Missing the mark on malaria?

A quantitative study of the effects of the 2007 Malawian malaria treatment change on under-five mortality

Abstract
Malaria continues to impose a high burden on the Malawian population, in particular on children under the age of five, accounting for about 20 percent of all deaths among under-fives in 2000. In an effort to curb these numbers, the Malawian government launched a new Malaria Strategic Plan in 2005, aimed at reducing malaria morbidity and mortality. As part of this policy the treatment regimen for malaria was changed in accordance to the World Health Organization recommendations in December 2007. This paper aims to analyze the consequences of this change by examining the effects of the new treatment on the group most severely affected by malaria – children under the age of five. Using a Difference-in-difference method I estimate the impact on under-five mortality by combining data on in-patient malaria mortality among under-fives, and data from the 2010 Demographic and Health Survey. My strategy generated results that show no significant effect of the new and better treatment on the considered age group. Rather, my findings seem to counter previous theories on higher income and educational levels reducing child mortality, suggesting further studies in the particular context are needed.

Keywords: Under-five mortality, Difference-in-difference, Malaria, Malawi

Bachelor's thesis in Economics, 15 credits

Fall Semester 2019

Cecilia Smitt Meyer

Supervisor: Annika Lindskog

Department of Economics

School of Business, Economics and Law

University of Gothenburg

Table of Contents

1. INTRODUCTION

Decreasing under-five mortality is one of the targets stated by the World Health Organization (WHO) in the third Sustainable Development Goal (SDG): "By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1000 live births and under-five mortality to at least as low as 25 per 1000 live births" (World Health Organization. Sustainable Development Goal 3: Health, no date).

In Malawi there has been a strong trend in the reduction of the under-five mortality with a relative decline in child deaths between 1996 and 2010 of 41 percent. In 1992 the under-five mortality was 234 per 1000 live births, compared to 188 in 2000. However, this decline decreased between 2004 and 2010, when the under-five mortality comprised 133 and 112 deceased children per 1000 live births (World Health Organization, 2013).

The mortality rates of children can be considered a fundamental measurement of the general health status within a country (Wang, 2003). The health of children affects not only the available time, and thus productiveness, of its caregivers – failing health early in life also often impacts health as an adult and consequently, as argued by Currie and Madrian in 1999, affects future labor force participation and wages negatively. Assuring a healthy youth is therefore of great interest to any country and in particular in Malawi – a country in which 46.17 percent of the population was aged 0-14 years in 2018 (Central Intelligence Agency, 2019).

In Malawi, malaria is the primary cause of under-five mortality. As shown by Kanyuka et al. (2016), malaria accounted for about 20 percent of all deaths in children under the age of five in 2000. Curbing these numbers in an effort to meet the SDG goal the Malawian government increased its malaria control interventions by, in 2005, launching the new Malaria Strategic Plan named "Scaling up Malaria Control Interventions". One of the main targets mentioned was to "halve malaria mortality and morbidity by the year 2010 […]" and that "At least 80% of those suffering from malaria fever have access to and are able to use correct and appropriate treatment within 24 hours. At least 80% of the population has access to appropriate treatment by 2010." (Ministry of Health, 2005, p. 19).

The launch of the Malaria Strategic Plan included several actions to reduce mortality and morbidity from malaria such as prevention by increased distribution of Insecticide treated nets (ITN), as well as a pilot launch of Indoor residual spraying (IRS), in the Nkhotakhota district in 2007 (Chanda et al., 2016). In addition, the strategy included the change of malaria treatment from Sulfadoxine-Pyrimethamine (SP) to Artemisinin-based combination therapies (ACT). The treatment switch related back to a high resistance to SP among malaria parasites (where in Malawi the Plasmodium falciparum parasite accounts for over 85 percent of all malaria infections) as well as to the World Health Organization (WHO) recommended

treatment for malaria (World Health Organization, 2010). The drug switch was rolled out nationwide in December 2007 (Ministry of Health, 2005).

2. RESEARCH QUESTION

In an effort to provide some insight into the effectiveness of the malaria health policy I will in this paper attempt to estimate what effect the changed malaria treatment regimen had on the under-five mortality. Ultimately, I try to answer the question;

What effect did the new malaria treatment policy, implemented in December 2007, have on the under-five mortality in Malawi?

Using a Difference-in-difference strategy, I estimate the possible effects of the treatment switch on affected cohorts. Further, I relate my findings to a health and development economics theoretical framework.

The continuation of this paper considers the theoretical framework and particular context in which my study is carried out, followed by section 5 presenting previous research on the matter. In section 6 and 7 my chosen method and data is presented and discussed, and the results are found in part 8. The discussion is to be found in section 9.

3. THEORETICAL FRAMEWORK

This section discusses theories on factors assumed to have a direct effect on my outcome as well as theories concerning determinants of health – a foundation for my choice of control variables. This is followed by background information on the Malawian health care system and quality of care, and later by a summary of previous research.

Health, income and information in a low-income context

While attempting to estimate the effect of a medical improvement on under-five mortality, surrounding factors and the role they play must be carefully considered. Ideally in the case of malaria medication in Malawi, the implementation of the medicine would be rolled out in December 2007 and, from one day to another, the new and better treatment would be given to all children presenting with malaria symptoms, resulting in a reduction in malaria as well as overall mortality. However, as summarized by Mosley and Chen (1984), such a technological improvement must not only focus on the possible biological improvements to be made. To what extent the medicinal upgrade is provided and if it is used effectively must also be considered.

Prior to discussing such aspects, it is of fundamental value that one is in agreement with the definition of health. In my paper I make use of the Grossman model, discussed in the *Handbook of Health Economics* (Grossman, 2000), in which health is measured as a capital stock contributing to human capital. Health is considered affected by the different costs of investment in health such as vaccinations and other medical care. Additionally, health is considered to vary over time, increasing or decreasing with the level of health input and age, where health investments today will have an effect in times to come.

The model puts some emphasis on income levels, prognosticating individuals with higher income to have more available resources to spend on goods of any kind, including health inputs (Bhattacharya, Hyde and Tu, 2014). This resonates with the study by Mosley and Chen (1984) in which the authors discuss that the household level of income may determine whether the mother has to work or not, or if she can primarily take care of the child as well as have time for things such as prenatal care and health care visits. This theoretical framework is further echoed in a study on 24 developing countries by Minujin and Delamonica (2003) in which it was found that a child from the bottom wealth quintile is three times as likely to die before reaching the age of five compared to a child from the top wealth quintile. Similar results are presented in a study on 55 countries by Houweling and Kunst (2010) with findings of higher mortality rates for children from poorer wealth quintiles. Plausibly the income level of a Malawian family may affect whether the mentioned technological upgrade (the better medicine as a result of the policy) is in fact used effectively or not. To a child of a poor single mother living in a rural context, the new upgrade may not be available due to the fact that the family simply lives too far away to be able to access the new treatment – assuming the mother has insufficient income to be able to provide for travel costs to a health clinic (a result of the implementation was that medication was to be available at health centers and no longer at shops/ pharmacies etc.). Additionally low-income levels may affect the health of the child through access to food and water; arguably inputs into health.

As briefly touched upon, the mother is most likely to be the one caring for the child and the health of the child is influenced by several characteristics of the mother. Mosley and Chen (1984) discuss how the mother's knowledge level may impact how she cares for the child. This reasoning follows the so-called *efficient producer hypothesis* stating that "better-educated individuals are more efficient producers of health" (Bhattacharya, Hyde and Tu, 2014, p. 58). The authors state that several mechanisms could play a role; attending school may result in mothers learning necessary health skills, and schooling may also lead to better investment choices in health as well as provide the necessary skills to read instructions or calculate exact dosages. The above reasoning has in fact been found to translate into the health of an individual's children. Thomas, Strauss and Henriques (1991) found, in a study from Brazil, that mothers' access to information largely explains the strong positive effect of a mother's education on the height of the child. This echoes a study by Caldwell (1979) showing that the education of a mother influences the health of a child through several vectors such as challenging norms and beliefs about child care and health. Further studies on the effects of educational attainment of the parents are presented in a paper by Hobcraft, Mcdonald and Rutstein (1984) in which the authors state that with education follows expanded knowledge on required vaccinations and how to access and utilize health care among other things and accordingly female education affects child mortality. These theories could perhaps prove to be true in the particular context, assuming that mothers who are educated will perhaps be better equipped to follow a new malaria regimen guideline.

Health care consumption and quality of care

In a study by Dupas (2011) the author finds that within a low-income setting such as Malawi, there seem to be issues with lack of information as well as knowledge on how to process it.

Dupas further argues that health economics and health care behaviors within a low-income setting differs from the neoclassical theoretical framework in which fully informed individuals consider the benefits and costs of an investment and make informed decisions regarding health. Dupas finds that even when reliable and free preventive health care is provided such as immunization and ITNs, it is not necessarily consumed. As stated above, Dupas allot some of this on the lack of information and processing of it, – however she also mentions the low quality of health care provided as well as the fact that, due to low income levels, investments into health are not always made. Dupas also mentions a sometimes apparent lack of foresight and ultimately identify the need for public policy stressing the matter of interventions resulting in health care being accessible and effective.

The accessibility and effectiveness of interventions, generalized in the Mosley and Chen framework (1984), has been found to correlate with residency. Kanyuka et al. (2016) found that in Malawi, children living in urban settings were 21 percent less likely to die compared to children residing in a rural area – a number that did not change between 2000 and 2004. Deuchert and Wunsch (2010) argue that the higher concentration of poverty in rural areas as well as the potential low access to health care may explain the higher mortality rates within these areas. In a study by Wang (2003) several factors are shown to impact the under-five mortality; income, vaccination coverage, health expenditure as share of GDP, and some sanitation access aspects – in particular that of access to a pit latrine and electricity, some of which are primarily found in an urban setting.

Having access to health care is however not necessarily the same as receiving correct and effective treatment. Das et al. (2016) show in a study in rural India that while the population mainly had great access to health care, the quality of care provided was very low. Only about 15 percent of public health providers offered a correct diagnosis for one of three fairly uncomplicated diseases. Additionally, the paper emphasizes the apparent issues with over- and under-treatment. The authors discuss the insufficient case management being a result of health care providers lacking sufficient training, along with low diagnostic effort among public health care providers. The findings correlate those of Dupas (2011) who presents literature dissecting the matter of the low quality of care provided in many low-income country settings, and the issue with large spendings – at times on treatment that have no effect. In particular described by Dupas, is a study by Reyburn et al. (2004) which showed that in-patients at 10 Tanzanian hospitals received treatment for malaria, all the while only 46 percent of these patients had malaria parasites in their blood. These findings are further echoed in a study by Abiiro, Mbera and De Allegri (2014) in which interviews with rural residents in two southern districts of Malawi have been conducted. The authors findings point to the public health care providing low quality health care as well as lacking personnel and treatment. Additionally, the authors point out that transportation costs and treatment payments at mission or private facilities put such a stress on rural citizens that they sometime avoid seeking care altogether. Following this theoretical framework it becomes apparent that for the new treatment regimen to have effect, the implementation is of importance – as well as the perception and information about it among the population, to avoid a situation in which citizens simply do not make use of the upgrade.

Health investments and malaria prevalence

While Dupas (2011) finds that few resources are spent on preventative care, several studies have still shown that access to and usage of ITN among under-fives significantly reduces mortality rates. Lengeler (2004) summarizes these findings stating that for five trials measuring mortality it was shown that the under-five mortality in sub-Saharan Africa dropped by 20 percent due to the usage of ITNs. Fegan et al. (2007) showed that ITN usage accounted for a 44 percent decrease in under-five mortality over a studied two-year period. The ITN usage is closely linked to exposure to malaria parasitemia, a contributing factor to child mortality. In Malawi, between 2000 and 2010, the distribution of malaria risk remained largely consistent, as shown in a study by Bennett et al. (2013). The method of calculating district level population-adjusted prevalence rates is lengthily discussed within the study, the main takeaway being that the estimated levels are to be understood as the estimated rate of infected out of the total population. Throughout the time period the prevalence was lowest in the urban areas (Blantyre, Lilongwe and Mzuzu) as well as in the central and northern highlands. Roughly half of the children under five years of age, in 2010 corresponding to 1.3 million, were estimated to be living in high malaria transmission intensity areas (Bennett et al., 2013).

Child characteristics

Age of the child and differences in mortality rates

In my analysis I consider mortality for children between 3 and 59 months of age. The term under-five mortality is frequently used in this paper since it corresponds to the term used in the SDGs and by WHO among many others. Under-five mortality is traditionally split into two categories where neonatal mortality (deaths from birth up until 28 days) and post-neonatal mortality together comprise the infant mortality-segment (all deaths up to 12 months of age). Under-five deaths are deaths that occur prior to the child turning five years (World Health Organization 2005). As found by Kanyuka et al. (2016) the decrease in mortality rates differed between the neonatal group and the rest between 2000 and 2014 in Malawi. The decrease in neonatal mortality was slower (the child mortality rate was estimated to have dropped from 247 to 71 deaths between 1990 and 2013, compared to the neonatal numbers at 50 and 23 deaths per 1000 live births respectively).

Gender

Differences in malaria mortality and malaria exposure between genders have been discussed partly by Ferrão et al. (2017) and within the paper *Gender, health and malaria* (World Health Organization, 2007). While the discussion revolved mainly around differences in malaria risk exposure and treatment seeking behavior for adult men and women, Lemani (2013), in her master thesis, also found that child mortality in Malawi between 2004 and 2010 was affected by the sex of the child, with males being at greater at risk of dying.

Summary

It can be assumed that several mother and household characteristics, in particular those concerning education and income, determine the health and ultimately life status for a considered child. Thus these factors should matter when estimating the effect of the new

treatment regimen, the assumption being that with greater educational attainment and higher income, channeled by the uptake of information and treatment guidelines, lower under-five mortality rates should follow. As found by the above discussed academics, several child characteristics may or may not work in synergy with these larger determinants, leading me to consider and control for aspects such as gender and age. Additionally, which has been briefly touched above, the aspect of contextual factors such as availability of the new treatment – a result of the implementation of the policy, timely accessibility to health care and diagnostic skills are other necessary aspects to be considered. These features are further discussed in the *Health care and malaria treatment in a Malawian context* and *Previous Research* sections below.

4. Health care and malaria treatment in a Malawian context

The Malawian health care system

Malawi is a landlocked country bordering Mozambique, Zambia and Tanzania. Since the division of the Mwanza district into Mwanza and Neno districts in 2003, Malawi comprise of 28 districts divided into three regions; the Northern, the Central and the Southern region (Central Intelligence Agency, 2019). The Northern region includes Chitipa, Karonga, Likoma, Mzimba, Nkhata Bay and Rumphi districts. The Central region includes Dedza, Dowa, Kasungu, Lilongwe, Mchinji, Nkhotakhota, Ntcheu, Ntchisi and Salima districts and the Southern region includes Balaka, Blantyre, Chikwawa, Chiradzulu, Machinga, Mangochi, Mulanje, Mwanza, Nsanje, Thyolo, Phalombe, Zomba and Neno districts. Likoma is Malawi's smallest district comprising of only 10,429 inhabitants (Statistical Yearbook, 2010). Figure 1 in Appendix 4 portrays Malawi's geographic position, the 28 districts and 3 regions.

In Malawi, health care and health care services are primarily provided by the public or by private non-for-profit (PNFP) sectors which all follow the Ministry of Health guidelines (The President's Malaria Initiative, 2016). There are also several religious providers with the Christian Health Association (CHAM) being the largest. In 2014 CHAM was estimated to provide roughly 29 percent of all health care services. Public health care is free of charge for all Malawians while the PNFP and the private sector usually charge a nominal fee. However basic care for malaria is included in what is called an essential health package (EHP) which is delivered for free at both public and CHAM health care facilities. The EHP, which has been implemented since 2004, includes treatment of uncomplicated malaria in children and adults as well as treatment of severe malaria (Hennessee et al., 2017). As pointed out in correspondence by Yates (2016) Malawi is interesting in the sense that, 1964 aside, the country is the only one in sub-Saharan Africa that have never charged user fees in public health facilities. Further, Malawi stand out since out-of-pocket expenditures for health care constitute to only around 12 percent for an individual, to be compared with an average of 40 percent for 15 other sub-Saharan countries (Leive and Xu, 2008).

Health care services at a community level in Malawi are provided through Health Surveillance Assistants (HSAs) or Community Health Workers (CHWs) where the former receive six weeks of training of health pre-service training and the latter are volunteers that receive no formal training and rather serve as a channel for the community they serve. The

HSAs and the CHWs work together as a team (Makwero, 2018). The HSAs focus on preventive interventions and are community-based government-employed health extension workers. Primary care is available through clinics and health centers, while district and central hospitals provide secondary and tertiary care. Uncomplicated malaria is treated by HSAs at a community level or in the outpatient department at health care facilities and severe cases of malaria are treated at district and central hospitals, after referral (President's Malaria Initiative, 2016). The HSAs and CHWs play a particularly large role in health care provision in hard-to-reach areas, as stated in a report on Community Health Worker incentives (African Strategies for Health, 2015). The report further states that the number of CHWs increased by 53 percent between 2004 and 2010, corresponding to an increase from 5453 to 8369. Despite this, the staffing norms remained unmet and virtually all health facilities failed to meet the so-called program requirements for service delivery.

Quality of health care, case management and initial implementation

While health care is universal and mostly free, the quality of the Malawian health care system is low, ranked in The World Health Report at 185 of 191 in 2000 (World Health Organization, 2000). The WHO ranking system comprised of five factors; the distribution of health and the overall level of health, the distribution of responsiveness and the overall level of responsiveness, and finally the distribution of financial contribution. As discussed by Moise et al. (2017) there are several reasons for Malawi's position; lack of skill set, lack of equipment and/or technology, corruption and theft of medication, lack of manpower and low motivation among personnel, among others. This lack of quality manifests itself in relation to the provision of EHP, where in 2002 only 9 percent of all government and mission health facilities managed to provide an EHP. While this number can be expected to have improved, possibly in relation to the fact that in 2010 about 85 percent of all Malawians lived within 8 kilometers of a health facility, it indicates the qualitative struggles of Malawian health care. The low level of provision became evident when implementing the new malaria treatment in December 2007.

As previously mentioned, the treatment for malaria was changed in 2007 from treatment with SP to treatment with ACTs. Studies however show that the knowledge of how to manage treatment with ACT is quite low among health care providers. In a study analyzing the quality of Malaria management conducted in April-May 2011 Steinhardt et al. (2014) showed that 83 percent of the interviewees had received training on malaria case management. However, only 67 percent of the patients with malaria were correctly prescribed ACT, this four years after the roll out of the treatment. The study further showed that the training in Malaria case management was roughly around 80 percent in any facility and that a copy of the malaria treatment guidelines was available at about 72 percent of the health centers but only at around 60 and 50 percent respectively of the district and rural hospitals. Additionally, the study highlights the lack of availability of ACT, finding that only 81.2 percent of the health care facilities within the study had some type of first-line treatment in stock. The study also concluded that at district hospitals the availability of the second-line treatment for malaria (Amodiaquine Artesunate (Aa/Asaq)) was at 79.9 percent, however for community hospitals and health centers this number was as low as 6 percent.

From a report on ACT monitoring and malaria control activities it can be concluded that the initial implementation of the ACT suffered greatly from stock-outs during the first months (Ministry of Health, 2008). The new treatment policy clearly stated the use of ACTs, more specifically Lumefantrine-Artemether (LA), for the treatment of uncomplicated malaria as of December 2007. Prior to this, most clinical staff in government CHAM health facilities had received training on drug and case management between October 2007 and the launch in December 2007. The implementation was halted due to wide-spread complaints of stock-out by the end of February 2008. 47 percent of the facilities monitored reported experiences of diverse levels of the stock-out, however the stock-out reported for other malaria medication than LA was even higher.

Treatment seeking

In regard to malaria treatment it was the norm up until 2011 to use presumptive treatment among febrile patients (The DHS Program, 2014). While prompt and effective treatment is a must to prevent malaria related mortality, a qualitative study by Chibwana et al. (2009) from the Mwanza district including 46 health workers and 151 caregivers, showed that most childhood fevers are initially treated outside the health care system and primarily at home with treatment other than antimalarials. Some reasons for this are stated to be low quality of care at health care facilities as well as drug availability and distance. It is further concluded that self-treatment in homes for fevers categorized as "mild" was more likely than for fevers categorized as "severe", for which treatment was often sought from the health care system. In the study, the authors further mention that ACT treatment is available only at a health facility level, contrasting the availability of SP, which prior to the switch was available at shops and pharmacies.

Treatment before and after the new treatment regimen

As stated in the Malaria Strategic Plan, prior to the treatment switch the first level treatment was Sulfadoxine-Pyrimethamine (SP), including all patient groups. The recommendation was that of presumptive diagnosis of uncomplicated malaria and prompt treatment with SP. Severe malaria cases were to be referred to hospital and treated with Quinine. SP was to be available at shops as well as at health facilities (Ministry of Health, 2005).

Clearly stated in the National Protocol for the Treatment of Malaria is that, after the treatment switch, for uncomplicated malaria the recommended first-line treatment is Lumefantrine-Artemether (LA), an ACT. The second line treatment is Amodiaquine Artesunate (Aa/Asaq). When severe malaria is suspected at a community level there should be prompt treatment with rectal Artesunate and the patient should be referred to a health facility. At a health center level the first treatment should be intramuscular (IM) Artesunate. If this is not available or contraindicated, the malaria should be treated with IM Quinine. If neither is available, the treatment order is as follows; parenteral Artesunate, or if this is unavailable or contraindicated, parenteral Quinine should be used. Worth noting is that children weighing under 5 kg are treated with Quinine. This is true both for the pre- *and* post-reform periods. (Ministry of Health, 2013). While it is discussed to what extent and to what age, it has been

shown that infants in endemic malaria areas are resistant to the most common malaria parasite in Malawi; Plasmodium falciparum (Hviid and Staalsoe 2004; D'Alessandro et al., 2012).

5. PREVIOUS RESEARCH

As presented in the *Theoretical framework* section, there exist substantial literature on drivers of child mortality in a developing context. Further, several studies have reviewed the drivers of the reduction in mortality rates over the past decades, specifically in Malawi (this is also true for neighboring countries). In her master thesis, Lemani (2013) studied features possibly determining child mortality in Malawi using data from national surveys conducted in 2004 and 2010. Some of her main findings were that child mortality in Malawi is strongly associated by demographic and socioeconomic factors such as mother's education, sex of the child and wealth index.

In a study by Moise et al. (2017) the authors did not find one single explanatory variable to be significant in explaining the decrease of infant mortality in Malawi between 1990 and 2010. However, the authors found infant mortality rates to be substantially lower in the northern region, a region which also have the highest proportion of educated mothers within the country, and thus drew the conclusion that the lower rates in the northern part of the country were a result of the higher female education levels.

In its assessment of Malawian health care policies Kanyuka et al. (2016) found that between 2006 and 2011 the allocation to health as the total share of the budget increased from 4.6 percent to 7.2 percent. Additionally, they found that the quality of health care prevailed at a low level, some major reasons being lack of personnel as well as lack of performance of trained personnel. Within the paper they also highlighted data displaying frequent stock-outs in health centers and facilities and suggested that the differences in mortality rates apparent in the northern region compared to the central and southern regions are probable to be due to lower levels of HIV, higher literacy frequency, greater wealth and a higher density of health facilities in the northern parts of the country.

The effects of the malaria reduction strategy have previously been evaluated in a study from 2017 by Hershey et al., with the use of national household surveys. The authors main findings were that the malaria control policy probably did contribute to the found reduction in all-cause child mortality between 2000 and 2010 and that a large part was due to the increase in ITN coverage and use. Further the authors found a minor change in the usage of prompt malaria treatment, with an increase from 19.4 percent in 2000 to 24.1 percent in 2010. The authors also found that care seeking behaviors for febrile children changed between 2000 and 2010, increasing from 35 to 65 percent.

The effect of ACT-medication on mortality rates in Zanzibar has been evaluated in a study using clinical and parasitological surveys by Bhattarai et al. (2007). The major findings from the study showed that, after the introduction of ACT-treatment in Zanzibar in 2003, child mortality decreased within two years. Further shown in the study, the decrease between 2002 and 2005 in child mortality was as large as 71 percent. The authors discuss the possible

reasons for such a large effect of a treatment regimen change, highlighting the probable positive impact of the implementation being fast and effective. The authors also mention the absence of stock-outs and the increase in care seeking for under-fives during the study period, mentioning a previous study in which a negative bond was found between health seeking attitudes and ineffective malaria treatment. Lastly the authors contribute some of the care seeking behaviors to the fact that the study was set in a region in which the entire population have to travel less than 5 km to access a health facility.

6. METHOD AND DATA

Choice of empirical Strategy

Described by Ryan, Burgess and Dimick (2015), the use of the Difference-in-difference (DID) strategy to evaluate the effects of health policies has increased remarkably over the last twenty years. Further mentioned by Abadie (2005) the model is thoroughly applied within economics to assess policy impact on specific groups. Ryan, Burgess and Dimick (2015) explain how the strategy considers, at the simplest level, two groups where one is exposed to some sort of policy or intervention while the other is not. The two groups form a treatment and a control group and over time, the difference between the two groups, after exposure to the intervention, is the difference-in-difference – also considered the effect of the intervention. However, more widely used, is estimation by regression, allowing for statistical testing and the addition of control variables.

By using the DID strategy it is possible to consider, as in my case, an exogenous change and changes over time for different cohorts. As in my case, I have data on my variable of interest (the child being either alive or deceased), at an individual level but not necessarily for the same individual at the two time periods making any model using a fixed effect strategy improper, as discussed by Angrist and Pischke (2009). Making use of the DID method one has to, apart from the usual statistical assumptions required for regression, make the assumption of parallel trends and common shocks for both the treatment and the control group. The importance of the parallel trends concept is discussed by Angrist and Pishcke and in summary they state that had no intervention occurred, the changes with time would, for the treatment and control group alike, assumed to have been the same. As for aspect of the common shocks, the key takeaway is that both groups will be equally affected by other occurrences from the time of intervention and onward.

My ultimate goal is to test the hypothesis that the new treatment regimen reduced the under-five mortality in Malawi. In order to make use of the DID setup one typically compares two groups over time where one group is exposed to some sort of treatment while the other is not, as stated above (Gaynor, Moreno-Serra and Propper, 2013). In my case however, the treatment regimen change was rolled out at a set time on a national level and therefore no control group seem to exist. However, I use the variation in in-patient under-five malaria mortality rates among 25 of Malawi's 28 districts to identify districts with high potential for an effect of the drug on the under-five mortality and districts with low potential. High malaria mortality districts are then being considered treated while the low malaria mortality districts are not thought of as such. Consequently children within districts with high malaria mortality

rates pre-reform are assumed to be greater affected by the new malaria treatment than those situated in low malaria mortality districts. The impact of the new treatment (be it first or second line or treatment for severe malaria) can therefore be identified as an interaction between a dummy variable indicating the level of malaria mortality rates or treatment intensity and a dummy for the pre- or post-reform time period. I have used the following model

$$(1)\ Y_{it} = \beta_0 + \beta_1 P + \beta_2 T + \beta_3 (PxT) + \beta_k X_k + \varepsilon$$

where Y is the outcome variable which for child *i* take the value 0 if the child has died and the value 1 if the child is alive in the time period *t*. β_0 is a constant, P is a dummy for the post-reform period, T is a dummy for low/ high mortality district (treatment intensity) and the interaction term, PxT (Post*Treatment), is the impact of the drug switch. $\beta_k X_k$ denote a set of control variables and ε the error term. All calculations and specifications are further expanded in the *Analysis* section.

Data

I have used three types of data sources for my analysis. The first type of data stem from the Demographic and Health Surveys (DHS) Program. I have, for the descriptive statistics on treatment seeking behavior and types of treatment for febrile children, used Children's recode files (including information on all children born during the last five years to the interviewees) from the 2000, 2004 and 2010 DHS-surveys. For my main analysis I have used the Birth's recode files from the 2010 DHS survey in which every child ever born to an interviewed woman (15-49 years) constitute one record. Sampling procedures used for the DHS data will not be discussed within the scope of this thesis but have been previously (Rutstein and Rojas, 2006). The DHS-data includes information on several demographic and health related topics such as household characteristics, full birth histories and the health of the children of the interviewees (The DHS Program, 2000; 2004; 2010)

The second type of data comes from the Malawi National Statistics Office. This data is used to estimate under-five in-patient malaria mortality in respective districts pre and post the treatment switch. I have used data from the 2008 and 2011 Statistical Yearbooks which provide data on several health indicators such as under-five in-patient deaths due to malaria, under-five population and under-five new malaria cases, all grouped at a district level. The 2008 Yearbook contains data for the period July 2006 to June 2007 and the data for the July 2010 to June 2011 time period stem from the 2011 Yearbook (National Statistics Office of Malawi, 2008; 2011).

The third type of data, displaying population-adjusted prevalence, PA*Pf*PR_{2-10}-rates, stem from a study on malaria transmission rates. The prevalence rates are presented at a district level and illustrate 2005-levels (Bennett et al., 2013).

For some datasets the Likoma district have been included, while for others it has not. Observations from the district is included in the descriptive statistics for types of treatment

given to febrile children. It is further included in all analysis using the 2010 DHS data since DHS has combined it with observations on the Nkhata Bay district. It has however not been included in the data used to calculate the variation in under-five malaria mortality and it is not included in the prevalence-data. This inconsistency is further discussed under *Data limitations.* The Neno district was a part of Mwanza district until 2003 and the observations for the Neno district are therefore coded as observations belonging to the Mwanza districts for all my datasets when necessary. Mentioned in a report on epidemiology by Okiro et al. (2014), indoor residual spraying (IRN) was carried out as a pilot project in the Nkhotakhota district between December 2007 and 2010 and due to this, all observations from the district have been excluded from my datasets. All my data is continuously grouped on 25 of Malawi's 28 districts. Due to the fact that children under 5 kg have not de facto been exposed to a treatment change, I have excluded all observations of children aged less than 3 months, assuming that at 3 months of age, even children with low birthweight have reached 5 kg.

Descriptive statistics on treatment seeking behaviors and types of malaria treatment
All interviews for the DHS 2000 were conducted between July and November in 2000. For the 2000-DHS the sample comprised of 9564 children. The sample size for the 2004 DHS include 9148 children. The descriptive statistics for treatment seeking behaviors and frequency of fever for under-fives are presented in Table A1 and Table A2 in Appendix 1.

The descriptive statistics for types of treatment given as response to malaria are presented in Appendix 2. Only children who had a fever in the last two weeks and who were given some type of treatment are included in these statistics since these were the criteria for asking mothers about types of medication. For the 2004 DHS the sample contain 1032 children and for 2010 DHS the sample include 2677 children. Observations on Likoma district have, for DHS 2004, been recoded as Nkhata Bay observations.

Data used for the main analysis

For my main analysis I have used the 2010 DHS survey and the Birth's recode file, data from the Statistical Yearbooks and data on prevalence rates. All DHS-interviews were conducted between June and October 2010.

To generate information on mortality among under-fives pre- and post-treatment, I initially generated variables including only observations on living children 3-59 months of age at corresponding time periods pre- and post-treatment. The treatment policy was implemented nationwide in December 2007. The length of the pre- and post-periods are the same and the pre-treatment period considered is January 2006 until January 2007. The post-treatment period is January 2009 until January 2010. Additionally, the time between the periods in relation to when the treatment policy was implemented (December 2007) are of equal length. These strategies yielded a sample size of 15 361 and 16 763 children respectively. Reasons for choosing these specific pre- and post-treatment periods are further expanded in the *Analysis* section. Data on under-five in-patient malaria mortality and malaria prevalence was matched, and dummy and interaction variables were created accordingly.

Data limitations

For all datasets the management of observations from the Likoma district is somewhat of an issue. Observations on Likoma district is present in the 2004 DHS and the 2011 Yearbooks and included in the Nkhata Bay observations in the 2010 DHS. For 2000 DHS and for the 2008 Statistical Yearbook there is no mentioning of the district or any observations from it. As for the descriptive statistics I have chosen to – when data is available for both time periods – include the observations in my descriptive statistics. When information on the district is not available I have chosen to interpret it as if data on the district has not been sampled (this is also true for the data on malaria prevalence). For the descriptive statistics on treatment seeking behavior, observations on the Likoma district are not included for any time period.

For the descriptive statistics part, the inconsistent data from the district is not necessarily a problem. For the main analysis the inconsistency of the data is more of an issue. Calculating the variation, observations of the district must be assumed to not have been included in the 2008 Statistical Yearbook which in turn have led me to drop the observations from the district from the 2011 Statistical Yearbook. Therefore no observations for this district is considered in regard to my calculations of the variation in in-patient under-five malaria mortality. The same applies to prevalence rates. However, since the observations are included in the Nkhata Bay district for data from the 2010 DHS I have had no choice but to include these observations in my master set and ultimately in my outcome as well as for several of my explanatory variables. While this is not ideal, one should keep in mind that the district is very small and the observations from the district should therefore not generate any considerable bias. (E.g.; the 2004 DHS Birth's recode include only 49 records of all children ever born to interviewed women residing in Likoma district.)

Limitations with the data from the Statistical Yearbooks

For the 2008 Statistical Yearbook the table of contents does not relate back to the information presented in the head of the actual tables, in which it is clearly stated that the data presented reflects the time period between July 2006 and June 2007. To make sure the data presented actually match the years of interest, the overall population for the respective periods (clearly stated in all Yearbooks) have been cross-checked and found to correspond accordingly. I have therefore assumed the table of content to be incorrect and the data within the table to be correct. As for the data from the 2011 Yearbook all numbers have been rounded to tens and hundreds.

Another issue with the data from the Yearbooks is that there is no information on how the data has been collected. The cited source in the Yearbooks is the Malawian Ministry of Health but no further references are given. Additionally, there is no information on when the data was collected. The Ministry of Health provides no supplementary information on how or when the data was collected and thus I cannot be sure that the data presented depict the true number of in-patient deaths (or any other data given for that matter) and instead this have had to be assumed.

7. ANALYSIS

Identification strategy

As previously mentioned, the malaria policy roll out was nationwide thereby effectively eliminating the traditional DID setup with a treatment group and a control group. Gaynor, Moreno-Serra and Propper (2013) face similar difficulties analyzing the impact of the introduction of competition on health outcomes among several patients in the UK. In their case the intervention (pro-competition policy) was also rolled out nationwide thus eliminating the classical use of the DID strategy. However, they argue in the paper that the reform itself will, due to the varying structure of hospitals (determined by geographical factors) prior to the reform, result in varying intensity of the reform on hospitals, effectively forming treatment and control groups. (Simply put; hospitals in a concentrated market will be less exposed to the reform after the insertion than a hospital in a less concentrated market.)

Whether or not an individual (or other outcome of choice) is exposed to an intervention or not is also time-dependent. In a paper examining the effects of a school reform in Indonesia, Duflo (2001) use age as a determinant to whether or not, or to what extent, a cohort of individuals was exposed to the reform. Additionally, Duflo, whose strategy Gaynor, Moreno-Serra and Propper made use of, identify several regions in which the effect should have a stronger impact than in others (assuming that individuals within regions that previously had few schools would benefit more from the reform).

Following the reasoning by Duflo and Gaynor, Moreno-Serra and Propper, with data from the Statistical Yearbook from 2008, I generate under-five in-patient malaria mortality rates at a district level prior to the policy change and use as a source of variation in mortality.

By using this strategy, I have been able to identify districts that, prior to the policy, had high rates of in-patient under-five mortality due to malaria. Under-five in-patient malaria mortality rates were calculated setting under-five in-patient malaria deaths as the nominator and the under-five population as the denominator and multiplying by 1000, giving the under-five in-patient mortality rate due to malaria of all children under the age of five per 1000 under-five population for each district. This method of calculating under-five mortality resonates that used by the DHS (The DHS Program. Guide to DHS Statistics DHS-7, no date).

By exploiting the variation in the in-patient under-five malaria mortality rates among the 25 of Malawi's 28 districts, I identified districts with high malaria mortality rates and districts with low malaria mortality rates. Whether a district was considered to be a high or low district depend on if the malaria mortality rate for the district was found to be above or below the median in-patient under-five malaria mortality rate for all districts in the given time period. By using the median and not the mean I leave out any outlying districts. Next the mean for all districts considered high malaria mortality districts pre-treatment (Chikwawa, Nsanje, Phalombe, Mwanza, Mchinji, Dedza, Ntcheu, Mangochi, Salima, Kasungu, Rumphi and Karonga) was estimated. For these same twelve districts I then calculated a mean malaria mortality rate post-treatment and this same procedure was then carried out for the districts

with low malaria mortality rates. The categorization of the districts and their respective mortality rates are presented in Appendix 5, Table A8 and Figure 3.

As previously argued the high malaria mortality districts are considered to have a high potential for an effect of the new treatment regimen on under-five mortality while the low malaria mortality districts are considered to have a lower potential. This classification, inspired by the above discussed strategies deployed by Duflo (2001) and later by Gaynor, Moreno-Serra and Propper (2013), enables me to consider high malaria mortality districts to make up a treatment group while the low malaria mortality districts constitute the control group. A further interpretation of this is that the variation in malaria mortality rates in the different districts can be understood as the treatment intensity.

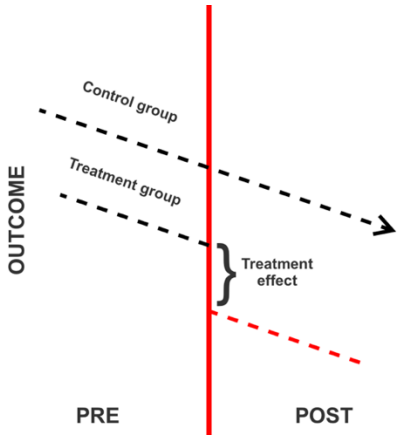
Following this reasoning, while assuming that there would have been no systematic differences in regard to changes in mortality in the different districts without the implementation of the reform, the causal effect of the new malaria treatment on under-five mortality can be estimated by the following model.

$$(2)\ \hat{\delta} = \left(\overline{U-five\ mort}_{post,treat} - \overline{U-five\ mort}_{post,control}\right) - \left(\overline{U-five\ mort}_{pre,treat} - \overline{U-five\ mort}_{pre,control}\right)$$

where *post* denotes post-policy and *pre* pre-policy. *Treat* denotes the districts with high in-patient under-five malaria mortality rates and *control* all other districts. It is a necessity for my set-up not only that these mortality rates do vary between the districts (which they do) but also that I find the treated group post-treatment to deviate from the control group (which it does).

Figure 2 below illustrates the basic concept of a DID setup depicting the underlying assumption of the parallel trend. The dotted line represents the counterfactual outcome in the treatment group, had no intervention occurred and the marked vertical line illustrate the intervention.

Figure 2 – The DID concept and illustration of parallel trends



While $\hat{\delta}$ provide an estimate of the causal effect of the new malaria medication on in-patient under-five malaria mortality (using the means at a district level) it should be noted, as further discussed by Ryan, Burgess and Dimick (2015), that the estimate should be seen as an average treatment effect within the high mortality districts. Furthermore, this estimated effect relies on the assumption that no other factors have had any impact on the mortality rates during this time period. To be able to verify if the yielded results are statistically significant, and to estimate the effect on a representative sample and not only for in-patients, I run the regression specified in model (1) with the use of the 2010 DHS dataset.

Estimating the effect by regression

Using the 2010 DHS Birth's recode datasets I have specified two cohorts, one comprising of children aged 3-59 months at the beginning of my pre-policy period; January 2006 – January 2007 (up until January, not including it) and one consisting of children aged 3-59 months at the beginning of my post-policy period (January 2009 – January 2010). The pre- and post-periods have been chosen for two reasons. Firstly since I want to use time periods as close to the actual treatment as possible, thus minimizing the risk of other factors playing a role and possibly creating noise. Secondly, due to the fact that implementation halted, the post-treatment period choice was that of a somewhat later period to make sure that the policy had in fact been rolled out allowing for estimation of possible effects.

YPOST – the outcome variable of interest

Considering the specified children in the beginning of each cohort, that is in January 2006 and January 2009, I then observed the same children at the end of each time period, creating a dummy taking the value 1 if the child was alive and value 0 if the child had died in (up until, not including) January 2007 and January 2010 respectively. These respective variables (YPRE and YPOST) measure mortality at an individual level and constitute my outcome pre- and post-policy. YPOST (Y), my dependent variable of interest takes the value 0 and 1 accordingly.

Dummies and interaction term

Identifying high and low in-patient under-five malaria mortality districts allow me to create a dummy variable (called *highlow*), taking the value 1 if the district is considered a high malaria mortality district pre-policy and 0 if not. A time variable takes the value 1 if the individual is in the post-policy cohort and the value 0 if not. The cutoff for the time-variable is December 2007. The interaction term is constructed by multiplying the time and the *highlow*-variable. This interaction variable takes the value 1 if the individual resides in a high malaria mortality district *and* is in the affected cohort and 0 if both of these conditions are not met.

Control variables

All of my control variables are measured at either a household level or at a district level. For variables reported at a household level, I have in general chosen to assume that the household characteristics also apply to the child of the respondent. All data used have been matched to the 2010 DHS dataset. My choice of controls is further discussed in the *Theory* section. For

the variables on mother and household characteristics all answers reflect the situation at the time of interview.

Mother's educational attainment and literacy level

As a measurement of the mother's education I have used a dummy variable taking the value 1 for mothers who have completed primary school and further and 0 if the mother is not educated at all, corresponding to not having finished primary or higher education. Since primary level is, according to Starfish Malawi (2019) usually completed between the age of 6 and 14, this dichotomous categorization should lead to the variable staying constant over time. The same reasoning applies to the literacy variable which is also a dummy taking the value 1 if the mother can read (from the DHS reported as the mother being able to read a full presented sentence) and 0 if the mother cannot read (including mothers who cannot read the full sentence). Children whose mothers were visually impaired, where values were missing or where the mothers spoken language was not presented for the DHS reading test, have been dropped. The reason for including education as well as literacy is that attending school is not necessarily a guarantee for a mother being literate (as observable from Table 3).

Wealth quintile

Socioeconomic status of the household the child belongs to is approximated with the help of the wealth index provide in the DHS-data. The wealth index is split into five quintiles; poorest, poor, middle, richer and richest (middle is used as reference). The index is calculated by DHS on the basis of several household characteristics and, as described by the DHS program, include ownership of things such as a bike or radio and residence conditions such as toilet facilities and source of drinking water. While the wealth index is useful in regard to it depicting some relevant household characteristics it does not come without flaws. One reason for this is that it sums an average wealth level of the household instead of presenting an actual income level. It should be pointed out that income, an absolute measure, is not captured by the DHS. Additionally, the wealth index captures some household traits which may in themselves have an explanatory power on my outcome. The effect will in fact be muddled in the sense that I won't be able to break down if the possible effect is due to access to electricity or some other of the variables constituting the wealth index and proven in previous studies (Wang, 2003) to have an effect on child mortality, such as access to a pit latrine. Further, this variable may in fact change over time and is thus dropped in my robustness check.

Prevalence rates

While the authors argue that the prevalence rates did not change significantly between 2000 and 2010 I am still only interested in the 2005-rates since the new policy regimen may in fact have affected the rates after its introduction in 2007 (a treatment to which the parasite is not resistant will plausibly lead to a greater amount of parasites being killed). This variable is a dummy taking the value 1 if the child resides in a high-prevalence district (high districts have a mean prevalence larger than 37.8918 percent) and 0 otherwise.

Urban/rural
Since this is a variable that may change over time due to things such as urban migration, marriage and others, I have controlled for children whose mothers moved within the last three years (between the pre- and post-periods). These observations have been dropped in the robustness checks.

Region
The region variable is included mainly due to the fact that within the empirical research presented on Malawi, it is repeatedly found that literacy rates and educational attainment among women are consequently found to be better in the northern region of Malawi. As presented, findings show that literacy has an effect on child mortality which allow for the assumption that residing in the northern region may affect your survival probabilities and the variable should because of this be included as a control. To generate an estimate of the effect of the northern region I have used the central region as reference.

Age and gender
Lastly, the age and sex of the child are included as controls. As shown in Table 7, mortality frequency and rates go down with age, although this decrease is not linear. The different ages of the child are split into the following groups; (3-6 months (0), 7-12 months (1), 13-24 months (2) 25-36 months (3), 37-48 months (4), 49-59 months (5)). The female sex and the 3-6 months age group are used as reference.

Excluded control variables
Following the argumentation by Wang (2003) I acknowledge that some effects may be challenging, if not impossible, to quantify. In my case the state capacity to not only provide health services but also manage this and many other economic policies are simply not observable. Further, some variables of interest such as distance to nearest health facility, is not included in the DHS survey. These factors, as argued by Wang, most likely has a real effect not only on health and thus under-five mortality, it may also affect other variables included in my model such as wealth, educational level etc. These apparent issues have been solved through excluding several control variables for which it is plausible to assume that changes have occurred between my pre- and post-treatment periods, such as ITN coverage and use and immunization rates as explained below. While the strategy is a necessity it also leads to a major weakness, that of excluding several control variables, proven from previous research to impact under-five mortality.

ITN
In the 2010 DHS used for my main analysis, data on ITN possession is reported at a household level. No data is available on ITN usage by deceased children and additionally, the households are asked about ITN ownership and usage at the point of interview. Since I in my analysis split parts of the Birth's recode files into pre- and post-treatment cohorts including all children aged 3-59 months in January 2006 and January 2009 respectively it must for all control variables be assumed that these have not changed markedly within this three-year time period, as well as up until the time of interview. As for ITN ownership and usage such an

assumption would not be plausible given that in 2008, as a part of the malaria control scale up, some mass distribution of ITNs took place, as stated in the WHO bulletin by Chanda et al. (2016). Given these issues I have not included a variable on ITN, be that of ownership or usage.

Immunization and other child health characteristics
While immunization rates most certainly can be argued to be a relevant variable to control for, the DHS data only provide information on vaccination for living children. It is possible to calculate a district average immunization rate and apply it to all children in each cohort, alive or deceased. However, as argued under *ITN* above, it may not be plausible to assume that immunization rates did not change between my pre- and post-period. For instance the measles immunization rate increased from 83 percent in 2006 to 93 percent in 2010 (The World Bank 2019).

The above reasoning is true for other factors found to be determining the overall health of the child thus predicting the child's survival chances. From the DHS data no information is given for deceased children on characteristics such as nutritional status, HIV-prevalence, anemia levels etc. These characteristics have therefore had to be excluded.

Other excluded variables of interest
Within my paper I have to some extent focused on the quality of health care (e.g. case management). Optimally this would have been a control included in the regression. However, quality of health care is not easily measured, as discussed by Das et al. (2016), nor is it reported in the available data. Furthermore, the data lack information on accessibility of health care. Due to this, no controls for health care access or quality of care are included in my analysis.

8. RESULTS

Descriptive statistics on treatment seeking behaviors and treatment regimen

Treatment seeking and possible disparities
Descriptive statistics on percentage of febrile children and treatment seeking behaviors for children aged 3 to 59 months, during the DHS survey in 2000 and during the DHS survey in 2004, are presented in Table A1 and A2 in Appendix 1.

Apparent from the tables is that the percentage of children who had a fever in the 2 weeks preceding the survey decreased slightly between the two survey periods, from 41.67 percent nationally in 2000 to 38.55 in 2004. From the 2004 DHS it is shown that the highest percentages of children with a fever were found in the Phalombe district (56.47) and Nkhata Bay district (50.41) while the lowest were found in Chiradzulu (20.00) and Rumphi (19.05) districts.

Among children who had a fever, treatment was sought at some point (either as first, second, third or fourth response) for about 14.98 percent nationally in the 2000 DHS which increased by one percentage point to 15.98 in the 2004 DHS. From the 2004 DHS it is shown that

Thyolo and Ntchisi districts stand out at the higher end where for 24.45 and 24.50 percent respectively health care was sought at some point for a febrile child. At the lower end we see Chitipa (9.57) and Rumphi (5.95) districts.

The overall treatment seeking average for districts with high levels of under-five in-patient malaria mortality rates was at 15.2 percent in 2004. While this was slightly lower than the national average, it was not by much, assuring that no systematic deviations for treatment seeking behaviors seem to have existed between individuals residing in high and low malaria mortality districts prior to the treatment change policy.

Treatment regimen for malaria

One important assumption when analyzing the possible effects of the treatment switch on under-five mortality, and in particular in light of the discussed implementation issues, is the assumption that the treatment regimen has in fact changed. The provided descriptive analysis in Table A3-A7 in Appendix 2 illustrate the treatment for febrile children prior to and after the treatment reform. It is in fact clearly shown that there was a substantial decrease in the previous first line treatment (SP/ (Fansidar)) between 2004 and 2010. Not surprisingly the decrease correlated with an increase in ACT treatment. In Table A3 it is shown that in 2004 an average of 80.23 percent of febrile children treated with a malaria medication were given SP/Fansidar. In the DHS 2010-survey this number had decreased to 4.03 percent, as seen in Table A4. While ACT was not an answer option in the 2004 DHS-survey it is clear from the 2010-survey that the treatment was widely used where 82.78 percent were given an ACT. It is in short apparent that the policy in fact led to a change in first-line treatment of malaria.

As for treatment with Artesunate, used for severe malaria, the change is however not apparent. Instead we see a decrease in Artesunate treatment from 0.19 percent in the 2004 DHS-survey to 0.11 percent in the 2010 DHS-survey. However, these numbers relate back to only a few individuals receiving this treatment, a basis for which it is inappropriate to draw any further conclusions. Notably we do see that the Quinine treatments have decreased and that the second-line treatment for malaria, Amodiaquine Artesunate (Aa/Asaq), treatment lies in the 2010 DHS-survey at 0.37 percent (not reported in the 2004 DHS survey). When depicting malaria treatment on region it is clear that the northern region districts, Chitipa, Karonga, Rumphi, Nkhata Bay and Mzimba, stand out. In these districts the usage of ACT is substantially lower (60.32 percent compared to the national average of 82.78 percent) and the treatment given is quite often “Other” (27.75). Additionally, it is shown that in three of these northern region districts, Karonga, Mzimba and Nkhata Bay, there was a decrease in Quinine-use between the 2004 and 2010 survey-periods. Further evident from the statistics is that the usage of ACT seems to decrease as educational attainment and wealth increase. Additionally, the usage of SP/Fansidar prior to the new treatment regimen was lowest among children whose mothers had higher educational attainment and was of greater wealth. Instead the usage of Quinine was greater within these groups.

Descriptive statistics for the main analysis

The following depict data used for my main analysis and thus consist of a total of 25,969 children, some of which are present in both the pre- and post-policy cohorts. Table 1 illustrates the age distribution among the two cohorts and Table 2 depicts the mortality distribution within the age groups.

Table 1 – Age distribution within the representative sample

	YPRE (Jan06-Jan07)		YPOST (Jan09-Jan10)	
Age groups	**Freq. (n)**	**(%)**	**Freq.(n)**	**(%)**
3-6 months	1187	7.73	1291	7.70
7-12 months	1689	11.00	1752	10.45
13-24 months	3854	25.09	3650	21.77
15-36 months	3626	23.61	3320	19.81
37-48 months	2660	17.32	3343	19.94
49-59 months	2345	15.27	3407	20.32
Total	**15 361**	**100.00**	**16 763**	**100.00**

Source: DHS (2010)

Table 2 – Mortality distribution for age groups pre- and post-treatment

	YPRE (Jan06-Jan07)				YPOST (Jan09-Jan10)			
Age groups	**Deceased (n)**	**Deceased (%)**	**Alive (n)**	**Alive (%)**	**Deceased (n)**	**Deceased (%)**	**Alive (n)**	**Alive (%)**
3-6 months	36	3.03	1151	96.97	37	2.87	1254	97.13
7-12 months	39	2.31	1650	97.69	32	1.83	1720	98.17
13-24 months	60	1.56	3794	98.44	61	1.67	3589	98.33
15-36 months	37	1.02	3589	98.98	30	0.90	3290	99.10
37-48 months	13	0.49	2647	99.51	17	0.51	3326	99.49
49-59 months	5	0.21	2340	99.79	11	0.32	3396	99.68
Total	**190**	**1.23**	**15 171**	**98.77**	**188**	**1.12**	**16 575**	**98.88**

Source: DHS (2010)

In Table 2 it is clearly shown that children aged 2 years or younger face larger risks of mortality than children older than 2 years. Of the sample for the pre-treatment period cohort, consisting of 15 361 individuals, 190 died within the year accounting for 1.23 percent of the cohort. The post-policy cohort consist of 16 763 children, 188 of these died during the observed year which correspond to 1.12 percent.

Table 3 present some household and mother's characteristics of the considered children. Evident from the table we see that most frequently the mothers have finished primary education and that roughly half of all mothers were able to read the full sentence presented to them, while the other half could not fully do so. The vast majority of all children reside in a rural setting while the distribution between wealth quintiles is fairly equal, although with fewer individuals found within the "richest" quintile.

Table 3 – Characteristics of mother/ household at time of interview (2010)

Characteristics	Freq. (n)	(%)
Mother's educational level		
no education	5440	20.95
finished primary or higher	20 529	79.05
Literacy		
can't read	12 663	48.76
can read	13 306	51.24
Urban/rural		
urban	2588	9.97
rural	23 381	90.03
Wealth index		
poorest	5798	22.33
poorer	5590	21.53
middle	5622	21.65
richer	5227	20.13
richest	3732	14.37

Source: DHS (2010)

DID results tabulated

Calculations showed that pre-policy the median in-patient under-five malaria mortality rate was about 1.553 for all districts. When converting, to more easily compare with the representative sample, 0.1553 children out of 100 living children died. Calculating by the Difference-in-difference method, using model (2), generated an estimate of -.8366, as shown in Table 4 below. These figures are to be remembered to give an estimate per thousand children and is further to be understood as "average treatment effects on the treated, rather than average treatment effects" (Ryan, Burgess and Dimick, p. 1216, 2015). The estimate may be interpreted as the causal effect of the policy on the under-five in-patient malaria mortality among children residing in high-mortality districts.

Table 4 – Means of in-patient under-five malaria mortality by pre- and post- in-patient cohorts and level of treatment intensity[1]

	Treat	***Control***	***Difference***
Pre	2.8858	1.106	1.7798
Post	2.2012	1.258	.9432
Difference	-0,6846	0,152	-.8366

[1] The means depict the under-five in-patient malaria mortality per 1000 under-five population at a district level

DID results by regression

All of my regression analysis has been conducted using the Stata software (version 16.0 for Mac)[2]. Regarding the significance level, only p-values smaller than 0.05 (5 %) are considered statistically significant. However, p-values less than 0.1 will be presented and discussed equally.

Running the regression (1), regressing time, the *highlow*-dummy and the interaction term on the cohort affected by the treatment, YPOST (Y), generated a DID coefficient (β_3) of -.0087 as presented in Table 5 below. The reported standard error was .0058 and the reported p-value 0.153. The constant β_0 (0.9915) is the intercept depicting the average value of Y when all other values are equal to zero. β_1 (-0.0096) is the time-coefficient and show the expected change in mortality between the two observed time periods. β_2 (-0.0004), the coefficient for the *highlow*-dummy, give the difference in the average value of Y between treatment and control groups, prior to the treatment. However, the interaction term (β_3), is of most interest, depicting the expected average change in mortality before and after the policy for the treatment and control. The interpretation is thus that the effect of the policy was that the risk of dying, for individuals within the post-policy cohort residing in high-mortality districts in comparison with low-mortality districts, decreased by an average of 0.0087.

Table 5 – Regression analysis

Mortality (Y)	**Coef.**	**St. Err.**	**[95% confidence interval]**	
Time	-.0096**	.0039	-.0178	-.0017
Highlow	-.0004	.0016	-.0038	.0030
Interaction term	-.0087	.0058	-.0206	.0034
Constant	.9915**	.0010	.9894	.9937
R-squared	0.0030		N	16 763
F-test	8.70		Prob > F	0.0004

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Using the entire variation in treatment intensity at the district level rather than creating the *highlow*-dummy variable indicating whether a child resides in a high or low mortality district, yield the results presented in Table 6 below. This only slightly deviates the estimate increasing it from -0.0087 (1) to -.0103. Neither estimates for the interaction term were found to be significant at any level.

[2] StataCorp, College Station, Texas, USA

Table 6 – Regression analysis with variation in treatment intensity

Mortality (Y)	**Coef.**	**St. Err.**	**[95% confidence interval]**	
Time	-.0089**	.0039	-.01686	-.0010
Treatment intensity	709.3549	712.6665	-761.5164	2180.226
Interaction term	-.0103	.0063	-.0233	.0027
Constant	.9899**	.0019	.9860	.9938
R-squared	0.0030		N	16 763
F-test	7.96		Prob > F	0.0007

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

DID by regression with control variables

Adding control variables yield similar results, presented in Table 7 below. The DID estimate was found to be -.0089 and the R^2 increased somewhat in comparison to my original regression (1), from 0.0030 to 0.0070. As for my controls I found, unsurprisingly, that prevalence and time have a significant positive respectively negative impact on mortality at a 5 percent level. The northern region is also found to have a significantly positive effect on mortality at a 5 percent level. Apparent from the results is that age seem to have a sometimes significant effect on mortality, and that higher ages seem to result in a decrease. Wealth, educational attainment, literacy and type of residency is not significant at any level.

For all regressions with control variables, an estimate for ages 49-59 months have been omitted from the output by Stata due to collinearity. As a precautionary measure I have therefore checked the variation inflation factor (VIF). The VIF is a measure which help explain how strong of a linear relationship there is between the explanatory variable of interest and the other explanatory variables, where VIFs greater than 10 is typically considered troublesome (Su, Yan and Tsai, 2012).The VIF was for none of my variables found to be larger than four and hence I have not further gone into detail on the matter of multicollinearity.

Table 7 – Regression analysis with control variables

Mortality (Y)	Coef.	St. Err.	[95% confidence interval]	
Time	-.0212**	.0047	-.0309	-.0115
Highlow	-.0004	.0016	-.0037	.0029
Interaction term	-.0089	.0058	-.0208	.0030
Educated	.0035	.0022	-.0009	.0080
Literacy	8.56e-06	.0019	-.0039	.0039
Urban	.0025	.0024	-.0024	.0075
Northern	.0085**	.0020	.0043	.0127
Southern	.0030	.0017	-.0006	.0066
Male	-.0023	.0018	-.0060	.0014
7-12 months	.0104**	.0044	.0012	.0195
13-24 months	-.0136**	.0025	-.0187	-.0085
25-36 months	-.0060**	.0016	-.0092	-.0027
37-48 months	-.0020	.0018	-.0056	.0016
Prevalence	.0005**	.0002	.0001	.0009
Poorest (wealth quint.)	.0003	.0020	-.0039	.0044
Poorer (wealth quint.)	-.0026	.0024	-.0076	.0024
Richer (wealth quint.)	.0001	.0028	-.0056	.0058
Richest (wealth quint.)	.0008	.0025	-.0044	.0061
Constant	.9766**	.0079	.9604	.9929
R-squared	0.0030		N	16 763
F-test	12.01		Prob > F	0.0000

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Summary

Throughout all regressions, the coefficient of my interaction term (β_3) remain at somewhat the same level, even if it increases slightly when the entire variety in in-patient under-five malaria mortality is used rather than a dummy. The size of the effect in relation to the confidence interval makes it possible to draw the conclusion that the sign is negative for all regressions. However, it should be stated that I, for no regression, have found this estimate to be significant at a 5 percent level. In other words I cannot conclude that the 2007 change in malaria regimen have had a statistically significant causal effect on the under-five mortality in Malawi.

Observable from the different outputs is that when including controls in the regression the R-squared increase from 0.0030 in the original regression to 0.0070 suggesting that with controls the model explains 0.7 percent of the variation in the data, rather than 0.3 percent. Throughout my analysis I find that being situated within the northern region increases mortality as compared to an apparent decrease presented in my output when opting to use the northern region as a reference group. This leads me to interpret the region as being a

determinant of the effect of the treatment regimen, suggesting that the effect differs from region to region. The same is true for age, where the effect differs from negative to positive depending on the age of the child.

Clustering

Running regressions I have opted to make use of the clustering option, available in Stata. The aspect of clustering is discussed by Bertrand, Duflo and Mullainathan (2004) arguing that estimating DID-estimates with usual ordinary least squared (OLS) standard errors may generate too small standard errors, partly due to the fact that the dependent variables used for DID generally are serially correlated. The authors instead propose the use of cluster-robust standard errors to account for this, and as further discussed by Cameron and Miller (2015), this clustering should correspond to the largest aggregate level and source of variation – in my case the district level.

The result of clustering may show a large difference between clustered standard errors and ordinary standard errors (Statas default). Running the original regression without the clustered option yield standard errors for the DID estimate of .0042 (as compared to those with the clustering option of .0058) which do in fact show that my clustered standard errors are larger than the OLS-errors, indicating some serial correlation (Wooldridge, 2014).

Robustness checks

I have conducted three robustness checks which control for whether or not my findings from previous regressions hold when dropping some of my control variables and observations.

The first check considers the aspect of migration. Type of place of residency may in fact differ over time and running a robustness check where individuals, whose mothers moved between the observation periods are excluded, is suitable. Due to this, children whose mothers moved between the pre- and post-policy periods *and* who moved from one type of setting (e.g. rural) to another type of setting (e.g. urban) have been dropped. This strategy generated an estimate for the interaction term of -.0010 and, with control variables included, -.0102. Both estimates were found to be significant at a 10 percent level, however not at a 5 percent level. The R-squared increased to 0.0072 when controls were included in the regression as compared to 0.0031 when estimating the original regression (1). The results from these regressions are found in Table R1 and R2 in Appendix 3.

The second robustness check concerns the wealth index as wealth may very well be something that changes between the pre- and post-policy period. Dropping the wealth variable resulted in an estimate for the interaction term of -.0088, shown in Table R3. The effect of dropping wealth as a control is evidently practically zero when comparing the new estimate to the one depicted in Table 7 above.

The final robustness check considers the issue with several districts lying close to the cut-off, marking whether or not a district is considered to be a high or low malaria mortality district (and thus if it is considered to be a part of the treatment or control group). When conducting

my check I chose to exclude all observations from districts where the mortality rate was either higher than 1.253 or lower than 1.853 (keeping observations from districts with mortality rates further than 0.3 from the cut-off of 1.553). The reasoning regarding this check is further expanded under *Limitations with my model of choice* below. Observations from the following low-mortality districts were dropped; Chiradzulu, Thyolo, Nkhata Bay, Machinga , Balaka, Ntchisi and Dowa. Observations from the high-mortality districts Karonga, Dedza and Nsanje were also dropped. The results of this final robustness check are presented in Table R4 and R5 in Appendix 3. Observable is that dropping observations from the above presented districts did not result in my estimate of the interaction term to be significant. This is true considering regressions both with and without control variables included. As observable the estimate did however decrease to about -0.0027, without and with control variables. Further, my R-squared increased ever so slightly to 0.0037 and 0.0080 respectively. Another deviation from my original regression is that being a boy seemed to decrease mortality by 0.0043. This estimate was found to be significant at a 10 percent level, however not at a 5 percent level.

Overall, I can conclude that checking for wealth has close to no effect on my previous estimates and thus my model is robust to this check. However, I find that dropping observations for children whose mothers have changed type of residency within the least three years result in an increase of my estimate as well as for this estimate to be statistically significant at a 10 percent level. However, one should keep in mind that my chosen confidence level is at 5 percent. While the deviation is not very large, it does suggest that my model is not necessarily robust in regard to the urban migration aspect and arguably a model taking this aspect into account is preferable. When dropping all observations from districts considered too close to the cut-off point the estimated effect of the treatment becomes somewhat smaller than that presented in Table 5 and Table 7 above, while still not being significant.

Limitations with my model of choice

As prior discussed the main assumption regarding parallel trends and commons shocks must be found to hold in order for the DID strategy to be valid. While it has not been possible to control for the parallel trends assumption (a visual depiction has not been doable due to lack of malaria mortality data for previous years) I have instead considered, following the strategy deployed by Gaynor, Moreno-Serra and Propper (2013), a quite short observational period to maximize the likelihood of the assumption to hold. In doing so I also considered that the launch of the Malaria Strategic Plan did include several strategies to try and reduce malaria mortality, most notably through the treatment regimen switch but also through the introduction of IRN and through mass distribution of ITNs. These actions were rolled out at different times in different districts. However, my chosen time period and the exclusion of the Nkhotakhota district, have effectively allowed me to uphold the common shocks assumption in this regard. While this has in fact been done in relation to the Malaria Strategic Plan, the importance of the assumption may still pose a threat to the validity of my research. Simply put; other health related policies targeting under-fives (mass vaccination campaigns etc.) or other shocks (e.g. economic or food-insecurity related) could potentially have occurred affecting the two groups differently. One such possible shock is the expansion of CHWs

within the time period. While possibly a threat to the validity one should keep in mind that the increase in CHWs came at a time in which the population increased, according to the United Nations World Population Prospects 2019, from 12.626 million in 2004 to 14.540 million in 2010 (United Nations, 2019). This may be argued to have "leveled out" the increase, although I have no way of knowing the distribution of the CHWs expansion. In theory it could then be the case that the increase in CHWs occurred in high mortality districts only – such a scenario would in fact threaten the validity of the research.

While making use of the same strategy as Duflo (2001), later used by Gaynor, Moreno-Serra and Propper (2013), I have argued throughout my thesis that districts with high in-patient under-five malaria mortality rates, and thus a large potential for an effect of the treatment, could be considered to make up the treatment group. My strategy to identify high and low mortality districts considered a cut-off at the median in-patient under-five malaria mortality rate (1.553). All districts with a higher mortality rate formed the treatment group and all districts with a lower rate constituted the control group. However, as evident from Table A8 and Figure 3 in Appendix 5 and as discussed under *Robustness checks* above, several districts lie close to the cut-off point and therefore such a dichotomous categorization may not have been entirely suitable considering these close-lying districts. Nonetheless, further evident from the table and figure, several districts do lie quite far from the median. Additionally, as shown when conducting my robustness checks, dropping observations from the districts considered to lie too close to the cut-off, didn't result in my interaction term being found to be significant. Although the estimated interaction term became slightly smaller the test still proved my model to be fairly robust in this sense. All things considered I therefore still regard my chosen strategy to carry weight, being a reasonable method deployed.

9. DISCUSSION

The aim of this paper was to, by using a DID strategy and variation in under-five in-patient malaria mortality among 25 of Malawi's districts, estimate the effect on under-five mortality of a national policy change in malaria treatment imposed in December 2007.

Apparent from the descriptive data on mortality is that between the observed cohorts there was a slight decrease in mortality, from a mortality rate in the pre-cohort of 1.23 percent compared to that in the post-cohort of 1.12 percent, or in other words; out of 100 children in the pre-cohort, about 1.23 died whereas out of 100 children in the post-cohort this number decreased to about 1.12 deceased children. The estimated under-five *in-patient* malaria mortality rates pre- and post-policy for the treatment and control districts were 0.2886 and 0.1106 pre- and 0.2201 and 0.258 post-treatment per 100 living children respectively. Evidently the in-patient under-five malaria mortality rates were lower both in the pre- and post-periods compared to the representative samples depicting the rates of all types of under-five mortality. This is quite unsurprising since malaria is not the only cause of under-five mortality.

Considering the results from my regressions, I found that the new and better treatment did seem to have a negative effect on the under-five mortality in the post-policy cohort.

Additionally, I expected this effect to be small – which is what I found. However, I did not find this effect to be statistically significant at a five percent level (although the effect was found to be significant at a ten percent level when controlling for children whose mothers had moved between the pre and post-periods). Further evident from my calculations is that the tabulated effect (Model 2) of the treatment on in-patient under-five malaria mortality is smaller than the effect found from the regressions (Model 1); -.8366 compared to -.0087 and -.0089 respectively (with and without controls included in the regression). When comparing the estimates one must keep in mind that the tabulated effect is depicted per thousand children, if converting this to match my regression results the estimated effect is -0,0008366. One must once again keep in mind that this estimate shows the effect on the *in-patient* under-five malaria mortality while the regression outputs present the estimated effect on the overall mortality among children that are not only hospitalized. These deviations are perhaps not very surprising considering that the individual level data depict overall mortality and that it is plausible that this individual data therefore contain more noise such as mortality linked to other factors than malaria and to malaria mortality in an outpatient-setting.

The differing results do point to several interesting contextual factors perhaps contributing not only to the higher mortality rates out of hospital but also to the insignificant effect found in the representative sample. One aspect to keep in mind is that for uncomplicated malaria the first-line treatment is LA (ACT), typically given as a part of the EHP and to be available at all health care facilities. Even if the accessibility of this treatment after the implication was not perfect, LA was, in the evaluation by the Ministry of Health (2008), still found to be less frequently out of stock compared to other antimalarials. Considering this it may very well be that there was in fact a great effect of the treatment change but that I have not been able to find such an effect due to the fact that I consider *in-patient* malaria mortality as a source of variation. Thus, a study which instead make use of overall malaria mortality disparities within the country or at a district level would perhaps prove the policy to have an effect, echoing the findings by Bhattarai et al. (2007), who found the switch to ACT to have a great impact on under-five mortality in Zanzibar.

Additionally, one further contextual aspect to consider is the fact that it is plausible to assume that that once you have been admitted to the hospital with severe malaria you are more likely to get the correct treatment, hence you are more likely to actually achieve the new and better treatment at a hospital rather than at, say, a village clinic or health center. This was also shown by Steinhardt et al. (2014) who found that the second line treatment for malaria, Amodiaquine Artesunate (Aa/Asaq), was available at only 6 percent of the health centers in 2011 to be compared with 79.9 percent at district hospitals. Another aspect of this is that prior to the regimen change, SP was available at shops, pharmacies etc., while after the switch ACT was only available at health care facilities. While this strategy may have prevented some over-treatment and is in theory a good strategy to possibly achieve prompt and correct treatment for malaria, it may perhaps also explain the greater mortality rates and the insignificant effect on the representative sample, this due to the fact that the accessibility to prompt treatment dropped. This follows Hershey et al. (2017) who found that the change in usage of prompt malaria treatment only went up by about 4.7 percent between 2000 and 2010.

Considering this, one must also regard that the treatment seeking behaviors for febrile children show that even for children with prevailing fever, care was to a large extent not sought from a formal health provider (care was sought only for 15.98 percent of febrile children in 2004). Possibly my chosen measure of variation is in fact not depicting the reality very well since it may be the case that a vast majority of children with malaria never do in fact seek treatment or seek treatment late, as shown by Chibwana et al. (2009) and Abiiro, Mbera and De Allegri (2014). Consequently a majority of the deaths may have occurred outside of the health care system.

Another possible explanation of the effect being smaller in the in-patient setting compared to the effect on the representative sample is the possibility that the observed in-patients deviate from the representative sample in the sense that they may perhaps represent in large parts children with certain characteristics. As shown in the study by Chibwana et al. (2009), conducted in a rural setting, a majority of the respondents mentioned only seeking health care for severe child-fevers. Further Abiiro, Mbera and De Allegri (2014) find, in a similar qualitative study, that some rural residents avoid seeking care altogether due to the related cost (transportation etc.). Since the in-patient data contain no information on the patients other than life and malaria status as well as district it may very well be the case that some rural or poorer children do not end up being in-patients at all. However I did not find wealth nor type of residency to have a significant impact on the overall under-five mortality and, as shown my Mathanga et al. (2012), there was a large increase in reported malaria cases between 2005 and 2009, from about 3.7 million to 6.1 million, perhaps contradicting such a conclusion.

Interestingly neither education nor literacy or wealth were found to have a significant impact on mortality. Additionally, as presented in Table A4 in Appendix 2, in four out of five of the northern districts (observations from Likoma district is included in the Nkhata Bay observations) the usage of ACT was, in 2010, surprisingly low. From the presented theory by Kanyuka et al. (2016) the obvious findings would be that, due to the fact that the northern population is better educated, have higher income etc., they would also in general have a greater uptake of the technological improvement. The findings further contradict other previous research on the matter, where Caldwell (1979) and Hobcraft, Mcdonald and Rutstein (1984) among others have found greater literacy skills and education of the mother of the child to have the effect of a reduction on childhood mortality. Several studies, including Mosley and Chen (1984) as well as Minujin and Delamonica (2003), have proposed that greater income also affect under-five mortality negatively. This indicates that there may be some greater deviations in regard to the northern region in comparison to the rest of the country suggesting further studies within this area.

Apparent from my study, the ambitious target for 2010 of "At least 80% of those suffering from malaria fever have access to and are able to use correct and appropriate treatment within 24 hours.", stated within the Malaria Strategic Plan, does not seem to have been met. This considering that I not only gained insignificant results of the new and better treatment, but also given that I found care-seeking behaviors to prevail at low levels throughout 2010. However, Hershey et al. (2017) found that the policy, not only the treatment aspect of it but

also the introduction of ITNs and IRNs, did in fact decrease the under-five mortality nationwide. Additionally, the authors found that care seeking behaviors for febrile children went up from 35 percent in 2000 to 65 percent in 2010. One final explanation for my discrepant findings could very well be that the chosen post-policy period lies to close to the time of intervention. I have chosen a fairly short time interval in order to maximize the odds of the parallel trends assumption to hold. However, such a large transformation as trying to change a health care providing behavior in a low-income low state capacity setting for the entire population, must be assumed to take some time – especially in rural less accessible parts of the country. If so, then a similar study, perhaps deploying a different strategy in order to consider a longer time for implementation, may reproduce the results generated by Hershey et al. (2017).

9. REFERENCES

Abadie, A., (2005). Semiparametric Difference-in-Differences Estimators. *The Review of Economic Studies.* 72(1), p.1-19.

Abiiro, G., Mbera, G. & De Allegri, M., (2014). Gaps in universal health coverage in Malawi: A qualitative study in rural communities. *BMC Health Services Research,* 14(1), p.234.

African Strategies for Health. (2015). *COMMUNITY HEALTH WORKER INCENTIVES: LESSONS LEARNED AND BEST PRACTICES FROM MALAWI.* Accessed 2019-12-11 from https://www.msh.org/sites/default/files/chw_incentives.lessons_and_best_practices_for_malawi.november_2015_ash_final.pdf

Angrist, J.D. & Pischke, J.-S., (2009). Mostly Harmless Econometrics: An Empiricist's Companion, *Princeton: Princeton University Press.*

Bennett, A., P., et al., (2013). Mapping malaria transmission intensity in Malawi, 2000-2010. *American Journal of Tropical Medicine and Hygiene,* 89(5), pp.840–849. (supplementary PDF) Accessed 2019-11-20 from http://www.ajtmh.org/content/journals/10.4269/ajtmh.13-0028#supplementary_data

Bertrand, M., Duflo, E. & Mullainathan, S., (2004). HOW MUCH SHOULD WE TRUST DIFFERENCES-IN-DIFFERENCES ESTIMATES? *The Quarterly Journal of Economics,* pp.249–275.

Bhattacharya, J., Hyde, T. & Tu, P., (2014). *Health economics.* Palgrave Macmillan.

Bhattarai, A. et al., (2007). Impact of artemisinin-based combination therapy and insecticide-treated nets on malaria burden in Zanzibar. *PLOS Medicine,* 4(11), p.e309.

Caldwell, J.C., (1979). Education as a Factor in Mortality Decline An Examination of Nigerian Data. *Population Studies,* 33(3), pp.395–413.

Central Intelligence Agency. (2019) *THE WORLD FACTBOOK MALAWI*. Accessed 2019-12-05 from https://www.cia.gov/library/publications/the-world-factbook/geos/mi.html

Chanda, E. et al., (2016). Scale-up of integrated malaria vector control: lessons from Malawi. *Bulletin of the World Health Organization,* 94(6), pp.475–480.

Chibwana, A. et al., (2009). Socio-cultural predictors of health-seeking behaviour for febrile under-five children in Mwanza-Neno district, Malawi. *Malaria Journal,* 8(1), p.219.

Cameron, A. & Miller, D., (2015). A practitioner's guide to cluster- robust inference. *Journal of Human Resources,* 50(2), pp.317–372.

Currie, J. & Madrian, R. (1999). 'Health, Health Insurance and the Labor Market' in O. Ashenfelter and D. Card (eds.) *Handbook of Labor Economics*. Elsevier Science B.V. pp. 3309-3415.

D'Alessandro, U. et al., (2012). Malaria in infants aged less than six months - is it an area of unmet medical need? *Malaria Journal,* 11(1), p.400.

Das, J. et al., (2016). Quality and Accountability in Health Care Delivery: Audit-Study Evidence from Primary Care in India. *American Economic Review,* 106(12), pp.3765–3799.

Deuchert, E., & Wunsch, C., (2010) *Evaluating Nationwide Health Interventions when Standard Before-After Doesn't Work: Malawi's ITN Distribution Program.* CESIFO WORKING PAPER NO. 3036. Accessed 2019-12-11 from https://www.researchgate.net/publication/45685399_Evaluating_Nationwide_Health_Interventions_When_Standard_Before-After_Doesn't_Work_Malawi's_ITN_Distribution_Program

The DHS Program. *Guide to DHS Statistics DHS-7*. Accessed 2019-12-03 from (DHS Program https://dhsprogram.com/Data/Guide-to-DHS-Statistics/Early_Childhood_Mortality.htm

The DHS Program. (2000). *Malawi Demographic and Health Survey 2000.* Accessed 2019-11-13 from https://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfmhttps://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfm

The DHS Program. (2004). *Malawi Demographic and Health Survey 2004.* Accessed 2019-11-13 from https://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfm

The DHS Program. (2010). *Malawi Demographic and Health Survey 2010.* Accessed 2019-11-13 from https://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfm

DHS Program. (2014). *Malawi Malaria Indicator Survey 2014*. Accessed 2019-11-01 from https://dhsprogram.com/pubs/pdf/MIS18/MIS18.pdf

Dupas, P., (2011). Health Behavior in Developing Countries*. Annual Review of Economics*, 3, pp.425–449.

Duflo, E., (2001). Schooling and Labor Market Consequences of School Construction in Indonesia: Evidence from an Unusual Policy Experiment. *American Economic Review,* 91(4), pp.795–813.

Ferrão, J.L., et al. (2017). Malaria mortality characterization and the relationship between malaria mortality and climate in Chimoio, Mozambique. *Malaria Journal,* 16(1), pp.1–9.

Gaynor, M., Moreno-Serra, R. & Propper, C., (2013). Death by Market Power: Reform, Competition, and Patient Outcomes in the National Health Service. *American Economic Journal-Economic Policy,* 5(4), pp.134–166.

Grossman, M. (2000). 'The Human Capital Model' in Culyer, A. & Newhouse J. (eds.) *Handbook of Health Economics*. Amsterdam: North-Holland. pp. 347-408.

Hennessee, I. et al., (2017). Household costs among patients hospitalized with malaria: evidence from a national survey in Malawi, 2012. *Malaria Journal,* 16(1), pp.1–12.

Hershey, C.L. et al., (2017). Malaria Control Interventions Contributed to Declines in Malaria Parasitemia, Severe Anemia, and All-Cause Mortality in Children Less Than 5 Years of Age in Malawi, 2000–2010. *The American Journal of Tropical Medicine and Hygiene,* 97(3_Suppl), pp.76–88.

Hobcraft, J.N., Mcdonald, J.W. & Rutstein, S.O., (1984). Socio-economic factors in Infant and child mortality: A cross-national comparison. *Population Studies,* 38(2), pp.193–223.

Houweling, T.A.J. & Kunst, A.E., (2010). Socio-economic inequalities in childhood mortality in low- and middle-income countries: a review of the international evidence. *British Medical Bulletin,* 93(1), pp.7–26.

Hviid, L. & Staalsoe, T., (2004). Malaria immunity in infants: a special case of a general phenomenon? *Trends in Parasitology*, 20(2), pp.66–72.

Kanyuka, M. et al., (2016). Malawi and Millennium Development Goal 4: a Countdown to 2015 country case study. *The Lancet Global Health*, 4(3), pp.e201–e214.

Leive, Adam & Xu, Ke, (2008). Coping with out-of-pocket health payments: empirical evidence from 15 African countries/Comment les menages font-ils face aux depenses de sante a leur charge : donnees empiriques provenant de 15 pays d'Afrique/Afrontar los pagos directos en salud: datos empirica de 15 paises africanos. *Bulletin of the World Health Organization,* 86(11), pp.849–856.

Lemani, C., (2013). *Modelling Covariates of Infant and Child Mortality in Malawi.* Master thesis at the University of Cape Town. Accessed 2019-12-11 from https://open.uct.ac.za/handle/11427/5895

Makwero, M.T., (2018). Delivery of primary health care in Malawi. *African Journal of Primary Health Care & Family Medicine*, 10(1), pp.e1–e3.

Mathanga, D.P. et al., (2012). Malaria control in Malawi: Current status and directions for the future. *Acta Tropica,* 121(3), pp.212–217.

Ministry of Health. (2013). *GUIDELINES FOR THE TREATMENT OF MALARIA IN MALAWI, 4th Edition.* Accessed 2019-12-11 from https://www.severemalaria.org/sites/mmv-smo/files/content/attachments/2017-03-03/Malawi%202013%20Edition%20of%20Malaria%20Treatment%20Guidelines.pdf

Ministry of Health. (2005). *Malaria Strategic Plan 2005–2010: Scaling up Malaria Control Interventions*. Lilongwe, Malawi.

Ministry of Health. (2008). *Republic of Malawi Ministry of Health National Malaria Control Program Supervision Report for Monitoring ACT and Malaria Control Activities*. Accessed 2019-09-18 from https://apps.who.int/medicinedocs/documents/s18367en/s18367en.pdf

Minujin, A. & Delamonica, E., (2003). Mind the gap! Widening child mortality disparities. *Journal of human development and capabilities*, 14(3), pp.397–418.

Moise, I.K. et al., (2017). Assessing the reduction in infant mortality rates in Malawi over the 1990-2010 decades. *Global Public Health*, 12(6), pp.757–779.

Mosley, W.H. & Chen, L.C., (1984). An Analytical Framework for the Study of Child Survival in Developing Countries. *Population and Development Review*, 10, pp.25–45.

National Statistics Office of Malawi. (2008). *Statistical Yearbook 2008.* Accessed 2019-11-05 from http://www.nsomalawi.mw/index.php?option=com_content&view=article&id=87%3Astatistical-yearbook-2008&catid=2&Itemid=64

National Statistics Office of Malawi. (2011). *Statistical Yearbook 2011.* Accessed 2019-11-05 from http://www.nsomalawi.mw/images/stories/data_on_line/general/yearbook/2011%20Statistical%20Yearbook.pdf

Okiro, A., E., et al. (2014). *An epidemiological profile of malaria and its control in Malawi. A report prepared for the Ministry of Health, the Roll Back Malaria Partnership and the Department for International Development*. Accessed 2019-12-11 from https://web-archive.lshtm.ac.uk/www.linkmalaria.org/sites/link/files/content/attachments/2018-09-24/Malawi-Epi-Report-2014.pdf

The President's Malaria Initiative. (2016). *Evaluation of the impact of malaria control interventions on all-cause mortality in children under five in Malawi, 2000–2010 - Malawi Malaria Impact Evaluation Group.* Accessed 2019-10-31 from https://reliefweb.int/sites/reliefweb.int/files/resources/Malawi%20-%20Malaria%20Impact%20Evaluation%20Report.pdf

Reyburn, H. et al., (2004). Overdiagnosis of malaria in patients with severe febrile illness in Tanzania: a prospective study. *BMJ*, 329(7476), pp.1212–1215.

Rutstein, S. & Rojas, G. (2006). *Guide to DHS Statistics*. Calverton, Maryland: ORC

Ryan, A.M., Burgess, J.F. & Dimick, J.B., (2015). Why We Should Not Be Indifferent to Specification Choices for Difference-in-Differences*. Health Services Research,* 50(4), pp.1211–1235.

Starfish Malawi (2019). *Education in Malawi*. Accessed 2019-12-16 from http://starfishmalawi.com/education-in-malawi

Steinhardt, L. et al., (2014). Quality of Malaria Case Management in Malawi: Results from a Nationally Representative Health Facility Survey: e89050. *PLOS ONE,* 9(2), p.e89050.

Su, X., Yan, X. & Tsai, C.L., (2012). Linear regression. *Wiley Interdisciplinary Reviews: Computational Statistics,* 4(3), pp.275–294.

Thomas, D., Strauss, J. & Henriques, M.-H., (1991). How Does Mother's Education Affect Child Height? *The Journal of Human Resources*, 26(2), pp.183–211.

Wang, L., (2003). Determinants of child mortality in LDCs - Empirical findings from demographic and health surveys. *Health Policy*, 65(3), pp.277–299.

Wooldridge, J.M., (2014). *Introduction to econometrics.* Europe, Middle East and Africa. Cengage Learning.

The World Bank (2019). *Immunization, measles (% of children ages 12-23 months) – Malawi.* Accessed 2019-11-28 from https://data.worldbank.org/indicator/SH.IMM.MEAS?locations=MW

World Health Organization (2007). *Gender and health information sheet*. Geneva: World Health Organization.

World Health Organization (2010). *Guidelines for the Treatment of Malaria, 2nd edition.* Geneva: World Health Organization.

World Health Organization (2013). *Progress & impact series, Focus on Malawi - Country Reports Number 6, April 2013.* Geneva: World Health Organization.

World Health Organization. *Sustainable Development Goal 3: Health*. Accessed 2019-09-18 from https://www.who.int/topics/sustainable-development-goals/targets/en/

World Health Organization. (2000). *The world health report 2000 – health systems: Improving performance*. Geneva: World Health Organization.

World Health Organization. (2005). *The World Health Report 2005: Make every mother and child count.* Geneva: World Health Organization.

United Nations. (2019). *World Population Prospects 2019*. Accessed 2019-12-10 from https://population.un.org/wpp/DataQuery/ *(custom data acquired via website).*

Yates, R., (2016). Child mortality in Malawi. *The Lancet Global Health,* 4(7), p.e444.

10. APPENDICES

Appendix 1

Table A1 – Proportion of under-fives with a fever two weeks preceding the DHS survey, by district

	Had a fever in last two weeks (%)			
	2000		2004	
District	**Yes**	**No**	**Yes**	**No**
Balaka	37.91	62.09	29.94	70.06
Blantyre	41.42	58.58	30.19	69.81
Chikwawa	53.92	46.08	25.65	74.35
Chiradzulu	41.94	58.06	20.00	80.00
Chitipa	32.33	67.67	21.28	78.72
Dedza	38.22	61.78	40.11	59.89
Dowa	58.14	41.86	46.20	53.80
Karonga	36.57	63.43	25.48	74.52
Kasungu	44.63	55.37	42.21	57.79
Lilongwe	36.47	63.53	38.71	61.29
Machinga	35.70	64.30	34.64	65.36
Mangochi	42.28	57.72	36.43	63.57
Mchinji	38.43	61.57	44.20	55.80
Mulanje	47.55	52.45	45.47	54.53
Mwanza	44.90	55.10	41.18	58.82
Mzimba	34.21	65.79	28.77	71.23
Nkhata Bay	59.84	40.16	50.41	49.59
Nsanje	52.41	47.59	38.76	61.24
Ntcheu	51.04	48.96	34.92	65.08
Ntchisi	48.30	51.70	53.64	46.36
Phalombe	49.42	50.58	56.47	43.53
Rumphi	16.87	83.13	19.05	80.95
Salima	44.88	55.12	43.09	56.91
Thyolo	35.98	64.02	47.79	52.21
Zomba	37.52	62.48	41.64	58.36
Total	**41.67**	**58.33**	**38.55**	**61.45**

Source: DHS (2000; 2004)

Table A2 – Proportion of under-fives with a fever and whom health care was sought for in the two weeks preceding the DHS survey, by district

Ever contacted health care as a response to fever (%)				
	2000		2004	
District	**Yes**	**No**	**Yes**	**No**
Balaka	17.03	82.97	12.57	87.43
Blantyre	15.04	84.96	11.32	88.68
Chikwawa	26.62	73.38	11.90	88.10
Chiradzulu	12.90	87.10	11.43	88.57
Chitipa	15.04	84.96	9.57	90.43
Dedza	15.87	84.13	16.80	83.20
Dowa	14.47	85.53	15.21	84.79
Karonga	13.50	86.50	11.46	88.54
Kasungu	13.59	86.41	13.99	86.01
Lilongwe	13.02	86.98	14.99	85.01
Machinga	14.38	85.62	13.39	86.61
Mangochi	16.06	83.94	16.11	83.89
Mchinji	13.43	86.57	16.96	83.04
Mulanje	13.74	86.26	18.11	81.89
Mwanza	17.35	82.65	13.45	86.55
Mzimba	13.51	86.49	10.86	89.14
Nkhata Bay	27.05	72.95	23.14	76.86
Nsanje	19.31	80.69	20.16	79.84
Ntcheu	20.47	79.53	15.25	84.75
Ntchisi	17.69	82.31	24.50	75.50
Phalombe	11.63	88.37	22.94	77.06
Rumphi	9.64	90.36	5.95	94.05
Salima	16.21	83.79	17.72	82.28
Thyolo	12.73	87.27	24.45	75.55
Zomba	12.40	87.60	20.82	79.18
Total	**14.98**	**85.02**	**15.98**	**84.02**

Source: DHS (2000; 2004)

Appendix 2

Table A3 – Malaria treatment given as response to fever (%) 2004, by district

District	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	Artesunate
Balaka	87.50	0.00	0.00	12.50	0.00
Blantyre	83.72	4.65	0.00	11.63	0.00
Chikwawa	83.33	0.00	0.00	16.67	0.00
Chiradzulu	83.33	16.67	0.00	0.00	0.00
Chitipa	100.00	0.00	0.00	0.00	0.00
Dedza	91.18	0.00	0.00	5.88	2.94
Dowa	63.33	16.67	0.00	20.00	0.00
Karonga	61.90	0.00	0.00	38.10	0.00
Kasungu	69.12	4.41	0.00	26.47	0.00
Lilongwe	77.59	1.72	0.00	18.97	1.72
Machinga	82.61	1.45	0.00	15.94	0.00
Mangochi	85.71	1.59	0.00	12.70	0.00
Mchinji	59.09	9.09	0.00	31.82	0.00
Mulanje	80.88	1.47	0.00	17.65	0.00
Mwanza	69.23	0.00	0.00	30.77	0.00
Mzimba	72.46	1.45	0.00	26.09	0.00
Nkhata Bay	50.00	0.00	3.85	46.15	0.00
Nsanje	85.71	0.00	0.00	14.29	0.00
Ntcheu	85.19	0.00	0.00	14.81	0.00
Ntchisi	95.24	4.76	0.00	0.00	0.00
Phalombe	69.23	3.85	0.00	26.92	0.00
Rumphi	87.50	12.50	0.00	0.00	0.00
Salima	85.19	3.70	2.47	8.64	0.00
Thyolo	91.13	0.00	0.81	8.06	0.00
Zomba	82.83	1.01	0.00	16.16	0.00
Total	**80.23**	**2.42**	**0.39**	**16.76**	**0.19**

Source: DHS (2004)

Table A4 - Malaria treatment given as response to fever (%) 2010, by district

District	SP/ Fansidar	Chloro-quinine	Amodia-quinine	Quinine	ACT	Artesunate	Aa/Asaq	Other
Balaka	0.00	0.00	0.00	11.11	86.11	0.00	0.00	2.78
Blantyre	6.00	0.00	1.00	19.00	72.00	0.00	0.00	2.00
Chikwawa	5.56	0.00	0.00	1.85	92.59	0.00	0.00	0.00
Chiradzulu	5.38	1.08	1.08	3.23	88.17	0.00	1.08	0.00
Chitipa	11.76	0.00	0.00	1.96	47.06	0.00	0.00	39.22
Dedza	3.74	0.00	0.00	8.41	85.05	0.00	2.80	0.00
Dowa	2.82	0.00	0.00	7.04	90.14	0.00	0.00	0.00
Karonga	1.22	0.00	0.00	2.44	57.32	0.00	0.00	39.02
Kasungu	2.34	0.00	0.00	11.68	85.51	0.00	0.47	0.00
Lilongwe	5.00	0.00	1.00	17.00	74.00	0.00	2.00	1.00
Machinga	0.94	0.00	0.00	9.43	88.68	0.00	0.00	0.94
Mangochi	6.15	0.00	0.00	10.77	81.54	0.00	0.00	1.54
Mchinji	4.03	0.00	0.00	5.37	90.60	0.00	0.00	0.00
Mulanje	5.79	0.00	0.00	4.13	90.08	0.00	0.00	0.00
Mwanza	0.85	0.00	0.00	3.39	95.34	0.00	0.00	0.42
Mzimba	9.52	0.00	0.00	3.97	67.46	0.79	0.79	17.46
Nkhata Bay	1.27	0.00	0.00	3.80	79.75	2.53	0.00	12.66
Nsanje	5.56	0.00	0.00	4.63	88.89	0.00	0.00	0.93
Ntcheu	1.30	0.00	0.00	12.99	85.71	0.00	0.00	0.00
Ntchisi	8.75	0.00	0.00	2.50	88.75	0.00	0.00	0.00
Phalombe	6.21	0.00	0.00	6.83	85.71	0.00	0.00	1.24
Rumphi	7.14	0.00	0.00	10.20	44.90	0.00	0.00	37.76
Salima	2.16	0.00	0.00	12.23	82.73	0.00	1.44	1.44
Thyolo	3.26	0.00	0.00	6.52	90.22	0.00	0.00	0.00
Zomba	1.04	0.00	0.00	5.21	93.75	0.00	0.00	0.00
Total	**4.03**	**0.04**	**0.11**	**7.55**	**82.78**	**0.11**	**0.37**	**5.01**

Source: DHS (2010)

Table A5 – Malaria treatment given as response to fever (%), by region

Distribution of types of antimalarials 2004

Region	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	Artesunate
Northern	68.94	1.52	0.76	28.79	0.00
Central	78.30	4.40	0.59	16.13	0.59
Southern	84.08	1.43	0.18	14.31	0.00
Total	**80.23**	**2.42**	**0.39**	**16.76**	**0.19**

Distribution of types of antimalarials 2010

Region	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	ACT	Artesunate	Aa/Asaq	Other
Northern	6.19	0.00	0.00	4.82	60.32	0.69	0.23	27.75
Central	3.52	0.00	0.11	9.93	85.27	0.00	0.85	0.32
Southern	3.68	0.08	0.15	6.75	88.50	0.00	0.08	0.77
Total	**4.03**	**0.04**	**0.11**	**7.55**	**82.78**	**0.11**	**0.37**	**5.01**

Source: DHS (2004; 2010)

Table A6 – Malaria treatment given as response to fever (%), by highest educational attainment of the mother[3]

Distribution of types of antimalarials 2004

Mothers educ.	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	Artesunate
No educ	81.86	3.26	0.93	13.49	0.47
Primary	80.53	2.34	0.15	16.98	0.00
Secondary	76.69	1.50	0.75	20.30	0.75
Higher	0.00	0.00	0.00	100.00	0.00
Total	**80.23**	**2.42**	**0.39**	**16.76**	**0.19**

Distribution of types of antimalarials 2010

Mothers educ.	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	ACT	Artesunate	Aa/Asaq	Other
No education	3.86	0.00	0.00	7.16	87.88	0.00	0.28	0.83
Primary	4.17	0.05	0.15	7.05	83.07	0.10	0.26	5.15
Secondary	3.32	0.00	0.00	10.25	76.45	0.28	1.11	8.59
Higher	10.00	0.00	0.00	20.00	70.00	0.00	0.00	0.00
Total	**4.03**	**0.04**	**0.11**	**7.55**	**82.78**	**0.11**	**0.37**	**5.01**

Source: DHS (2004; 2010)

[3] Educational attainment depicts levels the mother has enrolled in but not necessarily completed

Table A7 – Malaria treatment given as response to fever (%), by wealth index

Distribution of types of antimalarials 2004

Wealth index	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	Artesunate
Poorest	83.04	4.68	1.17	11.11	0.00
Poorer	87.04	0.81	0.00	11.74	0.40
Middle	75.43	2.16	0.00	22.41	0.00
Richer	78.38	2.70	0.45	18.47	0.00
Richest	76.25	2.50	0.62	20.00	0.62
Total	**80.23**	**2.42**	**0.39**	**16.76**	**0.19**

Distribution of types of antimalarials 2010

Wealth index	SP/Fansidar	Chloroquinine	Amodiquinine	Quinine	ACT	Artesunate	Aa/Asaq	Other
Poorest	4.47	0.00	0.00	6.13	84.44	0.00	0.50	4.47
Poorer	3.20	0.00	0.17	5.72	87.21	0.17	0.17	3.37
Middle	5.38	0.00	0.15	5.84	85.25	0.00	0.15	3.23
Richer	3.31	0.21	0.21	9.92	78.93	0.00	0.83	6.61
Richest	3.20	0.00	0.00	13.08	72.97	0.58	0.29	9.88
Total	**4.03**	**0.04**	**0.11**	**7.55**	**82.78**	**0.11**	**0.37**	**5.01**

Source: DHS (2004; 2010)

Appendix 3

Table R1 – Regression analysis, migrants dropped

Mortality (Y)	Coef.	St. Err.	[95% confidence interval]	
Time	-.0091*	.0041	-.0175	-.0007
Highlow	-.00003	.0017	-.0035	.0034
Interaction term	-.0010*	.0058	-.0219	.0020
Constant	.9914**	.0011	.9892	.9936
R-squared	0.0031		N	16 041
F-test	9.82		Prob > F	0.0002

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table R2 – Regression analysis with control variables, migrants dropped

Mortality (Y)	Coef.	St. Err.	[95% confidence interval]	
Time	-.0200**	.0048	-.0300	-.0101
Highlow	.0001	.0016	-.0031	.0034
Interaction term	-.0102*	.0058	-.0221	.0017
Educated	.0030	.0023	-.0017	.0078
Literacy	.0005	.0019	-.0035	.0044
Urban	.0016	.0031	-.0049	.0081
Northern	.0085**	.0022	.0040	.0130
Southern	.0029	.0017	-.0006	.0064
Male	-.0018	.0019	-.0057	.0021
7-12 months	.0082*	.0046	-.0013	.0177
13-24 months	-.0145**	.0025	-.0197	-.0094
25-36 months	-.0072**	.0016	-.0106	-.0039
37-48 months	-.0027	.0017	-.0063	.0009
Prevalence	.0005**	.0002	.0000	.0009
Poorest (wealth quint.)	.0000	.0021	-.0043	.0044
Poorer (wealth quint.)	-.0027	.0025	-.0078	.0025
Richer (wealth quint.)	.0009	.0028	-.0047	.0066
Richest (wealth quint.)	.0018	.0027	-.0039	.0075
Constant	.9775	.0083	.9603	.9947
R-squared	0.0072		N	16 041
F-test	17.68		Prob > F	0.0000

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table R3 – Regression analysis without wealth index variable

Mortality (Y)	Coef.	St. Err.	[95% confidence interval]	
Time	-.0213**	.0047	-.0310	-.0116
Highlow	-.0003	.0016	-.0036	.0030
Interaction term	-.0088	.0058	-.0208	.0031
Educated	.0037	.0023	-.0010	.0084
Literacy	.0001	.0018	-.0035	.0038
Urban	.0033	.0027	-.0022	.0088
Northern	.0087**	.0019	.0048	.0126
Southern	.0030*	.0017	-.0006	.0066
Male	-.0023	.0018	-.0060	.0014
7-12 months	.0103*	.0044	.0012	.0194
13-24 months	-.0136**	.0025	-.0187	-.0085
25-36 months	-.0060**	.0016	-.0092	-.0027
37-48 months	-.0020	.0018	-.0056	.0016
Prevalence	.0005**	.0002	.0001	.0008
Constant	.9764**	.0073	.9613	.9915
R-squared	0.0069		N	16 763
F-test	13.06		Prob > F	0.0000

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table R4 – Regression analysis without observations from districts close to cut-off

Mortality (Y)	Coef.	St. Err.	[95% confidence interval]	
Time	-.0148**	.0040	-.0232	-.0063
Highlow	-.0015	.0019	-.0055	.0025
Interaction term	-.0027	.0061	-.0157	.0104
Constant	.9928**	.0013	.9900	.9956
R-squared	0.0037		N	11 020
F-test	11.30		Prob > F	0.0004

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table R5 – Regression analysis without observations from districts close to cut-off

Mortality (Y)	**Coef.**	**St. Err.**	**[95% confidence interval]**	
Time	-.0253**	.0056	-.0372	-.0134
Highlow	.0004	.0018	-.0034	.0042
Interaction term	-.0027	.0061	-.0158	.0103
Educated	.0032	.0029	-.0029	.0093
Literacy	.0001	.0023	-.0049	.0050
Urban	.0043	.0030	-.0021	.0107
Northern	.0090**	.0024	.0040	.0140
Southern	.0025	.0021	-.0020	.0070
Male	-.0043*	.0023	-.0091	.0006
7-12 months	.0093	.0063	-.0041	.0227
13-24 months	-.0128**	.0035	-.0204	-.0053
25-36 months	-.0053**	.0019	-.0093	-.0012
37-48 months	-.0016	.0022	-.0063	.0032
Prevalence	.0004**	.0002	.0000	.0009
Poorest (wealth quint.)	-.0015	.0026	-.0071	.0040
Poorer (wealth quint.)	-.0016	.0030	-.0080	.0048
Richer (wealth quint.)	-.0001	.0035	-.0074	.0073
Richest (wealth quint.)	.0012	.0032	-.0056	.0080
Constant	.9781**	.0079	.9614	.9949
R-squared	0.0080		N	11 020
F-test	.[4]		Prob > F	.

Notes: All presented standard errors have been clustered by district.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

[4] Due to a now lesser number of clusters than included explanatory variables, Stata does not perform an F-test. Acknowledging this I have run a regression excluding age as a control which yielded close to identical results regarding my variables of interest while providing the following F-statistic; F-test 7.60, Prob > F 0.0002. Considering this, the fact that the estimated interaction term is -0.0027 with and without control variables and the fact that this is a robustness check regarding the effect of dropping considered observations where my primary interest is not this test statistic, I have chosen not to go into detail on the matter.

Appendix 4

Figure 1 - Map of Malawi depicting regions and districts

Source: DHS (2010)

Appendix 5

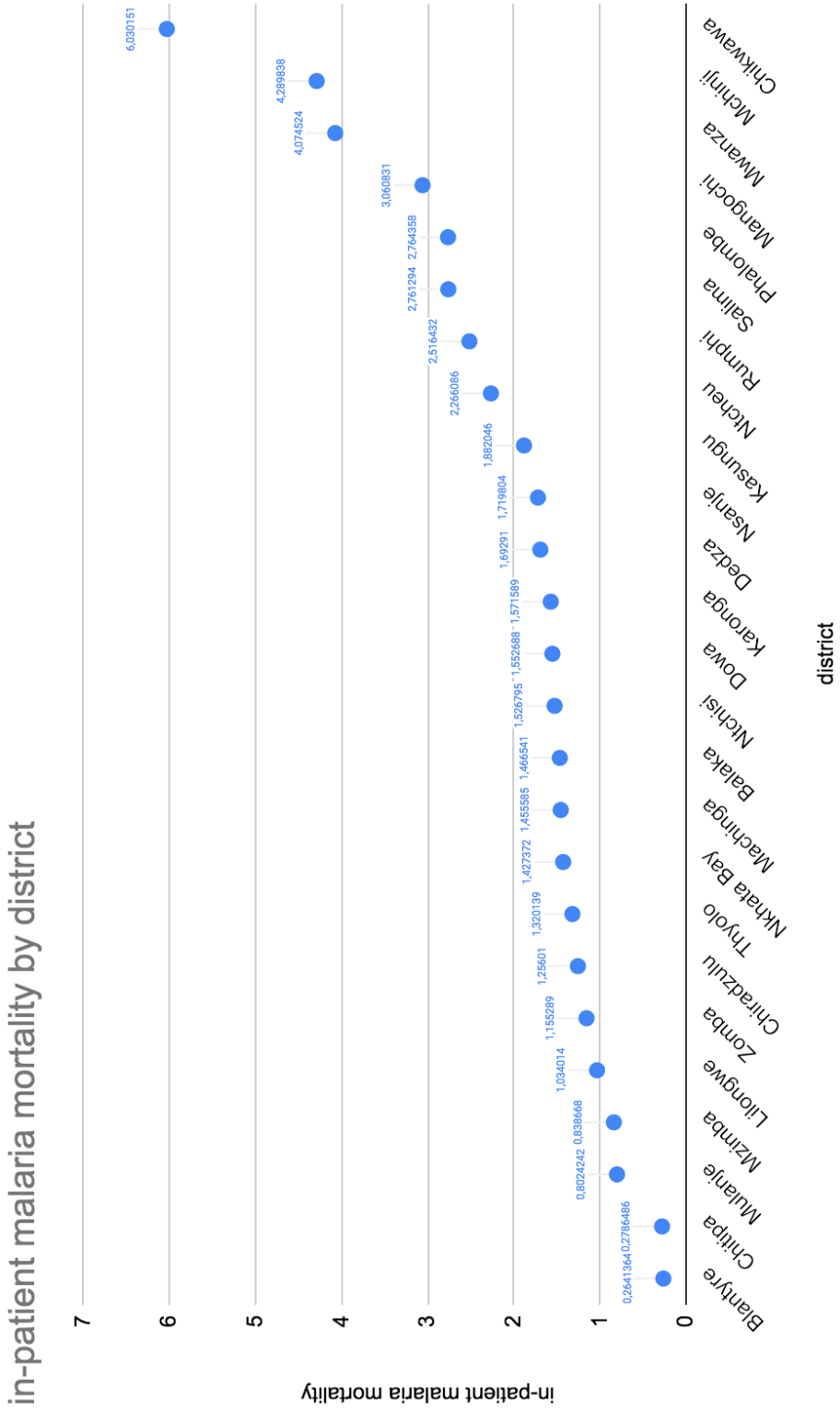
Table A8 – In-patient under-five malaria mortality rates in 25 districts prior to the reform

District	In-patient under-five malaria mortality
Blantyre	.2641364
Chitipa	.2786486
Mulanje	.8024242
Mzimba	.838668
Lilongwe	1.034014
Zomba	1.155289
Chiradzulu	1.25601
Thyolo	1.320139
Nkhata Bay	1.427372
Machinga	1.455585
Balaka	1.466541
Ntchisi	1.526795
Dowa	1.552688
*Karonga**	1.571589
*Dedza**	1.69291
*Nsanje**	1.719804
*Kasungu**	1.882046
*Ntcheu**	2.266086
*Rumphi**	2.516432
*Salima**	2.761294
*Phalombe**	2.764358
*Mangochi**	3.060831
*Mwanza**	4.074524
*Mchinji**	4.289838
*Chikwawa**	6.030151

Notes: All districts marked * are considered high malaria mortality districts forming my treatment group. All other districts make up the control group. The cut-off is the median; 1.553

Source: National Statistics Office of Malawi (2008)

Figure 3 – In-patient under-five malaria mortality at a district level prior to the policy implementation



Notes: The mortality rates are depicted per thousand children under the age of five

Source: National Statistics Office of Malawi (2008)