Microeconometric Evaluation of Malaria Control Programs in Sub-saharan Africa

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Summary

In this paper we estimate the effect of nationwide malaria control programs through bednet ownership in four sub-saharan countries: Cameroon, Malawi, Rwanda and Burkina Faso. We highlight the differences in the amount of investments in these countries as well as differences in implemented strategies. Two of these four countries, Rwanda and Malawi, are part of the President's Malaria Initiative (PMI) and therefore received substantial amount of funding from this initiative. Cameroon and Burkina Faso, on the other hand, received international monetary support from different sources. Therefore comparing these two groups might help us to evaluate PMI intervention strategies. The results show that only in Malawi the malaria control control programs lead to a significant decrease in child mortality.

JEL classification: C13,C21, I10, I12

Keywords: Bednet, Malaria, Subsaharan Africa, Nonlinear Models

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1 Introduction

In this paper we estimate the effect of nationwide malaria control programs on child mortality through bednet (insecticide treated mosquito net, i.e. ITN) ownership in four sub-saharan countries: Cameroon, Malawi, Rwanda and Burkina Faso. Malaria is one of the deathly diseases in Africa, especially in Subsaharan Africa. World Health Organization reports that 90% of the malaria related deaths in the world occurred in Africa in 2012 (World Health Organization, 2013). Public health literature provides us evidence on the negative correlation between bednet ownership and malaria incidences (Lengeler et al., 2004). Given the overwhelming empirical evidence on this relation ITNs are the primary tools for malaria control worldwide, thus, increasing ITN ownership is a primary goal of every malaria control programs. During the last decade, especially after 2005, the amount of resource dedicated to fight malaria increased substantially (see Njau et al., 2013; Snow et al., 2010; Snow and Marsh, 2010, among others). Not all countries, however, received the same amount of funding (World Health Organization, 2013, see country profiles in). Figure 1 presents contributions of different agents to malaria control programs in the countries we investigate. Although the allocation of the fundings are different in different countries, substantial proportion of the funding is usually dedicated to ITN campaigns.

In this paper, we use DHS (Demographic Health Survey) data to estimate the effect of investments to prevent malaria through bednet ownership. DHS is a household survey conducted in many countries as repeated cross-sections. The year of the survey differs for the countries in general. For each country we use two cross-sections so that the earlier wave is in pre-intervention period. Thus, we use the following surveys: Burkina Faso 2003 and 2010, Cameroon 2004 and 2011, Malawi 2004 and 2010, Rwanda 2005 and 2010. As it can be seen in Figure 1, for all countries we consider here the contributions increase substantially after first cross-section.

Figure 1: Contributions of different agents to malaria control programs

Source: Country Profiles (World Health Organization, 2013), Annex−3. The horizontal lines represent the survey years.

We use the econometric method proposed by Deuchert and Wunsch (2014) with a small modification. Briefly, the method is an adjustment of weighting estimator of the treatment effect for the applications where the treatment is nationwide and before-after comparison is not possible.

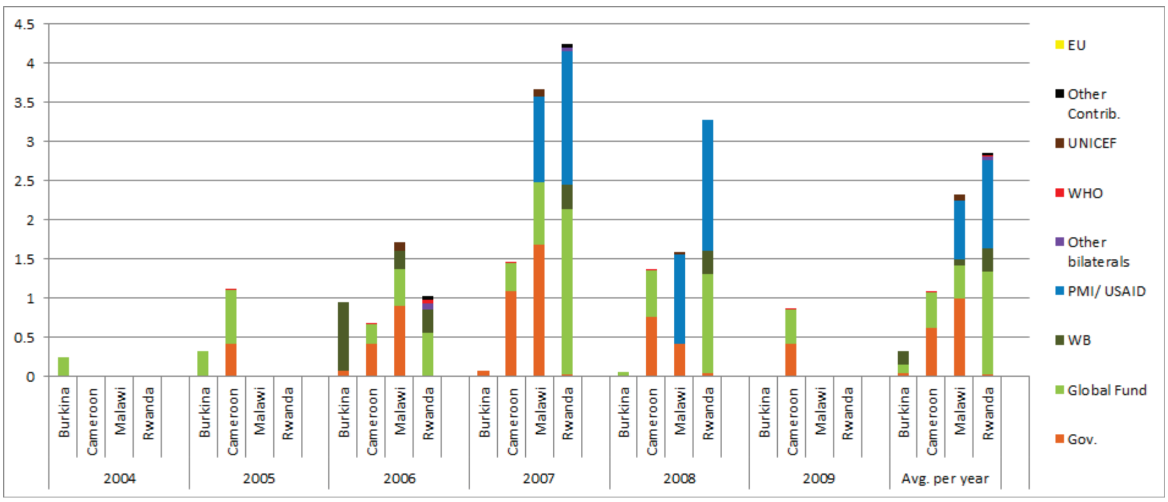
The paper is organized as follows. Section 2 provides some background information on malaria prevention campaigns. Section 3 summarizes the econometric method. Section 4 describes the data sets used and presents the estimation results. Section 5 discusses the results and concludes the paper.

2 Background

In this section we will provide background information on the countries we investigate as well as more information on malaria control programs in these countries.

Kouyate et al. (2007) show that malaria is the number one cause of morbidity and mortality in Burkina Faso. As it is clear from Figure 1 and Figure 2 which summarizes the per capita financing during the time interval between two surveys we use, smaller amount of financial contribution was received by Burkina Faso. Since the second survey we use for Burkina Faso is in 2010, it is less likely that we see any effect of the peak in 2009 in our results.

Figure 2: Contributions per capita for the time between two surveys.



Source: Country Profiles (World Health Organization, 2013)

Information on these countries, bednet campaigns, goals of the campaigns... to be written...

3 Method

Deuchert and Wunsch (2014) define the methodology using well-known potential outcome framework. What we are interested in is quantifying the effect of the investment between two years under consideration, I, on infant mortality Y in these four malaria endemic countries. The outcome variable is a binary variable which is equal to 1 if, at the time of measurement, a child who was born no more than 12 months before was no longer alive, and 0 otherwise. The variable I is equal to zero for the pre-intervention period, i.e. for the first cross-section, and equal to 1 for the post-intervention, i.e. for the second cross section. We have two potential outcomes: Y_1 potential outcome exposed to the investment ($I = 1$) and Y_0 not exposed to the investment ($I = 0$). Note that everyone in the first survey has $I = 0$ ad everyone in the second survey has $I = 1$. The treatment effect we estimate is the average effect for those who are exposed to the treatment. Formally,

$$\tau = \mathrm{E}\left[Y_1 - Y_0 \middle| I = 1\right]. \tag{3.1}$$

If we denote the pre-intervention period by $T = 0$ and post-intervention period by $T = 1$, given that everyone in the first survey has $I = 0$ ad everyone in the second survey has $I = 1$ the effect can be written as

$$\tau = \mathrm{E}\left[Y_1 - Y_0 \middle| I = 1\right] \equiv \mathrm{E}\left[Y_1 - Y_0 \middle| T = 1\right]. \tag{3.2}$$

As usual in econometric evaluation the problem is missing counterfactual outcome variable, i.e Y_0 is unobserved in post-intervention period and Y_1 is unobserved in pre-intervention period. Deuchert and Wunsch (2014) show that under certain assumptions the effect can be identified using the behavioral change, B, due to the investment The idea is to use the link between increased bednet usage (ownership) due to the increased financing and decreased infant mortality due to the increased bednet usage (ownership). As long as the investments are not directly affecting the health outcome, but only through a behavioral channel we can identify the causal effect. The set of assumptions are closely related to unconfoundedness assumptions and unconfoundedness of instrument assumptions in the literature. For the details see Deuchert and Wunsch (2014). (Further discussion will be added.)

Deuchert and Wunsch (2014) show that τ can be estimated by the following

$$\hat{\tau} = \frac{1}{N_1} \sum_{i=1}^{N_1} Y_{1i} \left\{ \frac{B_{1i}}{\hat{p}_1(X_{1i})} - \frac{1 - B_{1i}}{1 - \hat{p}_1(X_{1i})} \right\} (\hat{p}_1(X_{1i}) - \hat{p}_0(X_{1i})) \tag{3.3}$$

where N_1 is post-intervention sample size. B_t is behavior at t. In our case bednet ownership at time t. $\hat{p}_t(\cdot)$ is estimated probability of bednet ownership at time t. Without the last part in Eq. (3.3) the estimator becomes standard weighting estimator (Wooldridge, 2007). Due to unfavourable properties of this standard weighting estimator in small samples Imbens (2004) proposes to adjust the weights such that they add up to one. In the application we integrate this suggestion to the estimator in Eq. (3.3).

4 Data

For our analysis we use Measure DHS data for Burkina Faso 2003 and 2010, Cameroon 2004 and 2011, Malawi 2004 and 2010, Rwanda 2005 and 2010. Demographic and Health Surveys (DHS) are nationally-representative household surveys which provide a wealth of information on widely different topics for a sample of the countries that participate in the Measure DHS program. The standardized questionnaires across countries enables us comparison of the variables. Additional to the survey data we also use the GPS data for the clusters, i.e. the groupings of households that participated in the survey. GPS data allows us to determine the distance to the nearest body of water. Since closeness to water is highly correlated with malaria risk, GPS coordinates of the clusters are very valuable.

Since the identifying assumptions require unconfoundedness, having a rich set of covariates is highly important. We can categorize our control variables in five groups: (i) child characteristics, (ii) Mother's characteristics, (iii) Regional characteristics, (iv) Partner's characteristics, and (v) Household characteristics. All the variables are chosen following the existing literature on determinants of bednet ownership and infant mortality given data availability.

Child characteristics include age (hypothetical age for deceased children), gender, birth weight category and place of birth. Related to mother, we use information on age, education, ethnicity, religion, number of births given, employment status and height. In the survey mothers were asked whether certain situations constitute a big problem when medical help is needed, such as not knowing where to go or distance to the medical insinuation.[1] We also used this information to proxy accessibility of medical care. Whether the family was visited by a family worker in the past 12 months and whether any older children died are also included in the regression.

As regional characteristics in the survey we have information on the altitude of the cluster and the region of the cluster. Additionally, using the GPS coordinates of the clusters we calculated the distance to the closest water body and closest city for each cluster. Distance to the closest city is an important proxy for access to potentially better infrastructure. Distance to the water is used to as a proxy for malaria risk, since malaria risk is highly correlated with the distance to the water.[2]

[1]The problems listed were not always same in all countries and years.

[2]In order to determine the distance we used the GPS coordinated of water bodies and cities (down-

Partner's characteristics are age and education level of the partner if applicable. Lastly, household characteristics are summarized by a wealth index. We used the comparative wealth index suggested by Rutstein and Staveteig (2014).

Summary statistics of the variables for Burkina Faso in two years are given in Tables 4. The tables for the other countries are in the Appendix.

loaded from `http://www.diva-gis.org/`). The distances are calculated by georeferencing software ArcGIS.

Table 4.1: Summary statistics for Burkina Faso.

	Burkina Faso				
	2003		2010		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Outcome					
Infant Mortality	0.06	0.23	0.05	0.21	0.09
Behaviour					
Bednet ownership	0.43	0.49	0.78	0.41	0.00
Covariates					
Child Characteristics					
Age	0.50	0.31	0.51	0.30	0.44
Female	0.49	0.50	0.49	0.50	0.95
Size at birth (0.7% missing)	2.77	1.42	2.59	1.30	0.00
very large	0.28	0.45	0.33	0.47	0.00
average	0.52	0.50	0.54	0.50	0.11
very small	0.19	0.39	0.13	0.33	0.00
Place of birth					
home, other	0.61	0.49	0.24	0.43	0.00
public hospital	0.38	0.49	0.75	0.43	0.00
private hospital	0.01	0.08	0.01	0.09	0.21
Mother characteristics					
Age	28.05	7.23	27.77	6.78	0.14
16-19 years	0.11	0.31	0.10	0.29	0.18
20-24 years	0.26	0.44	0.26	0.44	0.92
25-29 years	0.24	0.43	0.27	0.44	0.03
30-34 years	0.18	0.39	0.20	0.40	0.24
35-39 years	0.12	0.33	0.12	0.33	0.74
40-44 years	0.07	0.25	0.05	0.22	0.03
44-49 years	0.02	0.14	0.01	0.10	0.00
Highest Education					
No education	0.87	0.33	0.83	0.38	0.00
Primary	0.09	0.28	0.11	0.31	0.01
Secondary, higher	0.04	0.20	0.06	0.24	0.00

Note: Source: DHS, own calculations. t-test refers to the equality of means.

Table 4.1 ***(cont'd)*:** Summary statistics for Burkina Faso.

Burkina Faso					
	2003		2010		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Ethnicity					
bobo	0.02	0.14	0.03	0.17	0.03
fulfulde / peul	0.07	0.26	0.10	0.30	000
gourounsi	0.05	0.21	0.04	0.20	0.25
lobi	0.09	0.29	0.04	0.19	0.00
mossi	0.52	0.50	0.52	0.50	0.90
sénoufo	0.05	0.22	0.05	0.22	0.60
other	0.20	0.40	0.22	0.42	0.04
Christian	0.27	0.44	0.27	0.45	0.50
Number of children ever born					
1	0.19	0.39	0.17	0.38	0.13
2	0.16	0.37	0.18	0.38	0.16
3	0.14	0.35	0.16	0.37	0.08
4	0.13	0.33	0.13	0.33	0.97
≥ 5	0.38	0.49	0.36	0.48	0.22
Knowledge of oral rehydration					
Never heard of	0.35	0.48	0.23	0.42	0.00
Heard of	0.04	0.20	0.03	0.18	0.14
None, other	0.60	0.49	0.73	0.44	0.00
Mother working	0.90	0.30	0.77	0.42	0.00
Problems in obtaining medical help					
permission to go	0.16	0.37	0.21	0.41	0.00
money	0.66	0.47	0.74	0.44	0.00
distance to health facility	0.49	0.50	0.48	0.50	0.28
not wanting to go alone	0.23	0.42	0.19	0.39	0.00
Visited by a family worker in previous 12 months	0.11	0.31	0.09	0.29	0.14
Any older children died	0.43	0.50	0.32	0.46	0.00
Mother's height (cm)	161.48	5.94	161.57	5.73	0.62
Height $<$ 1.50 m	0.02	0.15	0.01	0.10	0.00
Height 1.50-1.59	0.38	0.49	0.18	0.39	0.00
Height 1.60-1.69	0.52	0.50	0.28	0.45	0.00
Height $>$ 1.70	0.08	0.26	0.04	0.18	0.00

Note: Source: DHS, own calculations. t-test refers to the equality of means.

Table 4.1 ***(cont'd)*:** Summary statistics for Burkina Faso.

	Burkina Faso				
	2003		2010		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Regional Characteristics					
Altitude	300.87	50.59	288.00	81.25	0.00
≤300 m	0.46	0.50	0.44	0.50	0.11
>300 m	0.54	0.50	0.51	0.50	0.04
Distance to lake	53.63	40.88	62.11	52.21	0.00
<50	0.55	0.50	0.51	0.50	0.00
50-100	0.31	0.46	0.26	0.44	0.00
>100	0.13	0.34	0.17	0.38	0.00
Region					
boucle de mouhoun	0.07	0.26	0.09	0.28	0.04
cascades	0.06	0.23	0.06	0.25	0.29
centre	0.05	0.22	0.06	0.24	0.28
centre-est	0.06	0.24	0.08	0.27	0.03
centre-nord	0.09	0.28	0.08	0.27	0.28
centre-ouest	0.10	0.30	0.09	0.29	0.17
centre-sud	0.06	0.24	0.06	0.24	0.90
est	0.08	0.27	0.10	0.30	0.01
hauts basins	0.08	0.27	0.08	0.27	0.45
nord	0.09	0.28	0.08	0.28	0.86
plateau central	0.09	0.28	0.07	0.25	0.01
sahel	0.08	0.27	0.08	0.28	0.49
sud-ouest	0.10	0.29	0.07	0.25	0.00
Distance to next city	17.53	14.10	18.69	16.48	0.01
< 20	0.60	0.49	0.56	0.50	0.00
20-40	0.33	0.47	0.28	0.45	0.00
> 40	0.06	0.24	0.11	0.31	0.00
Partner Characteristics					
Has no partner	0.13	0.33	0.03	0.18	0.00
Highest Education	0.09	0.59	0.21	0.65	0.00
No education	0.84	0.36	0.79	0.41	0.00
Primary	0.07	0.25	0.12	0.33	0.00
Secondary, higher	0.04	0.20	0.07	0.25	0.00
Partner's age	35.07	17.64	38.08	13.82	0.00
16-30	0.16	0.37	0.19	0.40	0.00
31-40	0.28	0.45	0.35	0.48	0.00
40-50	0.43	0.50	0.42	0.49	0.25
Household Characteristics					
Wealth Index	-1.14	0.66	-1.11	0.70	0.18
Belongs to the poorest quantile	0.80	0.40	0.79	0.41	0.28
Belongs to the poorer quantile	0.10	0.30	0.11	0.31	0.28
Belongs to the middle quantile	0.03	0.17	0.03	0.17	0.97
Belongs to the richer quantile	0.03	0.18	0.03	0.18	0.75
Belongs to the richest quantile	0.03	0.18	0.03	0.18	0.77

Note: Source: DHS, own calculations. t-test refers to the equality of means.

In Table 4.2 we present estimated effects along with bootstrapped standard errors for all four countries. IPW1 refers to the estimator given in Eq. (3.3) and IPW2 is the adjusted version of this estimator. Very interestingly only significant effect is observed for Malawi. In Malawi, the investments on malaria prevention campaign decreased infant mortality by around 2 percentage points through increased bednet ownership. For other countries no such effect is observed. Now, the following step is to investigate how the money is invested on these countries, what was different in Malawi so that the campaigns were more effective there than other countries.

Table 4.2: Estimated treatment effects

		Burkina Faso	Cameroon	Malawi	Rwanda
IPW1	Effect	-0.011	-0.006	-0.021***	-0.014
	Bootstrapped Std. Err.	(0.010)	(0.008)	(0.007)	(0.020)
	t-stat	-1.164	-0.679	-2.800	-0.727
IPW2	Effect	-0.011	-0.006	-0.019***	-0.014
	Bootstrapped Std. Err.	(0.009)	(0.008)	(0.007)	(0.018)
	t-stat	-1.186	-0.779	-2.884	-0.770
	N_0	2399	1814	2651	1978
	N_1	3316	1432	4311	1730

Note: Estimated treatment effects

5 Conclusion

References

Deuchert E, Wunsch C. 2014. Evaluating nationwide health interventions: Malawi's insecticide-treated-net distribution programme. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* **177**: 523–552. ISSN 1467-985X. URL `http://dx.doi.org/10.1111/rssa.12031`

Imbens GW. 2004. Nonparametric estimation of average treatment effects under exogeneity: A review. *The Review of Economics and Statistics* **86**: pp. 4–29. ISSN 00346535. URL `http://www.jstor.org/stable/3211657`

Kouyate B, Sie A, Ye M, De Allegri M, Mueller O. 2007. The great failure of malaria control in africa: A district perspective from burkina faso. *PLoS Med* **4**: e127. URL http://dx.doi.org/10.1371%2Fjournal.pmed.0040127

Lengeler C, et al. 2004. Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database Syst Rev* **2**: 1–54.

Njau JD, Stephenson R, Menon M, Kachur SP, McFarland DA. 2013. Exploring the impact of targeted distribution of free bed nets on households bed net ownership, socio-economic disparities and childhood malaria infection rates: analysis of national malaria survey data from three sub-saharan africa countries. *Malaria Journal* **12**: 1–15.

Rutstein SO, Staveteig S. 2014. Making the demographic and health surveys wealth index comparable. Technical report, DHS Methodological Reports 9.

Snow RW, Marsh K. 2010. Malaria in africa: progress and prospects in the decade since the abuja declaration. *The Lancet* **376**: 137 – 139. ISSN 0140-6736. URL http://www.sciencedirect.com/science/article/pii/S0140673610605776

Snow RW, Okiro EA, Gething PW, Atun R, Hay SI. 2010. Equity and adequacy of international donor assistance for global malaria control: an analysis of populations at risk and external funding commitments. *The Lancet* **376**: 1409 – 1416. ISSN 0140-6736. URL http://www.sciencedirect.com/science/article/pii/S0140673610613402

Wooldridge JM. 2007. Inverse probability weighted estimation for general missing data problems. *Journal of Econometrics* **141**: 1281 – 1301. ISSN 0304-4076. URL http://www.sciencedirect.com/science/article/pii/S0304407607000437

World Health Organization. 2013. Who global malaria programme: World malaria report 2013. Technical report, WHO.