The only problem was that as the prevention was not very well organized, there did not exist any official reports or statistics about the prevention methods (G. Gachelin *et al*. 2018).

The new practice to eliminate mosquitos was the recommendation to wear hats. Moreover, mosquito nets and sprays were also part of new prevention suggestions. Importantly, it was discovered that most of the mosquito bites happened at houses, therefore the attention was aimed to cover the entrance of houses and the surroundings of beds. Furthermore, the threat of yellow fever increased, which caused even higher attention to the usage of preventive measures. Because of this danger, it was recommended to cover all windows and doors with mosquito nets. Unfortunately, this method was quite expensive as it was costly to buy such a large amount of nets and change it often to prevent from having holes in it. For this reason, this recommendation was not globally spread. Furthermore, walls in houses situated in threatened areas were painted whitely as the mosquito could be easily seen and killed there (G. Gachelin et al. 2018).

After World Wars, new substances were tried to kill several types of bugs. Namely, it was Pyrethrum and Chrysanthemum. After couple of surveillance, it was discovered that these plants did not have any satisfactory results in killing mosquitos (G. Gachelin et al. 2018).

Even higher expansion of malaria and yellow fever led countries and organizations to try new measures. One of them was to clear standing water from mosquitos and larvae. Larvae have been also destroyed in fields. However, this method caused many deaths of other animals living in fields, so it was not proved as being successful. Moreover, new solutions were tested. The aim was to find out whether they can be applied in the water to kill mosquitos and its larvae. Even solutions that were used for killing rats were applied against mosquitos. However, these attempts were not very successful at a large scale as for poorer countries it was still very costly (G. Gachelin et al. 2018).

After a couple of tests, the only solution that appeared to be effective was Paris green. Many countries started to use this type of solution. Even though this method was much cheaper and did not kill other animals, there occurred a problem. It was necessary to use this poison every two weeks, which was a problem in large or remote areas. Another approach was to use fish such as Gambusia to prevent waters from mosquitos and its larvae. It was shown that they can limit the number of mosquitos, but only temporarily. In 2001, there was an event in Kazakhstan, where the necessity to try other fish in different water conditions was discussed. However, it was difficult to measure whether these steps helped to decrease malaria as no data were available (WHO 2001).

In summary, there have been implemented and tested many different methods to eliminate mosquitos. However, most of them were unable to be spread on a large scale and had other limitations as well. Very efficient is to cover houses, but the equipment is costly. There does not exist one measure that would help solely to prevent malaria. Only the combination of various preventive measures may be helpful. This strategy has also been proofed when considering yellow fewer.

4 Literature review

Malaria prevention is a world-widely very important topic, therefore there exist and still arise new researches and papers about it. Unfortunately, there exists only a small number of studies that discover generally the topic of malaria prevention. Most of the studies are focused only on one preventive measure or only on one specific location – most frequently some African country or even only a small community there.

Study written by K. Wangdi *et al.* (2018) examines the prevention in general. They use data from existing studies and analyze and compare different preventive measures. The current studies were chosen based on title and abstract independently. After the primary selection, the whole text was evaluated and the most important points from the text including the year, country, measures, and many others were saved for further analysis. For the investigation, the authors used a generalized pairwise modeling framework (GPM) and the Bayesian approach. Subsequently, taking only a restricted part of the observations, a sensitivity analysis was initiated. Overall, 7940 citations were taken into the account, after deleting some of them, 30 citations were finally used for analysis. The years of interest were from 1988 to 2015. On the Bayesian approach, as mentioned in the study, there occurred a problem with the identification of prior distribution.

Finally, the results showed that the best and only statistically significant measure were insecticide-treated nets (ITN). The authors stated that the result ended up like this because the nets do not allow mosquitos to get on a body to take blood from their hosts. They also mention, that part of it can replace the effects of indoor residual sprayings (IRS), as the nets can be already impregnated. Furthermore, using both may be only helpful and may reduce malaria infection even more. As this study worked with older articles and data, it does not take into account new nets called long-lasting insecticide nets (LLIN). However, the usage of different data from different sources may be taken as a limitation of this study. Some of the articles were using data from threatened areas, while others have been studying places, where the infection of malaria is not so powerful. The authors also added that even though, the threat of malaria is decreasing, we still cannot say which preventive measure is the best, so it is better to use more of them to ensure that they help even a little bit to prevent from deaths from malaria. In addition, the authors mentioned that different studies show opposite results, where some say that ITNs and IRSs have the same effectivity and others state that none of these helps. This phenomenon may be seen throughout many studies searching for the best malaria prevention.

The study by J. Gimnig *et al.* (2016) has analyzed the effects of preventive measures in Western Kenya. Their main aim was to study especially two preventive measures – insecticide-treated nets and indoor residual sprayings. The reason was the ambiguity about these two measures in many other recent studies. Logistic regression, chi-square analysis and, general linear models have been implemented after receiving data from three various surveys conducted during three different climate conditions. For each of the surveys, the authors have chosen thirty areas in Kenya where the team of interviewers managed to travel. In addition to testing the effectivity of insecticide-treated nets and indoor residual sprayings separately, the interaction term was adopted as well. Furthermore, the age of interviewed people and the elevation in which the survey was conducted were also taken into the account. Even though insecticide-treated nets and indoor residual sprayings are amongst the most used measures in Africa, in this study insecticide-treated nets do not appear to be statistically significant. Furthermore, the authors concluded that indoor residual sprayings should be primarily used in places where malaria is likely to be destructed soon.

Many authors analyzed data already from existing researches such as the study mentioned above by K. Wangdi *et al.* (2018) or A. Hailu *et al.* (2018). This study explores the malaria situation in Ethiopia. The cost-effectiveness analysis was selected for this purpose, where three different states of health situations were used to catch the behavior of malaria illness. This analysis was primarily focused on the effectivity of indoor residual sprayings and long-lasting insecticide treated nets alone and on their common effects as well. To catch the likelihood of moving from one health state to another health state, transition probabilities were adopted. The data that have been used here are taken from existing studies analyzing the situation in different African countries. To proceed with the sensitivity analysis, probabilistic analysis with Monte Carlo simulation was practiced. The authors showed that indoor residual sprayings nor long-lasting insecticide treated nets are cost-effective. Furthermore, it was shown that the cost of long-lasting insecticide net per person for one year is 1,06 USD and for indoor residual spraying it is 3,07 USD.

Some of the studies aimed at a concrete group of people. Paper by K. Nyavor *et al.* (2017) studied the effects of insecticide-treated nets among pregnant women and mothers with small children under five years old. The authors have used cross-sectional data from 30 different communities in Ghana, where insecticide-treated nets started to be publicly distributed in the year 2000. The cluster technique has been adapted. The dataset was received by getting answers to questionaries and observation of habits adopted by local people. The questions were focused on the background of those people as well as their knowledge about malaria and the usage of insecticide-treated nets. The analysis has been done using the software STATA, where the explained variable was whether the mother owns the net. On explanatory variables, knowledge about malaria, preventive measures, health status and many other data received from the questionaries' were applied. Most of the families have received nets for free from Reproductive and Child Health Clinics. From the questionnaire, it was found out that around two-thirds of families have been informed about the threat of malaria and almost all women relied on the effectivity of nets. On the other hand, the questions helped to understand why some families do not use nets at all. Among the key reasons is the cost of nets, a knowledge where to get nets or absence of children during the distribution of nets.

However, as stated in the text, this study has some limitations. The answers from the questionnaire did not always match the reality of what has been observed. For example, not so many children were sleeping under the net as presented in the answers of mothers. Another limitation is that this survey was made at the end of the rainy season when the possibility of malaria infection is much higher and therefore the nets are used more frequently than during other months. Furthermore, long-lasting insecticide treated nets and insecticide-treated nets were taken as one preventive measure and the authors did not separate them properly. Finally, the authors compare the situation to other countries. They state that in Togo and Sierra Leone, less ownership of insecticide-treated nets has been recorded. There, only 3% of small children are using nets above their beds. They add, that in Ghana, a couple of campaigns are running to ensure that 100% of households will be using nets against mosquitos in the future. Therefore, governance aims to inform people about the consequences of malaria and how prevention may help.

Some papers intend to study the effects only of one preventive measure, sometimes also an alternative one, which is not very widely used. Article by J. Hogarh *et al.* (2018) inspects the impact of mosquito coils. Mosquito coils are based on the same principle as mosquito sprays, but they release spray continuously. As the authors expressed, primarily it sounds very attractive using the mosquito coils instead of ordinary sprays, but there exist many concerns about its effectivity as well as the impact on health. There have been doubts that constant spraying may be one of the sources of lung cancer or problems with breathing. For these reasons, the researchers tested the effectivity of coils to kill mosquitos and its danger for humans. They wanted to conclude whether the effectivity as a preventive control exceeds the risk of mosquito coils, therefore risk-benefit analysis was used as the methodology. The experiment took place in Ghana. Five different types of coils that are available in local markets were tested. The process was executed in small rooms and different type of spray was used at each of the room with the purpose to simulate ordinary conditions of local people as much as possible. After that, the same number of mosquitos was dropped in all rooms. Using several sensors and detectors, the pollution from the coils was continuously measured having also data about the pollution in the rooms prior to the usage of coils. Furthermore, the mosquito mortality was calculated as well. After the exploitation of the whole mosquito coil, the experiment showed that the mosquito mortality moved from 24% to 64%. However, this result did not correspond much with reality. It was observed that in real life, the mortality rate is only around 16%, which is a very low number. The difference in mosquito mortality when having and not having windows closed was statistically significant, having a higher effect in rooms with no ventilation. However, the concentration of CO was quite high in the rooms, especially when windows were closed and there was no natural airing. Having bigger rooms meant smaller effectivity of coils. These various conditions had to be tested separately as, during nights, the sheds are most likely closed having no natural ventilation. In summary, it was confirmed that the effectivity of coils to kill mosquitos is pretty small. Therefore, the authors expressed that mosquito coils should not replace standard usage of protection especially insecticide-treated nets and indoor residual sprayings and the usage of them in some areas of Ghana should be reconsidered. It is possible to use them only when other methods are not available or too expensive to have at least some protection.

The study conducted by J. Mangeni *et al.* (2016) and research by T. Solomon *et al.* (2019) examined how people use preventive measures during their daily lives. As a first important step, many organizations try to distribute preventive measures into remote areas regularly, but the second step is to explain properly how these measures should be used. The first mentioned study took place in Kenya and it was developed with the help of Webuye Health and demographic surveillance site. There, insecticide-treated nets have been used as the main tool for malaria prevention. However, in some areas number of people infected by malaria still does not decline, while in other places the progress after the distribution of nets is observable. Therefore, the authors have focused on places in Kenya, where the mortality is high, but the distribution of nets is provided there. An example can be Luhya ethnic group, where it was observed that people do not appropriately use the nets and they do not use them every night. This research was analyzed using the method of regression trees and lot quality assurance. Regression trees were constructed using consistent dependent variables. For this study, local infected people were divided based on age, gender, village, etc. Furthermore, observation of local people using preventive controls was part of the analysis as well. The second study was conducted in Ethiopia. It was an experiment, where long-lasting insecticide-treated were given to over three thousand households. Later, people were interviewed about the state and quality of the nets when using it regularly. For this purpose, the binomial regression model was used. Till now, all studies looking at the usage of long-lasting insecticide treated nets were only cross-sectional. The authors aimed to inspect the usage of these nets over some period. It was inspected that even though in the beginning all households got long-lasting insecticide-treated, their usage rapidly decreased and after two years only 8% of households were still using them.

The research by A. Magaco *et al.* (2019) took place in Mozambique. Mozambique has been chosen as the country of interest mainly because of the high prevalence of malaria there which reaches around 40% by children. The survey has been conducted among local people to ask them about the usage of indoor residual sprayings because, from previous literature, it was found out that the knowledge about sprays is not satisfactory and people are primarily afraid about the solution used in indoor residual sprayings. To get more information and more data, people who are using sprays constantly at homes, as well as people who refuse to use them, were questioned. The questions were focused on the recent situation of people and their habits towards the sprays. Furthermore, discussions among local people were provided together with an observation of their daily habits. Interesting results were obtained. People are very much influenced by the behavior and attitude of other people in their community and by the opinions of a local leader. Also, people who refuse to use sprays do not trust in its effectivity and rather prefer to use nets. Surprisingly, these are most likely higher educated people, who are afraid about the solution used in the sprays. The authors have indicated that to get more indoor residual sprayings into the households, first of all, the community leader has to be convinced about the effectiveness of prevention and consequently other people will follow him.

Next, there is a table (4.1) summarizing the most important studies which have been exploring the usefulness of malaria preventive measures.

Table 4.1: Overview of literature

Authors	Method	Results
K. Wangdi et al.	Generalized pairwise modeling framework and Bayesian approach	ITNs are statistically significant
J. Gimnig et al.	Logistic regression, chi square analysis and general linear models	No statistical significant evidence of ITNs
A. Hailu et al.	Cost-effectiveness analysis	No cost effectiveness for IRSs and LLINs
K. Nyavor et al.	Cluster technique	2/3 of families informed about malaria, 3% of small children are using nets in Togo and Sierra Leone
J. Hogarh et al.	Risk–benefit analysis	Mosquito coils are not efficient
J. Mangeni et al.	Regression trees	In Kenya, ITNs have been used as the main tool
T. Solomon et al.	Binominal regression model	After two years, only 8% of households still use LLINs
A. Magaco et al.	Cross-sectional, qualitative study	Community is influenced by the leader. People prefer to use ITNs rather than IRSs

Source: author’s computations.

5 Data

To analyze the problem of malaria prevention measures, data from the World Health Organization were collected. Every year, they publish a malaria report, where one can read everything about the development of malaria control and its success to reduce malaria deaths. Therefore, these reports were used to get as much data as possible and they were joined together to get such a large dataset that has not been earlier created nor used. Most of our yearly data are available from 2001 till 2018. Unfortunately, no relevant data were captured generally before. This was also a large problem in identifying the development of malaria earlier. Nowadays, we can work with at least some available data. All the data are captured for many countries around the world where malaria was present during these years. Therefore, countries from Africa, America, Eastern Mediterranean, South-East Asia, Western Pacific and some chosen countries from Europe are included. Overall, 97 countries were studied.

World Health Organization focuses on malaria properly. To make a clear plan of reducing malaria in the future, they have adopted a plan called Global Technical Strategy for Malaria 2016–2030. This plan includes aims that should be reached until 2030 to diminish malaria infection. Among the enthusiastic goals is to erase malaria in thirty-five countries. The timeline is set like this as it corresponds with the 2030 Agenda for Sustainable Development Goals. Of course, the most relevant duty is to provide prevention measures in all locations which correspond with getting more financing from various organizations. Furthermore, there exist other challenges as a lack of medical doctors in developing countries as well as a lack of hospitals and laboratory facilities. Besides, in locations with a high expansion of malaria, all possible sources of prevention control should be promoted. To reach all these goals, detailed observation and monitoring is needed (WHO 2015c).

During the years 2020 and 2025, WHO will control the compliance of these goals. Most of the goals were set together with the aims of governments. WHO has primarily set the main pillars to reach these aims. Among them are the availability of prevention measures and diagnosis facilities, promotion of these measures in different countries or acceleration of malaria monitoring (WHO 2015c).

In my analysis, many different prevention measures will be studied:

Insecticide-Treated Nets (ITNs)

This prevention measure is the most extended protection against mosquitos that is expanded all around the world, as it is one of the easiest to be used. It is applied not only to protect against malaria, but all diseases caused by mosquitos and other insects. Usually, mosquito nets are placed around and over beds to protect people sitting or lying underneath. Furthermore, for small babies, this intervention is very widely used as well. The mosquito nets include insecticides which reduces the number of insects flying to the house. When a mosquito sits on it, it can be killed by that. There have been tested many different nets made from different materials with different insecticides, as many of them had bad effects on human health and life. Pyrroles and Pyrethroids are allowed types of insecticide (Centers for Disease Control and Prevention, 2019).

The main difficulty of nets is the persistence of the insecticide in it. The effects of the insecticide last only from half a year to one year. After that, nets should be washed in a special liquid that consists of the insecticide. Of course, this is not done regularly as it is very costly and time-demanding for people living in rural and poor areas. Furthermore, the information about the necessity to rewash it is not publicly known, so people even do not have any idea that they should do it. Because of that, researchers are trying to find new toxic substances to be used against mosquitos. Some of the nets are filled with piperonyl butoxide (PBO), which should prolong the effectivity of insecticides. However, there are many doubts about whether it helps (Centers for Disease Control and Prevention, 2019).

Moreover, WHO expressed the importance of using nets especially by pregnant women, because at that time women are more likely to become ill. The usage of nets should be practiced from the beginning of the pregnancy and then still be used after the baby is born. This intervention should decrease the probability of child mortality (WHO 2019a).

Long-Lasting Insecticide-Treated Nets (LLINs)

Because of the main problem with the persistence of insecticide stated above, long-lasting insecticide nets are currently very popular. They are very newly discovered and many organizations still work on their effectivity. Their main advantage is that the insecticide inside the nets works minimally for three years. WHO is using fifteen different types of these nets to test their quality and persistence. Other organizations are involved in developing these nets including organizations such as the Center for Disease Control and Prevention (CDC).

Previously, these nets were preferred only by more vulnerable citizens, such as pregnant women or small children. Nowadays, WHO tries to make long-lasting insecticide-treated nets general prevention against malaria instead of conventional insecticide-treated nets. Around 2010, long-lasting insecticide-treated started to be spread by organizations mainly in Africa. Consequently, funds started to be allocated to the distribution of these nets. However, funds are still not satisfactory to cover all the expenditures for long-lasting insecticide-treated, therefore it is crucial to prolong the persistence of nets. There is an attempt to make them effective for five years and more (WHO 2019a). Nowadays, during active campaigns, nets are provided for free, which is sometimes the only solution to distribute them in the poorest locations. Furthermore, WHO distributes vouchers for a vulnerable population to buy these nets. As their usage is quite new, there is high hope in their effects in reducing malaria (Centers for Disease Control and Prevention 2019).

Indoor Residual Spraying (IRS)

As nets are the most used intervention reducing malaria, indoor residual spraying takes second place. The insecticide is applied inside the house, mainly on walls to kill insects when touching it. However, in contrast to nets, this measure does not protect people directly from mosquitos. It reduces the number of insects getting into the house. When older mosquitos get to the spray, it kills them rapidly. Most of the mosquitos fly directly to walls to wait there for people coming to the house to take their blood. That is why spray should be applied to walls.

There exist Global Plan for Insecticide Resistance Management (GPIRM) developed by WHO, which tries to deliver IRSs globally and control for correct application of it. Part of this program includes observing the conditions in the environment and villages to choose the right insecticide that would help most significantly (WHO 2015a).

Historically, indoor residual sprayings were not very popular as its usage did not lead to any success in reducing malaria. However, this was mainly caused by low funds, which were not sufficient to cover all locations to kill more mosquitos. That is why recently, organizations need to show the effectiveness of it to make people trust in it (Centers for Disease Control and Prevention 2019).

Rapid Diagnostic Tests (RDT)

These tests are a great discovery helping people to be aware of malaria and thus, diminish the number of deaths. It is a test that can observe whether there is a malaria infection in the blood of a person. The great advantage is that it can be used in poor countries, where hospitals with laboratory equipment are not available. Another improvement is that they can be used very simply and the results are very easily readable. The scientists heavily hope in the usage of these tests to reduce malaria deaths.

There exist various types of rapid diagnostic tests. Some of them can uncover only one type of mosquito infection, others are made to uncover several types. To use it, blood from a finger is needed. The blood will be put on a paper ban where it will be combined with an agent. An antibody is placed on the band. After the combination of the antibody and human blood, there will be seen whether some malaria infection is present if the band will stay colored. Furthermore, the test can also capture the intensity of infection being in the human body. The whole procedure lasts from fifteen to thirty minutes. On the other hand, there still exist some disadvantages. Firstly, the RDTs cannot recognize all sources of malaria infection, they simply cannot identify some species. Secondly, after the test has been realized, laboratory analysis should still be done. Of course, this is sometimes not possible in remote areas (WHO 2015b).

During the last years, these tests were widely distributed around the world especially during the campaigns of the World Health Organization. In 2017, their utilization rapidly increased. Furthermore, as the tests are still under development their nature is improving all the time. WHO emphasizes using rapid diagnostic tests which were accredited by them before. In the situation, the tests approved by WHO are not available, WHO advertised a few conditions the tests should have to make the results trustworthy (WHO 2015b).

Artemisinin-Based Combination Therapy (ACT)

Nowadays, the treatment that is used for curing malaria is called artemisinin-based therapy. It is the combination of artemisinin with the second drug. It should reduce the infection in the first three days of using it. WHO considers ACT to be the only effective treatment used for the successful cure of malaria. There currently exist five different types of ACTs. To decide which one to use, one should stem from the results of the laboratory examination. There does not exist any other cure that could be used to treat malaria, therefore WHO expresses the importance of improving and observing the effectivity of artemisinin-based combination therapy. Recently, ACTs have been expanded to almost all countries in the world, especially during campaigns, there is a high attempt to distribute them to Africa. Concretely, 198 million ACTs have been shared in 2016 (WHO 2018a).

The overall spread of ACTs is also due to the good tolerance of the human body to this type of medicine (WHO 2010).

Funds

Yearly, a high amount of funds is invested in the control of malaria and its prevention. Mostly, organizations and local governments invest in prevention measures. The investments are intended for the whole world, but mainly for the region of Africa. Concretely, in 2017 around three-quarter of all invested money was aimed for help in Africa. Other regions of interest are South-East Asia, the Americas, Eastern Mediterranean and Western Pacific. Looking at the division of funds, around one-third of money comes from local government and two-thirds comes from global organizations. During the last years, the amount of investment is stable. However, to reduce malaria more rapidly, it requires even higher investments (WHO 2018b).

Moreover, as the dependent variable in this analysis will be the number of deaths caused by malaria and the effects of the preventive measures will be studied, we take into the account other variables which could influence the overall situation in a particular country and therefore influence number of deaths caused by malaria. As a control variables, we will be using GDP per capita, a number of people living in a rural area and a dummy variable whether there happened a war conflict. Of course, adding other variables such as literacy rate or education would help, unfortunately, there do not exist relevant panel data for all of the years for all mentioned countries. More information about the selection of these variables will be provided in the chapter Methodology. Next, we can observe a summary statistics for all our variables (Table 5.1. and Table 5.2.). Minimum, maximum, mean, standard deviation and standard errors of all variables may be seen.

Table 5.1. – Summary statistics 1

	Deaths	Funds	LLIN+ITN	IRS	RDT
Min	0	0	0	0	0
Max	51842	2810718541	31439920	70853795	41089368
Mean	1352,4	36225807,3	1231580,7	1831314,9	557969,5
Standard Deviation	4392,5	128085851	3029685,9	7234261,7	2847829,1
Standard Errors	110,1	3258644	83579,5	228197,7	70087,5

Source: author's computations.

Table 5.2. – Summary statistics 2

	ACT	Population	GDP per capita	Rural population
Min	0	142262	111,9	58051
Max	32568349	1386395000	31353,4	888869466
Mean	1508669,2	56467963,7	3162,2	30859444,9
Standard Deviation	4004519	189578822,7	4541,8	111719129,1
Standard Errors	123996,2	4761844,3	110,6	2711182,2

Source: author's computations.

6 Methodology

6.1. Overview

As malaria is a very dangerous disease, which is spread almost all around the world, we may look at it from many points of view. That is also the reason why the research will be made by a few different techniques as we want to discover as much information as possible using the most recent available data. One of the greatest contributions of this thesis is the external validity. The existing studies such as the study by J. Gimnig *et al.* (2016), A. Hailu *et al*. (2018) or K. Nyavor *et al.* (2017) focus only on one region. Furthermore, other studies such as the study by J. Hogarh *et al.* (2018) analyze only one preventive measure, in this case, mosquito coils. The study by D. Asingizwe *et al.* (2019) examines the usage of long-lasting insecticide nets and indoor residual sprayings only. Generalized studies using the most recent data for the whole world can be hardly found.

Generally, this study aims to examine how useful various malaria preventive measures are. To measure their usefulness, we will study the development of malaria deaths in various countries. Therefore, we will be able to observe whether the preventive measures help to decrease malaria deaths and therefore whether they are appropriate and effective. Overall, we will see their effect on malaria deaths. As we have the advantage of long time spam in our dataset, we will see whether having a larger amount of preventive measures decline malaria deaths through some time. Measuring the usefulness of preventive measures is very important, as international organizations need to know in which preventive measures they should invest. After knowing which preventive measures are helpful, we will see how they are distributed around the world using the clustering method. Putting these results together, we will be able to say whether the most useful preventive measures are delivered into places, which experience the highest number of malaria deaths. We may find out that some regions need to get higher attention as the most useful preventive measures are not delivered there and international organizations put money into the wrong measures that do not help so much.

On the preventive measures, there exist many of them. We are analyzing the ones, for which the World Health Organization has available data. That means the ones which are monitored. Each year, the World Health Organization publishes an overview of yearly delivered preventive measures into every country. In the following chapter, more information about each variable will be discussed.

Having the advantage of panel data, one of the parts of this thesis will be panel data regression– random effect model and fixed effect model (more information in section 6.3). Both models will be conducted, their results and their validity will be tested. The effects of the distribution of mosquito nets (insecticide-treated nets and long-lasting insecticide-treated nets), distribution of indoor residual spraying, availability of preventive testing on malaria (rapid diagnostic tests), artemisinin-based combination therapy and the effect of funds on deaths caused by malaria will be studied. When doing this analysis, we must think about the endogeneity that might arise between deaths caused by malaria and preventive measures. Consequently, we will rely on panel data structure and add other variables such as war conflicts which may influence the inflow of international aid. Regarding different techniques, my hypothesis is that the fixed effect model should work better and should give us better results because of the problem of country-specific characteristics which might influence the endogeneity between deaths and preventive measures. The issue of endogeneity will be explored more deeply in the discussion part.

As the check for the robustness is needed, bootstrapping will be used. Furthermore, it is important to look at the common effect of sprays and nets. As mentioned in reports by WHO, having nets over the bed is not sufficient and the effect should be larger when using repellents as well. This corresponds to the study made by J. Gimnig *et al.* (2016), which explores the common effect as well. Therefore, we will also check the interaction term between ITNs and IRSs to study their common effect. In addition, we will use various control variables, as they may influence the dependent variable. The purpose of our explanatory variables will be described later in this chapter. In this study, the effect of GDP and people living in rural areas will be taken into account. As mentioned previously, data such as literacy rate would improve our analysis as well, unfortunately, we must work with a lack of data as some are not available for all years in all countries of interest. As we will compare differently-sized countries, all variables will be divided by population to get data per capita.

As mentioned above, the advantage of this research is having data for many countries all around the world which may lead to a comparison of different situations in different countries and their various malaria development. For this study, cluster analysis (k-means clustering and hierarchical clustering) will be used (more information in section 6.4). Using this technique, we may see whether countries from different continents behave similarly and we can observe the most important differences among various clusters. Especially, this may be helpful for developing countries, which do have a long way in front of themselves in fighting with malaria, as they may be inspired by other countries that are in a better situation. Furthermore, we will explore whether the most useful preventive measures are delivered to the most threatened clusters. We will study it from two different points of view. Firstly, we will conduct the cluster analysis on the overall dataset. As having panel data, we will be able to observe and compare the situation in different countries linked to some concrete year. Secondly, we will use the year 2017 to look at the current situation and see to which clusters our countries of interest belong. That means that we will compare the development of countries as well as the present situation using the technique of clustering.

One of the main advantages of this thesis is that according to my knowledge, such a large dataset has not been used to provide general analysis about the effects of malaria preventive measures. All the data available in my analysis were firstly taken manually from WHO databases and joined together to get such a large dataset.

In this thesis, many important aspects of the distribution of malaria preventive measures will be investigated. However, overall, we will focus on three main hypotheses. The first one has been already mentioned above. Namely, whether the fixed effect model or random effect model is preferred. Taking into account the country-specific characteristics and thus arising endogeneity, my hypothesis is that the fixed effect model should be used. We will use the Hausman test to check it formally. The second hypothesis is quite general and we will study it into more detail. Overall, it states which preventive measures are useful and whether they help to decrease malaria deaths. This question is quite difficult as many studies that were exploring it came to completely different results. This was visible in the literature review part, where almost every study concluded their results differently. The third hypothesis will be aimed at the cluster analysis. We will explore whether countries from similar continent experience similar development of malaria situation and whether they are equally supplied by preventive measures. This may help the international organizations to see whether they allocate their money efficiently or they should change their attitude towards some specific regions.

6.2. Variables

As mentioned above, the source of our variables of interest is the World Health Organization, which publishes an overview of delivered preventive measures into every country each year. In this chapter, we will not describe the meaning of preventive measures as it is already written in the chapter with data. However, we will discuss the usefulness of each variable in our analysis.

Starting with the preventive measures, overall, we expect them to have a linear negative impact on malaria deaths. On insecticide-treated nets and long-lasting insecticide-treated nets, it is expected that the estimated coefficient should be negative. Simply, using more insecticide-treated nets help to cover houses and therefore people in it. Thus, it should reduce malaria infection and therefore deaths caused by malaria. A similar pattern is expected for indoor residual spraying. As repellents protect people against mosquitos, the foreseen sign of effect on malaria deaths should be negative as well. Another important measure is the rapid diagnostic test. As these tests help to explore whether a person is infected by malaria, they should help a lot to prevent deaths. When a person finds out he/she has malaria, then he/she knows that it is not just some fever and the illness must be cured. Therefore, the expected sign of its effect is negative as well. Moreover, the effect is expected to be significant as this is a great discovery for people to know whether they are infected by malaria without the need to visit hospitals just preventively. On artemisinin-based combination therapy, it should help to eliminate malaria as well. However, the expected effect is not so straightforward. Firstly, it should be available especially in hospitals, which are however not accessible for many people from poor regions. Secondly, many people do not cure malaria and use artemisinin-based combination therapy only when they are seriously ill, especially in remote areas. The reason is simple, for people in remote or poor areas it is not easy to afford visiting hospitals. Therefore, they go there only when there might be no chance of being cured. On funds, there we might discuss whether their effect is only when converting funds into other preventive measures or they may affect malaria deaths solely as well. For this reason, apart from doing regression with all our variables, we will also proceed with regression analysis with all other preventive measures without funds and regression with only funds. Therefore, we can find out whether adding funds changes the results or it is not important at all. These modified regressions will be provided in the chapter discussion, as we want to go deeply into our results and advance our knowledge from previous results and discuss what is important for further analysis.

Apart from these preventive measures, we also use other explanatory variables in our analysis that might have a crucial effect on malaria deaths. Important is whether mosquitoes have satisfactory living conditions and whether they have contact with people. Especially how many mosquitos per person are there in countries. To measure this factor, we use a rural variable in our analysis. As studied by W.P. Schmidt *et al.* (2011), in rural areas, there is many times higher chance of being infected by mosquitos, as there occur more mosquitos per citizen. Another reason is that in rural areas, mosquitos have better availability of still but dirty water. This study was focused on dengue disease, but it can be applied for our analysis as the source of infection is the same. Therefore, the expected sign of this estimated coefficient is positive, as living in rural areas and thus living with more mosquitos highly increase the probability of malaria infection. This coefficient is expected to be significant.

Another crucial explanatory variable is GDP. It is a proxy for richness of the country, which is important in our analysis. When people are richer, they may afford more preventive measures. Also, when a country has more financial resources, it can build hospitals, educate people and pay highly educated people in healthcare so this variable may be used as the proxy for the healthcare system as well. Therefore, more GDP should lead to a decline in the number of malaria deaths.

On the other variable – war – this explanatory variable is added into our analysis as it may influence the exogenous fluctuation in the inflow of international aid into countries. Therefore, we use it as one possibility to deal with potential endogeneity.

6.3. Regression Analysis

In our analysis, we will work with panel data, which are also called longitudinal data as we have observations for many different countries over many years. Therefore, as we need to do regression analysis and we work with two dimensions, we will use regression techniques for longitudinal data and these are fixed effect models and random effects models. (E. Biorn et al. 2017).

6.3.1. Fixed effect model

Fixed effect models are named like that because we suppose some heterogeneity among our variables that are represented in our data as fixed parameters. That means that we consider each country having some individual attribute and we want to erase it to have the overall effect on deaths caused by malaria. Having our model:

$$\boldsymbol{Y_{it} = \beta_0 + B_1 X_{it} + \beta_2 Z_i + u_{it}} \tag{6.1}$$

where Z is the heterogeneity, X are independent coefficients, Y is the dependent coefficient in time t for countries i. We may rewrite this model (Ch. Hanck et al. 2019). We take:

$$\boldsymbol{\alpha_i = \beta_0 + \beta_2 Z_i} \tag{6.2}$$

and rewrite the original equation as:

$$\boldsymbol{Y_{it} = \alpha_i + B_1 X_{it} + u_{it}} \tag{6.3}$$

where $\boldsymbol{\alpha_i}$ is the intercept which is unique for each of our units. This model can be also rewritten using n-1 dummy variables including the intercept. A dummy variable is used for each unit; therefore, we can study the effect of each country. The final equation using the dummy variables would look like this:

$$\boldsymbol{Y_{it} = \beta_0 + B_1X_{it} + \gamma_2 D2_i + \gamma_3 D3_i + \cdots + \gamma_n Dn_i + u_{it}} \tag{6.4}$$

Back to our estimation of the model, we must prepare the equation with averages:

$$\boldsymbol{\bar{Y} = B_1\bar{X}_i + \alpha_i + \bar{u}_i} \tag{6.5}$$

Now, we will subtract the averaged equation (6.5) from the original equation (6.3):

$$\boldsymbol{(Y_{it} - \bar{Y}_\imath) = (\alpha_i - \alpha_i) + B_1(X_{it} - \bar{X}_i) + (u_{it} - \bar{u}_i)} \tag{6.6}$$

It can be observed that α_i cancels out. Finally, using the subtracted variables in the brackets, we can write the final equation (6.7) using variables with tilde:

$$\boldsymbol{\tilde{Y}_{it} = B_1\tilde{X}_{it} + \tilde{u}_{it}} \tag{6.7}$$

Our data are now called demeaned as we have subtracted the averages from the original data. This process can be also called within transformation (J.M. Woolridge, 2008).

In addition, as we want the fixed effect to be BLUE (best linear unbiased estimate), we would need to satisfy the following assumptions (J.M. Woolridge, 2008).:

- having the model with unobserved heterogeneity and parameters:

$$\boldsymbol{Y_{it} = \alpha_i + B_1X_{it} + u_{it}} \tag{6.8}$$

- having a sample that is random

- the independent variables should not have perfect linear relationships and they should be different over some period

- strict exogeneity:

$$\boldsymbol{E(u_{it}|X_i, a_i) = 0} \quad (6.9)$$

-homoscedasticity for all i and t (B. Baltagi, 2001):

$$\boldsymbol{Var(u_{it}|X_{i,}a_i) = \sigma^2} \quad (6.10)$$

-no serial correlation:

$$\boldsymbol{Cov(u_{it}, u_{is}|X_i a_i) = 0, for\ all\ s \neq t, s, t = 1, \dots, T} \quad (6.11)$$

-errors are iid with normal distribution: $\boldsymbol{Normal(0, \sigma_u^2)}$.

Furthermore, we should inspect degrees of freedom when performing fixed effect model. As we work with the averages, we give up a degree of freedom for each cross-section. Therefore, as having N*T observations, N degrees of freedom lost by each cross-section and having k variables, overall, we get NT-N-k degrees of freedom (J.M. Woolridge, 2008).

Before looking at the random effect model, we should state the difference between these two models. The main difference is that using the fixed effect model, we consider $\boldsymbol{a_i}$ to be correlated with $\boldsymbol{x_{j,it}}$ for j = 1..., K (B. Baltagi, 2001).:

$$\boldsymbol{Cov(a_i, x_{j,it}) \neq 0} \quad (6.12)$$

6.3.2. Random effect model

On the random effect model, we consider $\boldsymbol{a_i}$ to be uncorrelated with $\boldsymbol{x_{j,it}}$ for j = 1..., K:

$$\boldsymbol{Cov(a_i, x_{j,it}) = 0} \tag{6.13}$$

Having our model:

$$\boldsymbol{Y_{it} = \beta_0 + B_k X_{itk} + a_i + u_{it}} \tag{6.14}$$

with $\boldsymbol{a_i}$ not being correlated with $\boldsymbol{x_{itj}}$. Therefore, we do not need to cancel out $\boldsymbol{a_i}$ as we would get a weak estimator (J.M. Woolridge, 2008). To estimate our model, we will use so-called generalized least squares transformation and get so-called quasi-demeaned data, where $\boldsymbol{v_{it}}$ is the composite error term composed from $\boldsymbol{a_i + u_{it}}$ (J. Woolridge, 2008):

$$\boldsymbol{(Y_{it} - \lambda \overline{Y}) \; = \beta_0(1 - \lambda) + B_i(X_{itk} - \lambda \overline{X}_{ik}) + (v_{it} - \lambda \overline{v}_i)} \tag{6.15}$$

To have the best linear unbiased estimator, we need to satisfy the following assumptions (J.M. Woolridge, 2008):

- Having the model with unobserved heterogeneity and parameters:

$$\boldsymbol{Y_{it} = \alpha_i + B_1 X_{it} + u_{it}} \tag{6.16}$$

- having a sample that is random
- the independent variables should not have perfect linear relationships
- strict exogeneity:

$$E(u_{it}|X_i, a_i) = 0 \tag{6.17}$$

furthermore, with the assumption:

$$E(a_i|X_i) = \beta_0 \tag{6.18}$$

- homoscedasticity:

$$Var(u_{it}|X_{i,}a_i) = \sigma^2 \tag{6.19}$$

furthermore, with the assumption:

$$Var(a_i|X_i) = \sigma_a^2 \tag{6.20}$$

- no serial correlation:

$$Cov(u_{it}, u_{is}|X_i a_i) = 0, for\ all\ s \neq t, s, t = 1, \dots, T \tag{6.21}$$

- errors are iid with normal distribution: $Normal(0, \sigma_u^2)$

To test whether to prefer the fixed effect model or random effect model, we must use the knowledge about the correlation between a_i and $x_{j,it}$. For this purpose, the Hausman test is standardly used. The null hypothesis states that a_i and $x_{j,it}$ are uncorrelated, therefore we prefer to use the random effect model. On the other hand, the alternative hypothesis states that they are correlated and therefore, we will use the fixed effect model.

6.4. Cluster Analysis

Our next step in discovering the situation of malaria around the world is to perform the cluster analysis. Doing this process will help us to understand whether there exist similarities in countries being on the same continent. This technique will help us to divide our countries of interest with similar properties into the same cluster. We will proceed with two different methods – K-means clustering and hierarchical clustering. Before doing the analysis, we must be careful about the preprocessing step. The dataset must be rescaled to have the possibility to compare them properly.

6.4.1. K-means clustering

When performing the K-means clustering, firstly, we need to identify center points (often mean is used). Next, each data point will be matched to the nearest center point. Doing this process, we will get groups of data with similar properties. After having a new data member linked to a cluster, the center points are updated. This process is replicated and we match all data into some cluster until the center points are stable (P. Tan, 2018).

Furthermore, as we have to link our data to the nearest center point, the distance must be calculated. Mostly, the Euclidean distance is used. To measure whether the clustering has proceeded correctly we use the sum of squared errors. This means that each time we link the data to the center points and we compute errors. After that, the sum of squared errors is calculated. We can then compare the sum of square errors to choose which K-means do we use. We will use K-means with the smallest sum of square errors (P. Tan, 2018):

$$\boldsymbol{SSE} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{K}} \sum_{\boldsymbol{x}\in\boldsymbol{C_i}} \boldsymbol{dist}(\boldsymbol{c_i}, \boldsymbol{x})^{\boldsymbol{2}} \tag{6.22}$$

Another important thing to identify is the number of clusters. There exist various methods. Among the most frequently used ones are the elbow method and the silhouette method. On the elbow method, we want the within-cluster sum of squares to be as small as possible. The elbow method chooses a number of clusters such that the within-cluster sum of squares does not improve when adding other clusters (L. Kaufmann, 1990). The silhouette method is based on the calculation of the average silhouette for our data. We find the proper number of clusters when having an average silhouette which is maximized. By silhouette, we mean the average distance measured between clusters (L. Kaufmann, 1990).

6.4.2. Hierarchical clustering

There exist two main types of hierarchical clustering – agglomerative and divisive. On agglomerative, we consider each point as being a cluster and we put points together and link clusters. The second mentioned method is the opposite one. We consider our points as being in only one cluster, which will be divided into more clusters. The agglomerative methods are used more often.

In our analysis, we will use a method called Ward`s method. Here, we consider each cluster having its central point. In each step, the sum of squared errors is measured after linking two clusters. This is similar to k-means clustering. Finally, dendrogram will graphically show us the results of the hierarchical clustering. Using dendrogram, we can observe how the clusters were created in time together with a final number of clusters.

6.5. Bootstrapping

To verify the stability of our results obtained when doing panel data regression analysis, we will use bootstrap. Therefore, we will look at the confidence intervals and see whether our estimates are robust or whether they differ when computing our model many times. If for each variable, the estimates will be close to each other and the confidence interval will be narrow, we can then rely on the values and our model. This is a very important step as we need to know whether we can trust our model and whether our estimates are stable.

As bootstrap uses many samples generated from the whole dataset, this method can be also called a resampling method. Before proceeding with bootstrap, we need to focus on two preprocessing steps. Firstly, we need to choose the size of a sample we will be using. Our samples will have the same size as the whole original dataset. Secondly, we need to look at the number of repetitions. For our purpose, we have chosen 1000 iterations. After making these two preprocessing steps done, each time we will randomly choose a sample with replacement from our original dataset. Having these samples, our panel data model will proceed and the statistics will be calculated for each of our randomly chosen samples (Brownlee, 2018).

Below, the calculation of bootstrap is showed.

- We will suppose having a sample $Z = [(y_1, x_1), \ldots, (y_n, x_n)]$.
- We have a vector of parameters θ based on Z, $\hat{\theta}_z$ is its estimator.
- We will choose k observations from our sample Z, always with replacement.
- For each sample, we will calculate $\hat{\theta}(b)_k$, b = 1...B.
- Proceeding it B times, our attribute is calculated using $\widehat{\Theta} = [\hat{\theta}(1)_k, \ldots, \hat{\theta}(B)_k]$ (Greene, 2012).

7 Results

7.1. Panel Data Regression Analysis

Starting with panel data analysis, we want to discover the effects of malaria preventive measures on deaths caused by malaria. The strong advantage of this study is the usage of the most recent available data and possibly the largest dataset for this purpose that can be made. As mentioned above, apart from having the preventive measures in our analysis, we need to control for other variables as well. First arises the problem of endogeneity, therefore we have added a dummy variable war which indicates one if the country experienced a war conflict in some year and zero otherwise. Therefore, we will rely on exogenous variation in the arrival of international aid, which can be exactly caused by war conflict. The war dataset is taken from The Peace Research Institute Oslo. Furthermore, we need to add control variables as the malaria situation may be affected by other sources as well. The main problem here is the availability of data. As the advantage of our analysis is having such large dataset for many years and many countries, there is the second side and that is the unavailability of much data especially in some poor African countries. More on this topic will be provided in the chapter called a discussion. Finally, as control variables – GDP per capita and the proportion of people living in rural areas will be used. These datasets are available from The World Bank for all our countries and years of interest.

We will firstly look at the analysis of our whole dataset, we will proceed with fixed effect model and random effect model. Then, we will test which model is the valid one using the Hausman test as described in the chapter Methodology. After that, we will proceed with the analysis only for African data. The reason is simple, Africa is far behind other continents regarding the malaria situation, therefore it is very important to look at the situation separately as there exists the highest potential to improve the situation. We will be able to study whether the situation in Africa corresponds with the overall situation or whether the impact of preventive measures does affect deaths differently. In addition, as we have seen in the literature chapter, the situation in Africa is so bad that most of the studies are focused only on the African continent. As the aim of this thesis is to add new knowledge about the malaria situation, we need to consider Africa solely as well to be able to compare the results with other studies and bring a new understanding of the situation. Furthermore, we will conduct modified models together with the discussion of limitations and assumptions, which will be provided in the chapter called discussion. As the incubation period is short in contrast to other diseases, it will help us to see the consequences immediately.

Starting with the whole dataset, we have proceeded with the fixed effect model and random effect model. The dependent variable are malaria deaths, the independent variables are funds, insecticide-treated nets together with long-lasting insecticide-treated nets, indoor residual spraying, rapid diagnostic tests, artemisinin-based combination therapy, GDP, rural population, war and interaction term between insecticide-treated nets and indoor residual spraying, all variables are per capita to compare differently sized countries. The results of the models can be seen in table 7.1 (standard errors are in parentheses).

Table 7.1: Panel data regression – general

	Fixed effect model	Random effect model
Funds	-2.8489e-08 (2.7284e-08)	-1.6902e-08 (2.7770e-08)
ITN	7.1227e-05 (4.4516e-05)	7.4480e-05. (4.4326e-05)
IRS	-3.3237e-04*** (5.7686e-05)	-2.8489e-04*** (5.4348e-05)
RDT	-1.1739e-04** (4.0825e-05)	-1.5229e-04*** (3.9216e-05)
ACT	3.0075e-05*** (3.2226e-06)	3.5025e-05*** (3.2101e-06)
GDP	-3.9469e-09 (3.3808e-09)	-7.3712e-** (2.3441e-09)
Rural	9.8304e-04*** (2.0134e-04)	1.5012e-04* (7.1240e-05)
War	-3.8812e-05* (1.6986e-05)	-5.0634e-05** (1.5677e-05)
ITN:IRS	-2.8192e-04*** (8.3036e-05)	-2.5372e-04** (8.3211e-05)
R-squared	0.24372	0.20514

Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1

Source: author's computations.

Observing the results obtained from the fixed effect model, we can see that some of our variables are significant. Indoor residual spraying is significant and the effect is according to our expectations. Having more indoor residual sprayings means lower malaria deaths. On the other hand, the effect of insecticide-treated nets is opposite. However, this effect is not statistically significant. That corresponds to some studies as the effect of nets is not significant unless using it together with indoor residual sprayings. The study by J. Gimnig et al. (2016) concluded that insecticide-treated nets are not statistically significant as well. Furthermore, a rapid diagnostic test is also significant, having the expected effect on malaria deaths. GDP is not significant. However, living in rural areas increases malaria deaths. That is clear, as more mosquitos can be found in nature rather than in cities (W.P. Schmidt *et al.* 2011). Therefore, countries having more people living in rural areas are more threatened by malaria. If the effect was the opposite, it would be surprising for us. Unforeseen is the effect of the dummy variable war. However, it may be caused by the fact that when a country experiences a war, there is no clear evidence of the effects causing deaths. In addition, malaria is not such an important topic for countries being in conflict. Looking at the interaction term, the effect is significant with the sign we would suppose. The combination of using both preventive measures has a useful effect on malaria deaths. Overall R-Squared is 0.24372.

Looking at the results obtained by the random effect model, we can compare them to results received by the fixed effect model. We can spot some differences there. We can see that signs of our variables are the same, however, sometimes the magnitude of the effects differs. The magnitude of indoor residual spraying is smaller in absolute value when doing a random effect model. The significance levels of rapid diagnostic test, rural variable and war variable have slightly changed. The main difference is that GDP is significant having the expected effect on malaria deaths. The effect of the interaction term is in magnitude very similar, however, the standard error is larger when looking at the random effect model. The R-Squared is 0.20514.

Now, we have to test which of our model is the better one. As described in the methodology section, we will test our models using the Hausman test. We know that the null hypothesis is that random effect model should be used, the alternative hypothesis is in favor of the fixed effect model. After proceeding the test, we have obtained p-value <2.2e-16, therefore we can reject the null hypothesis. Therefore, we state that the fixed effect model is the better one as compared to the inconsistent random effect model, the fixed effect model is consistent.

In addition, we will look at the results in Africa. Africa is chosen for being studied more properly as the situation there is worse than in other continents.

Furthermore, the situation there is so bad that most of the studies are focused only on the malaria situation in Africa as for example study by A. Hailu *et al*. (2018) or K. Nyavor *et al.* (2017) studying Ethiopia and Ghana, respectively. Therefore, it is important to know which preventive measures improve the situation there. Again, the fixed effect model and random effect model were proceeded followed by the Hausman test. The p-value of the test was 1.506e-05, therefore we can conclude that the random effect model is inconsistent and we will rely on the fixed effect model. Results of the fixed effect model and random effect model for Africa are summarized in table 7.2 (standard errors are in parentheses).

Table 7.2: Panel data regression - Africa

	Fixed effect model	Random effect model
Funds	-3.7765e-08 (3.8739e-08)	-2.5956e-08 (3.9639e-08)
ITN	1.0498e-04 (6.6905e-05)	4.3091e-05 (6.7406e-05)
IRS	-2.4021e-04** (8.8165e-05)	-3.0215e-04*** (8.3266e-05)
RDT	-4.4674e-05 (6.4182e-05)	-1.7049e-04** (5.9335e-05)
ACT	2.8590e-05*** (4.6898e-06)	3.5722e-05*** (4.6257e-06)
GDP	-4.3310e-08*** (1.0446e-08)	-3.4784e-08*** (7.6606e-09)
Rural	1.9030e-*** (4.1664e-04)	5.5359e-05 (1.5832e-04)
War	-6.1413e-05* (2.9785e-05)	-7.8717e-05** (2.8918e-05)
ITN:IRS	-3.5493e-04** (1.2195e-04)	-2.1435e-04. (1.2286e-04)
R-squared	0.31404	0.24672
Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1		

Source: author's computations.

We will especially focus on the results obtained by the fixed effect model, as the other model is not consistent. We can examine that the results are not seriously different from the general one. On the other hand, we can find some interesting factors there. One of them is the significant effect of GDP. This may be caused by the fact that countries in Africa are among the poorest ones and having even little more GDP per capita can improve the situation in the country very much. Therefore, apart from the overall situation, GDP per capita is a very important factor in Africa. Another difference is the effect of RDT which is not significant. This has a very simple explanation. Many areas in Africa are remote and do not have any access to hospitals. Therefore, even if someone uses the test and finds out he/she has malaria, it is not easy to quickly get to a hospital. Thus, in Africa, we first need to distribute preventive measures such as indoor residual sprayings or insecticide-treated nets and provide funds to maintain access to hospitals and then rapid diagnostic tests would help. Again, we can see that living in rural areas highly worsens the situation, as it means being exposed to mosquitos as confirmed by W.P. Schmidt *et al.* (2011).

Concluding our analysis, we can see that the effects are not so straightforward and the measures affecting the situation of malaria must be strongly elaborated. One example may be the effect of rapid diagnostic tests, which is not significant in Africa as discussed previously. Furthermore, we can say that having indoor residual spraying and insecticide-treated nets together is one of the best solutions to prevent malaria in Africa. Indoor residuals sprayings solely are significant as well and therefore may help. Thus, especially in poorer countries or countries with a large proportion of the population living in rural areas, it is necessary for organizations to know that indoor residual sprays should be strongly favored. Overall, our intention was to study two different hypotheses. Firstly, whether fixed effect model should be preferred over the random effect model. Secondly, whether the distribution of malaria preventive measures helps to decrease malaria deaths. The first hypothesis was confirmed using the Hausman test because of the country-specific characteristics that influence the relation between malaria deaths and malaria preventive measures. The second hypothesis is not that straightforward, most of the preventive measures do help, but as we have discussed earlier in this chapter, the situation is not that easy. Therefore, we may conclude that the hypothesis was partly confirmed.

7.2. Bootstrapping

In the previous part of this chapter, we have gone through the panel regression analysis. Based on the results, we summarized conclusions about the effects of malaria preventive measures. However, a very important aspect is to verify the stability of our results. Therefore, we could rely on them. For this purpose, we will use the simulation-based method - bootstrap. We will get the confidence intervals to see whether our results are stable and whether they are still similar after a thousand repetitions. Concretely, we will proceed 1000 iterations taking our whole dataset. Each time, a random sample will be chosen where we will use our observations with replacement and new values will be calculated. Finally, we will summarize the results and look at the 0.05 quantile, 0.5 quantile and 0.95 quantile for all variables to see a 90% confidence interval. Therefore, we will be able to see how diverged are our coefficients. As we want to proceed together with our results, firstly, we will observe bootstrap results for the whole dataset and secondly, we will discover the stability for African data. Table 7.3 shows the results of the world situation.

Table 7.3: Bootstrap quantiles

	Quantiles			Fixed effect model
Coefficients	0.05	0.5	0.95	estimates
Funds	-1.562032e-06	-3.097375e-08	1.058590e-09	-2.8489e-08
ITN	-1.498493e-05	7.035490e-05	1.648174e-04	7.1227e-05
IRS	-5.052998e-04	-2.874469e-04	-6.297488e-05	-3.3237e-04
RDT	-1.996429e-04	-1.081467e-04	-2.088252e-05	-1.1739e-04
ACT	-4.508499e-06	2.938932e-05	5.557606e-05	3.0075e-05
GDP	-9.139911e-09	-2.688017e-09	2.146086e-09	-3.9469e-09
Rural	0.0005965364	0.0009876285	0.0014638472	9.8304e-04
War	-7.296458e-05	-3.904800e-05	-1.053250e-05	-3.8812e-05
ITN:IRS	-0.0004243765	-0.0003044291	-0.0002233431	-2.8192e-04

Source: author’s computations.

Observing the results, we can see that the original variables which were significant are mostly very stable. Firstly, looking at indoor residual spraying, the 0.5 quantile is very similar to the estimate and the outer quantiles are very close to this number having the same effect with almost the same magnitude. Therefore, we can conclude that the effect of indoor residual spraying is very stable. The very same is true for the rapid diagnostic test. All the values by different quantiles are very close to each other and the effect and magnitude of the results are very clear and stable. The two complementary variables - rural variable and war – are very stable as well. The 0.5 quantile is the same as the original panel data regression estimate. The 0.05 quantile and 0.95 quantile show very similar values as the median. The confidence interval of the interaction term is also very narrow and thus stable. All the variables discussed above can be taken as very stable ones. Looking at the GDP and funds, the 0.5 quantile corresponds with the estimates. The outer quantiles are not so close to the median however, we must look at the values which are very close to zero, especially by GDP. Observing insecticide-treated nets and artemisinin-based combination therapy, the 0.5 quantiles are very similar to the original estimates however, the confidence interval lies on both sides of zero. Hence, we can see different signs of values, which is very crucial for our analysis. However, the effect of nets was not significant. Overall, we may state that proceeding a thousand iterations, our model is stable with some tiny exceptions, for example the artemisinin-based combination therapy. The original statistically significant variables are very similar after proceeding the model many times, therefore we can rely on our results. To sum up, the bootstrapping method for stability checking was very important, as it confirmed our results and conclusions about malaria preventive measures.

Now, we will generate the same analysis for the African continent as we want to check the stability of all our results. Again, 1000 iterations have proceeded. Table 7.4 shows a summary of the results.

Table 7.4: Bootstrap quantiles – Africa

Coefficients	Quantiles 0.05	0.5	0.95	Fixed effect model estimates
Funds	-8.143303e-07	-4.289926e-08	-4.660653e-09	-3.7765e-08
ITN	8.167014e-06	1.078281e-04	2.204781e-04	1.0498e-04
IRS	-4.197515e-04	-2.059289e-04	-3.832477e-06	-2.4021e-04
RDT	-1.510456e-04	-4.338926e-05	6.499643e-05	-4.4674e-05
ACT	-5.820099e-06	3.058488e-05	5.080566e-05	2.8590e-05
GDP	-8.975157e-08	-4.408847e-08	-1.858356e-08	-4.3310e-08
Rural	0.0009755241	0.0018691285	0.0027209278	1.9030e-03
War	-1.135695e-04	-6.112303e-05	-1.718896e-05	-6.1413e-05
ITN:IRS	-5.239911e-04	-3.956792e-04	-2.941332e-04	-3.5493e-04

Source: author's computations.

At first sight, we can see that the results look very stable. Concretely, starting with the complementary variables – GDP, rural variable and war – all values calculated for different quantiles are very close to each other corresponding with the estimate that we got from panel data regression analysis. That is very important as all these variables were statistically significant. Looking at the interaction term, the range of the confidence interval is narrow and the estimate is very stable. The same is true for funds, insecticide-treated nets, and indoor residual spraying. Therefore, we may conclude that these variables are very stable. Inspecting the rapid diagnostic tests, the 0.5 quantiles is very similar to the estimate obtained by regression analysis. However, the confidence interval is not so narrow as before. Similarly, as before, the stability of artemisinin-based therapy is not so clear. The 0.5 quantile is very similar to the estimate however, the confidence interval is not so narrow and it includes zero, thus the sign may change. Overall, inspecting the stability of the results in Africa, we may conclude that our results are stable. Again, there are some exceptions like before, namely, the artemisinin-based combination therapy. To deepen our understanding of the malaria preventive measures, in the following cluster analysis we will be able to observe which countries are the most threatened ones, on which regions organization should focus and which measures are the most important ones in various countries.

7.3. Cluster Analysis

7.3.1. Cluster analysis – recent situation

On the cluster analysis, we can put our countries in separate clusters to observe and analyze which countries have similar properties. Furthermore, we can discuss different values of our variables of interest in each cluster. We will proceed with the cluster analysis from two different points of view. Firstly, we will study the recent situation and see which countries belong to the same cluster using the year 2017. This year has been chosen, as that year we have data for most of the countries and we can still inspect the recent situation. Secondly, we will use the fact that we have panel data and incorporate all-time information. Therefore, we will study the situation in different countries in various years. We will proceed with the cluster analysis where we will group countries with years to different clusters. From this point of view, we will see the development of the countries. Therefore, we will be able to say whether the situation in some country for some year is similar to another country in the same or different year. All analysis is made in software R and Rstudio.

Firstly, to monitor the current situation, we have selected data for the year 2017. To measure the distance among them, we had to make our data scaled. Before doing the cluster analysis, we need to select a number of clusters that are appropriate for our dataset. For this reason, we have applied the elbow method. The chosen number of clusters is set to be four, which can be seen on a graph 7.1 below.

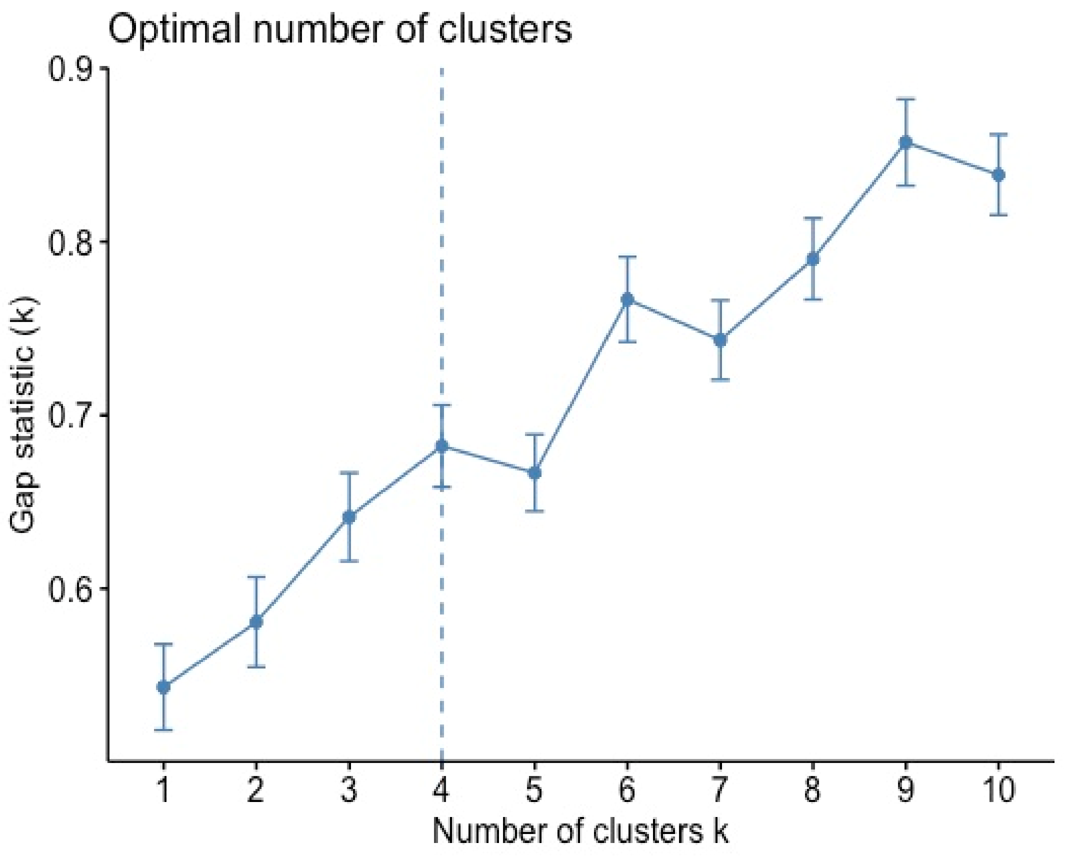

Figure 7.1: Optimal number of clusters 2017

Source: author's computations.

Having set the number of clusters, we will proceed with two different methods: k-means clustering and hierarchical clustering. Results of k-means clustering are displayed in graph 7.2. The table (7.5) with the average values of variables for each cluster can be seen on the page 50.

Figure 7.2: K-means clustering 2017

Source: author’s computations.

Table 7.5: K-means clustering 2017 - summary statistics

Cluster	1	2	3	4
Deaths_mean	4.857795e-05	2.902106e-06	3.085092e-05	1.864294e-04
Funds_mean	35.7026032	0.7481338	3.2496284	6.5910141
ITN_mean	0.177300030	0.003587858	0.069392973	0.454858003
IRS_mean	0.52929929	0.01148973	0.05144956	0.07859347
RDT_mean	0.194707408	0.003963353	0.084500223	0.496784142
ACT_mean	0.0328937961	0.0002732514	0.0444437656	0.4179016008
GDP_mean	1923.5514	9989.7681	2070.0174	856.5437
Rural_mean	0.4663763	0.2940195	0.6186344	0.6263770
War_mean	0.33333333	0.00000000	0.50000000	0.07142857

Source: author's computations.

We can see the division of countries to several clusters. We can observe that the first cluster is the smallest one and includes only three countries – Cabo Verde, Sao Tome and Principe, and Chad. These countries are specific as they receive on average quite a lot of funds per capita. Furthermore, the number of delivered indoor residual sprayings per capita is on average 0.53 which is heavily above the average considering all countries. The average GDP per capita for this cluster is 1923, 6 USD.

Looking at the second cluster, 21 countries are included there. Among them are for example Argentina, Bolivia, Brazil, Republic of Korea or Saudi Arabia. These countries have the best position in terms of malaria situation from our whole dataset. The number of deaths belongs to the smallest one with the largest average GDP per capita. Furthermore, these are the lucky countries with no wars during the year 2017.

In addition, this cluster is characterized by the smallest proportion of people living in rural areas.

The third cluster is the largest one having 30 countries such as Afghanistan, Haiti, Namibia, Niger, Thailand or Viet Nam. The average GDP per capita for these countries is 2070,02 USD therefore slightly higher than the first cluster. Looking at the other variables, mean ITNs per capita is 0,07, IRSs per capita is on average 0,05, RDTs per capita is on average 0,08 and ACT per capita is on average 0,04. However, these countries are characterized by the highest proportion of wars.

Analyzing the fourth cluster, 14 countries are included there. These are mainly African countries such as the Central African Republic, Gambia, Guinea, Mozambique, Sierra Leone or Zambia. The situation in these countries is the worst one regarding malaria deaths. The GDP per capita is on average only 856,5 USD. The proportion of the population living in rural areas is the greatest one from our four analyzed clusters. As we have seen the division to various clusters, it is quite visible that each cluster is characterized by its unique specifications.

Secondly, doing the hierarchical clustering, we can see the results presented in the dendrogram (graph 7.3.) and table 7.6.

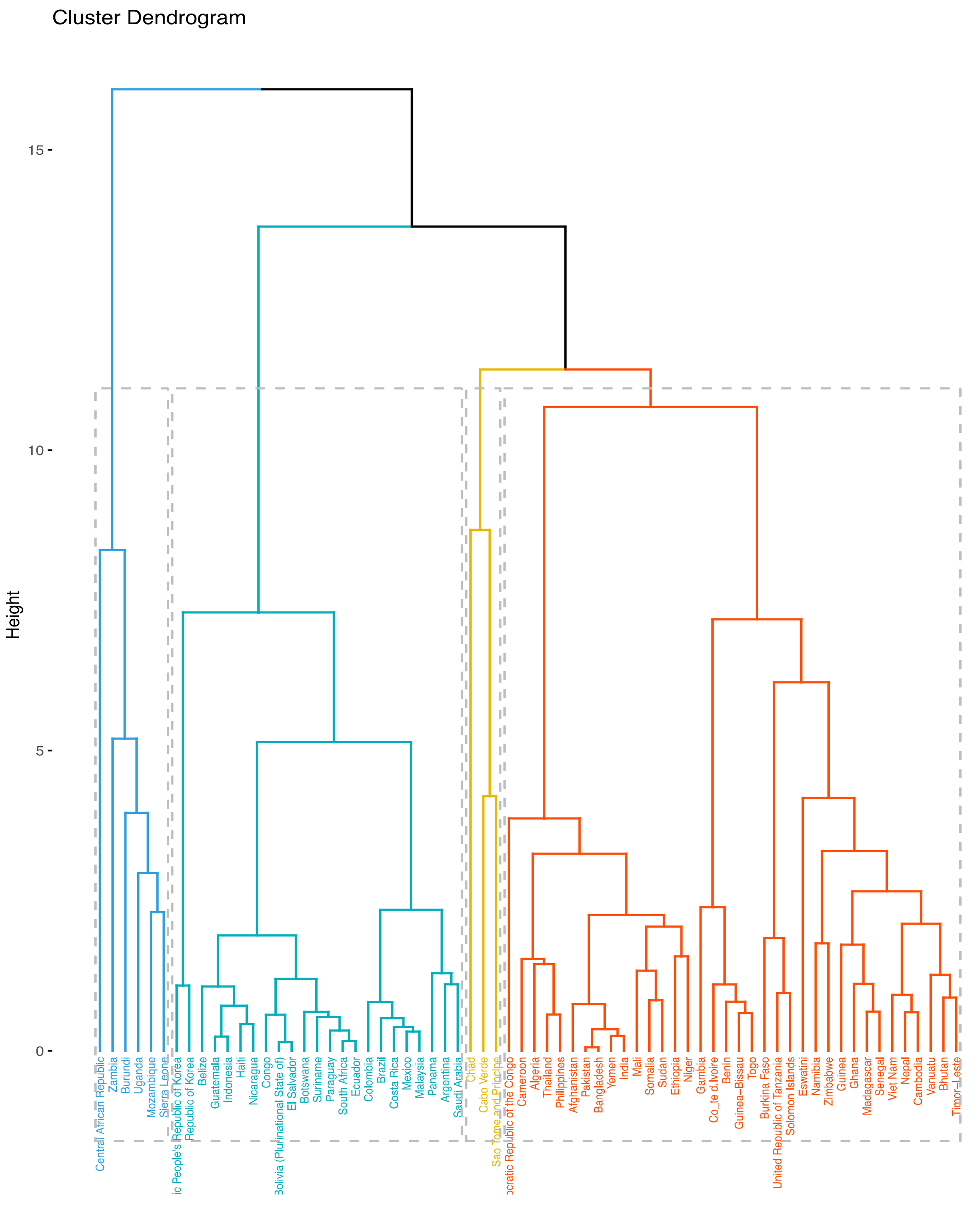

Figure 7.3: Cluster dendogram 2017

Source: author's computations.

Table 7.6: Hierarchical clustering 2017 - summary statistics

Cluster	1	2	3	4
Deaths_mean	5.257936e-05	2.697256e-06	2.735982e-04	4.857795e-05
Funds_mean	4.0888204	0.8092876	6.6104517	35.7026032
ITN_mean	0.144527170	0.006085592	0.530366584	0.177300030
IRS_mean	0.04840944	0.01482562	0.13355847	0.52929929
RDT_mean	0.155747707	0.004654366	0.643207871	0.194707408
ACT_mean	0.0857797763	0.0002494904	0.6826439051	0.0328937961
GDP_mean	1792.0914	9369.8935	642.4032	1923.5514
Rural_mean	0.6191578	0.3119540	0.6730164	0.4663763
War_mean	0.4166667	0.0000000	0.1666667	0.3333333

Source: author’s computations.

Analyzing the results, the first cluster (color red) consists of 36 countries. Among them, we can find Afghanistan, Namibia, Niger, Pakistan or Zimbabwe. This cluster is characterized by average GDP per capita being 1792 USD. Mean of ITNs per capita is 0,14, mean of IRSs per capita is 0,04, RDTs per capita is on average 0,15 and mean of ACT per capita is 0,08. This cluster is defined by the highest proportion of wars. The proportion of people living in rural areas is 0,62.

The second cluster (color green) consists of a smaller number of countries - concretely 23 countries. This cluster is similar to the second cluster when using k-means clustering. Here are the countries with the best position among all four clusters.

Argentina, Brazil, Paraguay, Saudi Arabia or South Africa are one of the countries belonging to this cluster. The average GDP per capita is 9369, 9 USD, therefore the highest GDP per capita compared to the other three clusters. Also, these countries do not experience any wars. In addition, the proportion of people living in rural areas is also the smallest one.

On the third cluster (color blue), its main specification is the highest probability of malaria deaths per person. Additionally, the average GDP per capita is the smallest one – only 642 USD per person. On the other hand, the proportion of people living in rural areas is on average the highest from all clusters. Countries belonging to this cluster are for example Central African Republic, Mozambique or Sierra Leone.

The fourth cluster (color yellow) is the smallest one including only three countries – Chad, Cabo Verde, and Sao Tome and Principe. Therefore, this cluster is the same as the first cluster from the analysis above. The main definition of this cluster is a high supply of funds per capita. The average values are very similar as when doing k-means clustering.

Overall, we could see that doing cluster analysis gave us very interesting results regarding the recent situation. We could easily observe the difference between countries, especially between the Americas and the African continent. We could analyze that the worst conditions are still by African countries. On the other hand, the best position for malaria elimination can be spotted in South American countries and some countries from Asia. Using these results, it can be clearly observed which countries would need more funds and preventive measures and which are relatively satisfied. That can help especially international organizations to see which type of countries should they invest in. Furthermore, we can detect that both methods of clustering gave us very analogous results.

7.3.2. Cluster analysis – overall situation

Secondly, we will look at the cluster analysis from a different point of view. This time, we will create clusters with respect to country and year at the same time. Therefore, we will be able to compare the situation among countries for many years and observe their stage of development with respect to malaria. That will help us to understand the evolution of the situation in different countries. As previously, we will start by scaling our data. Secondly, we need to find an optimal number of clusters. Again, we will use the elbow method. Looking at the graph 7.4, we have chosen the number of clusters to be equal to four, as simulating our data many times, the elbow was always stable in the fourth cluster.

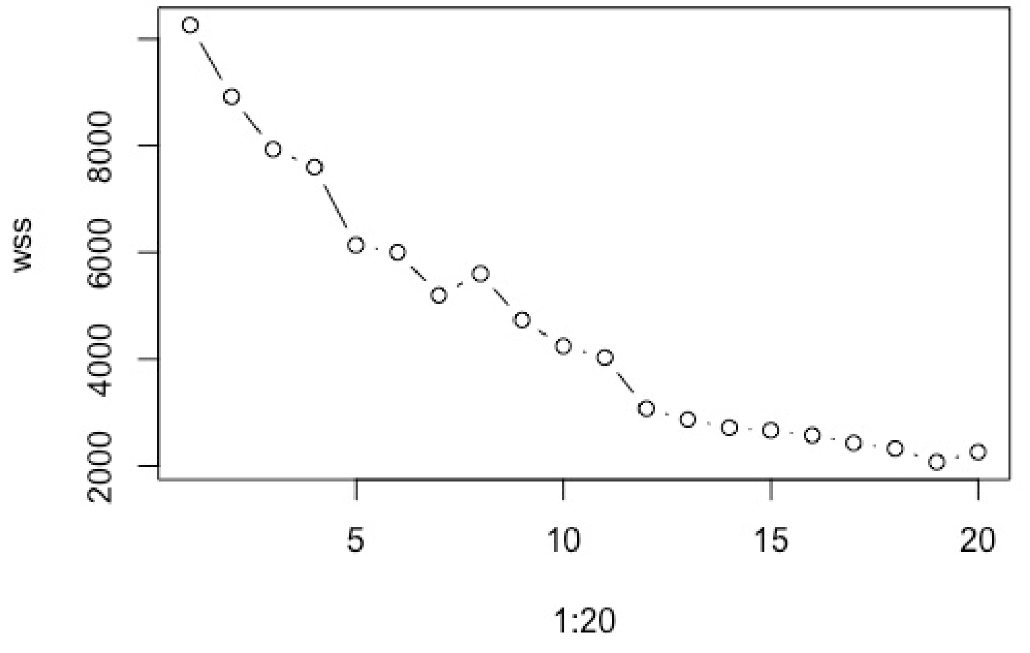

Figure 7.4: Optimal number of clusters – general

Source: author's computations.

After getting the proper number of clusters, we will proceed with the analysis. Representing these results graphically is not that easy as before, because apart from countries, we are using years as well. Therefore, in the appendix, you can find tables with years and countries for each cluster. If there is a sign "1", it means the country in that year belongs to that cluster. On table 7.7, we can see an overview of continents being represented in each cluster. Below, one can find the summary statistics for each cluster (table 7.8).

Table 7.7: Clustering – overview of continents

Cluster	Africa	America	Eastern Mediterraean	Europe	South-East Asia	Western Pacific
1	43	128	13	8	14	23
2	323	87	1	43	54	65
3	5	0	0	0	0	0
4	98	11	42	14	42	13

Source: author's computations.

Table 7.8: Panel data clustering – summary statistics

Cluster	1	2	3	4
Deaths_mean	1.120073e-05	0.0001405829	0.0001180181	5.100645e-05
Funds_mean	33.85618	8.313147	2.977126	2.004391
ITN_mean	0.007285737	0.3603046	0.06394088	0.05500577
IRS_mean	0.02515817	0.2316537	0.05564729	0.03549497
RDT_mean	0.00165293	0.3633729	0.0107318	0.0169123
ACT_mean	0.1055496	0.2880076	0.2038651	0.05886024
GDP_mean	10540.71	1175	1691.655	2223.861
Rural_mean	0.2674841	0.5896175	0.6078436	0.6077161
War_mean	0.02857143	0.1014493	0	1

Source: author's computations.

Studying the first cluster, it is mainly represented by the countries from the American continent. Furthermore, the years of interest in American countries are mainly the most recent ones. For example, Paraguay is represented here since 2010. Apart from one year, the same is true for Bolivia. Brazil includes all years since 2007 and the Dominican Republic since 2005. The second strongest continent is Africa. Namely, South Africa with years 2009 - 2017, Botswana during 2008 - 2017 or Equatorial Guínea during a couple of last years. In addition, a couple of other countries such as Indonesia since 2015 are also present in this cluster. Looking at the mean values, the average GDP per capita is the highest one from all clusters. Oppositely, the proportion of people living in rural areas is the smallest among all clusters. In addition, this cluster is characterized by the smallest average malaria deaths per person and the proportion of wars is limited as well. We could say that this cluster has the best position in malaria development from all countries and years of interest in our dataset. Clearly visible is the situation of Africa, where recently only some countries face a similar situation as America has been already facing earlier. Therefore, the situation in America is clearly shifted by many years in contrast to the situation in some African countries. However, most of the African countries experience a worse situation and are not even shown in this cluster.

On the second cluster, it is strongly dominated by African countries. Some African countries are displayed throughout many years such as the Democratic Republic of Congo, Eritrea, Ghana, Guinea or Senegal. On the other hand, some African countries do represent mainly earlier years, for example, Botswana till 2007, Gabon till 2003 or Nigeria till 2009. On countries from different continents, we can observe Costa Rica till 2004, Bangladesh between the years 2007 to 2015, China in 2009 or Thailand in 2002. The cluster is characterized by the highest proportion of malaria deaths per person on average and the lowest average GDP per capita. We could say that countries belonging to this cluster are facing the worst malaria situation from the whole sample. It is observable that some African countries were placed in this cluster when they were coming through a bad situation, but now they belong to another cluster with better conditions.

The third cluster is the smallest one having only three countries – Cabo Verde during 2002, 2005 and 2006, Equatorial Guinea in 2008 and Sao Tome and Principe in 2002. On average, 60% of the population lives in rural areas. The average distribution of ACTs per capita is one of the highest. During these years, these countries did not experience any wars.

The fourth cluster includes mostly countries from Africa, the Eastern Mediterranean, and South-East Asia. In contrast to the previous clusters, which were mostly represented by one continent, this cluster is more fragmentized. One can find here countries such as Bangladesh for the last couple of years, the Philippines since 2006, Somalia since 2013, Turkey till 2009 or Yemen since 2009. The average distribution of preventive measures is one of the lowest, especially for ACTs. The distribution of IRSs is also quite small in contrast to other clusters. The poor distribution of preventive measures may be caused by the fact that these countries were experiencing war during the exposed years. That may explain the problem of low preventive supply.

Proceeding with the cluster analysis, we got the division of countries into various groups. We have found similarities among countries belonging to the same cluster. That is a very important aspect for organizations facing the problem of the distribution of preventive measures to various countries. Having this analysis, it can be visible which countries do need specific measures and where there is a large lack of commodities. Apart from that, we have compared the situation countries are facing. This showed us that for example not every country in Africa needs to be supplied equally, as some of them have already reached a better position as America is facing now. From our analysis, we can conclude that the strongest attention needs to be given to countries in clusters 2 and 4 as there is the highest proportion of malaria deaths, but the availability of preventive measures is not satisfactory.

Overall, we wanted to study the third hypothesis whether countries in the same continents belong to the same cluster and therefore the malaria situation is similar in these countries. This hypothesis was partly confirmed. Most countries from Africa do belong to one cluster however, some countries are shifted to the cluster with American countries. That is true especially for African countries which experience a better situation with malaria. Most countries from America belong to one cluster as the situation is much better there especially with contrast to Africa. Countries from the Eastern Mediterranean and South-East Asia are more mixed among the other clusters.

8 Discussion

As the advantage of this study is having dataset for all countries which are threatened by malaria throughout the time, of course, it is possible to find some disadvantages and limitations. Certainly, malaria preventive measures are not the only factors affecting malaria deaths. Therefore, we need to take into account the control variables as well. However, for such a general study, it is not easy to find many control variables. Therefore, for further studies hopefully, more new data will be recorded. This might be an example of literacy rate or education which is not fully accessible for all years of interest we are analyzing in our study. However still, on malaria, there does not exist so much data, thus we need to wait a couple of years to be able to create a new dataset. As we have been doing panel data regression, we need to solve some issues. In this chapter, we will adjust our models by proceeding analysis with heteroscedasticity and autocorrelation-consistent standard errors and consequently, we will discuss those different results and see whether they improve our analysis and how different they are. These procedures will help us to improve the problem of heteroscedasticity and autocorrelation. On the next page, a summary of an adjusted model may be seen (table 8.1).

Table 8.1: Robust errors

	Fixed effect model	Fixed effect model - robust errors
Funds	-2.8489e-08 (2.7284e-08)	-2.8489e-08. (1.6993e-08)
ITN	7.1227e-05 (4.4516e-05)	7.1227e-05 (5.7697e-05)
IRS	-3.3237e-04*** (5.7686e-05)	-3.3237e-04** (1.0638e-04)
RDT	-1.1739e-04** (4.0825e-05)	-1.1739e-04** (3.9934e-05)
ACT	3.0075e-05*** (3.2226e-06)	3.0075e-05*** (4.2155e-06)
GDP	-3.9469e-09 (3.3808e-09)	-3.9469e-09 (3.7169e-09)
Rural	9.8304e-04*** (2.0134e-04)	9.8304e-04** (3.3759e-04)
War	-3.8812e-05* (1.6986e-05)	-3.8812e-05* (1.5451e-05)
ITN:IRS	-2.8192e-04*** (8.3036e-05)	-2.8192e-04* (1.1828e-04)
Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1		

Source: author’s computations.

Analyzing the modified model, one cannot see any enormous difference to the original models. All significant variables remained still significant, some significant levels have changed, for example, rural variable or indoor-residual spraying, which are however still significant. The highest difference may be spotted by the interaction term, which is now significant at the 0.05 significance level. On the other hand, looking at the funds, there the standard error is much smaller.

When doing our analysis, we have always concentrated on the overall situation and situation in Africa as there the problem of malaria is the worst and thus this continent must be inspected more properly. Therefore, the modification we have made to our general model has also proceeded for Africa. The results are shown in table 8.2.

Table 8.2: Robust errors - Africa

	Fixed effect model	Fixed effect model - robust errors
Funds	-3.7765e-08 (3.8739e-08)	-3.7765e-08* (1.8992e-08)
ITN	1.0498e-04 (6.6905e-05)	1.0498e-04 (6.4002e-05)
IRS	-2.4021e-04** (8.8165e-05)	-2.4021e-04* (1.0170e-04)
RDT	-4.4674e-05 (6.4182e-05)	-4.4674e-05 (5.0061e-05)
ACT	2.8590e-05*** (4.6898e-06)	2.8590e-05*** (4.5855e-06)
GDP	-4.3310e-08*** (1.0446e-08)	-4.3310e-08** (1.4745e-08)
Rural	1.9030e-*** (4.1664e-04)	1.9030e-** (5.9507e-04)
War	-6.1413e-05* (2.9785e-05)	-6.1413e-05* (2.4034e-05)
ITN:IRS	-3.5493e-04** (1.2195e-04)	-3.5493e-04** (1.2958e-04)
Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1		

Source: author’s computations.

Looking at the model, it is clear that the results are quite similar to the original model. There are only some minor differences. Similarly, as in the model for the general data with heteroscedasticity and autocorrelation-consistent robust standard errors, the effect of funds has become significant. Having more funds per capita means lower malaria deaths. However, the effect is very small. Overall, the conclusions of our analysis and the effects of malaria preventive measures on malaria deaths remain similar because the significance levels did not change strongly. Therefore, for Africa as well as for the whole world, proceeding panel data regression with heteroscedasticity and autocorrelation-consistent robust standard errors only confirmed our conclusions about the effects of malaria preventive measures.

In the chapter methodology, we have been exploring funds in our regression analysis. We might think whether the effect of funds may be only when converting them into other preventive measures or solely as well. Therefore, we will proceed with regression analysis with only other preventive measures and second with only funds and compare the results. Hence, we will be able to say, whether having funds in our analysis changes the results. We have done it using heteroscedasticity and autocorrelation-consistent robust standard errors. Table 8.3 provides a summary.

Table 8.3: Panel data regression - funds

	Fixed effect model - all variables	Fixed effect model - without funds	Fixed effect model - only funds	Random effect model - all variables	Random effect model - without funds	Random effect model - only funds
Funds	-2.8489e-08. (1.6993e-08)		-1.6045e-08** (5.3989e-09)	-1.6902e-08 (1.6356e-08)		-6.6984e-09* (3.2699e-09)
ITN	7.1227e-05 (5.7697e-05)	7.1481e-05 (5.7777e-05)		7.4480e-05 (5.9919e-05)	7.5034e-05 (5.9832e-05)	
IRS	-3.3237e-04** (1.0638e-04)	-3.2178e-04** (1.0905e-04)		-2.8489e-04** (1.0756e-04)	-2.7891e-04** (1.0604e-04)	
RDT	-1.1739e-04** (3.9934e-05)	-1.1825e-04** (3.9809e-05)		-1.5229e-04** (4.9133e-05)	-1.5239e-04** (4.9100e-05)	
ACT	3.0075e-05*** (4.2155e-06)	3.0351e-05*** (4.1389e-06)		3.5025e-05** (1.1026e-05)	3.5175e-05** (1.0973e-05)	
GDP	-3.9469e-09 (3.7169e-09)	-3.9656e-09 (3.7354e-09)	-1.1291e-09 (2.6769e-09)	-7.3712e-** (2.6976e-09)	-7.3604e-09** (2.6998e-09)	-5.0338e-09* (2.5621e-09)
Rural	9.8304e-04** (3.3759e-04)	9.7644e-04** (3.3536e-04)	1.6840e-03*** (1.8286e-04)	1.5012e-04** (5.1719e-05)	1.4899e-04** (5.1653e-05)	2.8197e-04*** (5.0613e-05)
War	-3.8812e-05* (1.5451e-05)	-3.8841e-05* (1.5431e-05)	-3.6676e-05* (1.5786e-05)	-5.0634e-05** (1.8857e-05)	-5.0597e-05** (1.8779e-05)	-5.1536e-05** (1.8335e-05)
ITN:IRS	-2.8192e-04* (1.1828e-04)	-2.8365e-04* (1.1917e-04)		-2.5372e-04* (1.0699e-04)	-2.5517e-04* (1.0698e-04)	

Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1

Source: author's computations.

Looking at the results, it is visible that models with and without funds are quite similar with regards to the explanatory variables. The coefficients are relatively similar having the same sign and the significance levels did not change at all. However, looking at the consistent fixed effect model with robust errors, funds are significant at the 0.1 significance level. Proceeding with the regression with funds only, funds are significant at the 0.01 significance level. Overall, we may see that when adding funds to the regression with all variables, the significance level has changed however, being still significant without any fundamental change to the other explanatory variables.

Another issue is the endogeneity, which may be present among deaths and malaria preventive measures. It means that countries suffering from more deaths caused by malaria will receive higher attention and therefore more supply of malaria preventive measures. There are more ways how to deal with this problem. In this thesis, we have relied on panel data structure and therefore a long period. As the endogeneity between preventive measures and malaria deaths may be caused by country-specific characteristics, the fixed effect model may help to deal with it. As mentioned in the methodology section, the fixed effect model helps us to eliminate these individual attributes to see the overall effect on malaria deaths. Apart from using the fixed effect model, we may add other variables that exogenously affect the inflow of aid into countries. That can be caused for example by war or outbreak. For that reason, war conflict was used in our analysis.

9 Conclusion

The main aim of the thesis was to inspect the malaria preventive measures around the world in general. Namely, to examine which preventive measures are useful, whether greater availability of them helps to decrease malaria deaths and how they are distributed around the world in different regions. For this reason, all results were made for the whole world examining countries that are threatened by malaria. Our yearly data were taken from the World Health Organization mostly from 2001 to 2018. Also, our results were examined for the African continent separately, because the situation is much worse there in contrast to the rest of the world. Besides, most of the studies are focused only on Africa, for example, a study by J. Mangeni *et al.* (2016), J. Gimnig *et al.* (2016), A. Hailu *et al*. (2018) or K. Nyavor *et al.* (2017), so we want our study to be comparable to them. On the other hand, studying the preventive measures generally is very important as to my best knowledge, generalized studies about the effects of malaria prevention measures using the most recent data cannot be almost found.

First, we have proceeded with the panel data regression. Namely, a fixed-effect model and random-effect model were conducted and followed by the Hausman test. This test showed that the fixed effect model should be favored. The usefulness of the malaria preventive measures was calculated in terms of malaria deaths in each country. The explanatory variables were insecticide-treated nets with long-lasting insecticide-treated nets, indoor residual spraying, funds, rapid diagnostic tests, artemisinin-based combination therapy, GDP, the population living in rural areas, a dummy variable whether a country experienced war and the interaction term among insecticide-treated nets and indoor-residual sprayings. The results for the whole world showed that indoor residual sprayings and rapid diagnostic tests are significant and lead to a decrease in malaria deaths. The effect of insecticide-treated nets was not significant, however, the interaction term was significant with the expected negative effect on malaria deaths. This confirmed the results of J. Gimnig *et al.* (2016), who considered insecticide-treated nets not being significant unless using it together with indoor-residual sprayings. On the other hand, this contrasts with a study by K. Wangdi *et al.* (2018), who considers nets as being significant. However, this study states that all other preventive measures are important to fight against malaria too. On the proxy variable for the number of mosquitos, the effect of the rural variable was significant stating that more malaria deaths occur in rural areas. This is confirmed by W.P. Schmidt *et al.* (2011). Surprisingly, experiencing a war means a lower number of malaria deaths. This can be explained by the fact that when a country experiences a war, malaria is not so important topic and many people die because of a war. However, the effect of this variable was very small. Doing the bootstrapping to measure the stability of our results, all the above-mentioned significant variables were very stable having very narrow confidence intervals. We may, therefore, rely on the effects of the explanatory variables. The unexpected positive effect was found out by the artemisinin-based combination therapy. However, the bootstrapping showed us that this value is not stable and the 90% confidence interval included both signs. Furthermore, we have discussed that as artemisinin-based combination therapy is mainly used in hospitals, people use it only in very bad conditions, especially in poor locations, where access to hospitals is not common. Therefore, the effect is not so straightforward. In addition, we have proceeded with heteroscedasticity and autocorrelation-consistent standard errors, where we can observe only minor changes. All significant variables remained still significant, however, with some small changes of significant levels (rural variable or indoor-residual spraying). Only, the standard error of the interaction term has become larger, however, the variable remained significant at 0.05 significance level. On the other hand, the effect of funds has become significant having a negative impact on malaria deaths. Moreover, the effect of funds was examined more properly. We have proceeded with regression without funds and funds only to explore whether the effect is not only when translating it to other preventive measures. It was shown that the effect of other variables did not change at all when adding funds, but the effect of funds was still significant when having it as the only preventive measure.

Next, we have proceeded with panel data regression only for the African continent. The results were very similar. The difference was in GDP and rapid-diagnostic tests. GDP has become significant. That is logical as, for poor countries in Africa, even a bit higher GDP per capita means better living conditions. In contrary to the general results, rapid-diagnostic tests were not statistically significant. As explained, Africa is experiencing such bad conditions with malaria that the primary preventive measures such as sprayings or nets must be delivered there firstly. After eliminating some malaria cases and improving access to hospitals, rapid diagnostic tests might help. Again, to verify the stability of our results, bootstrapping was used. Except for rapid-diagnostic tests and artemisinin-based combination therapy, all other variables were very stable. Furthermore, proceeding with the heteroscedasticity and autocorrelation-consistent standard errors, the effect of funds has become significant as for the general data. The significance of other variables did not almost change. Therefore, conducting heteroscedasticity and autocorrelation-consistent standard errors, it only confirmed our results obtained from the panel data regression. That is true for our general data as well as the African data. Furthermore, with some exceptions, the check for stability confirmed our results that indoor residual sprayings should be favored over insecticide-treated nets. When using insecticide-treated nets, it is better to use them in combination with sprayings to receive an expected effect on malaria deaths. Furthermore, when the situation with malaria improves, rapid diagnostic tests should be delivered. However, as seen from our results, this is valid only for countries with better conditions.

Next, we have proceeded with the clustering. Firstly, the year 2017 has been used to observe the current situation. We have divided our regions into four clusters. Each cluster was defined by its unique values of our variables of interest. The same was true for the clusters made for the whole dataset. Generally, we have found out that most of the African countries belong to the cluster with the worst conditions. That means a cluster with the highest number of malaria deaths per person and the highest proportion of people living in rural areas. Furthermore, these countries are supplied by insecticide-treated nets rather than indoor-residual sprayings. This is confirmed by J. Mangeni *et al.* (2016), who has studied a situation in some regions of Kenya where the number of malaria deaths does not decline. This study states that insecticide-treated nets are the primary measures that are used there. But, some African countries have belonged to this cluster earlier and now having better conditions, they moved to the cluster where there are mostly American countries. There, the situation is much better, having the lowest number of malaria deaths. Furthermore, the funds invested in these countries are enormously higher than in other clusters. Moreover, this is the only cluster where more indoor residual sprayings rather than insecticide-treated nets were delivered. The next cluster is more diversified having countries from Africa, the Eastern Mediterranean, and South-East Asia. These countries were experiencing war during the exposed years. That might explain a very poor supply of malaria preventive measures. Again, the supply of indoor-residual spraying should be empowered there.

Overall, from the panel data regression, we have found out that indoor residual sprayings should be favored over insecticide-treated nets. Proceeding with robust standard errors and bootstrapping, it confirmed our results. Next, we have found out that rapid diagnostic tests may improve the situation of malaria deaths. However, they should be used in countries with better malaria conditions. Countries with worse conditions should be primarily supplied by sprayings or sprayings and nets together. From the cluster analysis, we could observe that not every African country needs to be supplied equally. Some African countries have already reached the position the American countries are facing right now. Observing the results of clustering, more insecticide-treated nets are delivered in contrast to indoor-residual sprayings. However, as the result of indoor-residual sprayings is so stable, organizations should prefer its distribution to improve the situation with malaria.

As explained in the discussion part, we have tried to use as much data as possible. However, adding other variables such as the literacy rate or education would certainly improve our results. However, such data for all our countries through many years are not available now. Hopefully, for further analysis, these data will be available. Moreover, some preventive measures are still very new and therefore, their effect can not be properly analyzed. Thus, after a couple of years, this analysis could be conducted again using newly available data with a longer period.

Bibliography

ASINGIZWE, D., P. M. POORTVILET, C.J.M. KOENRAADT, A.J.H. VAN VLIET, C.M. INGABIRE, L. MUTESA & C. LEEUWIS (2019):" Role of individual perceptions in the consistent use of malaria preventive measures: mixed methods evidence from rural Rwanda." *Malaria Journal* **18(1)**: pp.1-19.

BALTAGI, B. H. (2001): "Econometric Analysis of Panel Data (2 ed.)".

BIORN, E. (2017): „Econometrics of Panel Data: Methods and Applications." *1st ed. Oxford : OUP Oxford.*

BROWNLEE, J. (2018):" Statistical Methods for Machine Learning: Discover how to Transform Data into Knowledge with Python." pp. 129-150.

CENTERS FOR DISEASE CONTROL AND PREVENTION (2019): "How to Reduce Malaria's Impact." https://www.cdc.gov/malaria/malaria_worldwide/reduction/itn.html. Accessed: 21-09-2019.

GACHELIN, G., P. GARNER, E. FERRONI, JP. VERHAVE & A. OPINEL (2018): "Evidence and strategies for malaria prevention and control: a historical analysis." *Malaria Journal* **17(1)**: pp. 1-18.

GIMNIG, J., P. OTIENO, V WERE et al. (2019): "The Effect of Indoor Residual Spraying on the Prevalence of Malaria Parasite Infection, Clinical Malaria and Anemia in an Area of Perennial Transmission and Moderate Coverage of Insecticide Treated Nets in Western Kenya." *Plos One* **11(1):** pp. 1-29.

GREENE, W.H. (2012): "Econometric Analysis, 7th edition." *Prentice Hall:* pp. 603 – 633.

HAILU, A., B. LINDTJØRN, W. DERESSA, T. GARI, E. LOHA & B. ROBBERSTAD (2018): "Cost-effectiveness of a combined intervention of long lasting insecticidal nets and indoor residual spraying compared with each intervention alone for malaria prevention in Ethiopia." *Cost Effectiveness and Resource Allocation* **16(1):** pp. 1-17.

HANCK, CH., M. ARNOLD, A. GERBER & M. SCHMELZER (2019): "Introduction to Econometrics with R." *University of Duisburg-Essen.*

HOGARH, J., T. AGYEKUM, C. BEMPAH, E. OWUSU-ANSAH, S. AVICOR, G. AWANDARE, J. FOBIL & K. OBIRI-DANSO (2018): "Environmental health risks and benefits of the use of mosquito coils as malaria prevention and control strategy." *Malaria Journal* **17(1)**: pp. 1-12.

HOROWITZ, J.L. (2001): "The Bootstrap." Handbook of Econometrics, vol. 5, Elsevier Science, B.V., pp. 3159-3228.

KAUFMAN, L., & P. ROUSSEEUW (1990): "Finding Groups in Data: An Introduction to Cluster Analysis."

MAGAÇO, A., C. BOTÃO, P. NHASSENGO, M. SAIDE, A. UBISSE, S. CHICUMBE & R. ZULLIGER (2019): "Community knowledge and acceptance of indoor residual spraying for malaria prevention in Mozambique: a qualitative study." *Malaria Journal* **18(1)**: pp. 1-12.

MANGENI, J., D. MENYA, A. OBALA, A. PLATT & W. O'MEARA (2016): "Development and validation of a rapid assessment tool for malaria prevention." *Malaria Journal* **15**: pp. 1-12.

NYAVOR, K., M. KWEKU, I. AGBEMAFLE, W. TAKRAMAH, I. NORMAN, E. TARKANG & F. BINKA (2017): "Assessing the ownership, usage and knowledge of Insecticide Treated Nets (ITNs) in Malaria Prevention in the Hohoe Municipality, Ghana." *Pan African Medical Journal* **28**: pp. 1-8.

PEACE RESEARCH INSTITUTE OSLO. https://www.prio.org/Data/. Accesssed: 14-11-2019.

SCHMIDT, W.P, M. SUZUKI, V.D. THIEM, R.G. WHITE, A. TSUZUKI, L.M. YOSHIDA, H. YANAI, U. HAQUE, L.H. THO, D.D. ANH & K. ARIYOSHI (2011): "Population Density, Water Supply, and the Risk of Dengue Fever in Vietnam: Cohort Study and Spatial Analysis." *Plos Medicine* **8(8)**.

SOLOMON, T., E. LOHA, W. DERESSA, T. GARI, H. OVERGAARD & B. LINDTJØRN (2019): "Low use of long-lasting insecticidal nets for malaria prevention in south-central Ethiopia: A community-based cohort study." *Plos One* **14**: pp. 1-21.

TAN, P., M. STEINBACH, A. KARPATNE & V. KUMAR (2018): "Introduction to Data Mining (Second Edition)." pp. 487 – 568.

WANGDI, K., L. FURUYA-KANAMORI, J. CLARK et al. (2018): "Comparative effectiveness of malaria prevention measures: a systematic review and network meta-analysis." *Parasites [online]* **11(1)**: pp. 1-13.

WHO (2001): "Malaria vectors and approaches to their control in malaria affected countries of the WHO European Region: the proceedings of a regional meeting on vector biology and control." https: //www.euro.who.int/__data/assets/pdf_file/0005/98780/E76649.pdf. Accessed: 21-09-2019.

WHO (2010): "Good procurement practices for artemisinin-based antimalarial medicines." https://apps.who.int/iris/bitstream/handle/10665/44248/9789241598927_eng.pdf?sequence=1. Accessed: 22-09-2019.

WHO (2015a): "Indoor residual spraying: an operational manual for indoor residual spraying (IRS) for malaria transmission control and elimination – 2nd ed." https://apps.who.int/iris/bitstream/handle/10665/177242/9789241508940_eng.pdf;jsessionid=D4B42EAF7DBB6B5760AA37DA17C554F9?sequence=1. Accessed: 21-

09-2019.

WHO (2015b): “The role of RDTs in malaria control.” https://www.who.int/malaria/areas/diagnosis/rapid-diagnostic-tests/role_in_malaria_control/en/. Accessed: 22-09-2019.

WHO (2015c): “Global technical strategy for malaria 2016-2030.” https://apps.who.int/iris/bitstream/handle/10665/176712/9789241564991_eng.pdf?sequence=1. Accessed: 23-12-2019.

WHO (2018a): “Overview of malaria treatment.” https://www.who.int/malaria/areas/treatment/overview/en/. Accessed: 21-09-2019.

WHO (2018b): “This year's World malaria report at a glance.” https://www.who.int/malaria/media/world-malaria-report-2018/en/. Accessed: 22-09-2019.

WHO (2019a): “Insecticide-treated nets to reduce the risk of malaria in pregnant women.” https://www.who.int/elena/titles/bednets_malaria_pregnancy/en/. Accessed: 21-09-2019.

WHO (2019b): “World malaria report 2019.” https://www.who.int/publications-detail/world-malaria-report-2019. Accessed: 24-02-2020.

WOOLRIDGE, J. M. (2008):” Introductory Econometrics: A Modern Approach.”

WORLD BANK. https://www.worldbank.org. Accessed: 27-09-2019.

Appendix

Table A.1: General clustering – cluster 1

	Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Angola	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
2	Argentina	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
3	Azerbaijan	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
4	Bolivia (Plurinational State of)	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1
5	Botswana	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
6	Brazil	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
7	Cabo Verde	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
8	China	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
9	Colombia	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1
10	Congo	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
11	Costa Rica	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
12	Democratic People's Republic of Korea	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
13	Dominican Republic	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
14	Ecuador	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	1
15	El Salvador	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
16	Equatorial Guinea	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0
17	Gabon	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0
18	Guatemala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	Indonesia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
20	Iran (Islamic Republic of)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
21	Malaysia	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
22	Mexico	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
23	Nicaragua	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
24	Panama	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
25	Paraguay	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
26	Peru	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
27	Republic of Korea	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
28	Saudi Arabia	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
29	South Africa	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
30	Suriname	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
31	Turkey	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0
32	Venezuela (Bolivarian Republic of)	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0

Source: author's computations.

Table A.2: General clustering – cluster 2

	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Angola	0	0	0	1	0	1	1	0	1	0	1	1	0	0	0	0	0	0
2	Azerbaijan	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0
3	Bangladesh	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0
4	Belize	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
5	Benin	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	1	1
6	Bhutan	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1
7	Bolivia (Plurinational State of)	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
8	Botswana	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
9	Burkina Faso	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	Burundi	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	1	1
11	Cabo Verde	0	0	0	1	1	0	0	1	1	0	1	1	1	1	0	1	1	1
12	Cambodia	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
13	Cameroon	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0
14	Central African Republic	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1
15	Chad	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
16	China	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
17	Co_te dĚlvoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18	Comoros	0	0	0	0	0	1	1	1	1	0	1	1	0	1	1	1	0	0
19	Congo	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
20	Costa Rica	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
21	CŞte d'Ivoire	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	1	1	0
22	Democratic Republic of the Congo	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	0
23	Dominican Republic	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Ecuador	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
25	El Salvador	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
26	Eritrea	0	0	1	1	0	1	1	1	0	1	1	0	0	0	0	0	0	0
27	Eswatini	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
28	Gabon	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Gambia	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	Ghana	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	Guatemala	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0
32	Guinea	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1
33	Guinea-Bissau	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1
34	Guyana	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0
35	Haiti	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1
36	Honduras	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
37	Indonesia	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0
38	Kenya	0	0	1	1	1	1	1	0	0	0	1	0	1	1	1	0	0	0
39	Kyrgyzstan	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
40	Lao People's Democratic Republic	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
41	Liberia	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0

42	Madagascar	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
43	Malawi	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0
44	Mali	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
45	Mauritania	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	1	1	0
46	Mozambique	0	0	0	0	0	0	0	1	1	0	1	1	1	0	1	1	0	1
47	Namibia	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
48	Nepal	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
49	Nicaragua	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
50	Niger	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	0	0	0
51	Nigeria	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0
52	Panama	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
53	Papua New Guinea	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
54	Paraguay	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
55	Rwanda	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0
56	Sao Tome and Principe	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
57	Senegal	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1
58	Sierra Leone	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
59	Solomon Islands	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
60	Sri Lanka	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
61	Tajikistan	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0
62	Thailand	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	Timor-Leste	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
64	Togo	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1
65	Uganda	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
66	United Republic of Tanzania	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1
67	Uzbekistan	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0
68	Vanuatu	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1
69	Viet Nam	0	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
70	Yemen	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
71	Zambia	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
72	Zimbabwe	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Source: author's computations.

Table A.3: General clustering – cluster 3

	Country	2002	2005	2006	2008
1	Cabo Verde	1	1	1	0
2	Equatorial Guinea	0	0	0	1
3	Sao Tome and Principe	1	0	0	0

Source: author's computations.

Table A.4: General clustering – cluster 4

	Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Afghanistan	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1
2	Algeria	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
3	Angola	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
4	Azerbaijan	0	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0
5	Bangladesh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6	Burundi	0	1	0	1	1	0	1	0	0	0	0	0	1	1	0	0
7	Cambodia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
8	Cameroon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
9	Central African Republic	0	0	0	0	1	0	0	1	1	0	1	1	0	0	0	0
10	Chad	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1
11	Colombia	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	0
12	Congo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
13	Democratic Republic of the Congo	0	0	0	0	1	1	1	0	0	1	1	1	1	0	1	1
14	Eritrea	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
15	Ethiopia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	India	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
17	Iran (Islamic Republic of)	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
18	Kenya	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
19	Mali	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1
20	Mauritania	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
21	Mozambique	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
22	Myanmar	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0
23	Niger	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1
24	Nigeria	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
25	Pakistan	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1
26	Philippines	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
27	Rwanda	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
28	Senegal	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
29	Somalia	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
30	Sri Lanka	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
31	Sudan	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
32	Suriname	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0
33	Tajikistan	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
34	Thailand	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	Turkey	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
36	Uganda	0	0	0	0	1	1	1	1	0	1	0	1	0	1	1	1
37	Uzbekistan	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
38	Yemen	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1

Source: author's computations.