Essays on the Effects of Climate Patterns and Rice Cultivation on Malaria Risk: Evidence from Sub-Saharan Africa

Extended Summary of Ph.D. Dissertation

By

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1. Introduction

Despite significant advances in malaria control interventions, the disease remains significantly prevalent, particularly in sub-Saharan Africa (SSA). Every year, there are 200 to 300 million cases, resulting in one to three million deaths, with children accounting for more than 90% of the deaths in SSA (WHO, 2019). Besides worsening the health status of individuals, malaria poses a huge economic burden in several ways: (1) it leads to lower labor productivity (Asenso-Okyere et al., 2011); (2) it reduces educational and economic status outcomes (Burlando, 2012; Cutler et al., 2010; Gallup & Sachs, 2001), hence lowering human capital accumulation, and (3) it reduces investment due to high treatment and prevention expenditure (Haakenstad et al., 2019). Therefore, an understanding of the factors that cause malaria is crucial for reducing the related economic burden.

The epidemiology of malaria is influenced by multiple factors, with two main factors that have changed in recent years that exacerbate malaria transmission risk i.e., change in climatic conditions and expansion of agricultural land, particularly rice cultivation. The studies on climate and malaria are mainly in epidemiological literature that analyze the effect of temperature and precipitation on the mosquito life cycle. These studies found that the reproductive rate of mosquitoes increases between 0.5-4.0% as the temperature gets warmer (Beck-Johnson et al., 2017; Lafferty, 2009; Paaijmans et al., 2009). The optimal threshold of temperature for mosquito growth may vary from species to species, typically between 20°C and 30°C (Nabi & Qader, 2009; Khasnis & Nettleman, 2005;Casman and Dowlatabadi, 2002). On the other hand rainfall often leads to stagnant water, which is critical for mosquito breeding (Ayanlade et al., 2013; Mafwele & Lee, 2022; Ngarakana-Gwasira et al., 2016). Monthly precipitation greater or equal to 80mm creates a conducive ground for egg laying and larva stage in the mosquito life cycle (Ayanlade et al., 2013). Studies on the effect of rice cultivation on malaria risk are classified into two lines of literature. The studies in the first line of literature suggested that rice fields are ideal habitats for mosquitoes due to the heavy water requirement of rice cultivation (Chan et al., 2022). Conversely, the studies in the other line of literature suggest that rice production increases income, which can improve health through accessing preventative mechanisms. This contradicting idea is called the Paddies' paradox (Ijumba et al., 2001).

The first chapter of this dissertation examines the effect of climate patterns on community-level malaria incidence and child-level malaria prevalence in SSA. The second chapter examines the effect of rice cultivation on malaria risk.

As for contributions to existing literature, the first empirical chapter contributes to existing literature in several ways. First, a few studies in economics have quantified the impact of climate on malaria risk. While some studies have examined the effect of temperature and precipitation on malaria risk, they mainly focus on one country or specific site a country. We analyze this effect in cross-country settings in SSA by including as many countries as possible. Second, we analyze the heterogeneity in the effect of climate on malaria risk across different socio-economic groups. Third, we analyze whether the heterogeneity in the effect of climate on malaria avoidance behavior can explain the heterogeneity in the effect of climate on malaria risk across different socio-economic groups. The second empirical chapter contributes to the literature by (1) estimating the heterogeneity in the effect of rice cultivation on malaria risk among countries and over time, and (2) providing the possible mechanisms for heterogeneity among countries. Both studies contribute to the literature by utilizing large, disaggregated data sets covering as many countries as possible in SSA, which will help enhance our understanding of the complex relationships among agricultural land use, climate change, and malaria risk.

2. Methodology

This study combines data from three sources: Demographic and Health Surveys (DHSs), ERA-5 MONTHLY of Copernicus Climate Change Service, and the Advancing Research on Nutrition and Agriculture (AReNA) project. This data gives us an advantage in exploring the underlying questions in wide coverage by including multiple countries in SSA. Throughout the estimation, we use Ordinary Least Square (OLS) with a set of fixed effects to capture unobserved time-variant and time-invariant factors influencing malaria risk.

The malaria risk indicating variable at the community level is defined as weighted annual clinical cases of malaria in a community. At the child level, it is defined based on malaria test results. For the first empirical chapter, at the community level, climate patterns were measured by two variables: the annual share of mosquito-friendly months in terms of temperature and precipitation, and the shock in the annual share of mosquito-friendly months by taking the deviation from the long-run mean of the annual share of mosquito friendly months. At the child level, climate patterns were measured in two variables: the pre-survey month being mosquito-friendly in terms of temperature and precipitation. For the second empirical chapter, both at the community and child levels, the main explanatory variable is a dummy variable indicating the proportion of farmland allocated to rice in a community based on the median value.

3. Results/Discussion

The results of the first analytical chapter indicate that: (1) at the community level, an increase in the share of mosquito-friendly months in terms of temperature and precipitation increases malaria incidence. Moreover, the shock in the share of mosquito-friendly months increases malaria incidence, (2) at the child level, experiencing a mosquito-friendly environment increases the probability of child infection, especially in areas closer to water bodies and less-developed areas as proxied by luminosity, which is a measure of night light intensity in each community; (3) during mosquito-friendly months, mosquito net ownership rises in areas closer to water bodies. However, mosquito net usage is lower in areas closer to water bodies than in areas farther away from water bodies. In both more and less luminous areas, mosquito net ownership increases during mosquito-friendly periods. This increase is greater in more luminous areas, particularly among wealthier households. Mosquito net usage by children increases in more luminous areas but not in less luminous ones.

In the second empirical chapter, the cross-country estimates show that having a proportion of rice land above the median is associated with an increase in malaria risk in some countries (e.g., Uganda) and decreased risk in others (e.g., Senegal). In countries where rice cultivation and malaria risk are positively correlated, we find that mosquito net ownership depends on wealth status. However, this is not the case in countries where rice cultivation and malaria risk are non-positively correlated indicating that mosquito net access for rice growers is comparable to the general population. One would naturally expect that if wealth does not explain the variation in health inputs, the abundance of mosquitoes in rice fields would lead to higher malaria rates. The next question we examined is where the effects of a large mosquito population go in the non-positive effect countries. We demonstrated that children are more likely to sleep under mosquito nets in communities with a higher proportion of rice land in countries with a non-positive rice-malaria relationship. This is not observed in countries with positive rice malaria relationship.

4. Conclusions

In a nutshell, by exploiting a large data set in SSA, this study estimates the effects of climate patterns and rice cultivation on malaria risk at the community and child levels. The results of the first empirical chapter show that experiencing a mosquito-friendly environment increases the risk of malaria, particularly for those who live closer to water bodies and in less developed areas. People from more developed areas respond more in terms of mosquito net usage when they experience a mosquito-friendly environment. The results of the second empirical chapter show rice cultivation increases malaria risk in some countries but not in other countries. Rice cultivation is not positively associated with malaria risk in countries where households own a mosquito net regardless of wealth status, and rice-growing communities tend to have children sleeping under mosquito nets. Rice cultivation is positively associated with malaria risk in countries where wealthier households are more likely to own bed nets, and rice-growing communities do not tend to have children sleeping under mosquito nets. Overall, the two empirical chapters reveal the importance of (1) targeting people closer to water bodies and in less developed areas; and (2) failing to consider the link between health and agriculture might undermine efforts to mitigate public health problems. Future agricultural policies must also consider the health consequences of agricultural expansion.

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