BMJ Open

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Kernel based Propensity Score Matching and Difference in Differences Analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-033356
Article Type:	Research
Date Submitted by the Author:	01-Aug-2019
Complete List of Authors:	Dwomoh, Duah; University of Ghana College of Health Sciences, Biostatistcs; University of Ghana College of Health Sciences, Biostatistics, School of Public Health Agyabeng, Kofi ; School of Public Health, College of Health Sciences, University of Ghana, P. O. Box LG13, Legon, Ghana Agbeshie, Kwame; Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana Incoom, Gabriel; Ghana Institute of Management and Public Administration, Department of Management Science, School of Business Nortey, Priscilla ; University of Ghana School of Public Health, Epidemiology Yawson, Alfred; University of Ghana, Community Health, School of Public, College of Health Sciences Bosomprah, Samuel; University of Ghana, Biostatistics, School of Public Health
Keywords:	Neonatal Mortality, Infant mortality, Kernel weighting, Propensity Score Matching, Free Maternal Healthcare Policy

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Kernel based Propensity Score Matching and Difference in Differences Analysis

Duah Dwomoh[1*], Kofi Agyabeng[1], Kwame Agbeshi[2], Gabriel Incoom[3], Priscilla Nortey[4], Alfred E. Yawson[5], Samuel Bosomprah[1]

[1] Department of Biostatistics, School of Public Health, University of Ghana, Accra.
[2] Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.
[3]Department of Management Science, School of Business, Ghana Institute of Management and Public Administration, Accra, Greater Accra, Ghana
[4] Department of Epidemiology and Disease Control, School of Public Health, University of Ghana, Accra.
[5] Department of Community Health, University of Ghana.

The email address of authors

Kofi Agyabeng: soothe1one@gmail.com
Kwame Agbeshi: kagbeshie@gmail.com
Gabriel Incoom: gabrielincoomghana@gmail.com
Priscilla Nortey: pnortey@gmail.com
Yawson Edwin Alfred: aeyawson@yahoo.com
Samuel Bosomprah: sbosomprah@gmail.com

Corresponding author: Duah Dwomoh: duahdwomoh@yahoo.com

Word count

Abstract: 289

Manuscript: 3825

Abstract

Objective Despite the huge financial investment in the Free Maternal Healthcare Policy (FMHCP) by the governments of Ghana and Burkina Faso, no study has quantified the impact of FMHCP on the relative reduction in neonatal and infant mortality rates using a more rigorous matching procedure with the difference in differences analysis. This study used several rounds of publicly available population-based complex survey data to determine the impact of FMHCP on neonatal and infant mortality rates in these two countries.

Design A quasi-experimental study to evaluate the free maternal healthcare policy implemented in Burkina Faso and Ghana between 2007 and 2014.

Setting Demographic and health surveys and maternal health survey conducted between 2000 and 2014 for Ghana, Burkina Faso, Nigeria, and Zambia.

Participants: Children born in the five years preceding the survey for Ghana, Burkina Faso, Nigeria, and Zambia**.**

Primary outcome measures Neonatal and infant mortality rates

Results The Kernel based propensity score matching coupled with difference in differences (DID) analysis with Modified Poisson showed that the FMHCP was associated with a 45% reduction in the risk of Neonatal Mortality Rate (NMR) in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76, p<0.001). In addition, Infant Mortality Rate (IMR) has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001).

Conclusions The FMHCP have a significant impact and still remains relevant in achieving Sustainable Development Goal 3 and could provide lessons for other sub-Saharan countries in the design and implementation of a similar policy.

Keywords

Neonatal Mortality, Infant mortality, Kernel weighting, and Propensity Score Matching, Free Maternal Healthcare Policy.

Word count
Abstract: 274
Main Manuscript: 4975

Strengths and limitations of this study

- The use of more rigorous Kernel based propensity score matching coupled with difference in differences (DID) analysis with Modified Poisson improves the robustness of the impact estimate.
- The study provides evidence that the implementation of free maternal healthcare policy (FMHCP) is associated with a significant reduction in the risk of neonatal and infant deaths in the two intervention countries.
- Evidence from this study can be used to inform policy decisions about the implementation of FMHCP in other sub-Saharan Africa countries.
- Since the data for the study originate from a complex survey (non-experimental design), our study could not control for several other confounding factors, hence, we cannot interpret these results as causal.

Introduction

Access to primary health care services remains low in many low- middle- income countries (LMIC). According to the World Health Organization report 2017, approximately half of the world population lacks access to essential health services and it is estimated that over 100 million still pushed into extreme poverty because of out of pocket health expenditure. Peters and colleagues [1] as well as Jacobs and colleagues [2] have classified these factors into four main dimensions, namely geographical access, financial access, availability of health care, and acceptability of health care service. Delay or lack of access to health care services due to financial constraints can affect child survival. Following the Abuja declaration for sub-Saharan African countries to spend 15% of its public spending on health care at the turn of the century, Ghana in 2003 set up a National Health Insurance Scheme (NHIS) as a way of improving UHC[3]. In September 2003, a policy exempting women in its four poorest regions of Ghana from delivery care fees was introduced by the Government of Ghana in an attempt to increase skilled birth attendance and reduce inequality in use of healthcare services [4]. The policy was rolled out in all the 10 regions by the end of April 2005 but with serious challenges. Notable among them was the fact that the disbursement of funds to accredited health facilities was not forthcoming and by October 2005 some health facilities started to charge clients again [4]. In July 2008, the government of Ghana through the National Health Insurance Scheme (NHIS) implemented a national user fee maternal care exemption policy to improve financial access to maternal health services and reduce maternal, perinatal, neonatal and infant mortality rates. The policy was popularly referred to as the free maternal healthcare policy (FMHCP). The main aim of the policy was to address financial barriers to demand health care services.

Burkina Faso is one of the countries in Sub-Saharan Africa (SSA) that failed to achieve the target for MDG goal number 5 (reduction of maternal mortality by 75% between 1990 and 2015) [5]. That notwithstanding, tremendous efforts have been made by Burkina Faso towards ensuring equitable access to maternal care services. For instance, maternal health financing and delivery reforms were developed and implemented, among which are the abolition of user fees for antenatal care (ANC) services in 2002, subsidization of delivery costs for all women by 80% and by 100% for the poorest in 2007 and exemption of the poorest from payment of all user fees for all curative and preventive health services in 2009 [6 7]. In this article, we refer to the policy implemented in Burkina Faso as FMHCP for easy reference to countries that have implemented the intervention.

Nigeria, for instance, did not have a clear federal policy on user fees in maternal and child health, and the regional variation at the primary and secondary level is vast [8]. Although Zambia removed user fees in 2006 in rural areas only [9 10], they had not been implemented properly and no impact had been seen in the following year or two [11]. That notwithstanding, fees are still payable (by cash) in urban areas and financial constraints still remains a significant barrier to institutional delivery [11]. The impact of these policies, particularly on access to health services and neonatal mortality has not been evaluated using rigorous methods, and so the empirical basis for defending these policies is weak [12]. To determine the effectiveness of FMHCP in contributing to a reduction in the mortality rate relative to countries that do not have such policy, Kernel based propensity score matching with the difference in differences analysis was applied. Using quasi experimental design, the goal of this study is to determine whether the full implementation of FMHCP in Ghana and Burkina Faso contributed to the relative reduction in neonatal and infant mortality rates between 2008 and 2014 compared to Nigeria and Zambia without such significant national health financing policy on maternal healthcare.

Methods and analyses

Data sources

The data used in this study were obtained from 11 separate Demographic and Health Surveys (DHS) and one Malaria Indicator Surveys (MIS). The DHS and MIS are a nationally representative cross-sectional survey that includes common questions about a year of birth and survival status of all births to women of reproductive age (15-49 years). The DHS and MIS datasets are freely available and could be downloaded at the DHS website (http://dhsprogram.com) after completing the online data request registration form. With the exception of Burkina Faso that could not provide DHS but MIS data for 2014, each country contributed 3 different DHS datasets that were conducted between 2000 and 2014. That is, we utilized the pre-baseline data from 2001/2003-2007/2008; baseline data: 2007/2008 and end-line data: 2013/2014. The unit of analysis in this study is the children of women born in 5 years (0-59 months) preceding the survey. Detailed distribution about number of live births in the five years preceding the survey, number of women age 15-49 interviewed, total number of women age 15-49 in the country at the time of the survey, year of survey and survey response rate for eligible women, NMR and IMR per 1000 live births, and cumulative incidence rate per 1000 person years at risk can be found in Table A of S1 Appendix.

Patients and public involvement

Patients and the public were not involved.

Primary outcome measures

The primary outcomes of interest were infant mortality (IMR) and the neonatal mortality rate (NMR). In this analysis, the Infant mortality rate (IMR) is defined as the probability of dying

between birth and first birthday whereas neonatal mortality rate (NMR) is defined as the probability of dying between birth and the first month of life [13]. All deaths that were recoded within the first 28 days after birth were coded as 1 or otherwise 0 in defining a binary indicator variable for neonatal mortality. For infant mortality, deaths within one year after birth in the five years preceding each survey were coded as 1 otherwise 0 to define a binary indicator for infant mortality.

Exposure to free maternal healthcare policy

Countries that have abolished at least 80% of user fee for institutional delivery in Sub-Saharan Africa between the periods of 2007-2014 and have readily available DHS or MIS data were included in the study as intervention countries. That notwithstanding, these countries should have conducted DHS between the periods of 2000-2008. This was necessary to test the parallel trend assumption which is a requirement for the validity of DID design and its estimate. There were only two countries that implemented user fee reforms for maternal healthcare between 2007 and 2008. Ghana and Burkina Faso met these inclusion criteria and therefore qualified as intervention countries. Although Zambia and Nigeria conducted DHS between 2000 and 2014, both countries did not have a universal exemption on user fees for institutional births during the study period and therefore qualified to be used in the comparison groups. A similar study based on quasi-experimental design has provided detail explanation as to why Zambia, Cameroon, and Nigeria could represent a valid comparison group compared to other countries in SSA in evaluating the impact of free maternal healthcare policy on intermediate and long term health outcomes [11]. Cameroon was excluded as comparison country in this study because there was no survey conducted in 2007/2008 which represents the full policy implementation year.

Covariates included in the matching procedure

The choice of the selected covariates in assessing risk factors of child survival was based on the analytical framework for the study of child survival in developing countries by Mosley and Chen

[14]. Specifically, we extracted data and performed the matching on the following variables: household ownership of bednets, child's age and gender, mother's age at the time of the survey, mother's education level, household wealth, sex of the household head, and whether the household was in the urban or rural area, birth order, multiple births and household size, household access to improved water and sanitation. We defined a household as having access to an improved water source if it has any of the following: piped water into the dwelling, yard, or plot; public tap or standpipe, tube-well, or borehole; a protected dug well or protected spring; rainwater; or bottled water. There is a direct correlation between access to an improved water source and infant survival [15]. This analysis defines a household as having an improved sanitation if it has any of the following types of toilet facilities, and if this facility is not shared with another household: a flush or pour flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit latrine; a pit latrine with a slab; or a composting toilet. There is an inverse relationship between access to improved sanitation and infant mortality. Increasing access to improved sanitation is associated with lower levels of infant mortality [15].

Statistical analyses based on DHS and MIS datasets

Since the study pooled data from different surveys, the women standard weights were de-normalized. This was achieved by dividing the women standard weight by the women survey sampling fraction, that is, the ratio of a total number of women aged 15-49 interviewed in the survey year over the total number of women aged 15-49 years in the country at the time of the survey. The total number of women aged 15-49 interviewed in the survey year was obtained from the DHS datasets, while the total number of women aged 15-49 years in the country at the time of the survey were obtained from our world in data (https://ourworldindata.org/). Complex survey design characteristics (weighting, stratification, and clustering) were adjusted in all the analysis. In particular, we used the sampling weights in the estimation of the propensity score model and also used the sampling weight times the Kernel weight obtained from the repeated

cross-section as the weight variable in the final outcome analysis. This analytic technique has been shown to produce unbiased treatment effect estimates that are generalizable to the original survey target population [16]. The Kernel function used in the weight estimation was Epanechnikov and the bandwidth selection was based on cross-validation of the means of covariates [17].

To determine the impact of the policy on NMR and IMR, we performed Kernel based propensity score matching with difference-in-differences (DID) analysis using a modified Poisson regression model with robust standard errors. The data for the study originates from multi-stage complex surveys and to assess the impact of the intervention, there is the need to replicate random assignment. In experimental study design with random assignment, treatment groups (countries with FMHCP) and control groups (countries with no such policy) are similar on all background characteristics (observed and unobserved) as a consequence of the randomization, allowing for straightforward comparison of outcomes. In contrast, in complex surveys, the intervention and comparison individuals may differ significantly on background characteristics. Thus, any difference in outcomes (neonatal and infant mortality rate) between the two groups may be due to these background covariates or to the intervention itself. Matching procedures, followed by regression adjustment on the matched sample, can often be a stronger approach for estimating causal effects than is regression on an unmatched sample [18].

The DID design is a known quasi-experimental method that is used frequently in policy evaluations to compare changes over time in a group unaffected by the policy intervention (comparison countries) to the changes over time in a group affected by the policy intervention (intervention countries) and attributes the "difference-in-differences" to the effect of the policy [19]. Several sensitivity analyses were conducted to determine the robustness of our results. We tested whether the policy impact estimate is robust to the type of model specification using logit, probit, and Cox proportional hazard models with robust standard errors. For the Cox model, the time-to-death with survival status as censoring indicator was modelled. Finally, we tested

whether the impact estimate is robust to different matching procedures. The DID design relies on the parallel trend assumption. This assumption states that in the absence of the intervention (free maternal healthcare policy), there would be no statistically significant difference in the trend of NMR and IMR between the intervention and the comparison countries. We relied on DHS data conducted between the year 2000 and 2008 to test this assumption. P-values less than 0.05 were considered as statistically significant. Data cleaning and analysis were conducted using Stata version 15 (StataCorp, College Station, Texas, USA).

Results

Results using data from 2007 to 2014 showed that approximately 9.2% [95% CI: 8.9-9.5] of the 110,748 children in our sample died before reaching age 5. Within the same period, there was a statistically significant difference in the proportion of deaths between countries with FMHCP and those with no such policy (FMHCP=6.2% [95% CI: 5.9-6.6]; no FMHCP=9.8% [95% CI: 9.5-10.1], Rao-Scot Chi-square test=159.6; p<0.001, Table 1). The proportion of infant deaths was 6.7% [95% CI: 6.5-7.0]. Among countries with FMHCP, the proportion of infant deaths was approximately 4.0% [95% CI: 3.6-4.3] compared countries with no FMHCP where infant deaths were 7.3% [95% CI: 7.1-7.6] and the difference was statistically significant (Rao-Scot Chi-square test=168.4; p<0.001, Table 1). The overall proportion of neonatal deaths was 3.5% [95% CI: 3.3-3.6]. FMHCP countries recorded 0.4% [95% CI: 0.3-0.4] neonatal deaths compared to 3.1% [95% CI: 2.9-3.3] recorded by countries with no FMHCP (Rao-Scot Chi-square test=76.7, p<0.001).

Table 1: Trend of neonatal and infant mortality between countries with and without FMHCP and description of the study participants: 2007/2008-2013/2014.

	Total %	Intervention: FMHCP implementation		Rao-Scot Chi-square
		No FMHP %[b]	FMHP %[b]	
All-cause mortality in the five years preceding the survey [95% CI]	9.2 [8.9-9.5]	9.8 [9.5-10.1]	6.2 [5.9-6.6]	159.60***
All-cause neonatal deaths in the five years preceding the survey [95% CI]	3.5 [3.3-3.6]	3.1 [2.9-3.3]	0.4 [0.3-0.4]	76.70***
All-cause infants deaths in the five years preceding the survey [95% CI]	6.7 [6.5-7.0]	7.3 [7.1-7.6]	4.0 [3.6-4.3]	168.40***
Sex of household head				114.03***
Male	97430 (88.4)	70247 (83.4)	27183 (16.6)	
Female	13318 (11.6)	9740 (74.3)	3578 (25.7)	
Wealth quintile				2.00
Poorest	26597 (23.3)	19264 (82.9)	7333 (17.1)	
Poorer	25526 (22.7)	18862 (83.3)	6664 (16.7)	
Middle	22913 (19.4)	16412 (81.4)	6501 (18.6)	
Richer	20303 (18.2)	14198 (80.7)	6105 (19.3)	
Richest	15409 (16.5)	11251 (82.9)	4158 (17.1)	
Household size				20.26***
1-4	26784 (25.8)	19215 (79.8)	7569 (20.2)	
5-7	45709 (41.5)	33951 (82.9)	11758 (17.1)	
8+	38255 (32.8)	26821 (83.5)	11434 (16.5)	
Access to improved water				121.32***
Improved	89000 (80.4)	61284 (80.1)	28049 (19.9)	
Unimproved	21000 (19.6)	18676 (91.4)	2711 (8.6)	
Missing	28 (0.01)	27 (98.4)	1 (1.6)	
Access to an improved toilet facility				195.72***
Improved, not shared	26000 (27.0)	22493 (91.7)	3817 (8.3)	
Improved, shared	21000 (22.5)	13047 (71.0)	7762 (29.0)	
Unimproved	63000 (50.1)	44120 (82.4)	19095 (17.6)	
Missing	414 (0.4)	327 (81.2)	87 (18.8)	
Place of residence				0.61
Urban	32627 (32.2)	25035 (82.9)	7592 (17.1)	
Rural	78121 (67.8)	54952 (82.0)	23169 (18.0)	
Household ownership of bednet				1013.52***
No bednet	43000 (46.4)	36880 (92.4)	6015 (7.6)	
Bednet	68000 (53.6)	43062 (73.6)	24746 (26.5)	
Missing	45 (0.06)	45 (100.0)	0 (0.0)	
Mothers current age				11.10***
<18 years	3558 (3.3)	2803 (86.5)	755 (13.5)	
18-34 years	80000 (71.5)	58000 (82.3)	22000 (17.7)	
35+	27000 (25.2)	20000(81.8)	7727 (18.2)	
Mothers education				44.98***
None	53000 (46.5)	32000 (79.4)	21000 (20.6)	
Primary	29000 (23.2)	24000 (86.6)	4475 (13.4)	
JHS	25000 (25.5)	20000 (81.7)	4686 (18.3)	
Secondary or higher	4241 (4.8)	3882 (92.4)	359 (7.6)	
Missing	16 (0.01)	11 (64.6)	5 (35.4)	
Birth order				271.39***
1st birth	24000 (21.1)	16000 (75.8)	8167 (24.2)	
2nd births	21000 (18.9)	14000 (76.1)	7351 (23.9)	
3rd births	17000 (15.2)	12000 (83.1)	4386 (16.9)	
4th births	49000 (44.8)	38000 (87.7)	11000 (12.3)	
Multiple births				10.19**
Single	110000 (96.4)	77000 (82.4)	30000 (17.6)	
Multiple	3994 (3.6)	2750 (79.1)	1244 (20.9)	

Child mortality estimate per country

Country	Year of survey	NMR per 1000 live births	IMR per 1000 live births	Cumulative incidence rate per 1000 person years at risk
Burkina Faso	2003	31	81	67.9 [61.9-74.6]
	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
Ghana	2003	43	64	30.0 [24.2-37.7]
	2008	30	50	28.5 [22.5-36.8]
	2014	29	41	15.1 [11.9-19.4]
Nigeria	2003	48	100	63.2 [55.6-72.1]
	2008	40	75	50.6 [47.7-53.7]
	2013	37	69	36.8 [34.3-39.6]
Zambia	2001-2002	37	95	70.5 [63.8-78.2]
	2007	34	70	44.7 [39.1-51.4]
	2014	24	45	26.5 [23.2-30.5]

Abbreviations: FMHP – Free maternal health policy; NMR: Neonatal mortality rate, IMR: Infant mortality rate. P-value notation: ***p<0.001, **p<0.01, *p<0.05. **%[b]** represents row percentages. Note: access to improved toilet facility had a missing observation of 0.4%.

NMR and IMR per 1000 live births decline between 2008 and 2014 in both FMHCP and non-FMHCP countries but the decline was steeper at all times in the FMHCP countries at various time points (Figure 1).

Figure 1: Kaplan Meier survival estimate (KMSE) at varying time points of free maternal healthcare policy implementation (FMHCP). Abbreviations: BF: Burkina Faso, GHA: Ghana, NIG: Nigeria, ZAM: Zambia

Results on balancing and common support diagnostics of the Kernel based matching

Balancing test based on standardized mean difference and ratio of variances of the observed covariates between the two sets of countries (FMHCP and non-FMHCP) were conducted before and after Kernel based matching. This was done to ascertain how the matching procedure has reduced biases in the means and variances of the observed covariates between FMHCP countries and non-FMHCP countries. The mean difference in the observed covariate between FMHCP countries and non-FMHCP reduced significantly after matching making the two groups as similar as possible (Table B in S1 Appendix). The ratio of variances in the covariate between the two sets countries was closer to 1 after matching than before matching (Table C in S1 Appendix). The results showed that the Kernel based propensity score matching reduced covariate imbalance between countries with and without FMHCP. The results from the Kernel density, cumulative distribution and the box-whisker plots in figure 2 showed that matching has made FMHCP and non-FMHCP countries more similar in terms of the observed covariates, hence any change in the risk of neonatal and infant deaths could be attributed to FMHCP.

Figure 2: Balancing the diagnostic test of the Kernel based propensity score matching

Results on the test of the parallel trend assumption

The test of parallel trends showed that, after controlling for baseline country characteristics, maternal, child and household characteristics including household ownership of bednet, both infant and neonatal mortality rate rates did not differ between countries with FMHCP and those with no FMHCP before the implementation of FMHCP (NMR: aRR=0.91, 95% CI 0.71-1.16; p>0.05; Table 2). Mortality rates were declining in all of the study countries during this time period (NMR: aRR=0.88, 95% CI: 0.75-1.02; IMR: aRR=0.84, 95% CI: 0.76-0.94, p<0.05, Table 2), but there was no evidence of trends being different between countries that have implemented FMHCP and comparison countries. In conclusion, the parallel trend assumption was not violated and therefore estimates from DID analyses were valid.

Table 2: Test of parallel trends assumption: Risk of neonatal and infant mortality prior to free maternal healthcare policy implementation (2001-2008): Modified Poisson model with robust standard error on the unmatched sample.

	Neonatal mortality: 2000-2008		Infant mortality: 2000-2008	
Covariates	**uRR [95% CI]**	**aRR [95% CI]**	**uRR [95% CI]**	**aRR [95% CI]**
Time Baseline: 2008	ref	ref	ref	ref
End-line: 2014	0.86* [0.75-0.99]	0.88 [0.75-1.02]	0.83*** [0.76-0.91]	0.84** [0.76-0.94]
Intervention				
No FMHP	ref	ref		ref
FMHP-assumed it exited	0.85 [0.72-1.01]	0.89 [0.71-1.11]	0.94 [0.84-1.05]	0.92 [0.79-1.07]
Time*FMHP	0.92 [0.74-1.15]	0.91 [0.71-1.16]	0.93 [0.81-1.08]	0.91 [0.78-1.08]
Sex of household head				
Male		ref		ref
Female		0.90 [0.73-1.11]		0.89 [0.76-1.03]
Mothers current age				
<18 years		ref		ref
18-34 years		0.90 [0.78-1.03]		0.91 [0.82-1.00]
35+		2.33* [1.02-5.30]		2.40* [1.10-5.26]
Place of residence				
Urban		ref		ref
Rural		1.35*** [1.14-1.60]		1.29*** [1.14-1.45]
Household size				
1-4		ref		ref
5-7		0.48*** [0.40-0.57]		0.49*** [0.43-0.55]
8+		0.43*** [0.35-0.52]		0.43*** [0.37-0.49]
Access to improved water				
Improved		ref		ref
Unimproved		1.08 [0.92-1.27]		1.13* [1.01-1.26]
Access to an improved toilet facility				
Improved, not shared		ref		ref
Improved, shared		0.81* [0.66-0.98]		0.76*** [0.66-0.87]
Unimproved		0.85 [0.72-1.01]		0.86* [0.77-0.97]
Mothers education				
None		ref		ref
Primary		1.01 [0.84-1.2]		0.94 [0.83-1.06]
JHS		0.84 [0.69-1.02]		0.73*** [0.63-0.83]
Secondary or higher		0.93 [0.59-1.44]		0.55** [0.39-0.78]
Birth order				
1st birth		ref		ref
2nd births		0.70** [0.57-0.86]		0.83* [0.71-0.98]
3rd births		0.71** [0.55-0.9]		0.99 [0.84-1.17]
4th births		1.03 [0.84-1.26]		1.20* [1.04-1.39]
Multiple births				
Single		ref		ref
Multiple		5.31*** [4.26-6.62]		3.70*** [3.11-4.40]
Household ownership of bednet				
No bednet		ref		ref
Bednet		0.91 [0.78-1.05]		0.95 [0.86-1.05]
Country Fixed Effect	Yes	Yes	Yes	Yes

Abbreviations: FMHP; Free maternal healthcare policy, aRR: Adjusted Relative Risk, uRR: Unadjusted Relative Risk, P-value notations: ***p<0.001, **p<0.01, *p<0.05. Note: With respect to Burkina Faso, 2010 demographic health survey data was used since they did not conduct any survey in 2008.

Impact of FMHCP on the risk of neonatal deaths

The results from the modified Poisson with DID using Kernel based matching showed that FMHCP is associated with 45% reduction in the risk of NMR in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76, p<0.001, Table 3). Sensitivity analyses based on different outcome model specification showed similar results (Table 3).

Table 3: Impact of the free maternal healthcare policy on neonatal mortality: Kernel based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error.

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel weighting	With Kernel weighting based on PSM	With Kernel weighting based on PSM	With Kernel weighting based on PSM	With Kernel weighting based on PSM	ATET weighting and PSM- IPTW	ATE weighting and PSM-
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.92[0.82, 1.03]	0.63*[0.42, 0.96]	0.62*[0.42, 0.91]	0.59[0.33, 1.07]	-0.35*[-0.69, -0.01]	-3.41**[0.46, 0.81]	0.67**[0.51, 0.86]
Intervention							
No FMHP	ref	ref	ref	ref	ref	ref	ref
FMHP	0.66***[0.53, 0.83]	0.94[0.74, 1.19]	0.96[0.77, 1.19]	0.95[0.62, 1.47]	-0.04[-0.28, 0.2]	-0.81[0.78, 1.11]	0.93[0.82, 1.07]
Time*FMHP	**0.56***[0.43, 0.73]**	**0.55***[0.40, 0.76]**	**0.55***[0.40, 0.74]**	**0.44*[0.22, 0.88]**	**-0.41*[-0.79, -0.02]**	**0.57***[0.42, 0.77]**	**0.71[0.46, 1.08]**
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.85*[0.73, 0.99]	0.73*[0.55, 0.97]	0.81[0.63, 1.04]	1.08[0.67, 1.74]	0.02[-0.24, 0.29]	-1.99*[0.65, 1]	0.78*[0.63, 0.95]
Mothers current age							
<18 years	ref	ref	ref	ref	ref	ref	ref
18-34 years	0.43***[0.35, 0.54]	0.51**[0.35, 0.75]	1.01[0.71, 1.43]	2.69**[1.4, 5.18]	0.59**[0.21, 0.98]	3.99***[0.39, 0.72]	0.53***[0.39, 0.71]
35+	0.46***[0.36, 0.59]	0.55**[0.35, 0.86]	1.29[0.85, 1.95]	6.7***[3.12, 14.38]	1.11***[0.67, 1.56]	-3.17**[0.39, 0.8]	0.5***[0.35, 0.72]
Place of residence							
Urban	ref	ref	ref	ref	ref	ref	ref
Rural	1.24**[1.08, 1.42]	1.23[0.87, 1.74]	1.2[0.88, 1.64]	1.04[0.65, 1.65]	0.05[-0.22, 0.32]	1.94[1, 1.6]	1.21[0.84, 1.74]
Wealth quintile							
Poorest	ref	ref	ref	ref	ref	ref	ref
Poorer	1.01[0.89, 1.15]	1.04[0.86, 1.27]	1.03[0.86, 1.24]	0.81[0.53, 1.23]	-0.1[-0.34, 0.14]	0.72[0.89, 1.28]	0.98[0.79, 1.22]
Middle	0.86[0.74, 1.01]	0.93[0.73, 1.18]	0.96[0.77, 1.19]	0.93[0.56, 1.54]	-0.03[-0.32, 0.27]	0.2[0.82, 1.27]	0.89[0.69, 1.16]
Richer	0.91[0.75, 1.1]	0.83[0.61, 1.13]	0.87[0.65, 1.16]	0.88[0.43, 1.79]	-0.06[-0.47, 0.34]	-0.64[0.7, 1.2]	0.86[0.61, 1.2]
Richest	0.86[0.68, 1.11]	0.95[0.56, 1.61]	1.01[0.62, 1.62]	1.04[0.46, 2.34]	0.05[-0.41, 0.52]	-0.87[0.6, 1.22]	0.88[0.55, 1.42]
Household size							
1-4	ref	ref	ref	ref	ref	ref	ref
5-7	0.42***[0.37, 0.49]	0.46***[0.38, 0.56]	0.55***[0.45, 0.65]	0.49**[0.31, 0.78]	-0.41**[-0.67, -0.15]	8.18***[0.38, 0.55]	0.42***[0.34, 0.51]
8+	0.35***[0.3, 0.4]	0.41***[0.33, 0.52]	0.48***[0.39, 0.59]	0.33***[0.22, 0.49]	-0.64***[-0.87, -0.41]	8.67***[0.32, 0.49]	0.38***[0.31, 0.46]
Access to improved water							
Improved	ref	ref	ref	ref	ref	ref	ref
Unimproved	1.06[0.93, 1.21]	1.06[0.87, 1.3]	1.06[0.89, 1.27]	1.28[0.88, 1.88]	0.15[-0.07, 0.36]	0.02[0.82, 1.22]	1.02[0.82, 1.28]
Access to improved toilet facility							
Improved, not shared	ref	ref	ref	ref	ref	ref	ref
Improved, shared	0.84*[0.72, 0.97]	0.97[0.78, 1.22]	0.97[0.79, 1.18]	1.08[0.72, 1.63]	0.04[-0.20, 0.28]	-0.43[0.78, 1.17]	0.90[0.70, 1.16]
Unimproved	0.84**[0.75, 0.94]	0.92[0.76, 1.11]	0.92[0.78, 1.10]	1.10[0.76, 1.59]	0.05[-0.15, 0.26]	-1.00[0.77, 1.09]	0.86[0.72, 1.04]
Mothers education							
None	ref	ref	ref	ref	ref	ref	ref
Primary	1.05[0.93, 1.20]	0.98[0.78, 1.23]	0.97[0.78, 1.20]	0.78[0.52, 1.18]	-0.14[-0.38, 0.10]	-0.80[0.76, 1.12]	0.99[0.79, 1.25]
JHS	0.94[0.80, 1.10]	0.93[0.69, 1.25]	0.86[0.65, 1.13]	0.62[0.35, 1.10]	-0.25[-0.57, 0.06]	-1.01[0.72, 1.11]	0.96[0.80, 1.16]
Secondary or higher	0.75[0.55, 1.03]	0.81[0.46, 1.41]	0.71[0.42, 1.21]	0.20***[0.08, 0.47]	-0.92***[-1.44, -0.41]	-1.37[0.45, 1.15]	0.79[0.43, 1.46]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	0.94[0.82, 1.09]	0.69**[0.54, 0.89]	0.62***[0.49, 0.77]	0.52*[0.30, 0.89]	-0.38*[-0.67, -0.08]	-2.89**[0.61, 0.91]	0.74*[0.59, 0.93]
3rd births	0.98[0.82, 1.18]	0.89[0.66, 1.2]	0.73*[0.56, 0.97]	0.60[0.34, 1.07]	-0.29[-0.61, 0.03]	-0.24[0.75, 1.25]	0.88[0.67, 1.15]
4th births	1.32**[1.12, 1.56]	1.18[0.90, 1.56]	0.87[0.67, 1.12]	0.46**[0.26, 0.81]	-0.44**[-0.76, -0.12]	2.21*[1.03, 1.58]	1.29*[1.00, 1.65]
Multiple births							
Single							
Multiple	5.84***[4.97, 6.86]	5.58***[4.25, 7.32]	4.73***[3.78, 5.92]	6.17***[2.47, 15.41]	0.96***[0.52, 1.4]	15.61***[4.74, 7.41]	5.58***[4.37, 7.12]
Household ownership of bednet							
No bednet							
Bednet	0.98[0.88, 1.09]	0.96[0.82, 1.12]	0.96[0.83, 1.11]	1.01[0.74, 1.37]	0.01[-0.16, 0.19]	-1.04[0.79, 1.07]	0.93[0.78, 1.1]
Country Fixed Effect	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**

Abbreviations: FMHP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, ref: reference category, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Impact of FMHCP on the risk of infant deaths

IMR has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001; Table 4). Series of sensitivity analysis that was conducted showed a similar impact of FMHCP (Table 4). The analysis adjusted for sex of the household head, mother's current age, mother's educational level, place of residence, wealth quintile, access to improved water and sanitation, birth order, multiple births and household ownership of bednet and country fixed-effect.

Table 4: Impact of the free maternal healthcare policy on infant mortality: Kernel based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel weighting and PSM	With Kernel weighting and PSM	With Kernel weighting and PSM	With Kernel weighting and PSM	With Kernel weighting and PSM	ATET weighting and PSM- IPTW	ATE weighting and PSM-
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.79***[0.73, 0.86]	0.62***[0.48, 0.8]	0.62***[0.49, 0.78]	0.45***[0.35, 0.58]	-0.45***[-0.59, -0.32]	0.64***[0.53, 0.78]	0.77**[0.64, 0.91]
Intervention							
No FMHCP	ref	ref	ref	ref	ref	ref	ref
FMHCP	0.72***[0.62, 0.84]	0.87[0.74, 1.03]	0.89[0.77, 1.04]	0.86[0.72, 1.02]	-0.09[-0.19, 0.01]	0.84*[0.74, 0.96]	0.83***[0.76, 0.92]
Time*FMHCP	0.49***[0.39, 0.61]	0.46***[0.36, 0.59]	0.45***[0.35, 0.57]	0.43***[0.33, 0.56]	-0.49***[-0.64, -0.34]	0.48***[0.37, 0.6]	0.55**[0.39, 0.77]
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.88*[0.78, 0.98]	0.75**[0.61, 0.92]	0.81*[0.68, 0.98]	0.96[0.79, 1.17]	-0.02[-0.13, 0.09]	0.87[0.74, 1.02]	0.88[0.75, 1.02]
Mothers current age							
<18 years	ref	ref	Ref	ref	ref	ref	ref
18-34 years	0.49***[0.41, 0.58]	0.49***[0.37, 0.66]	0.86[0.65, 1.14]	3.1***[2.2, 4.38]	0.63***[0.44, 0.81]	0.49***[0.38, 0.63]	0.59***[0.46, 0.75]
35+	0.49***[0.4, 0.59]	0.47***[0.33, 0.66]	0.95[0.69, 1.31]	5.74***[3.92, 8.4]	0.96***[0.75, 1.17]	0.46***[0.35, 0.61]	0.52***[0.39, 0.68]
Place of residence							
Urban	ref	ref	Ref	ref	ref	ref	ref
Rural	1.16**[1.05, 1.29]	1.2[0.96, 1.5]	1.19[0.97, 1.46]	1.18[0.96, 1.45]	0.09[-0.03, 0.2]	1.14[0.96, 1.36]	1.13[0.89, 1.45]
Wealth quintile							
Poorest	ref	ref	Ref	ref	ref	ref	ref
Poorer	1.02[0.92, 1.12]	1.01[0.87, 1.17]	1[0.87, 1.15]	0.97[0.81, 1.16]	-0.02[-0.12, 0.08]	1.04[0.91, 1.18]	0.99[0.86, 1.15]
Middle	0.88*[0.79, 0.98]	0.92[0.77, 1.11]	0.95[0.8, 1.12]	0.99[0.8, 1.23]	-0.01[-0.13, 0.11]	0.92[0.79, 1.07]	0.93[0.78, 1.11]
Richer	0.86*[0.75, 0.99]	0.91[0.7, 1.19]	0.95[0.74, 1.21]	0.93[0.68, 1.28]	-0.03[-0.2, 0.14]	0.89[0.72, 1.09]	0.8*[0.64, 1]
Richest	0.69***[0.57, 0.82]	0.78[0.54, 1.12]	0.81[0.58, 1.13]	0.8[0.57, 1.11]	-0.14[-0.32, 0.05]	0.68**[0.52, 0.89]	0.73[0.5, 1.06]
Household size							
1-4	ref	ref	Ref	ref	ref	ref	ref
5-7	0.43***[0.39, 0.47]	0.45***[0.38, 0.52]	0.52***[0.45, 0.59]	0.54***[0.45, 0.65]	-0.34***[-0.44, -0.24]	0.46***[0.4, 0.52]	0.43***[0.37, 0.5]
8+	0.35***[0.32, 0.39]	0.4***[0.34, 0.48]	0.46***[0.39, 0.54]	0.43***[0.35, 0.52]	-0.45***[-0.55, -0.34]	0.42***[0.36, 0.49]	0.38***[0.33, 0.45]
Access to improved water							
Improved	ref	ref	Ref	ref	ref	ref	ref
Unimproved	1.05[0.96, 1.16]	1.03[0.89, 1.19]	1.02[0.89, 1.17]	1.02[0.88, 1.17]	0[-0.07, 0.08]	0.99[0.86, 1.15]	1.05[0.9, 1.22]
Access to improved toilet facility							
Improved, not shared	ref	ref	Ref	ref	ref	ref	ref
Improved, shared	0.87*[0.78, 0.97]	0.94[0.79, 1.1]	0.94[0.81, 1.09]	0.82*[0.69, 0.97]	-0.11*[-0.2, -0.01]	0.97[0.83, 1.13]	0.94[0.78, 1.13]
Unimproved	0.88**[0.81, 0.96]	0.92[0.8, 1.05]	0.93[0.82, 1.05]	0.88[0.75, 1.02]	-0.07[-0.15, 0.02]	0.93[0.82, 1.05]	0.92[0.79, 1.06]
Mothers education							
None	ref	ref	Ref	ref	ref	ref	ref
Primary	0.9*[0.82, 0.99]	0.82*[0.7, 0.97]	0.82**[0.71, 0.95]	0.69***[0.58, 0.83]	-0.21***[-0.31, -0.11]	0.81**[0.71, 0.93]	0.89[0.76, 1.03]
JHS	0.88*[0.78, 0.98]	0.83[0.67, 1.02]	0.77**[0.64, 0.94]	0.54***[0.43, 0.67]	-0.35***[-0.47, -0.24]	0.82*[0.69, 0.97]	0.87[0.73, 1.03]
Secondary or higher	0.7**[0.56, 0.89]	0.78[0.53, 1.17]	0.71[0.48, 1.04]	0.38***[0.24, 0.58]	-0.55***[-0.78, -0.31]	0.78[0.53, 1.14]	0.69[0.43, 1.11]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	1.03[0.93, 1.15]	0.86[0.72, 1.03]	0.77**[0.65, 0.91]	0.6***[0.5, 0.73]	-0.27***[-0.38, -0.17]	0.94[0.82, 1.08]	0.84*[0.71, 1]
3rd births	1.2**[1.05, 1.37]	1.13[0.91, 1.4]	0.96[0.79, 1.17]	0.65***[0.52, 0.81]	-0.24***[-0.36, -0.12]	1.19[1, 1.43]	1.08[0.88, 1.34]
4th births	1.59***[1.42, 1.79]	1.63***[1.34, 1.98]	1.25*[1.05, 1.5]	0.7**[0.56, 0.86]	-0.2**[-0.32, -0.08]	1.66***[1.42, 1.93]	1.51***[1.23, 1.86]
Multiple births							
Single	ref	ref	ref	ref	ref	ref	ref
Multiple	4.37***[3.86, 4.95]	3.95***[3.16, 4.95]	3.57***[2.96, 4.3]	3.59***[2.75, 4.67]	0.72***[0.57, 0.87]	4.24***[3.58, 5.03]	4.43***[3.71, 5.29]
Household ownership of bednet							
No bednet	ref	ref	ref	ref	ref	ref	ref
Bednet	1.06[0.98, 1.14]	0.98[0.88, 1.09]	0.97[0.88, 1.08]	0.99[0.88, 1.12]	-0.01[-0.08, 0.06]	0.96[0.86, 1.06]	0.94[0.85, 1.05]
Country Fixed Effect	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**	**Adjusted**

Abbreviations: FMHCP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Discussion

This study quantified the contribution of FMHCP implementation in Ghana and Burkina Faso in the reduction of neonatal and infant mortality rates. Child mortality within the implementation period in these two countries was compared to mortality in Nigeria and Zambia that do not have a significant major health financing reform in the period under consideration. It remains among the few studies to have compared the effectiveness of FMHCP in the four SSA countries using the more rigorous matching procedure with DID. Our impact evaluation found that the implementation of FMHCP led to a substantial reduction in both neonatal and infant mortality. This finding is consistent with what has been reported previously in the literature based on similar analytic technique [20]. Although all the four countries studied did not attain the MDG 4, Ghana and Burkina Faso have seen a tremendous decline in the trend of neonatal and infant mortality rates over the years. FMHCP was associated with substantial statistically significant reductions in infant and neonatal mortality rates when these estimates were compared between Zambia and Nigeria.

It is estimated that the effective implementation of key maternal and child healthcare interventions could prevent up to 70% of neonatal deaths globally [21 22]. The advantages of increasing access to facility delivery, pre-and postnatal care through FMHCP are well documented in the literature [12 23]. FMHC contributes greatly to increased coverage of routine immunization as women who visit and deliver in recommended health facilities were more likely to benefit from early immunization. The policy also promotes early and accurate diagnosis of childhood illnesses after delivery and within the postpartum period. Education on malaria preventive measures after delivery and the administration of intermittent preventive treatment for pregnancy during antenatal are few of the benefits women derived from the policy. The FMHC is associated with high antenatal care attendance and institutional delivery by skilled

attendants (midwives, nurses, doctors) at the time of delivery which consequently reduced neonatal deaths and to a larger extent infant mortality [24 25]. Increasing access to the skilled birth attendant and emergency obstetric care is accepted as the most crucial intervention for reducing maternal and new-born deaths [26].

Strengths and limitations

This study has several strengths as well as some limitations. The advantages of using DHS as our primary source data have been well documented [27]. Paramount among these several advantages include high response rates, national coverage, high quality interviewer training, standardized data collection procedures across countries and consistent content over time, allowing comparability across populations cross-sectionally and over time. The use of DID models with Kernel based propensity scores weighting is seen as strong non-experimental study design options when randomization is not feasible and provides more robust inference [19].

The limitation of this study originates from the fact that the DID analytic technique is generally less robust than the randomized design even though the study established that the parallel trend assumption was not violated. We highlight the fact that our study could still suffer from the omission of important time-varying unobserved characteristics such as total annual health expenditure could bias our study results if the omitted variables affected Ghana, Burkina Faso, and comparison countries in different ways. The reason is that DID attributes to the FMHCP policy intervention any differences in mortality trends between the Ghana and comparison countries that occur from the time intervention begins (2008). If any other factor is present that affect the difference in trends between the two groups differently, then the estimate from DID could be biased. In particular, health funding sources like the United States President Malaria Initiative (PMI), President's Emergency Plan for AIDS Relief (PEPFAR) and the Global Fund for HIV, Tuberculosis, and malaria are few of the foreign aid that could have an impact on child mortality [28]. For instance, Ghana and Zambia received funding support from PMI in 2008 but

Burkina Faso has never benefitted from PMI and Nigeria only received funding from the PMI in 2011. Three out of the four countries studied continue to benefit from PEPFAR but received the support at different times (Ghana; 2007, Burkina Faso; not at all, Zambia and Nigeria in 2004). Ghana and Zambia still remain the only countries among the countries studied that have had the benefits of United States President Malaria Initiative since 2008 which also coincides with the year in which FMHCP policy became fully operational. The observed differentials among the four countries relative to foreign aid could impact on child mortality differently and bias the results.

With regards to Zambia and Nigeria, these two countries might not have a nationwide FMHCP but it is possible that there may be country specific interventions put in place to curb the menace of child mortality. Even among the intervention countries, there may be other specific interventions that are tailored towards child mortality but were not controlled in the current study. For instance, the "Rapid Scale-Up" program in Burkina Faso has a component that focuses on the integrated community case management and this policy has been found to reduce neonatal mortality by 6.2% [29]. Other interventions such as user fee exemption, mass radio campaign have all been found to be associated with an increase in the healthcare utilization among children under five in Burkina Faso which could have a direct positive impact in reducing neonatal mortality rate [30 31]. In addition to the aforementioned interventions, it is worth emphasizing that both Ghana and Burkina Faso receive support from the Global Fund in the fight against malaria, Tuberculosis and HIV since 2003 and this might have contributed to why Burkina Faso and Ghana might be doing better in terms of reducing infant and neonatal mortality rates. Despite the fact that our impact estimate of the policy may be imprecise and should be interpreted cautiously, we emphasized that the introduction of the FMHCP is associated with the reduction in both neonatal and infant mortality rates which is an encouraging finding and an important contribution to the literature on the colossal benefits of FMHCP. DID still remains one of the

robust quasi-experimental design to evaluate the impact of health intervention using cross-sectional time series data as it was the case in this study.

Policy implications

The findings from the study provide imperative evidence of an accelerated decline in child mortality rates after the introduction of FMHCP in the two West African countries. The additional investments in health tailored towards FMHCP implementation have yielded positive impacts. The implementation of the policy has reduced the financial burden associated with antenatal and postnatal care attendance and institutional delivery. Future studies should explore whether the investments made through FMHCP have spill-over effects beyond the usual benefits associated with the policy, such as women empowerment, higher investment in the private sector, higher school attainment and increase in employment rate which might, in turn, lead to greater economic development. As the population of women keeps increasing geometrically in SSA, Governments should consider an alternative source of financing to sustain the policy.

Conclusion

The motivation of the study is to obtain more reliable evidence of how the implementation of the free maternal healthcare policy (FMHC) in certain countries in the SSA has reduced child mortality compared to countries in the sub region with no such national policy. Our findings highlight the importance of FMHCP implementation in reducing the risk of neonatal and infant mortalities. We recommend that similar policy should be implemented in other lower and middle income SSA countries to reduce the prevalence of neonatal and infants deaths.

Acknowledgments

The authors duly acknowledge the Demographic and Health Survey Program funded by the U.S. Agency for International Development (USAID), other donors and Ghana Statistical Service for making their data available to the public. We do acknowledge all mothers that were interviewed.

Competing Interests

None declared

Author Contributions

DD, KA, PN conceived and designed the study. Data management and data cleaning were done by DD and KA. Statistical methods were drafted by DD and SB. PN, KA, SB, and AEY revised the draft critically. All authors have read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data sharing statement

All data sets are public data.

Patient consent

Not required.

Supporting information

S1 Table A: The summary trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

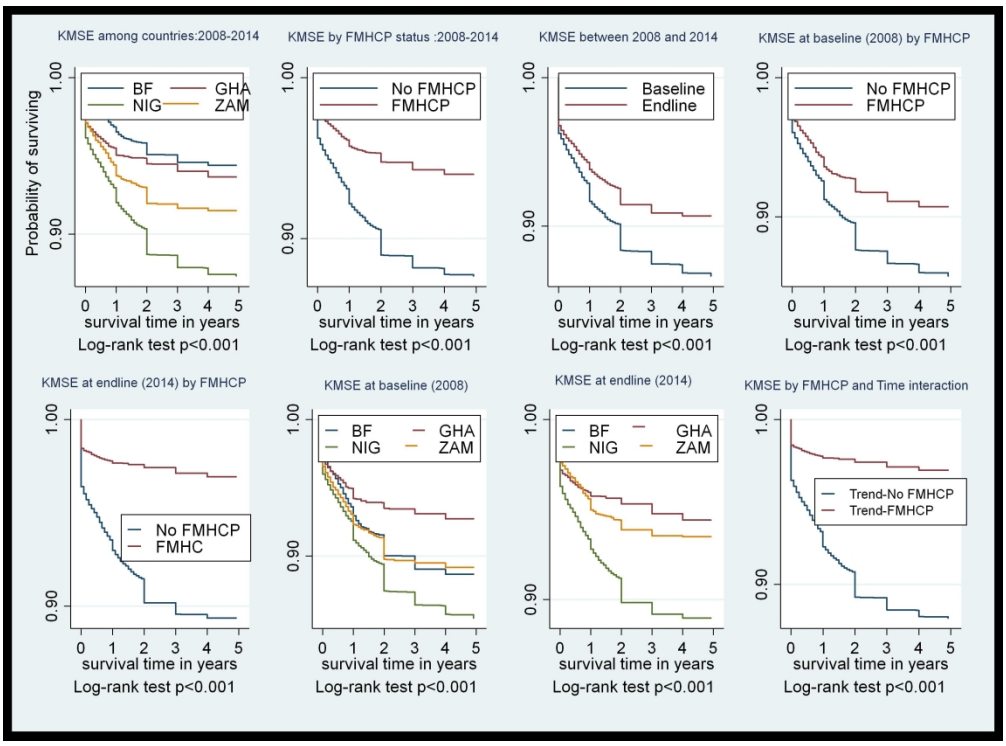
S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMNH and comparison group)

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group)

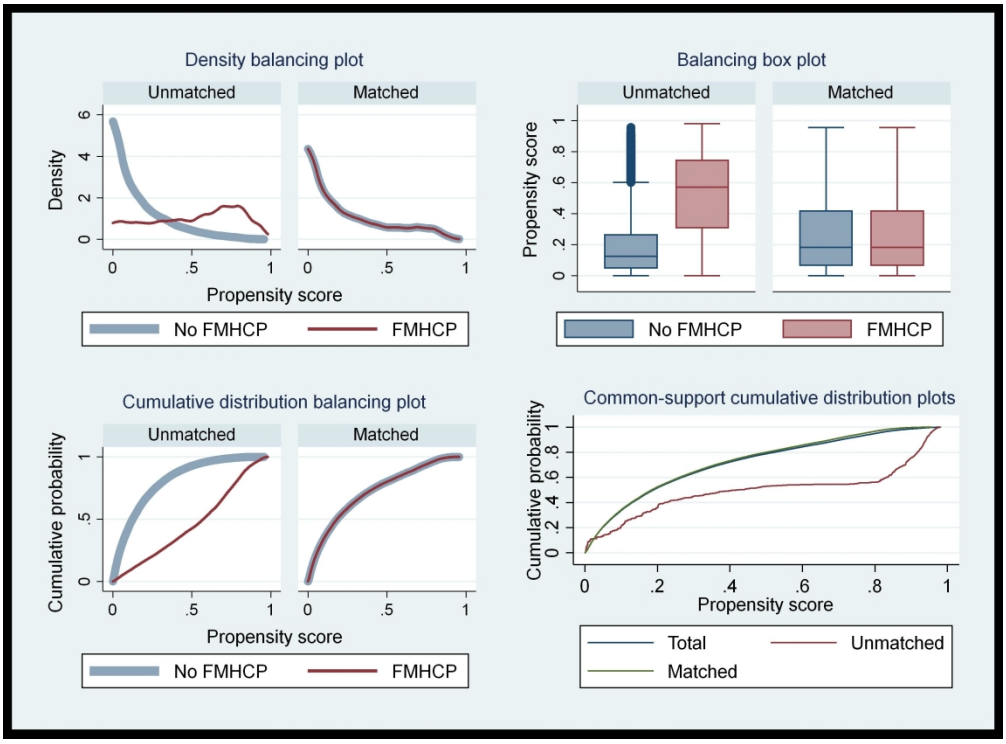
References

1. Peters DH, Garg A, Bloom G, et al. Poverty and access to health care in developing countries. Annals of the New York Academy of Sciences 2008;**1136**(1):161-71
2. Jacobs B, Bigdeli M, Annear PL, et al. Addressing access barriers to health services: an analytical framework for selecting appropriate interventions in low-income Asian countries. Health policy and planning 2011;**27**(4):288-300
3. Wang H, Otoo N, Dsane-Selby L. *Ghana National Health Insurance Scheme: improving financial sustainability based on expenditure review*: The World Bank, 2017.
4. Witter S, Arhinful DK, Kusi A, et al. The experience of Ghana in implementing a user fee exemption policy to provide free delivery care. Reproductive health matters 2007;**15**(30):61-71
5. Organization WH, UNICEF. Trends in maternal mortality: 1990-2015: estimates from WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. 2015
6. Belaid L, Ridde V. An implementation evaluation of a policy aiming to improve financial access to maternal health care in Djibo district, Burkina Faso. BMC pregnancy and childbirth 2012;**12**(1):143
7. Ridde V, Richard F, Bicaba A, et al. The national subsidy for deliveries and emergency obstetric care in Burkina Faso. Health policy and planning 2011;**26**(suppl_2):ii30-ii40
8. Okonofua F, Lambo E, Okeibunor J, et al. Advocacy for free maternal and child health care in Nigeria—results and outcomes. Health policy 2011;**99**(2):131-38
9. Yates R. Universal health care and the removal of user fees. The Lancet 2009;**373**(9680):2078-81
10. Witter S. Mapping user fees for health care in high-mortality countries-evidence from a recent survey. 2010
11. Leone T, Cetorelli V, Neal S, et al. Financial accessibility and user fee reforms for maternal healthcare in five sub-Saharan countries: a quasi-experimental analysis. BMJ open 2016;**6**(1):e009692
12. Dzakpasu S, Soremekun S, Manu A, et al. Impact of free delivery care on health facility delivery and insurance coverage in Ghana's Brong Ahafo Region. PloS one 2012;**7**(11):e49430
13. Ghana Statistical Service GHSG, and ICF International. . Ghana Demographic and Health Survey 2014. 2015
14. Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. Population and development review 1984;**10**(0):25-45
15. Fuentes R, Pfütze T, Seck P. Does access to water and sanitation affect child survival? A five country analysis: Human Development Report Office (HDRO), United Nations Development Programme …, 2006.
16. Ridgeway G, Kovalchik SA, Griffin BA, et al. Propensity score analysis with survey weighted data. Journal of causal inference 2015;**3**(2):237-49
17. Jann B. Kernel matching with automatic bandwidth selection. 2017
18. Stuart EA, Green KM. Using full matching to estimate causal effects in nonexperimental studies: examining the relationship between adolescent marijuana use and adult outcomes. Developmental psychology 2008;**44**(2):395
19. Stuart EA, Huskamp HA, Duckworth K, et al. Using propensity scores in difference-in-differences models to estimate the effects of a policy change. Health Services and Outcomes Research Methodology 2014;**14**(4):166-82
20. McKinnon B, Harper S, Kaufman JS, et al. Removing user fees for facility-based delivery services: a difference-in-differences evaluation from ten sub-Saharan African countries. Health policy and planning 2014;**30**(4):432-41
21. Adams AM, Madhavan S, Simon D. Women's social networks and child survival in Mali. Social science & medicine 2002;**54**(2):165-78
22. Darmstadt GL, Bhutta ZA, Cousens S, et al. Evidence-based, cost-effective interventions: how many newborn babies can we save? The Lancet 2005;**365**(9463):977-88

23. Browne JL, Kayode GA, Arhinful D, et al. Health insurance determines antenatal, delivery and postnatal care utilisation: evidence from the Ghana Demographic and Health Surveillance data. BMJ open 2016;**6**(3):e008175
24. Lagarde M, Palmer N. The impact of user fees on access to health services in low-and middle-income countries. Cochrane Database of Systematic Reviews 2011(4)
25. Ansah EK, Narh-Bana S, Asiamah S, et al. Effect of removing direct payment for health care on utilisation and health outcomes in Ghanaian children: a randomised controlled trial. PLoS medicine 2009;**6**(1):e1000007
26. Campbell OM, Graham WJ, group LMSSs. Strategies for reducing maternal mortality: getting on with what works. The lancet 2006;**368**(9543):1284-99
27. Corsi DJ, Neuman M, Finlay JE, et al. Demographic and health surveys: a profile. International journal of epidemiology 2012;**41**(6):1602-13
28. Jakubowski A, Stearns SC, Kruk ME, et al. The US President's Malaria Initiative and under-5 child mortality in sub-Saharan Africa: A difference-in-differences analysis. PLoS medicine 2017;**14**(6):e1002319
29. Munos M, Guiella G, Roberton T, et al. Independent evaluation of the Rapid Scale-Up program to reduce under-five mortality in Burkina Faso. The American journal of tropical medicine and hygiene 2016;**94**(3):584-95
30. Zombré D, De Allegri M, Ridde V. Immediate and sustained effects of user fee exemption on healthcare utilization among children under five in Burkina Faso: A controlled interrupted time-series analysis. Social Science & Medicine 2017;**179**:27-35
31. Sarrassat S, Meda N, Badolo H, et al. Effect of a mass radio campaign on family behaviours and child survival in Burkina Faso: a repeated cross-sectional, cluster-randomised trial. The Lancet Global Health 2018;**6**(3):e330-e41



889x652mm (96 x 96 DPI)



889x652mm (96 x 96 DPI)

Supplemental materials for Impact evaluation of the free maternal healthcare policy on infant and neonatal mortality in four sub-Saharan Africa countries: Difference in Differences with Kernel based Propensity Score Matching Analysis.

S1 Table A: A summary of the trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

	Intervention countries: Implemented free maternal healthcare policy						Comparison countries: No free maternal healthcare policy					
	Ghana			**Burkina Faso**			**Nigeria**			**Zambia**		
	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2010 Ref period: 2006-2010	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2009-2013	2001/2002 Ref period: 1998-2002	2007 Ref period: 2003-2007	2013/2014 Ref period: 2009-2013
Number of live births in five years preceding the interview	3844	2992	5884	10645	15044	6841	6029	28647	31482	6877	6401	13457
Number of women age 15-49 interviewed	5691	4916	9396	12477	17087	8 111	7620	33385	38948	7658	7146	16411
Total number of women age 15-49 in the country at the time of the survey	4170068	4891557	5655156	2451363	303054 5	3416421	256199 94	28997441	32791677	2143989	2506625	3129094
Survey response rate for eligible women interviewed (%)	95.7	96.5	97.3	96.3	98.4	98.7	95.0	97.0	97.9	96.4	97.0	96.0
NMR per 1000 live births	43	30	29	31	28	27.3	48	40	37	37	34	24
IMR per 1000 live births	64	50	41	81	65	61.4	100	75	69	95	70	45
Cumulative incidence rate per 1000 person years at risk: Infant deaths	30 [24.2-37.7]	28.5 [22.5-36.8]	15.1 [11.9-19.4]	67.9 [61.9-74.6]	44.3 [40.5-48.5]	23.7 [21.3-26.4]	63.2 [55.6-72.1]	50.6 [47.7-53.7]	36.8 [34.3-39.6]	70.5 [63.8-78.2]	44.7 [39.1-51.4]	26.5 [23.2-30.5]

Abbreviations: IMR: Infant mortality rate, NMR: Neonatal mortality rate.

S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMHCP and comparison group).

	Before Matching			After Matching		
	FMHCP	No FMHCP	Standardized Mean Difference	FMHCP	No FMHCP	Standardized Mean Difference
	Mean	Mean		Mean	Mean	
Sex						
Male	0.83	0.90	-0.19	0.83	0.81	0.06
Female	0.17	0.10	0.19	0.17	0.19	0.06
Wealth						
Poorest	0.23	0.23	-0.02	0.23	0.23	0.02
Poorer	0.21	0.23	-0.04	0.21	0.21	0.02
Middle	0.20	0.19	0.03	0.20	0.20	0.01
Richer	0.20	0.18	0.05	0.20	0.20	0.00
Richest	0.16	0.17	-0.02	0.16	0.16	0.01
Household size						
”	0.29	0.25	0.10	0.29	0.31	-0.03
5 -7	0.40	0.42	-0.03	0.40	0.41	0.01
8+	0.31	0.33	-0.06	0.31	0.29	0.04
Household access to an improved water source						
Improved	0.90	0.78	0.34	0.90	0.90	0.00
Not improved	0.10	0.22	-0.34	0.10	0.10	0.00
Household access to improved toilet						
Improved, not shared	0.13	0.30	-0.44	0.13	0.12	0.01
Improved, shared	0.37	0.19	0.40	0.37	0.39	0.04
Not improved	0.50	0.50	0.00	0.50	0.49	0.03
Geographic location						
Urban	0.31	0.32	-0.03	0.31	0.32	0.02
Rural	0.69	0.68	0.03	0.69	0.68	0.02
Household owns a mosquito net						
No	0.20	0.52	-0.71	0.20	0.20	0.01
Yes	0.80	0.48	0.71	0.80	0.80	0.01
0RWKHU¶V DJH DW FKLC						
< 18	0.03	0.03	-0.05	0.03	0.02	0.00
18 - 34	0.72	0.71	0.00	0.72	0.73	0.03
35+	0.26	0.25	0.02	0.26	0.24	0.03
Educational attainment						
None	0.54	0.45	0.19	0.54	0.53	0.02
Primary	0.17	0.24	-0.17	0.17	0.18	0.00
Secondary	0.26	0.25	0.02	0.26	0.27	0.02
Tertiary	0.02	0.05	-0.18	0.02	0.02	0.01
Birth order						
First	0.29	0.19	0.22	0.29	0.29	0.00
Second	0.26	0.17	0.20	0.26	0.26	0.00
Third	0.15	0.15	-0.02	0.15	0.14	0.01
Fourth or higher	0.31	0.48	-0.35	0.31	0.31	0.00
Birth type						
Single birth	0.96	0.97	-0.04	0.96	0.95	0.03
Multiple birth	0.04	0.03	0.04	0.04	0.05	0.03

Abbreviation: FMHCP: Free maternal healthcare policy

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group).

	Before matching			After matching		
	FMHCP Variance	No FMHCP Variance	Ratio	FMHCP Variance	No FMHCP Variance	Ratio
Sex						
Male	0.14	0.09	1.49	0.14	0.15	0.92
Female	0.14	0.09	1.49	0.14	0.15	0.92
Wealth						
Poorest	0.17	0.18	0.97	0.17	0.18	0.98
Poorer	0.17	0.18	0.95	0.17	0.16	1.03
Middle	0.16	0.16	1.05	0.16	0.16	1.02
Richer	0.16	0.15	1.08	0.16	0.16	1.00
Richest	0.13	0.14	0.96	0.13	0.14	0.98
Household size						
”	0.21	0.19	1.11	0.21	0.21	0.98
5 -7	0.24	0.24	0.99	0.24	0.24	1.00
8+	0.21	0.22	0.96	0.21	0.21	1.04
Household access to an improved water source						
Improved	0.09	0.17	0.51	0.09	0.09	0.99
Not improved	0.09	0.17	0.51	0.09	0.09	0.99
Household access to improved toilet						
Improved, not shared	0.11	0.21	0.53	0.11	0.11	1.02
Improved, shared	0.23	0.16	1.49	0.23	0.24	0.98
Not improved	0.25	0.25	1.00	0.25	0.25	1.00
Geographic location						
Urban	0.21	0.22	0.98	0.21	0.22	0.98
Rural	0.21	0.22	0.98	0.21	0.22	0.98
Household owns a mosquito net[3]						
No	0.16	0.25	0.64	0.16	0.16	0.98
Yes	0.16	0.25	0.64	0.16	0.16	0.98
0 R W K H U ¶ V D J H I **birth**						
< 18	0.02	0.03	0.74	0.02	0.02	1.02
18 - 34	0.20	0.20	1.00	0.20	0.20	1.04
35+	0.19	0.19	1.02	0.19	0.18	1.04
Educational attainment						
None	0.25	0.25	1.00	0.25	0.25	1.00
Primary	0.14	0.18	0.78	0.14	0.14	1.00
Secondary	0.19	0.19	1.02	0.19	0.20	0.98
Tertiary	0.02	0.05	0.39	0.02	0.02	0.92
Birth order						
First	0.21	0.16	1.31	0.20	0.21	1.00
Second	0.19	0.14	1.32	0.19	0.19	1.00
Third	0.12	0.13	0.96	0.12	0.12	1.02
Fourth or higher	0.21	0.25	0.86	0.21	0.21	1.00
Birth type						
Single birth	0.04	0.03	1.23	0.04	0.05	0.89
Multiple birth	0.04	0.03	1.23	0.04	0.05	0.89

Abbreviation: FMHCP: Free maternal healthcare policy

BMJ Open

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Propensity Score Kernel Matching and Difference in Differences Analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-033356.R1
Article Type:	Original research
Date Submitted by the Author:	16-Dec-2019
Complete List of Authors:	Dwomoh, Duah; University of Ghana College of Health Sciences, Biostatistcs; University of Ghana College of Health Sciences, Biostatistics, School of Public Health Agyabeng, Kofi ; School of Public Health, College of Health Sciences, University of Ghana, P. O. Box LG13, Legon, Ghana Agbeshie, Kwame; Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana Incoom, Gabriel; Ghana Institute of Management and Public Administration, Department of Management Science, School of Business Nortey, Priscilla ; University of Ghana School of Public Health, Epidemiology Yawson, Alfred; University of Ghana, Community Health, School of Public, College of Health Sciences Bosomprah, Samuel; University of Ghana, Biostatistics, School of Public Health
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Public health, Health policy, Health economics
Keywords:	Neonatal Mortality, Infant mortality, Kernel weighting, Propensity Score Matching, Free Maternal Healthcare Policy, PUBLIC HEALTH

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Propensity Score Kernel Matching and Difference in Differences Analysis

Duah Dwomoh[1*], Kofi Agyabeng[1], Agbeshi Kwame [2], Gabriel Incoom[3], Priscilla Nortey[4], Alfred E. Yawson[5], Samuel Bosomprah[1]

[1] Department of Biostatistics, School of Public Health, University of Ghana, Accra.
[2] Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.
[3]Department of Management Science, School of Business, Ghana Institute of Management and Public Administration, Accra, Greater Accra, Ghana
[4] Department of Epidemiology and Disease Control, School of Public Health, University of Ghana, Accra.
[5] Department of Community Health, University of Ghana.

The email address of authors

Kofi Agyabeng: soothe1one@gmail.com
Agbeshi Kwame: kagbeshie@gmail.com
Gabriel Incoom: gabrielincoomghana@gmail.com
Priscilla Nortey: pnortey@gmail.com
Yawson Edwin Alfred: aeyawson@yahoo.com
Samuel Bosomprah: sbosomprah@gmail.com

Corresponding author: Duah Dwomoh: duahdwomoh@yahoo.com

Word count

Abstract: 289

Manuscript: 3825

Abstract

Objective Despite the huge financial investment in the Free Maternal Healthcare Policy (FMHCP) by the governments of Ghana and Burkina Faso, no study has quantified the impact of FMHCP on the relative reduction in neonatal and infant mortality rates using a more rigorous matching procedure with the difference in differences analysis. This study used several rounds of publicly available population-based complex survey data to determine the impact of FMHCP on neonatal and infant mortality rates in these two countries.

Design A quasi-experimental study to evaluate the free maternal healthcare policy implemented in Burkina Faso and Ghana between 2007 and 2014.

Setting Demographic and health surveys and maternal health surveys conducted between 2000 and 2014 for Ghana, Burkina Faso, Nigeria, and Zambia.

Participants: Children born in the five years preceding the survey for Ghana, Burkina Faso, Nigeria, and Zambia.

Primary outcome measures Neonatal and infant mortality rates

Results The Propensity Score Kernel Matching coupled with difference in differences (DID) analysis with Modified Poisson showed that the FMHCP was associated with a 45% reduction in the risk of Neonatal Mortality Rate (NMR) in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76, p<0.001). In addition, Infant Mortality Rate (IMR) has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001).

Conclusions The FMHCP had a significant impact and still remains relevant in achieving Sustainable Development Goal 3 and could provide lessons for other sub-Saharan countries in the design and implementation of a similar policy.

Keywords
Neonatal Mortality, Infant mortality, Kernel weighting with Propensity Score, Free Maternal Healthcare Policy.

Word count
Abstract: 274
Main Manuscript: 4975

Strengths and limitations of this study

- The use of more rigorous Propensity Score Kernel Matching coupled with difference in differences (DID) analysis with Modified Poisson improves the robustness of the impact estimate.
- The study provides evidence that the implementation of free maternal healthcare policy (FMHCP) is associated with a significant reduction in the risk of neonatal and infant deaths in the two intervention countries.
- Evidence from this study can be used to inform policy decisions about the implementation of FMHCP in other sub-Saharan Africa countries.
- Since the data for the study originate from a complex survey (non-experimental design), our study could not control for several other confounding factors, hence, we cannot interpret these results as causal.

Introduction

Access to primary health care services remains low in many low- middle- income countries (LMIC). According to the World Health Organization report 2017, approximately half of the world population lacks access to essential health services and it is estimated that over 100 million still pushed into extreme poverty because of out of pocket health expenditure. Peters and colleagues [1] as well as Jacobs and colleagues [2] have classified these factors into four main dimensions, namely geographical access, financial access, availability of health care, and acceptability of health care service. Delay or lack of access to health care services due to financial constraints can affect child survival. Following the Abuja declaration for sub-Saharan African countries to spend 15% of its public spending on health care at the turn of the century, Ghana in 2003 set up a National Health Insurance Scheme (NHIS) as a way of improving UHC[3]. In September 2003, a policy exempting women in its four poorest regions of Ghana from delivery care fees was introduced by the Government of Ghana in an attempt to increase skilled birth attendance and reduce inequality in use of healthcare services [4]. The policy was rolled out in all the 10 regions by the end of April 2005 but with serious challenges. Notable among them was the fact that the disbursement of funds to accredited health facilities was not forthcoming and by October 2005 some health facilities started to charge clients again [4]. In July 2008, the government of Ghana through the National Health Insurance Scheme (NHIS) implemented a national user fee maternal care exemption policy to improve financial access to maternal health services and reduce maternal, perinatal, neonatal and infant mortality rates. The policy was popularly referred to as the free maternal healthcare policy (FMHCP). The main aim of the policy was to address financial barriers to demand health care services.

Burkina Faso is one of the countries in Sub-Saharan Africa (SSA) that failed to achieve the target for MDG goal number 5 (reduction of maternal mortality by 75% between 1990 and 2015) [5]. That notwithstanding, tremendous efforts have been made by Burkina Faso towards ensuring equitable access to maternal care services. For instance, maternal health financing and delivery reforms were developed and implemented, among which are the abolition of user fees for antenatal care (ANC) services in 2002, subsidization of delivery costs for all women by 80% and by 100% for the poorest in 2007 and exemption of the poorest from payment of all user fees for all curative and preventive health services in 2009 [6 7]. In this article, we refer to the policy implemented in Burkina Faso as FMHCP for easy reference to countries that have implemented the intervention.

Nigeria, for instance, did not have a clear federal policy on user fees in maternal and child health, and the regional variation at the primary and secondary level is vast [8]. Although Zambia removed user fees in 2006 in rural areas only [9 10], they had not been implemented properly and no impact had been seen in the following year or two [11]. That notwithstanding, fees are still payable (by cash) in urban areas and financial constraints still remain a significant barrier to institutional delivery [11]. The impact of these policies, particularly on access to health services and neonatal mortality has not been evaluated using rigorous methods, and so the empirical basis for defending these policies is weak [12]. To determine the effectiveness of FMHCP in contributing to a reduction in the mortality rate relative to countries that do not have such policy, Propensity Score Kernel Matching with the difference in differences analysis was applied. Using a quasi-experimental design, the goal of this study is to determine whether the full implementation of FMHCP in Ghana and Burkina Faso contributed to the relative reduction in neonatal and infant mortality rates between 2008 and 2014 compared to Nigeria and Zambia without such significant national health financing policy on maternal healthcare.

Methods and analyses

Data sources

The data used in this study were obtained from 11 separate Demographic and Health Surveys (DHS) and one Malaria Indicator Surveys (MIS). The DHS and MIS are a nationally representative cross-sectional survey that includes common questions about a year of birth and survival status of all births to women of reproductive age (15-49 years). The DHS and MIS datasets are freely available and could be downloaded at the DHS website (http://dhsprogram.com) after completing the online data request registration form. With the exception of Burkina Faso that could not provide DHS but MIS data for 2014, each country contributed 3 different DHS datasets that were conducted between 2000 and 2014. That is, we utilized the pre-baseline data from 2001/2003-2007/2008; baseline data: 2007/2008 and end-line data: 2013/2014. The unit of analysis in this study is the children of women born in 5 years (0-59 months) preceding the survey. Detailed distribution about number of live births in the five years preceding the survey, number of women age 15-49 interviewed, total number of women age 15-49 in the country at the time of the survey, year of survey and survey response rate for eligible women, NMR and IMR per 1000 live births, and cumulative incidence rate per 1000 person-years at risk can be found in Table A of S1 Appendix.

Patients and public involvement

Patients and the public were not involved.

Primary outcome measures

The primary outcomes of interest were infant mortality (IMR) and the neonatal mortality rate (NMR). In this analysis, the Infant mortality rate (IMR) is defined as the probability of dying between birth and first birthday whereas neonatal mortality rate (NMR) is defined as the probability of dying between birth and the first month of life [13]. All deaths that were recoded within the first 28 days after birth were coded as 1 or otherwise 0 in defining a binary indicator

variable for neonatal mortality. For infant mortality, deaths within one year after birth in the five years preceding each survey were coded as 1 otherwise 0 to define a binary indicator for infant mortality.

Exposure to free maternal healthcare policy

Countries that have abolished at least 80% of user fees for institutional delivery in Sub-Saharan Africa between the periods of 2007-2014 and have readily available DHS or MIS data were included in the study as intervention countries. That notwithstanding, these countries should have conducted DHS between the periods of 2000-2008. This was necessary to test the parallel trend assumption which is a requirement for the validity of DID design and its estimate. There were only two countries that implemented user fee reforms for maternal healthcare between 2007 and 2008. Ghana and Burkina Faso met these inclusion criteria and therefore qualified as intervention countries. Although Zambia and Nigeria conducted DHS between 2000 and 2014, both countries did not have a universal exemption on user fees for institutional births during the study period and therefore qualified to be used in the comparison groups. A similar study based on quasi-experimental design has provided a detail explanation as to why Zambia, Cameroon, and Nigeria could represent a valid comparison group compared to other countries in SSA in evaluating the impact of free maternal healthcare policy on intermediate and long term health outcomes [11]. Cameroon was excluded as a comparison country in this study because there was no survey conducted in 2007/2008 which represents the full policy implementation year.

Covariates assumed to be associated with child survival and included in the estimation of the propensity scores

The choice of the selected covariates in assessing risk factors of child survival was based on the analytical framework for the study of child survival in developing countries by Mosley and Chen [14]. Specifically, we extracted data and performed the estimation of the propensity scores as using the following variables: household ownership of bednets, child's age and gender, mother's age at the time of the survey, mother's education level, household wealth, sex of the household head,

and whether the household was in the urban or rural area, birth order, multiple births and household size, household access to improved water and sanitation. We defined a household as having access to an improved water source if it has any of the following: piped water into the dwelling, yard, or plot; public tap or standpipe, tube-well, or borehole; a protected dug well or protected spring; rainwater; or bottled water. There is a direct correlation between access to an improved water source and infant survival [15]. This analysis defines a household as having an improved sanitation if it has any of the following types of toilet facilities, and if this facility is not shared with another household: a flush or pour-flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit latrine; a pit latrine with a slab; or a composting toilet. There is an inverse relationship between access to improved sanitation and infant mortality. Increasing access to improved sanitation is associated with lower levels of infant mortality [15]. The estimation of the propensity scores were based on the binary logistic regression model.

Statistical analyses based on DHS and MIS datasets

Since the study pooled data from different surveys, the women's standard weights were de-normalized. This was achieved by dividing the women's standard weight by the women survey sampling fraction, that is, the ratio of the total number of women aged 15-49 interviewed in the survey year over the total number of women aged 15-49 years in the country at the time of the survey. The total number of women aged 15-49 interviewed in the survey year was obtained from the DHS datasets, while the total number of women aged 15-49 years in the country at the time of the survey was obtained from our world in data (https://ourworldindata.org/). Complex survey design characteristics (weighting, stratification, and clustering) were adjusted in all the analyses. In particular, we used the sampling weights in the estimation of the propensity score model and also used the sampling weight times the Kernel weight obtained from the repeated cross-section as the weight variable in the final outcome analysis. This analytic technique has been shown to produce unbiased treatment effect estimates that are generalizable to the original

survey target population [16]. The Kernel function used in the weight estimation was Epanechnikov and the bandwidth selection was based on cross-validation of the means of covariates [17].

To determine the impact of the policy on NMR and IMR, we performed a Propensity Score Kernel Matching with difference-in-differences (DID) analysis using a modified Poisson regression model with robust standard errors. We estimated average treatment effect (ATE) using propensity scores with Kernel weighting adjustment and inverse probability of treatment weighting (IPTW). The data for the study originates from multi-stage complex surveys and to assess the impact of the intervention, there is the need to replicate random assignment. In experimental study design with random assignment, treatment groups (countries with FMHCP) and control groups (countries with no such policy) are similar on all background characteristics (observed and unobserved) as a consequence of the randomization, allowing for straightforward comparison of outcomes. In contrast, in complex surveys, the intervention and comparison individuals may differ significantly on background characteristics. Thus, any difference in outcomes (neonatal and infant mortality rate) between the two groups may be due to these background covariates or to the intervention itself. Matching procedures, followed by regression adjustment on the matched sample, can often be a stronger approach for estimating causal effects than is regression on an unmatched sample [18].

The DID design is a known quasi-experimental method that is used frequently in policy evaluations to compare changes over time in a group unaffected by the policy intervention (comparison countries) to the changes over time in a group affected by the policy intervention (intervention countries) and attributes the "difference-in-differences" to the effect of the policy [19]. Several sensitivity analyses were conducted to determine the robustness of our results. We tested whether the policy impact estimate is robust to the type of model specification using logit, probit, and Cox proportional hazard models with robust standard errors. For the Cox model, the time-to-death with survival status as censoring indicator was modeled. Finally, we tested whether the impact estimate is robust to different weighting procedures. First, we employed, inverse

probability of treatment weighting (IPTW) given by $w_i = \frac{T_i}{e_i} + \frac{1-T_i}{1-e_i}$ where e_k is the estimated propensity score for individual k, and T_i is the treatment status indicator variable. The IPTW serves to weight both the treated and control groups up to the full sample, in the same way that survey sampling weights weight a sample up to a population [20]. We also apply weighting by the odds to estimate the average treatment effect on the treated (ATT) given by $w_i = T_i + (1 - T_i) \frac{e_i}{1-e_i}$. The DID design relies on the parallel trend assumption. This assumption states that in the absence of the intervention (free maternal healthcare policy), there would be no statistically significant difference in the trend of NMR and IMR between the intervention and the comparison countries. We relied on DHS data conducted between the years 2000 and 2008 to test this assumption. P-values less than 0.05 were considered as statistically significant. Data cleaning and analysis were conducted using Stata version 15 (StataCorp, College Station, Texas, USA).

Results

Results using data from 2007 to 2014 showed that approximately 9.2% [95% CI: 8.9-9.5] of the 110,748 children in our sample died before reaching age 5. Within the same period, there was a statistically significant difference in the proportion of deaths between countries with FMHCP and those with no such policy (FMHCP=6.2% [95% CI: 5.9-6.6]; no FMHCP=9.8% [95% CI: 9.5-10.1], Rao-Scot Chi-square test=159.6; p<0.001, Table 1). The proportion of infant deaths was 6.7% [95% CI: 6.5-7.0]. Among countries with FMHCP, the proportion of infant deaths was approximately 4.0% [95% CI: 3.6-4.3] compared countries with no FMHCP where infant deaths were 7.3% [95% CI: 7.1-7.6] and the difference was statistically significant (Rao-Scot Chi-square test=168.4; p<0.001, Table 1). The overall proportion of neonatal deaths was 3.5% [95% CI: 3.3-3.6]. FMHCP countries recorded 0.4% [95% CI: 0.3-0.4] neonatal deaths compared to 3.1% [95% CI: 2.9-3.3] recorded by countries with no FMHCP (Rao-Scot Chi-square test=76.7, p<0.001).

Table 1: Trend of neonatal and infant mortality between countries with and without FMHCP and description of the study participants: 2007/2008-2013/2014.

	Total %	Intervention: FMHCP implementation		Rao-Scot Chi-square
		No FMHP %[b]	FMHP %[b]	
All-cause mortality in the five years preceding the survey [95% CI]	9.2 [8.9-9.5]	9.8 [9.5-10.1]	6.2 [5.9-6.6]	159.60***
All-cause neonatal deaths in the five years preceding the survey [95% CI]	3.5 [3.3-3.6]	3.1 [2.9-3.3]	0.4 [0.3-0.4]	76.70***
All-cause infants deaths in the five years preceding the survey [95% CI]	6.7 [6.5-7.0]	7.3 [7.1-7.6]	4.0 [3.6-4.3]	168.40***
Sex of household head				114.03***
Male	97430 (88.4)	70247 (83.4)	27183 (16.6)	
Female	13318 (11.6)	9740 (74.3)	3578 (25.7)	
Wealth quintile				2.00
Poorest	26597 (23.3)	19264 (82.9)	7333 (17.1)	
Poorer	25526 (22.7)	18862 (83.3)	6664 (16.7)	
Middle	22913 (19.4)	16412 (81.4)	6501 (18.6)	
Richer	20303 (18.2)	14198 (80.7)	6105 (19.3)	
Richest	15409 (16.5)	11251 (82.9)	4158 (17.1)	
Household size				20.26***
1-4	26784 (25.8)	19215 (79.8)	7569 (20.2)	
5-7	45709 (41.5)	33951 (82.9)	11758 (17.1)	
8+	38255 (32.8)	26821 (83.5)	11434 (16.5)	
Access to improved water				121.32***
Improved	89000 (80.4)	61284 (80.1)	28049 (19.9)	
Unimproved	21000 (19.6)	18676 (91.4)	2711 (8.6)	
Missing	28 (0.01)	27 (98.4)	1 (1.6)	
Access to an improved toilet facility				195.72***
Improved, not shared	26000 (27.0)	22493 (91.7)	3817 (8.3)	
Improved, shared	21000 (22.5)	13047 (71.0)	7762 (29.0)	
Unimproved	63000 (50.1)	44120 (82.4)	19095 (17.6)	
Missing	414 (0.4)	327 (81.2)	87 (18.8)	
Place of residence				0.61
Urban	32627 (32.2)	25035 (82.9)	7592 (17.1)	
Rural	78121 (67.8)	54952 (82.0)	23169 (18.0)	
Household ownership of bednet				1013.52***
No bednet	43000 (46.4)	36880 (92.4)	6015 (7.6)	
Bednet	68000 (53.6)	43062 (73.6)	24746 (26.5)	
Missing	45 (0.06)	45 (100.0)	0 (0.0)	
Mothers current age				11.10***
<18 years	3558 (3.3)	2803 (86.5)	755 (13.5)	
18-34 years	80000 (71.5)	58000 (82.3)	22000 (17.7)	
35+	27000 (25.2)	20000(81.8)	7727 (18.2)	
Mothers education				44.98***
None	53000 (46.5)	32000 (79.4)	21000 (20.6)	
Primary	29000 (23.2)	24000 (86.6)	4475 (13.4)	
JHS	25000 (25.5)	20000 (81.7)	4686 (18.3)	
Secondary or higher	4241 (4.8)	3882 (92.4)	359 (7.6)	
Missing	16 (0.01)	11 (64.6)	5 (35.4)	
Birth order				271.39***
1st birth	24000 (21.1)	16000 (75.8)	8167 (24.2)	
2nd births	21000 (18.9)	14000 (76.1)	7351 (23.9)	
3rd births	17000 (15.2)	12000 (83.1)	4386 (16.9)	
4th births	49000 (44.8)	38000 (87.7)	11000 (12.3)	
Multiple births				10.19**
Single	110000 (96.4)	77000 (82.4)	30000 (17.6)	
Multiple	3994 (3.6)	2750 (79.1)	1244 (20.9)	

Child mortality estimate per country				
Country	Year of survey	NMR per 1000 live births	IMR per 1000 live births	Cumulative incidence rate per 1000 person years at risk
Burkina Faso	2003	31	81	67.9 [61.9-74.6]
	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
Ghana	2003	43	64	30.0 [24.2-37.7]
	2008	30	50	28.5 [22.5-36.8]
	2014	29	41	15.1 [11.9-19.4]
Nigeria	2003	48	100	63.2 [55.6-72.1]
	2008	40	75	50.6 [47.7-53.7]
	2013	37	69	36.8 [34.3-39.6]
Zambia	2001-2002	37	95	70.5 [63.8-78.2]
	2007	34	70	44.7 [39.1-51.4]
	2014	24	45	26.5 [23.2-30.5]

Abbreviations: FMHP – Free maternal health policy; NMR: Neonatal mortality rate, IMR: Infant mortality rate. P-value notation: ***p<0.001, **p<0.01, *p<0.05. %[b] represents row percentages. Note: access to improved toilet facility had a missing observation of 0.4%.

NMR and IMR per 1000 live births decline between 2008 and 2014 in both FMHCP and non-FMHCP countries but the decline was steeper at all times in the FMHCP countries at various time points (Figure 1).

Figure 1: Kaplan Meier survival estimate (KMSE) at varying time points of free maternal healthcare policy implementation (FMHCP). Abbreviations: BF: Burkina Faso, GHA: Ghana, NIG: Nigeria, ZAM: Zambia

Results on balancing and common support diagnostics of the Kernel-based matching

Balancing tests based on standardized mean difference and ratio of variances of the observed covariates between the two sets of countries (FMHCP and non-FMHCP) were conducted before and after Kernel-based matching. This was done to ascertain how the matching procedure has reduced biases in the means and variances of the observed covariates between FMHCP countries and non-FMHCP countries. The mean difference in the observed covariate between FMHCP countries and non-FMHCP reduced significantly after matching making the two groups as similar as possible (Table B in S1 Appendix). The ratio of variances in the covariate between the two sets countries was closer to 1 after matching than before matching (Table C in S1 Appendix). The results showed that the propensity score with Kernel-based matching reduced covariate imbalance between countries with and without FMHCP. The results from the Kernel density, cumulative distribution and the box-whisker plots in figure 2 showed that matching has made FMHCP and non-FMHCP countries more similar in terms of the observed covariates, hence any change in the risk of neonatal and infant deaths could be attributed to FMHCP.

Figure 2: Balancing the diagnostic test of the Kernel-based propensity score matching

Results on the test of the parallel trend assumption

The fixed-effects model controls for all time-invariant differences between the individuals and the country level factors such differences in geographic location, so the estimated coefficients of the fixed-effects models cannot be biased because of omitted time-invariant characteristics.

The test of parallel trends showed that, after controlling for baseline individual and country time-fixed effect characteristics, maternal, child and household characteristics including household ownership of bednet, both infant and neonatal mortality rate rates did not differ between countries with FMHCP and those with no FMHCP before the implementation of FMHCP (NMR: aRR=0.91, 95% CI 0.71-1.16; p>0.05; Table 2).

Mortality rates were declining in all of the study countries during this time period (NMR: aRR=0.88, 95% CI: 0.75-1.02; IMR: aRR=0.84, 95% CI: 0.76-0.94, p<0.05, Table 2), but there was no evidence of trends being different between countries that have implemented FMHCP and comparison countries. In conclusion, the parallel trend assumption was not violated and therefore estimates from DID analyses were valid.

Table 2: Test of parallel trends assumption: Risk of neonatal and infant mortality prior to free maternal healthcare policy implementation (2001-2008): Modified Poisson model with robust standard error on the unmatched sample.

	Neonatal mortality: 2000-2008		Infant mortality: 2000-2008	
Covariates	uRR [95% CI]	aRR [95% CI]	uRR [95% CI]	aRR [95% CI]
Time Baseline: 2008	ref	ref	ref	ref
End-line: 2014	0.86* [0.75-0.99]	0.88 [0.75-1.02]	0.83*** [0.76-0.91]	0.84** [0.76-0.94]
Intervention				
No FMHP	ref	ref		ref
FMHP-assumed it exited	0.85 [0.72-1.01]	0.89 [0.71-1.11]	0.94 [0.84-1.05]	0.92 [0.79-1.07]
Time*FMHP	0.92 [0.74-1.15]	0.91 [0.71-1.16]	0.93 [0.81-1.08]	0.91 [0.78-1.08]
Sex of household head				
Male		ref		ref
Female		0.90 [0.73-1.11]		0.89 [0.76-1.03]
Mothers current age				
<18 years		ref		ref
18-34 years		0.90 [0.78-1.03]		0.91 [0.82-1.00]
35+		2.33* [1.02-5.30]		2.40* [1.10-5.26]
Place of residence				
Urban		ref		ref
Rural		1.35*** [1.14-1.60]		1.29*** [1.14-1.45]
Household size				
1-4		ref		ref
5-7		0.48*** [0.40-0.57]		0.49*** [0.43-0.55]
8+		0.43*** [0.35-0.52]		0.43*** [0.37-0.49]
Access to improved water				
Improved		ref		ref
Unimproved		1.08 [0.92-1.27]		1.13* [1.01-1.26]
Access to an improved toilet facility				
Improved, not shared		ref		ref
Improved, shared		0.81* [0.66-0.98]		0.76*** [0.66-0.87]
Unimproved		0.85 [0.72-1.01]		0.86* [0.77-0.97]
Mothers education				
None		ref		ref
Primary		1.01 [0.84-1.2]		0.94 [0.83-1.06]
JHS		0.84 [0.69-1.02]		0.73*** [0.63-0.83]
Secondary or higher		0.93 [0.59-1.44]		0.55** [0.39-0.78]
Birth order				
1st birth		ref		ref
2nd births		0.70** [0.57-0.86]		0.83* [0.71-0.98]
3rd births		0.71** [0.55-0.9]		0.99 [0.84-1.17]
4th births		1.03 [0.84-1.26]		1.20* [1.04-1.39]
Multiple births				
Single		ref		ref
Multiple		5.31*** [4.26-6.62]		3.70*** [3.11-4.40]
Household ownership of bednet				
No bednet		ref		ref
Bednet		0.91 [0.78-1.05]		0.95 [0.86-1.05]
Country Fixed Effect	Yes	Yes	Yes	Yes

Abbreviations: FMHP; Free maternal healthcare policy, aRR: Adjusted Relative Risk, uRR: Unadjusted Relative Risk, P-value notations: ***p<0.001, **p<0.01, *p<0.05. Note: With respect to Burkina Faso, 2010 demographic health survey data was used since they did not conduct any survey in 2008.

Impact of FMHCP on the risk of neonatal deaths

The results from the modified Poisson with DID using Propensity Score Kernel Matching showed that FMHCP is associated with 45% reduction in the risk of NMR in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76,

p<0.001, Table 3). Sensitivity analyses based on different outcome model specification showed similar results (Table 3).

Table 3: Impact of the free maternal healthcare policy on neonatal mortality: Kernel-based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error.

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel weighting	With Kernel weighting based on PSM	With Kernel weighting based on PSM	With Kernel weighting based on PSM	With Kernel weighting based on PSM	ATET weighting and PSM- IPTW	ATE weighting and PSM-
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.92[0.82, 1.03]	0.63*[0.42, 0.96]	0.62*[0.42, 0.91]	0.59[0.33, 1.07]	-0.35*[-0.69, -0.01]	-3.41**[0.46, 0.81]	0.67**[0.51, 0.86]
Intervention							
No FMHP	ref	ref	ref	ref	ref	ref	ref
FMHP	0.66***[0.53, 0.83]	0.94[0.74, 1.19]	0.96[0.77, 1.19]	0.95[0.62, 1.47]	-0.04[-0.28, 0.2]	-0.81[0.78, 1.11]	0.93[0.82, 1.07]
Time*FMHP	0.56***[0.43, 0.73]	0.55***[0.40, 0.76]	0.55***[0.40, 0.74]	0.44*[0.22, 0.88]	-0.41*[-0.79, -0.02]	0.57***[0.42, 0.77]	0.71[0.46, 1.08]
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.85*[0.73, 0.99]	0.73*[0.55, 0.97]	0.81[0.63, 1.04]	1.08[0.67, 1.74]	0.02[-0.24, 0.29]	-1.99*[0.65, 1]	0.78*[0.63, 0.95]
Mothers current age							
<18 years	ref	ref	ref	ref	ref	ref	ref
18-34 years	0.43***[0.35, 0.54]	0.51**[0.35, 0.75]	1.01[0.71, 1.43]	2.69**[1.4, 5.18]	0.59**[0.21, 0.98]	3.99***[0.39, 0.72]	0.53***[0.39, 0.71]
35+	0.46***[0.36, 0.59]	0.55**[0.35, 0.86]	1.29[0.85, 1.95]	6.7***[3.12, 14.38]	1.11***[0.67, 1.56]	-3.17**[0.39, 0.8]	0.5***[0.35, 0.72]
Place of residence							
Urban	ref	ref	ref	ref	ref	ref	ref
Rural	1.24**[1.08, 1.42]	1.23[0.87, 1.74]	1.2[0.88, 1.64]	1.04[0.65, 1.65]	0.05[-0.22, 0.32]	1.94[1, 1.6]	1.21[0.84, 1.74]
Wealth quintile							
Poorest	ref	ref	ref	ref	ref	ref	ref
Poorer	1.01[0.89, 1.15]	1.04[0.86, 1.27]	1.03[0.86, 1.24]	0.81[0.53, 1.23]	-0.1[-0.34, 0.14]	0.72[0.89, 1.28]	0.98[0.79, 1.22]
Middle	0.86[0.74, 1.01]	0.93[0.73, 1.18]	0.96[0.77, 1.19]	0.93[0.56, 1.54]	-0.03[-0.32, 0.27]	0.2[0.82, 1.27]	0.89[0.69, 1.16]
Richer	0.91[0.75, 1.1]	0.83[0.61, 1.13]	0.87[0.65, 1.16]	0.88[0.43, 1.79]	-0.06[-0.47, 0.34]	-0.64[0.7, 1.2]	0.86[0.61, 1.2]
Richest	0.86[0.68, 1.11]	0.95[0.56, 1.61]	1.01[0.62, 1.62]	1.04[0.46, 2.34]	0.05[-0.41, 0.52]	-0.87[0.6, 1.22]	0.88[0.55, 1.42]
Household size							
1-4	ref	ref	ref	ref	ref	ref	ref
5-7	0.42***[0.37, 0.49]	0.46***[0.38, 0.56]	0.55***[0.45, 0.65]	0.49**[0.31, 0.78]	-0.41**[-0.67, -0.15]	8.18***[0.38, 0.55]	0.42***[0.34, 0.51]
8+	0.35***[0.3, 0.4]	0.41***[0.33, 0.52]	0.48***[0.39, 0.59]	0.33***[0.22, 0.49]	-0.64***[-0.87, -0.41]	8.67***[0.32, 0.49]	0.38***[0.31, 0.46]
Access to improved water							
Improved	ref	ref	ref	ref	ref	ref	ref
Unimproved	1.06[0.93, 1.21]	1.06[0.87, 1.3]	1.06[0.89, 1.27]	1.28[0.88, 1.88]	0.15[-0.07, 0.36]	0.02[0.82, 1.22]	1.02[0.82, 1.28]
Access to improved toilet facility							
Improved, not shared	ref	ref	ref	ref	ref	ref	ref
Improved, shared	0.84*[0.72, 0.97]	0.97[0.78, 1.22]	0.97[0.79, 1.18]	1.08[0.72, 1.63]	0.04[-0.20, 0.28]	-0.43[0.78, 1.17]	0.90[0.70, 1.16]
Unimproved	0.84**[0.75, 0.94]	0.92[0.76, 1.11]	0.92[0.78, 1.10]	1.10[0.76, 1.59]	0.05[-0.15, 0.26]	-1.00[0.77, 1.09]	0.86[0.72, 1.04]
Mothers education							
None	ref	ref	ref	ref	ref	ref	ref
Primary	1.05[0.93, 1.20]	0.98[0.78, 1.23]	0.97[0.78, 1.20]	0.78[0.52, 1.18]	-0.14[-0.38, 0.10]	-0.80[0.76, 1.12]	0.99[0.79, 1.25]
JHS	0.94[0.80, 1.10]	0.93[0.69, 1.25]	0.86[0.65, 1.13]	0.62[0.35, 1.10]	-0.25[-0.57, 0.06]	-1.01[0.72, 1.11]	0.96[0.80, 1.16]
Secondary or higher	0.75[0.55, 1.03]	0.81[0.46, 1.41]	0.71[0.42, 1.21]	0.20***[0.08, 0.47]	-0.92***[-1.44, -0.41]	-1.37[0.45, 1.15]	0.79[0.43, 1.46]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	0.94[0.82, 1.09]	0.69**[0.54, 0.89]	0.62***[0.49, 0.77]	0.52*[0.30, 0.89]	-0.38*[-0.67, -0.08]	-2.89**[0.61, 0.91]	0.74*[0.59, 0.93]
3rd births	0.98[0.82, 1.18]	0.89[0.66, 1.2]	0.73*[0.56, 0.97]	0.60[0.34, 1.07]	-0.29[-0.61, 0.03]	-0.24[0.75, 1.25]	0.88[0.67, 1.15]
4th births	1.32**[1.12, 1.56]	1.18[0.90, 1.56]	0.87[0.67, 1.12]	0.46**[0.26, 0.81]	-0.44**[-0.76, -0.12]	2.21*[1.03, 1.58]	1.29*[1.00, 1.65]
Multiple births							
Single							
Multiple	5.84***[4.97, 6.86]	5.58***[4.25, 7.32]	4.73***[3.78, 5.92]	6.17***[2.47, 15.41]	0.96***[0.52, 1.4]	15.61***[4.74, 7.41]	5.58***[4.37, 7.12]
Household ownership of bednet							
No bednet							
Bednet	0.98[0.88, 1.09]	0.96[0.82, 1.12]	0.96[0.83, 1.11]	1.01[0.74, 1.37]	0.01[-0.16, 0.19]	-1.04[0.79, 1.07]	0.93[0.78, 1.1]
Country Fixed Effect	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted

Abbreviations: FMHP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, ref: reference category, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Impact of FMHCP on the risk of infant deaths

IMR has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001; Table 4). Series of sensitivity analysis that was conducted showed a similar impact of FMHCP (Table 4). The analysis adjusted for sex of the household head, mother's current age, mother's educational level, place of residence, wealth quintile, access to improved water and sanitation, birth order, multiple births and household ownership of bednet and country fixed-effect.

Table 4: Impact of the free maternal healthcare policy on infant mortality: Kernel-based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel weighting with PS	With Kernel weighting with PS	With Kernel weighting PS	With Kernel weighting with PSM	With Kernel weighting with PS	ATET weighting using PS- IPTW	ATE weighting using PS
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.79***[0.73, 0.86]	0.62***[0.48, 0.8]	0.62***[0.49, 0.78]	0.45***[0.35, 0.58]	-0.45***[-0.59, -0.32]	0.64***[0.53, 0.78]	0.77**[0.64, 0.91]
Intervention							
No FMHCP	ref	ref	ref	ref	ref	ref	ref
FMHCP	0.72***[0.62, 0.84]	0.87[0.74, 1.03]	0.89[0.77, 1.04]	0.86[0.72, 1.02]	-0.09[-0.19, 0.01]	0.84*[0.74, 0.96]	0.83***[0.76, 0.92]
Time*FMHCP	0.49***[0.39, 0.61]	0.46***[0.36, 0.59]	0.45***[0.35, 0.57]	0.43***[0.33, 0.56]	-0.49***[-0.64, -0.34]	0.48***[0.37, 0.6]	0.55**[0.39, 0.77]
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.88*[0.78, 0.98]	0.75**[0.61, 0.92]	0.81*[0.68, 0.98]	0.96[0.79, 1.17]	-0.02[-0.13, 0.09]	0.87[0.74, 1.02]	0.88[0.75, 1.02]
Mothers current age							
<18 years	ref	ref	Ref	ref	ref	ref	ref
18-34 years	0.49***[0.41, 0.58]	0.49***[0.37, 0.66]	0.86[0.65, 1.14]	3.1***[2.2, 4.38]	0.63***[0.44, 0.81]	0.49***[0.38, 0.63]	0.59***[0.46, 0.75]
35+	0.49***[0.4, 0.59]	0.47***[0.33, 0.66]	0.95[0.69, 1.31]	5.74***[3.92, 8.4]	0.96***[0.75, 1.17]	0.46***[0.35, 0.61]	0.52***[0.39, 0.68]
Place of residence							
Urban	ref	ref	Ref	ref	ref	ref	ref
Rural	1.16**[1.05, 1.29]	1.2[0.96, 1.5]	1.19[0.97, 1.46]	1.18[0.96, 1.45]	0.09[-0.03, 0.2]	1.14[0.96, 1.36]	1.13[0.89, 1.45]
Wealth quintile							
Poorest	ref	ref	Ref	ref	ref	ref	ref
Poorer	1.02[0.92, 1.12]	1.01[0.87, 1.17]	1[0.87, 1.15]	0.97[0.81, 1.16]	-0.02[-0.12, 0.08]	1.04[0.91, 1.18]	0.99[0.86, 1.15]
Middle	0.88*[0.79, 0.98]	0.92[0.77, 1.11]	0.95[0.8, 1.12]	0.99[0.8, 1.23]	-0.01[-0.13, 0.11]	0.92[0.79, 1.07]	0.93[0.78, 1.11]
Richer	0.86*[0.75, 0.99]	0.91[0.7, 1.19]	0.95[0.74, 1.21]	0.93[0.68, 1.28]	-0.03[-0.2, 0.14]	0.89[0.72, 1.09]	0.8*[0.64, 1]
Richest	0.69***[0.57, 0.82]	0.78[0.54, 1.12]	0.81[0.58, 1.13]	0.8[0.57, 1.11]	-0.14[-0.32, 0.05]	0.68**[0.52, 0.89]	0.73[0.5, 1.06]
Household size							
1-4	ref	ref	Ref	ref	ref	ref	ref
5-7	0.43***[0.39, 0.47]	0.45***[0.38, 0.52]	0.52***[0.45, 0.59]	0.54***[0.45, 0.65]	-0.34***[-0.44, -0.24]	0.46***[0.4, 0.52]	0.43***[0.37, 0.5]
8+	0.35***[0.32, 0.39]	0.4***[0.34, 0.48]	0.46***[0.39, 0.54]	0.43***[0.35, 0.52]	-0.45***[-0.55, -0.34]	0.42***[0.36, 0.49]	0.38***[0.33, 0.45]
Access to improved water							
Improved	ref	ref	Ref	ref	ref	ref	ref
Unimproved	1.05[0.96, 1.16]	1.03[0.89, 1.19]	1.02[0.89, 1.17]	1.02[0.88, 1.17]	0[-0.07, 0.08]	0.99[0.86, 1.15]	1.05[0.9, 1.22]
Access to improved toilet facility							
Improved, not shared	ref	ref	Ref	ref	ref	ref	ref
Improved, shared	0.87*[0.78, 0.97]	0.94[0.79, 1.1]	0.94[0.81, 1.09]	0.82*[0.69, 0.97]	-0.11*[-0.2, -0.01]	0.97[0.83, 1.13]	0.94[0.78, 1.13]
Unimproved	0.88**[0.81, 0.96]	0.92[0.8, 1.05]	0.93[0.82, 1.05]	0.88[0.75, 1.02]	-0.07[-0.15, 0.02]	0.93[0.82, 1.05]	0.92[0.79, 1.06]
Mothers education							
None	ref	ref	Ref	ref	ref	ref	ref
Primary	0.9*[0.82, 0.99]	0.82*[0.7, 0.97]	0.82**[0.71, 0.95]	0.69***[0.58, 0.83]	-0.21***[-0.31, -0.11]	0.81**[0.71, 0.93]	0.89[0.76, 1.03]
JHS	0.88*[0.78, 0.98]	0.83[0.67, 1.02]	0.77**[0.64, 0.94]	0.54***[0.43, 0.67]	-0.35***[-0.47, -0.24]	0.82*[0.69, 0.97]	0.87[0.73, 1.03]
Secondary or higher	0.7**[0.56, 0.89]	0.78[0.53, 1.17]	0.71[0.48, 1.04]	0.38***[0.24, 0.58]	-0.55***[-0.78, -0.31]	0.78[0.53, 1.14]	0.69[0.43, 1.11]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	1.03[0.93, 1.15]	0.86[0.72, 1.03]	0.77**[0.65, 0.91]	0.6***[0.5, 0.73]	-0.27***[-0.38, -0.17]	0.94[0.82, 1.08]	0.84*[0.71, 1]
3rd births	1.2**[1.05, 1.37]	1.13[0.91, 1.4]	0.96[0.79, 1.17]	0.65***[0.52, 0.81]	-0.24***[-0.36, -0.12]	1.19[1, 1.43]	1.08[0.88, 1.34]
4th births	1.59***[1.42, 1.79]	1.63***[1.34, 1.98]	1.25*[1.05, 1.5]	0.7**[0.56, 0.86]	-0.2**[-0.32, -0.08]	1.66***[1.42, 1.93]	1.51***[1.23, 1.86]
Multiple births							
Single	ref	ref	ref	ref	ref	ref	ref
Multiple	4.37***[3.86, 4.95]	3.95***[3.16, 4.95]	3.57***[2.96, 4.3]	3.59***[2.75, 4.67]	0.72***[0.57, 0.87]	4.24***[3.58, 5.03]	4.43***[3.71, 5.29]
Household ownership of bednet							
No bednet	ref	ref	ref	ref	ref	ref	ref
Bednet	1.06[0.98, 1.14]	0.98[0.88, 1.09]	0.97[0.88, 1.08]	0.99[0.88, 1.12]	-0.01[-0.08, 0.06]	0.96[0.86, 1.06]	0.94[0.85, 1.05]
Country Fixed Effect	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted

Abbreviations: FMHCP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Discussion

This study quantified the contribution of FMHCP implementation in Ghana and Burkina Faso in the reduction of neonatal and infant mortality rates. Child mortality within the implementation period in these two countries was compared to mortality in Nigeria and Zambia that do not have a significant major health financing reform in the period under consideration. It remains among the few studies to have compared the effectiveness of FMHCP in the four SSA countries using the more rigorous matching procedure with DID. Our impact evaluation found that the implementation of FMHCP led to a substantial reduction in both neonatal and infant mortality. This finding is consistent with what has been reported previously in the literature based on similar analytic technique [21]. Although all the four countries studied did not attain the MDG 4, Ghana and Burkina Faso have seen a tremendous decline in the trend of neonatal and infant mortality rates over the years. FMHCP was associated with substantial statistically significant reductions in infant and neonatal mortality rates when these estimates were compared between Zambia and Nigeria.

It is estimated that the effective implementation of key maternal and child healthcare interventions could prevent up to 70% of neonatal deaths globally [22 23]. The advantages of increasing access to facility delivery, pre-and postnatal care through FMHCP are well documented in the literature [12 24]. FMHC contributes greatly to increased coverage of routine immunization as women who visit and deliver in recommended health facilities were more likely to benefit from early immunization. The policy also promotes early and accurate diagnosis of childhood illnesses after delivery and within the postpartum period. Education on malaria preventive measures after delivery and the administration of intermittent preventive treatment for pregnancy during antenatal are a few of the benefits women derived from the policy. The FMHC is associated with high antenatal care attendance and institutional delivery by skilled attendants (midwives, nurses, doctors) at the time of delivery which consequently reduced

neonatal deaths and to a larger extent infant mortality [25 26]. Increasing access to the skilled birth attendant and emergency obstetric care is accepted as the most crucial intervention for reducing maternal and new-born deaths [27].

Strengths and limitations

This study has several strengths as well as some limitations. The advantages of using DHS as our primary source data have been well documented [28]. Paramount among these several advantages include high response rates, national coverage, high-quality interviewer training, standardized data collection procedures across countries and consistent content over time, allowing comparability across populations cross-sectionally and over time. The use of DID models with Propensity Score Kernel Matching is seen as strong non-experimental study design options when randomization is not feasible and provides more robust inference [19].

The limitation of this study originates from the fact that the DID analytic technique is generally less robust than the randomized design even though the study established that the parallel trend assumption was not violated. We highlight the fact that our study could still suffer from the omission of important time-varying unobserved characteristics such as total annual health expenditure could bias our study results if the omitted variables affected Ghana, Burkina Faso, and comparison countries in different ways. The reason is that DID attributes to the FMHCP policy intervention any differences in mortality trends between the Ghana and comparison countries that occur from the time intervention begins (2008). If any other factor is present that affect the difference in trends between the two groups differently, then the estimate from DID could be biased. In particular, health funding sources like the United States President Malaria Initiative (PMI), President's Emergency Plan for AIDS Relief (PEPFAR) and the Global Fund for HIV, Tuberculosis, and malaria are few of the foreign aid that could have an impact on child mortality [29]. For instance, Ghana and Zambia received funding support from PMI in 2008 but Burkina Faso has never benefitted from PMI and Nigeria only received funding from the PMI in

2011. Three out of the four countries studied continue to benefit from PEPFAR but received the support at different times (Ghana; 2007, Burkina Faso; not at all, Zambia and Nigeria in 2004). Ghana and Zambia still remain the only countries among the countries studied that have had the benefits of United States President Malaria Initiative since 2008 which also coincides with the year in which FMHCP policy became fully operational. The observed differentials among the four countries relative to foreign aid could impact on child mortality differently and bias the results.

With regards to Zambia and Nigeria, these two countries might not have a nationwide FMHCP but it is possible that there may be country specific interventions put in place to curb the menace of child mortality. Even among the intervention countries, there may be other specific interventions that are tailored towards child mortality but were not controlled in the current study. For instance, the "Rapid Scale-Up" program in Burkina Faso has a component that focuses on the integrated community case management and this policy has been found to reduce neonatal mortality by 6.2% [30]. Other interventions such as user fee exemption, mass radio campaign have all been found to be associated with an increase in the healthcare utilization among children under five in Burkina Faso which could have a direct positive impact in reducing neonatal mortality rate [31 32]. In addition to the aforementioned interventions, it is worth emphasizing that both Ghana and Burkina Faso receive support from the Global Fund in the fight against malaria, Tuberculosis and HIV since 2003 and this might have contributed to why Burkina Faso and Ghana might be doing better in terms of reducing infant and neonatal mortality rates. Despite the fact that our impact estimate of the policy may be imprecise and should be interpreted cautiously, we emphasized that the introduction of the FMHCP is associated with the reduction in both neonatal and infant mortality rates which is an encouraging finding and an important contribution to the literature on the colossal benefits of FMHCP. DID still remains one of the

robust quasi-experimental design to evaluate the impact of health intervention using cross-sectional time series data as it was the case in this study.

Policy implications

The findings from the study provide imperative evidence of an accelerated decline in child mortality rates after the introduction of FMHCP in the two West African countries. The additional investments in health tailored towards FMHCP implementation have yielded positive impacts. The implementation of the policy has reduced the financial burden associated with antenatal and postnatal care attendance and institutional delivery. Future studies should explore whether the investments made through FMHCP have spill-over effects beyond the usual benefits associated with the policy, such as women empowerment, higher investment in the private sector, higher school attainment and increase in employment rate which might, in turn, lead to greater economic development. As the population of women keeps increasing geometrically in SSA, Governments should consider an alternative source of financing to sustain the policy.

Conclusion

The motivation of the study is to obtain more reliable evidence of how the implementation of the free maternal healthcare policy (FMHC) in certain countries in the SSA has reduced child mortality compared to countries in the sub-region with no such national policy. Our findings highlight the importance of FMHCP implementation in reducing the risk of neonatal and infant mortalities. We recommend that a similar policy should be implemented in other lower and middle-income SSA countries to reduce the prevalence of neonatal and infants deaths.

Acknowledgments

The authors duly acknowledge the Demographic and Health Survey Program funded by the U.S. Agency for International Development (USAID), other donors and Ghana Statistical Service for making their data available to the public. We do acknowledge all mothers that were interviewed.

Competing Interests

None declared

Author Contributions

DD, KA, PN conceived and designed the study. Data management and data cleaning were done by DD, GI and KA. Statistical methods were drafted by DD, SB, and GI. DD, PN, GI, KA, SB, and AEY revised the draft critically. All authors have read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data sharing statement

All data sets are public data.

Patient consent

Not required.

Supporting information

S1 Table A: The summary trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

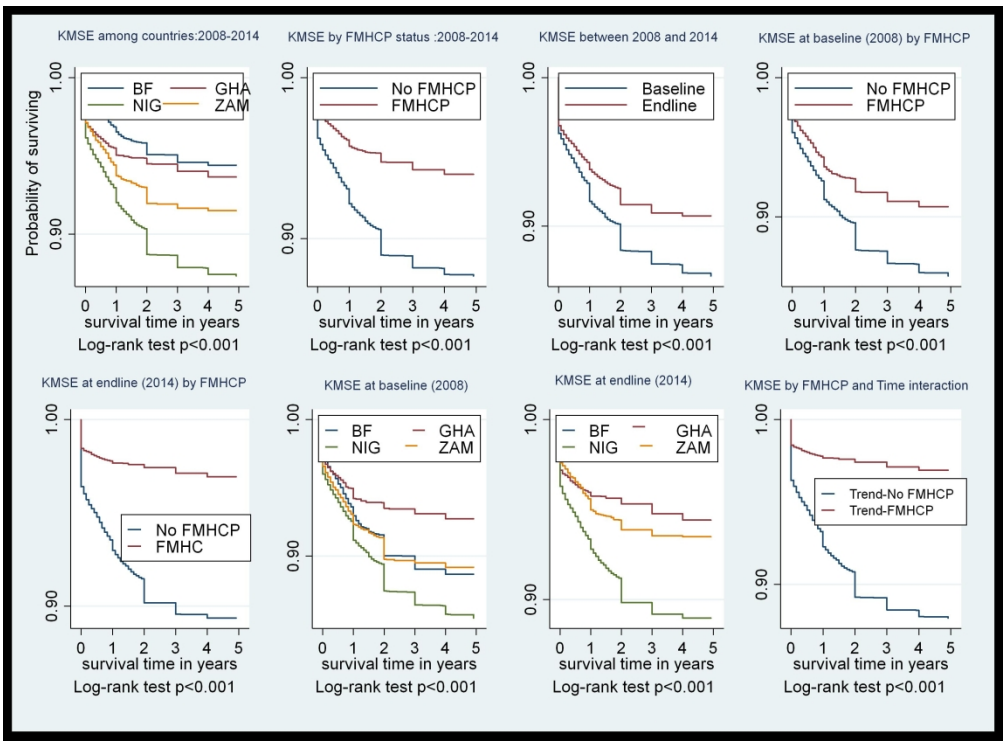
S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMNH and comparison group)

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group)

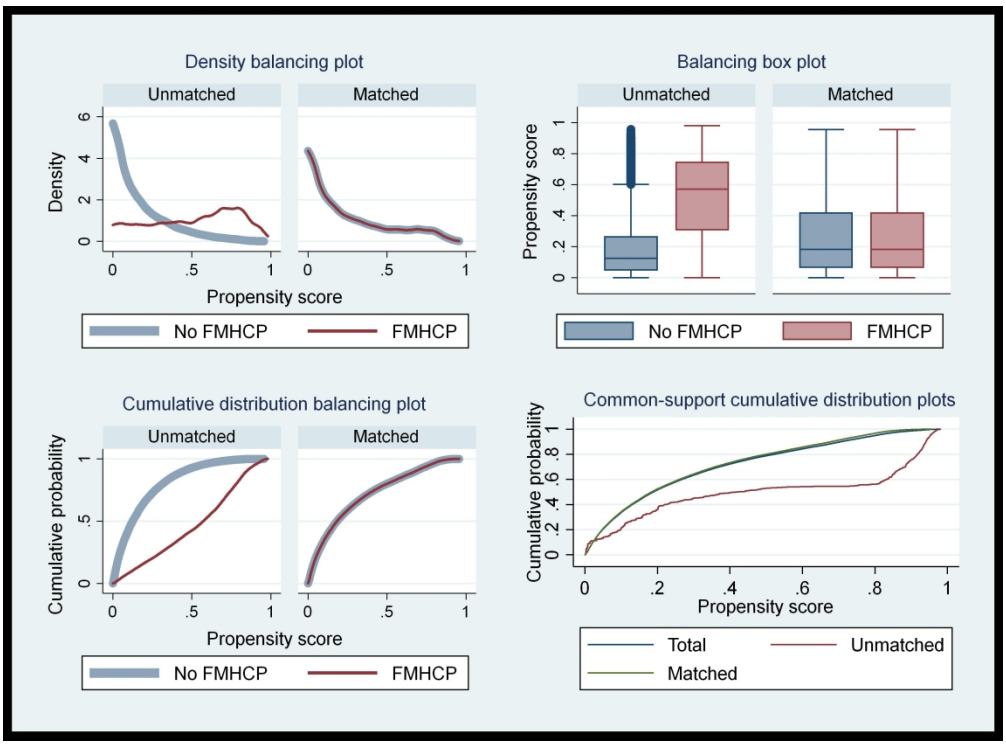
References

1. Peters DH, Garg A, Bloom G, et al. Poverty and access to health care in developing countries. Annals of the New York Academy of Sciences 2008;1136(1):161-71
2. Jacobs B, Bigdeli M, Annear PL, et al. Addressing access barriers to health services: an analytical framework for selecting appropriate interventions in low-income Asian countries. Health policy and planning 2011;27(4):288-300
3. Wang H, Otoo N, Dsane-Selby L. *Ghana National Health Insurance Scheme: improving financial sustainability based on expenditure review*: The World Bank, 2017.
4. Witter S, Arhinful DK, Kusi A, et al. The experience of Ghana in implementing a user fee exemption policy to provide free delivery care. Reproductive health matters 2007;15(30):61-71
5. Organization WH, UNICEF. Trends in maternal mortality: 1990-2015: estimates from WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. 2015
6. Belaid L, Ridde V. An implementation evaluation of a policy aiming to improve financial access to maternal health care in Djibo district, Burkina Faso. BMC pregnancy and childbirth 2012;12(1):143
7. Ridde V, Richard F, Bicaba A, et al. The national subsidy for deliveries and emergency obstetric care in Burkina Faso. Health policy and planning 2011;26(suppl_2):ii30-ii40
8. Okonofua F, Lambo E, Okeibunor J, et al. Advocacy for free maternal and child health care in Nigeria—results and outcomes. Health policy 2011;99(2):131-38
9. Yates R. Universal health care and the removal of user fees. The Lancet 2009;373(9680):2078-81
10. Witter S. Mapping user fees for health care in high-mortality countries-evidence from a recent survey. 2010
11. Leone T, Cetorelli V, Neal S, et al. Financial accessibility and user fee reforms for maternal healthcare in five sub-Saharan countries: a quasi-experimental analysis. BMJ open 2016;6(1):e009692
12. Dzakpasu S, Soremekun S, Manu A, et al. Impact of free delivery care on health facility delivery and insurance coverage in Ghana's Brong Ahafo Region. PloS one 2012;7(11):e49430
13. Ghana Statistical Service GHSG, and ICF International. . Ghana Demographic and Health Survey 2014. 2015
14. Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. Population and development review 1984;10(0):25-45
15. Fuentes R, Pfütze T, Seck P. Does access to water and sanitation affect child survival? A five country analysis: Human Development Report Office (HDRO), United Nations Development Programme …, 2006.
16. Ridgeway G, Kovalchik SA, Griffin BA, et al. Propensity score analysis with survey weighted data. Journal of causal inference 2015;3(2):237-49
17. Jann B. Kernel matching with automatic bandwidth selection. 2017
18. Stuart EA, Green KM. Using full matching to estimate causal effects in nonexperimental studies: examining the relationship between adolescent marijuana use and adult outcomes. Developmental psychology 2008;44(2):395
19. Stuart EA, Huskamp HA, Duckworth K, et al. Using propensity scores in difference-in-differences models to estimate the effects of a policy change. Health Services and Outcomes Research Methodology 2014;14(4):166-82
20. Lunceford JK, Davidian MJSim. Stratification and weighting via the propensity score in estimation of causal treatment effects: a comparative study. 2004;23(19):2937-60
21. McKinnon B, Harper S, Kaufman JS, et al. Removing user fees for facility-based delivery services: a difference-in-differences evaluation from ten sub-Saharan African countries. Health policy and planning 2014;30(4):432-41
22. Adams AM, Madhavan S, Simon D. Women's social networks and child survival in Mali. Social science & medicine 2002;54(2):165-78

23. Darmstadt GL, Bhutta ZA, Cousens S, et al. Evidence-based, cost-effective interventions: how many newborn babies can we save? The Lancet 2005;365(9463):977-88
24. Browne JL, Kayode GA, Arhinful D, et al. Health insurance determines antenatal, delivery and postnatal care utilisation: evidence from the Ghana Demographic and Health Surveillance data. BMJ open 2016;6(3):e008175
25. Lagarde M, Palmer N. The impact of user fees on access to health services in low-and middle-income countries. Cochrane Database of Systematic Reviews 2011(4)
26. Ansah EK, Narh-Bana S, Asiamah S, et al. Effect of removing direct payment for health care on utilisation and health outcomes in Ghanaian children: a randomised controlled trial. PLoS medicine 2009;6(1):e1000007
27. Campbell OM, Graham WJ, group LMSSs. Strategies for reducing maternal mortality: getting on with what works. The lancet 2006;368(9543):1284-99
28. Corsi DJ, Neuman M, Finlay JE, et al. Demographic and health surveys: a profile. International journal of epidemiology 2012;41(6):1602-13
29. Jakubowski A, Stearns SC, Kruk ME, et al. The US President's Malaria Initiative and under-5 child mortality in sub-Saharan Africa: A difference-in-differences analysis. PLoS medicine 2017;14(6):e1002319
30. Munos M, Guiella G, Roberton T, et al. Independent evaluation of the Rapid Scale-Up program to reduce under-five mortality in Burkina Faso. The American journal of tropical medicine and hygiene 2016;94(3):584-95
31. Zombré D, De Allegri M, Ridde V. Immediate and sustained effects of user fee exemption on healthcare utilization among children under five in Burkina Faso: A controlled interrupted time-series analysis. Social Science & Medicine 2017;179:27-35
32. Sarrassat S, Meda N, Badolo H, et al. Effect of a mass radio campaign on family behaviours and child survival in Burkina Faso: a repeated cross-sectional, cluster-randomised trial. The Lancet Global Health 2018;6(3):e330-e41



284x208mm (300 x 300 DPI)



284x208mm (300 x 300 DPI)

Supplemental materials for Impact evaluation of the free maternal healthcare policy on infant and neonatal mortality in four sub-Saharan Africa countries: Difference in Differences with Kernel based Propensity Score Matching Analysis.

S1 Table A: A summary of the trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

	Intervention countries: Implemented free maternal healthcare policy						Comparison countries: No free maternal healthcare policy					
	Ghana			**Burkina Faso**			**Nigeria**			**Zambia**		
	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2010 Ref period: 2006-2010	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2009-2013	2001/2002 Ref period: 1998-2002	2007 Ref period: 2003-2007	2013/2014 Ref period: 2009-2013
Number of live births in five years preceding the interview	3844	2992	5884	10645	15044	6841	6029	28647	31482	6877	6401	13457
Number of women age 15-49 interviewed	5691	4916	9396	12477	17087	8 111	7620	33385	38948	7658	7146	16411
Total number of women age 15-49 in the country at the time of the survey	4170068	4891557	5655156	2451363	303054 5	3416421	256199 94	28997441	32791677	2143989	2506625	3129094
Survey response rate for eligible women interviewed (%)	95.7	96.5	97.3	96.3	98.4	98.7	95.0	97.0	97.9	96.4	97.0	96.0
NMR per 1000 live births	43	30	29	31	28	27.3	48	40	37	37	34	24
IMR per 1000 live births	64	50	41	81	65	61.4	100	75	69	95	70	45
Cumulative incidence rate per 1000 person years at risk: Infant deaths	30 [24.2-37.7]	28.5 [22.5-36.8]	15.1 [11.9-19.4]	67.9 [61.9-74.6]	44.3 [40.5-48.5]	23.7 [21.3-26.4]	63.2 [55.6-72.1]	50.6 [47.7-53.7]	36.8 [34.3-39.6]	70.5 [63.8-78.2]	44.7 [39.1-51.4]	26.5 [23.2-30.5]

Abbreviations: IMR: Infant mortality rate, NMR: Neonatal mortality rate.

S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMHCP and comparison group).

	Before Matching			After Matching		
	FMHCP	No FMHCP	Standardized Mean Difference	FMHCP	No FMHCP	Standardized Mean Difference
	Mean	Mean		Mean	Mean	
Sex						
Male	0.83	0.90	-0.19	0.83	0.81	0.06
Female	0.17	0.10	0.19	0.17	0.19	0.06
Wealth						
Poorest	0.23	0.23	-0.02	0.23	0.23	0.02
Poorer	0.21	0.23	-0.04	0.21	0.21	0.02
Middle	0.20	0.19	0.03	0.20	0.20	0.01
Richer	0.20	0.18	0.05	0.20	0.20	0.00
Richest	0.16	0.17	-0.02	0.16	0.16	0.01
Household size						
≤ 4	0.29	0.25	0.10	0.29	0.31	-0.03
5 -7	0.40	0.42	-0.03	0.40	0.41	0.01
8+	0.31	0.33	-0.06	0.31	0.29	0.04
Household access to an improved water source						
Improved	0.90	0.78	0.34	0.90	0.90	0.00
Not improved	0.10	0.22	-0.34	0.10	0.10	0.00
Household access to improved toilet						
Improved, not shared	0.13	0.30	-0.44	0.13	0.12	0.01
Improved, shared	0.37	0.19	0.40	0.37	0.39	0.04
Not improved	0.50	0.50	0.00	0.50	0.49	0.03
Geographic location						
Urban	0.31	0.32	-0.03	0.31	0.32	0.02
Rural	0.69	0.68	0.03	0.69	0.68	0.02
Household owns a mosquito net						
No	0.20	0.52	-0.71	0.20	0.20	0.01
Yes	0.80	0.48	0.71	0.80	0.80	0.01
Mother's age at child's birth						
< 18	0.03	0.03	-0.05	0.03	0.02	0.00
18 - 34	0.72	0.71	0.00	0.72	0.73	0.03
35+	0.26	0.25	0.02	0.26	0.24	0.03
Educational attainment						
None	0.54	0.45	0.19	0.54	0.53	0.02
Primary	0.17	0.24	-0.17	0.17	0.18	0.00
Secondary	0.26	0.25	0.02	0.26	0.27	0.02
Tertiary	0.02	0.05	-0.18	0.02	0.02	0.01
Birth order						
First	0.29	0.19	0.22	0.29	0.29	0.00
Second	0.26	0.17	0.20	0.26	0.26	0.00
Third	0.15	0.15	-0.02	0.15	0.14	0.01
Fourth or higher	0.31	0.48	-0.35	0.31	0.31	0.00
Birth type						
Single birth	0.96	0.97	-0.04	0.96	0.95	0.03
Multiple birth	0.04	0.03	0.04	0.04	0.05	0.03

Abbreviation: FMHCP: Free maternal healthcare policy

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group).

	Before matching			After matching		
	FMHCP Variance	No FMHCP Variance	Ratio	FMHCP Variance	No FMHCP Variance	Ratio
Sex						
Male	0.14	0.09	1.49	0.14	0.15	0.92
Female	0.14	0.09	1.49	0.14	0.15	0.92
Wealth						
Poorest	0.17	0.18	0.97	0.17	0.18	0.98
Poorer	0.17	0.18	0.95	0.17	0.16	1.03
Middle	0.16	0.16	1.05	0.16	0.16	1.02
Richer	0.16	0.15	1.08	0.16	0.16	1.00
Richest	0.13	0.14	0.96	0.13	0.14	0.98
Household size						
≤ 4	0.21	0.19	1.11	0.21	0.21	0.98
5 -7	0.24	0.24	0.99	0.24	0.24	1.00
8+	0.21	0.22	0.96	0.21	0.21	1.04
Household access to an improved water source						
Improved	0.09	0.17	0.51	0.09	0.09	0.99
Not improved	0.09	0.17	0.51	0.09	0.09	0.99
Household access to improved toilet						
Improved, not shared	0.11	0.21	0.53	0.11	0.11	1.02
Improved, shared	0.23	0.16	1.49	0.23	0.24	0.98
Not improved	0.25	0.25	1.00	0.25	0.25	1.00
Geographic location						
Urban	0.21	0.22	0.98	0.21	0.22	0.98
Rural	0.21	0.22	0.98	0.21	0.22	0.98
Household owns a mosquito net[3]						
No	0.16	0.25	0.64	0.16	0.16	0.98
Yes	0.16	0.25	0.64	0.16	0.16	0.98
Mother's age at child's birth						
< 18	0.02	0.03	0.74	0.02	0.02	1.02
18 - 34	0.20	0.20	1.00	0.20	0.20	1.04
35+	0.19	0.19	1.02	0.19	0.18	1.04
Educational attainment						
None	0.25	0.25	1.00	0.25	0.25	1.00
Primary	0.14	0.18	0.78	0.14	0.14	1.00
Secondary	0.19	0.19	1.02	0.19	0.20	0.98
Tertiary	0.02	0.05	0.39	0.02	0.02	0.92
Birth order						
First	0.21	0.16	1.31	0.20	0.21	1.00
Second	0.19	0.14	1.32	0.19	0.19	1.00
Third	0.12	0.13	0.96	0.12	0.12	1.02
Fourth or higher	0.21	0.25	0.86	0.21	0.21	1.00
Birth type						
Single birth	0.04	0.03	1.23	0.04	0.05	0.89
Multiple birth	0.04	0.03	1.23	0.04	0.05	0.89

Abbreviation: FMHCP: Free maternal healthcare policy

BMJ Open

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Propensity Score Kernel Matching and Difference in Differences Analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-033356.R2
Article Type:	Original research
Date Submitted by the Author:	29-Jan-2020
Complete List of Authors:	Dwomoh, Duah; University of Ghana College of Health Sciences, Biostatistcs; University of Ghana College of Health Sciences, Biostatistics, School of Public Health Agyabeng, Kofi ; School of Public Health, College of Health Sciences, University of Ghana, P. O. Box LG13, Legon, Ghana Agbeshie, Kwame; Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana Incoom, Gabriel; Ghana Institute of Management and Public Administration, Department of Management Science, School of Business Nortey, Priscilla ; University of Ghana School of Public Health, Epidemiology Yawson, Alfred; University of Ghana, Community Health, School of Public, College of Health Sciences Bosomprah, Samuel; University of Ghana, Biostatistics, School of Public Health
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Public health, Health policy, Health economics
Keywords:	Neonatal Mortality, Infant mortality, Free Maternal Healthcare Policy, PUBLIC HEALTH

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Impact evaluation of the free maternal healthcare policy on the risk of neonatal and infant deaths in four sub-Saharan Africa countries: A quasi-experimental design with Propensity Score Kernel Matching and Difference in Differences Analysis

Duah Dwomoh[1*], Kofi Agyabeng[1], Agbeshi Kwame [2], Gabriel Incoom[3], Priscilla Nortey[4], Alfred E. Yawson[5], Samuel Bosomprah[1]

[1] Department of Biostatistics, School of Public Health, University of Ghana, Accra.
[2] Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.
[3]Department of Management Science, School of Business, Ghana Institute of Management and Public Administration, Accra, Greater Accra, Ghana
[4] Department of Epidemiology and Disease Control, School of Public Health, University of Ghana, Accra.
[5] Department of Community Health, University of Ghana.

The email address of authors

Kofi Agyabeng: soothe1one@gmail.com
Agbeshi Kwame: kagbeshie@gmail.com
Gabriel Incoom: gabrielincoomghana@gmail.com
Priscilla Nortey: pnortey@gmail.com
Yawson Edwin Alfred: aeyawson@yahoo.com
Samuel Bosomprah: sbosomprah@gmail.com

Corresponding author: Duah Dwomoh: duahdwomoh@yahoo.com

Word count

Abstract: 289

Manuscript: 3825

Abstract

Objective Despite the huge financial investment in the Free Maternal Healthcare Policy (FMHCP) by the governments of Ghana and Burkina Faso, no study has quantified the impact of FMHCP on the relative reduction in neonatal and infant mortality rates using a more rigorous matching procedure with the difference in differences analysis. This study used several rounds of publicly available population-based complex survey data to determine the impact of FMHCP on neonatal and infant mortality rates in these two countries.

Design A quasi-experimental study to evaluate the free maternal healthcare policy implemented in Burkina Faso and Ghana between 2007 and 2014.

Setting Demographic and health surveys and maternal health surveys conducted between 2000 and 2014 for Ghana, Burkina Faso, Nigeria, and Zambia.

Participants: Children born in the five years preceding the survey for Ghana, Burkina Faso, Nigeria, and Zambia.

Primary outcome measures Neonatal and infant mortality rates

Results The Propensity Score Kernel Matching coupled with difference in differences (DID) analysis with Modified Poisson showed that the FMHCP was associated with a 45% reduction in the risk of Neonatal Mortality Rate (NMR) in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76, p<0.001). In addition, Infant Mortality Rate (IMR) has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001).

Conclusions The FMHCP had a significant impact and still remains relevant in achieving Sustainable Development Goal 3 and could provide lessons for other sub-Saharan countries in the design and implementation of a similar policy.

Keywords
Neonatal Mortality, Infant mortality, Kernel matching with Propensity Score, Free Maternal Healthcare Policy.

Word count
Abstract: 274
Main Manuscript: 4975

Strengths and limitations of this study

- The use of more rigorous statistical methods and data from repeated cross-sectional surveys improves the robustness of the impact estimate.
- This remains the first study that has quantified the impact of free maternal healthcare policy (FMHCP) on child survival.
- Evidence from this study can be used to inform policy decisions about the implementation of FMHCP in other sub-Saharan Africa countries.
- Unobserved factors could bias our study results if these factors affected interventions and comparison countries in different ways.
- We cannot interpret our results as causal since the data originate from a crossectional study design.

Introduction

Access to primary health care services remains low in many low- middle- income countries (LMIC). According to the World Health Organization report 2017, approximately half of the world population lacks access to essential health services and it is estimated that over 100 million still pushed into extreme poverty because of out of pocket health expenditure. Peters and colleagues [1] as well as Jacobs and colleagues [2] have classified these factors into four main dimensions, namely geographical access, financial access, availability of health care, and acceptability of health care service. Delay or lack of access to health care services due to financial constraints can affect child survival. Following the Abuja declaration for sub-Saharan African countries to spend 15% of its public spending on health care at the turn of the century, Ghana in 2003 set up a National Health Insurance Scheme (NHIS) as a way of improving UHC[3]. In September 2003, a policy exempting women in its four poorest regions of Ghana from delivery care fees was introduced by the Government of Ghana in an attempt to increase skilled birth attendance and reduce inequality in use of healthcare services [4]. The policy was rolled out in all the 10 regions by the end of April 2005 but with serious challenges. Notable among them was the fact that the disbursement of funds to accredited health facilities was not forthcoming and by October 2005 some health facilities started to charge clients again [4]. In July 2008, the government of Ghana through the National Health Insurance Scheme (NHIS) implemented a national user fee maternal care exemption policy to improve financial access to maternal health services and reduce maternal, perinatal, neonatal and infant mortality rates. The policy was popularly referred to as the free maternal healthcare policy (FMHCP). The main aim of the policy was to address financial barriers to demand health care services.

Burkina Faso is one of the countries in Sub-Saharan Africa (SSA) that failed to achieve the target for MDG goal number 5 (reduction of maternal mortality by 75% between 1990 and 2015) [5]. That notwithstanding, tremendous efforts have been made by Burkina Faso towards ensuring equitable access to maternal care services. For instance, maternal health financing and delivery reforms were developed and implemented, among which are the abolition of user fees for antenatal care (ANC) services in 2002, subsidization of delivery costs for all women by 80% and by 100% for the poorest in 2007 and exemption of the poorest from payment of all user fees for all curative and preventive health services in 2009 [6 7]. In this article, we refer to the policy implemented in Burkina Faso as FMHCP for easy reference to countries that have implemented the intervention.

Nigeria, for instance, did not have a clear federal policy on user fees in maternal and child health, and the regional variation at the primary and secondary level is vast [8]. Although Zambia removed user fees in 2006 in rural areas only [9 10], they had not been implemented properly and no impact had been seen in the following year or two [11]. That notwithstanding, fees are still payable (by cash) in urban areas and financial constraints still remain a significant barrier to institutional delivery [11]. The impact of these policies, particularly on access to health services and neonatal mortality has not been evaluated using rigorous methods, and so the empirical basis for defending these policies is weak [12]. To determine the effectiveness of FMHCP in contributing to a reduction in the mortality rate relative to countries that do not have such policy, Propensity Score Kernel Matching with the difference in differences analysis was applied. Using a quasi-experimental design, the goal of this study is to determine whether the full implementation of FMHCP in Ghana and Burkina Faso contributed to the relative reduction in neonatal and infant mortality rates between 2008 and 2014 compared to Nigeria and Zambia without such significant national health financing policy on maternal healthcare.

Methods and analyses

Data sources

The data used in this study were obtained from 11 separate Demographic and Health Surveys (DHS) and one Malaria Indicator Surveys (MIS). The DHS and MIS are a nationally representative cross-sectional survey that includes common questions about a year of birth and survival status of all births to women of reproductive age (15-49 years). The DHS and MIS datasets are freely available and could be downloaded at the DHS website (http://dhsprogram.com) after completing the online data request registration form. With the exception of Burkina Faso that could not provide DHS but MIS data for 2014, each country contributed 3 different DHS datasets that were conducted between 2000 and 2014. That is, we utilized the pre-baseline data from 2001/2003-2007/2008; baseline data: 2007/2008 and end-line data: 2013/2014. The unit of analysis in this study is the children of women born in 5 years (0-59 months) preceding the survey. Detailed distribution about number of live births in the five years preceding the survey, number of women age 15-49 interviewed, total number of women age 15-49 in the country at the time of the survey, year of survey and survey response rate for eligible women, NMR and IMR per 1000 live births, and cumulative incidence rate per 1000 person-years at risk can be found in Table A of S1 Appendix.

Patients and public involvement

Patients and the public were not involved.

Primary outcome measures

The primary outcomes of interest were infant mortality (IMR) and the neonatal mortality rate (NMR). In this analysis, the Infant mortality rate (IMR) is defined as the probability of dying between birth and first birthday whereas neonatal mortality rate (NMR) is defined as the probability of dying between birth and the first month of life [13]. All deaths that were recorded within the first 28 days after birth were coded as 1 or otherwise 0 in defining a binary indicator

variable for neonatal mortality. For infant mortality, deaths within one year after birth in the five years preceding each survey were coded as 1 otherwise 0 to define a binary indicator for infant mortality.

Exposure to free maternal healthcare policy

Countries that have abolished at least 80% of user fees for institutional delivery in Sub-Saharan Africa between the periods of 2007-2014 and have readily available DHS or MIS data were included in the study as intervention countries. That notwithstanding, these countries should have conducted DHS between the periods of 2000-2008. This was necessary to test the parallel trend assumption which is a requirement for the validity of DID design and its estimate. There were only two countries that implemented user fee reforms for maternal healthcare between 2007 and 2008. Ghana and Burkina Faso met these inclusion criteria and therefore qualified as intervention countries. Although Zambia and Nigeria conducted DHS between 2000 and 2014, both countries did not have a universal exemption on user fees for institutional births during the study period and therefore qualified to be used in the comparison groups. A similar study based on quasi-experimental design has provided a detail explanation as to why Zambia, Cameroon, and Nigeria could represent a valid comparison group compared to other countries in SSA in evaluating the impact of free maternal healthcare policy on intermediate and long term health outcomes [11]. Cameroon was excluded as a comparison country in this study because there was no survey conducted in 2007/2008 which represents the full policy implementation year.

Covariates assumed to be associated with child survival and included in the estimation of the propensity scores

The choice of the selected covariates in assessing risk factors of child survival was based on the analytical framework for the study of child survival in developing countries by Mosley and Chen [14]. Specifically, we extracted data and performed the estimation of the propensity scores as using the following variables: household ownership of bednets, child's age and gender, mother's age at the time of the survey, mother's education level, household wealth, sex of the household head,

and whether the household was in the urban or rural area, birth order, multiple births and household size, household access to improved water and sanitation. We defined a household as having access to an improved water source if it has any of the following: piped water into the dwelling, yard, or plot; public tap or standpipe, tube-well, or borehole; a protected dug well or protected spring; rainwater; or bottled water. There is a direct correlation between access to an improved water source and infant survival [15]. This analysis defines a household as having an improved sanitation if it has any of the following types of toilet facilities, and if this facility is not shared with another household: a flush or pour-flush to piped sewer system, septic tank, or pit latrine; a ventilated improved pit latrine; a pit latrine with a slab; or a composting toilet. There is an inverse relationship between access to improved sanitation and infant mortality. Increasing access to improved sanitation is associated with lower levels of infant mortality [15]. The estimation of the propensity scores was based on the binary logistic regression model that adjusted for the complex survey design structure of the dataset (weighting, stratification and clustering).

Statistical analyses based on DHS and MIS datasets

Since the study pooled data from different surveys, the women's standard weights were de-normalized. This was achieved by dividing the women's standard weight by the women survey sampling fraction, that is, the ratio of the total number of women aged 15-49 interviewed in the survey year over the total number of women aged 15-49 years in the country at the time of the survey. The total number of women aged 15-49 interviewed in the survey year was obtained from the DHS datasets, while the total number of women aged 15-49 years in the country at the time of the survey was obtained from our world in data (https://ourworldindata.org/). Complex survey design characteristics (weighting, stratification, and clustering) were adjusted in all the analyses. In particular, we used the sampling weights in the estimation of the propensity score model and also used the sampling weight times the Kernel weight obtained from the repeated

cross-section as the weight variable in the final outcome analysis. This analytic technique has been shown to produce unbiased treatment effect estimates that are generalizable to the original survey target population [16]. The Kernel function used in the weight estimation was Epanechnikov and the bandwidth selection was based on cross-validation of the means of covariates [17].

To determine the impact of the policy on NMR and IMR, we performed a Propensity Score Kernel Matching with difference-in-differences (DID) analysis using a modified Poisson regression model with robust standard errors. We estimated the average treatment effect (ATE) using propensity scores with Kernel matching adjustment and inverse probability of treatment weighting (IPTW). The data for the study originates from multi-stage complex surveys and to assess the impact of the intervention, there is the need to replicate random assignment. In experimental study design with random assignment, treatment groups (countries with FMHCP) and control groups (countries with no such policy) are similar on all background characteristics (observed and unobserved) as a consequence of the randomization, allowing for straightforward comparison of outcomes. In contrast, in complex surveys, the intervention and comparison individuals may differ significantly on background characteristics. Thus, any difference in outcomes (neonatal and infant mortality rate) between the two groups may be due to these background covariates or to the intervention itself. Matching procedures, followed by regression adjustment on the matched sample, can often be a stronger approach for estimating causal effects than regression on an unmatched sample [18].

The DID design is a known quasi-experimental method that is used frequently in policy evaluations to compare changes over time in a group unaffected by the policy intervention (comparison countries) to the changes over time in a group affected by the policy intervention (intervention countries) and attributes the "difference-in-differences" to the effect of the policy [19]. Several sensitivity analyses were conducted to determine the robustness of our results. We tested whether the policy impact estimate is robust to the type of model specification using logit,

probit, and Cox proportional hazard models with robust standard errors. For the Cox model, the time-to-death with survival status as a censoring indicator was modeled. Finally, we tested whether the impact estimate is robust to different weighting procedures. First, we employed, inverse probability of treatment weighting (IPTW) given by $w_i = \frac{T_i}{e_i} + \frac{1-T_i}{1-e_i}$ where e_k is the estimated propensity score for individual k, and T_i is the treatment status indicator variable. The IPTW serves to weigh both the treated and control groups up to the full sample, in the same way, that surveys sampling weights weigh a sample up to a population [20]. We also apply weighting by the odds to estimate the average treatment effect on the treated (ATT) given by $w_i = T_i + (1-T_i)\frac{e_i}{1-e_i}$. The DID design relies on the parallel trend assumption. This assumption states that in the absence of the intervention (free maternal healthcare policy), there would be no statistically significant difference in the trend of NMR and IMR between the intervention and the comparison countries. We relied on DHS data conducted between the years 2000 and 2008 to test this assumption. P-values less than 0.05 were considered as statistically significant. Data cleaning and analysis were conducted using Stata version 15 (StataCorp, College Station, Texas, USA).

Results

Results using data from 2007 to 2014 showed that approximately 9.2% [95% CI: 8.9-9.5] of the 110,748 children in our sample died before reaching age 5. Within the same period, there was a statistically significant difference in the proportion of deaths between countries with FMHCP and those with no such policy (FMHCP=6.2% [95% CI: 5.9-6.6]; no FMHCP=9.8% [95% CI: 9.5-10.1], Rao-Scot Chi-square test=159.6; p<0.001, Table 1). The proportion of infant deaths was 6.7% [95% CI: 6.5-7.0]. Among countries with FMHCP, the proportion of infant deaths was approximately 4.0% [95% CI: 3.6-4.3] compared countries with no FMHCP where infant deaths were 7.3% [95% CI: 7.1-7.6] and the difference was statistically significant (Rao-Scot Chi-

square test=168.4; p<0.001, Table 1). The overall proportion of neonatal deaths was 3.5% [95% CI: 3.3-3.6]. FMHCP countries recorded 0.4% [95% CI: 0.3-0.4] neonatal deaths compared to 3.1% [95% CI: 2.9-3.3] recorded by countries with no FMHCP (Rao-Scot Chi-square test=76.7, p<0.001).

Table 1: Trend of neonatal and infant mortality between countries with and without FMHCP and description of the study participants: 2007/2008-2013/2014.

	Total %	Intervention: FMHCP implementation		Rao-Scot Chi-square
		No FMHP %[b]	FMHP %[b]	
All-cause mortality in the five years preceding the survey [95% CI]	9.2 [8.9-9.5]	9.8 [9.5-10.1]	6.2 [5.9-6.6]	159.60***
All-cause neonatal deaths in the five years preceding the survey [95% CI]	3.5 [3.3-3.6]	3.1 [2.9-3.3]	0.4 [0.3-0.4]	76.70***
All-cause infants deaths in the five years preceding the survey [95% CI]	6.7 [6.5-7.0]	7.3 [7.1-7.6]	4.0 [3.6-4.3]	168.40***
Sex of household head				114.03***
Male	97430 (88.4)	70247 (83.4)	27183 (16.6)	
Female	13318 (11.6)	9740 (74.3)	3578 (25.7)	
Wealth quintile				2.00
Poorest	26597 (23.3)	19264 (82.9)	7333 (17.1)	
Poorer	25526 (22.7)	18862 (83.3)	6664 (16.7)	
Middle	22913 (19.4)	16412 (81.4)	6501 (18.6)	
Richer	20303 (18.2)	14198 (80.7)	6105 (19.3)	
Richest	15409 (16.5)	11251 (82.9)	4158 (17.1)	
Household size				20.26***
1-4	26784 (25.8)	19215 (79.8)	7569 (20.2)	
5-7	45709 (41.5)	33951 (82.9)	11758 (17.1)	
8+	38255 (32.8)	26821 (83.5)	11434 (16.5)	
Access to improved water				121.32***
Improved	89000 (80.4)	61284 (80.1)	28049 (19.9)	
Unimproved	21000 (19.6)	18676 (91.4)	2711 (8.6)	
Missing	28 (0.01)	27 (98.4)	1 (1.6)	
Access to an improved toilet facility				195.72***
Improved, not shared	26000 (27.0)	22493 (91.7)	3817 (8.3)	
Improved, shared	21000 (22.5)	13047 (71.0)	7762 (29.0)	
Unimproved	63000 (50.1)	44120 (82.4)	19095 (17.6)	
Missing	414 (0.4)	327 (81.2)	87 (18.8)	
Place of residence				0.61
Urban	32627 (32.2)	25035 (82.9)	7592 (17.1)	
Rural	78121 (67.8)	54952 (82.0)	23169 (18.0)	
Household ownership of bednet				1013.52***
No bednet	43000 (46.4)	36880 (92.4)	6015 (7.6)	
Bednet	68000 (53.6)	43062 (73.6)	24746 (26.5)	
Missing	45 (0.06)	45 (100.0)	0 (0.0)	
Mothers current age				11.10***
<18 years	3558 (3.3)	2803 (86.5)	755 (13.5)	
18-34 years	80000 (71.5)	58000 (82.3)	22000 (17.7)	
35+	27000 (25.2)	20000(81.8)	7727 (18.2)	
Mothers education				44.98***
None	53000 (46.5)	32000 (79.4)	21000 (20.6)	
Primary	29000 (23.2)	24000 (86.6)	4475 (13.4)	
JHS	25000 (25.5)	20000 (81.7)	4686 (18.3)	
Secondary or higher	4241 (4.8)	3882 (92.4)	359 (7.6)	
Missing	16 (0.01)	11 (64.6)	5 (35.4)	
Birth order				271.39***
1st birth	24000 (21.1)	16000 (75.8)	8167 (24.2)	
2nd births	21000 (18.9)	14000 (76.1)	7351 (23.9)	
3rd births	17000 (15.2)	12000 (83.1)	4386 (16.9)	
4th births	49000 (44.8)	38000 (87.7)	11000 (12.3)	
Multiple births				10.19**
Single	110000 (96.4)	77000 (82.4)	30000 (17.6)	
Multiple	3994 (3.6)	2750 (79.1)	1244 (20.9)	

	Child mortality estimate per country			
Country	Year of survey	NMR per 1000 live births	IMR per 1000 live births	Cumulative incidence rate per 1000 person-years at risk
Burkina Faso	2003	31	81	67.9 [61.9-74.6]
	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
Ghana	2003	43	64	30.0 [24.2-37.7]
	2008	30	50	28.5 [22.5-36.8]

	2014	29	41	15.1 [11.9-19.4]
Nigeria	2003	48	100	63.2 [55.6-72.1]
	2008	40	75	50.6 [47.7-53.7]
	2013	37	69	36.8 [34.3-39.6]
Zambia	2001-2002	37	95	70.5 [63.8-78.2]
	2007	34	70	44.7 [39.1-51.4]
	2014	24	45	26.5 [23.2-30.5]

Abbreviations: FMHP – Free maternal health policy; NMR: Neonatal mortality rate, IMR: Infant mortality rate. P-value notation: ***p<0.001, **p<0.01, *p<0.05. %[b] represents row percentages. Note: access to improved toilet facilities had a missing observation of 0.4%.

NMR and IMR per 1000 live births decline between 2008 and 2014 in both FMHCP and non-FMHCP countries but the decline was steeper at all times in the FMHCP countries at various time points (Figure 1).

Figure 1: Kaplan Meier survival estimate (KMSE) at varying time points of free maternal healthcare policy implementation (FMHCP). Abbreviations: BF: Burkina Faso, GHA: Ghana, NIG: Nigeria, ZAM: Zambia

Results on balancing and common support diagnostics of the Kernel-based matching

Balancing tests based on standardized mean difference and ratio of variances of the observed covariates between the two sets of countries (FMHCP and non-FMHCP) were conducted before and after Kernel-based matching. This was done to ascertain how the matching procedure has reduced biases in the means and variances of the observed covariates between FMHCP countries and non-FMHCP countries. The mean difference in the observed covariate between FMHCP countries and non-FMHCP reduced significantly after matching making the two groups as similar as possible (Table B in S1 Appendix). The ratio of variances in the covariate between the two sets countries was closer to 1 after matching than before matching (Table C in S1 Appendix). The results showed that the propensity score with Kernel-based matching reduced covariate imbalance between countries with and without FMHCP. The results from the Kernel density, cumulative distribution and the box-whisker plots in figure 2 showed that matching has made FMHCP and non-FMHCP countries more similar in terms of the observed covariates, hence any change in the risk of neonatal and infant deaths could be attributed to FMHCP.

Figure 2: Balancing the diagnostic test of the Kernel-based propensity score matching

Results on the test of the parallel trend assumption

The fixed-effects model controls for all time-invariant differences between the individuals and the country level factors such differences in geographic location, so the estimated coefficients of the fixed-effects models cannot be biased because of omitted time-invariant characteristics.

The test of parallel trends showed that after controlling for baseline individual and country time-fixed effect characteristics, maternal, child and household characteristics including household ownership of bednet, both infant and neonatal mortality rate rates did not differ between countries with FMHCP and those with no FMHCP before the implementation of FMHCP (NMR: aRR=0.91, 95% CI 0.71-1.16; p>0.05; Table 2).

Mortality rates were declining in all of the study countries during this time period (NMR: aRR=0.88, 95% CI: 0.75-1.02; IMR: aRR=0.84, 95% CI: 0.76-0.94, p<0.05, Table 2), but there was no evidence of trends being different between countries that have implemented FMHCP and comparison countries. In conclusion, the parallel trend assumption was not violated and therefore estimates from DID analyses were valid.

Table 2: Test of parallel trends assumption: Risk of neonatal and infant mortality prior to free maternal healthcare policy implementation (2001-2008): Modified Poisson model with robust standard error on the unmatched sample.

	Neonatal mortality: 2000-2008		Infant mortality: 2000-2008	
Covariates	uRR [95% CI]	aRR [95% CI]	uRR [95% CI]	aRR [95% CI]
Time Baseline: 2008	ref	ref	ref	ref
End-line: 2014	0.86* [0.75-0.99]	0.88 [0.75-1.02]	0.83*** [0.76-0.91]	0.84** [0.76-0.94]
Intervention				
No FMHP	ref	ref		ref
FMHP-assumed it exited	0.85 [0.72-1.01]	0.89 [0.71-1.11]	0.94 [0.84-1.05]	0.92 [0.79-1.07]
Time*FMHP	0.92 [0.74-1.15]	0.91 [0.71-1.16]	0.93 [0.81-1.08]	0.91 [0.78-1.08]
Sex of household head				
Male		ref		ref
Female		0.90 [0.73-1.11]		0.89 [0.76-1.03]
Mothers current age				
<18 years		ref		ref
18-34 years		0.90 [0.78-1.03]		0.91 [0.82-1.00]
35+		2.33* [1.02-5.30]		2.40* [1.10-5.26]
Place of residence				
Urban		ref		ref
Rural		1.35*** [1.14-1.60]		1.29*** [1.14-1.45]
Household size				
1-4		ref		ref
5-7		0.48*** [0.40-0.57]		0.49*** [0.43-0.55]
8+		0.43*** [0.35-0.52]		0.43*** [0.37-0.49]
Access to improved water				
Improved		ref		ref
Unimproved		1.08 [0.92-1.27]		1.13* [1.01-1.26]
Access to an improved toilet facility				
Improved, not shared		ref		ref
Improved, shared		0.81* [0.66-0.98]		0.76*** [0.66-0.87]
Unimproved		0.85 [0.72-1.01]		0.86* [0.77-0.97]
Mothers education				
None		ref		ref
Primary		1.01 [0.84-1.2]		0.94 [0.83-1.06]
JHS		0.84 [0.69-1.02]		0.73*** [0.63-0.83]
Secondary or higher		0.93 [0.59-1.44]		0.55** [0.39-0.78]
Birth order				
1st birth		ref		ref
2nd births		0.70** [0.57-0.86]		0.83* [0.71-0.98]
3rd births		0.71** [0.55-0.9]		0.99 [0.84-1.17]
4th births		1.03 [0.84-1.26]		1.20* [1.04-1.39]
Multiple births				
Single		ref		ref
Multiple		5.31*** [4.26-6.62]		3.70*** [3.11-4.40]
Household ownership of bednet				
No bednet		ref		ref
Bednet		0.91 [0.78-1.05]		0.95 [0.86-1.05]
Country Fixed Effect	Yes	Yes	Yes	Yes

Abbreviations: FMHP; Free maternal healthcare policy, aRR: Adjusted Relative Risk, uRR: Unadjusted Relative Risk, P-value notations: ***p<0.001, **p<0.01, *p<0.05. Note: With respect to Burkina Faso, 2010 demographic health survey data was used since they did not conduct any survey in 2008.

Impact of FMHCP on the risk of neonatal deaths

The results from the modified Poisson with DID using Propensity Score Kernel Matching showed that FMHCP is associated with 45% reduction in the risk of NMR in Ghana and Burkina Faso compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.55, 95% CI: 0.40-0.76, p<0.001, Table 3). Sensitivity analyses based on different outcome model specification showed similar results (Table 3).

Table 3: Impact of the free maternal healthcare policy on neonatal mortality: Kernel-based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error.

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel matching	With Kernel matching based on PSM	With Kernel matching based on PSM	With Kernel matching based on PSM	With Kernel matching based on PSM	ATET weighting and PSM- IPTW	ATE weighting and PSM-
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.92[0.82, 1.03]	0.63*[0.42, 0.96]	0.62*[0.42, 0.91]	0.59[0.33, 1.07]	-0.35*[-0.69, -0.01]	0.61**[0.46, 0.81]	0.67**[0.51, 0.86]
Intervention							
No FMHP	ref	ref	ref	ref	ref	ref	ref
FMHP	0.66***[0.53, 0.83]	0.94[0.74, 1.19]	0.96[0.77, 1.19]	0.95[0.62, 1.47]	-0.04[-0.28, 0.2]	-0.81[0.78, 1.11]	0.93[0.82, 1.07]
Time*FMHP	0.56***[0.43, 0.73]	0.55***[0.40, 0.76]	0.55***[0.40, 0.74]	0.44*[0.22, 0.88]	-0.41*[-0.79, -0.02]	0.57***[0.42, 0.77]	0.71[0.46, 1.08]
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.85*[0.73, 0.99]	0.73*[0.55, 0.97]	0.81[0.63, 1.04]	1.08[0.67, 1.74]	0.02[-0.24, 0.29]	-1.99*[0.65, 1]	0.78*[0.63, 0.95]
Mothers current age							
<18 years	ref	ref	ref	ref	ref	ref	ref
18-34 years	0.43***[0.35, 0.54]	0.51**[0.35, 0.75]	1.01[0.71, 1.43]	2.69**[1.4, 5.18]	0.59**[0.21, 0.98]	3.99***[0.39, 0.72]	0.53***[0.39, 0.71]
35+	0.46***[0.36, 0.59]	0.55**[0.35, 0.86]	1.29[0.85, 1.95]	6.7***[3.12, 14.38]	1.11***[0.67, 1.56]	-3.17**[0.39, 0.8]	0.5***[0.35, 0.72]
Place of residence							
Urban	ref	ref	ref	ref	ref	ref	ref
Rural	1.24**[1.08, 1.42]	1.23[0.87, 1.74]	1.2[0.88, 1.64]	1.04[0.65, 1.65]	0.05[-0.22, 0.32]	1.94[1, 1.6]	1.21[0.84, 1.74]
Wealth quintile							
Poorest	ref	ref	ref	ref	ref	ref	ref
Poorer	1.01[0.89, 1.15]	1.04[0.86, 1.27]	1.03[0.86, 1.24]	0.81[0.53, 1.23]	-0.1[-0.34, 0.14]	0.72[0.89, 1.28]	0.98[0.79, 1.22]
Middle	0.86[0.74, 1.01]	0.93[0.73, 1.18]	0.96[0.77, 1.19]	0.93[0.56, 1.54]	-0.03[-0.32, 0.27]	0.2[0.82, 1.27]	0.89[0.69, 1.16]
Richer	0.91[0.75, 1.1]	0.83[0.61, 1.13]	0.87[0.65, 1.16]	0.88[0.43, 1.79]	-0.06[-0.47, 0.34]	-0.64[0.7, 1.2]	0.86[0.61, 1.2]
Richest	0.86[0.68, 1.11]	0.95[0.56, 1.61]	1.01[0.62, 1.62]	1.04[0.46, 2.34]	0.05[-0.41, 0.52]	-0.87[0.6, 1.22]	0.88[0.55, 1.42]
Household size							
1-4	ref	ref	ref	ref	ref	ref	ref
5-7	0.42***[0.37, 0.49]	0.46***[0.38, 0.56]	0.55***[0.45, 0.65]	0.49**[0.31, 0.78]	-0.41**[-0.67, -0.15]	8.18***[0.38, 0.55]	0.42***[0.34, 0.51]
8+	0.35***[0.3, 0.4]	0.41***[0.33, 0.52]	0.48***[0.39, 0.59]	0.33***[0.22, 0.49]	-0.64***[-0.87, -0.41]	8.67***[0.32, 0.49]	0.38***[0.31, 0.46]
Access to improved water							
Improved	ref	ref	ref	ref	ref	ref	ref
Unimproved	1.06[0.93, 1.21]	1.06[0.87, 1.3]	1.06[0.89, 1.27]	1.28[0.88, 1.88]	0.15[-0.07, 0.36]	0.02[0.82, 1.22]	1.02[0.82, 1.28]
Access to an improved toilet facility							
Improved, not shared	ref	ref	ref	ref	ref	ref	ref
Improved, shared	0.84*[0.72, 0.97]	0.97[0.78, 1.22]	0.97[0.79, 1.18]	1.08[0.72, 1.63]	0.04[-0.20, 0.28]	-0.43[0.78, 1.17]	0.90[0.70, 1.16]
Unimproved	0.84**[0.75, 0.94]	0.92[0.76, 1.11]	0.92[0.78, 1.10]	1.10[0.76, 1.59]	0.05[-0.15, 0.26]	-1.00[0.77, 1.09]	0.86[0.72, 1.04]
Mothers education							
None	ref	ref	ref	ref	ref	ref	ref
Primary	1.05[0.93, 1.20]	0.98[0.78, 1.23]	0.97[0.78, 1.20]	0.78[0.52, 1.18]	-0.14[-0.38, 0.10]	-0.80[0.76, 1.12]	0.99[0.79, 1.25]
JHS	0.94[0.80, 1.10]	0.93[0.69, 1.25]	0.86[0.65, 1.13]	0.62[0.35, 1.10]	-0.25[-0.57, 0.06]	-1.01[0.72, 1.11]	0.96[0.80, 1.16]
Secondary or higher	0.75[0.55, 1.03]	0.81[0.46, 1.41]	0.71[0.42, 1.21]	0.20***[0.08, 0.47]	-0.92***[-1.44, -0.41]	-1.37[0.45, 1.15]	0.79[0.43, 1.46]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	0.94[0.82, 1.09]	0.69**[0.54, 0.89]	0.62***[0.49, 0.77]	0.52*[0.30, 0.89]	-0.38*[-0.67, -0.08]	-2.89**[0.61, 0.91]	0.74*[0.59, 0.93]
3rd births	0.98[0.82, 1.18]	0.89[0.66, 1.2]	0.73*[0.56, 0.97]	0.60[0.34, 1.07]	-0.29[-0.61, 0.03]	-0.24[0.75, 1.25]	0.88[0.67, 1.15]
4th births	1.32**[1.12, 1.56]	1.18[0.90, 1.56]	0.87[0.67, 1.12]	0.46**[0.26, 0.81]	-0.44**[-0.76, -0.12]	2.21*[1.03, 1.58]	1.29*[1.00, 1.65]
Multiple births							
Single							
Multiple	5.84***[4.97, 6.86]	5.58***[4.25, 7.32]	4.73***[3.78, 5.92]	6.17***[2.47, 15.41]	0.96***[0.52, 1.4]	15.61***[4.74, 7.41]	5.58***[4.37, 7.12]
Household ownership of bednet							
No bednet							
Bednet	0.98[0.88, 1.09]	0.96[0.82, 1.12]	0.96[0.83, 1.11]	1.01[0.74, 1.37]	0.01[-0.16, 0.19]	-1.04[0.79, 1.07]	0.93[0.78, 1.1]
Country Fixed Effect	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted

Abbreviations: FMHP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, ref: reference category, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Impact of FMHCP on the risk of infant deaths

IMR has reduced significantly in both Ghana and Burkina Faso by approximately 54% after full implementation of FMHCP compared to Nigeria and Zambia (adjusted relative risk [aRR]=0.46, 95% CI: 0.36-0.59, p<0.001; Table 4). The series of sensitivity analysis that was conducted showed a similar impact of FMHCP (Table 4). The analysis adjusted for sex of the household head, mother's current age, mother's educational level, place of residence, wealth quintile, access to improved water and sanitation, birth order, multiple births and household ownership of bednet and country fixed-effect.

Table 4: Impact of the free maternal healthcare policy on infant mortality: Kernel-based propensity score matching with the difference in differences analysis using modified Poisson with robust standard error

	Sensitivity analysis based on different model specification						
	Modified Poisson Model: Clustering, weighting, and stratification were adjusted		Cox-proportional hazard Model: Clustering, weighting, and stratification were adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Poisson Model: Clustering, weighting, and stratification were adjusted	
	No Kernel matching with PS	With Kernel matching with PS	With Kernel matching PS	With Kernel matching with PSM	With Kernel matching with PS	ATET weighting using PS- IPTW	ATE weighting using PS
	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
Time							
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref
End-line: 2014	0.79***[0.73, 0.86]	0.62***[0.48, 0.8]	0.62***[0.49, 0.78]	0.45***[0.35, 0.58]	-0.45***[-0.59, -0.32]	0.64***[0.53, 0.78]	0.77**[0.64, 0.91]
Intervention							
No FMHCP	ref	ref	ref	ref	ref	ref	ref
FMHCP	0.72***[0.62, 0.84]	0.87[0.74, 1.03]	0.89[0.77, 1.04]	0.86[0.72, 1.02]	-0.09[-0.19, 0.01]	0.84*[0.74, 0.96]	0.83***[0.76, 0.92]
Time*FMHCP	0.49***[0.39, 0.61]	0.46***[0.36, 0.59]	0.45***[0.35, 0.57]	0.43***[0.33, 0.56]	-0.49***[-0.64, -0.34]	0.48***[0.37, 0.6]	0.55**[0.39, 0.77]
Sex of household head							
Male	ref	ref	ref	ref	ref	ref	ref
Female	0.88*[0.78, 0.98]	0.75**[0.61, 0.92]	0.81*[0.68, 0.98]	0.96[0.79, 1.17]	-0.02[-0.13, 0.09]	0.87[0.74, 1.02]	0.88[0.75, 1.02]
Mothers current age							
<18 years	ref	ref	Ref	ref	ref	ref	ref
18-34 years	0.49***[0.41, 0.58]	0.49***[0.37, 0.66]	0.86[0.65, 1.14]	3.1***[2.2, 4.38]	0.63***[0.44, 0.81]	0.49***[0.38, 0.63]	0.59***[0.46, 0.75]
35+	0.49***[0.4, 0.59]	0.47***[0.33, 0.66]	0.95[0.69, 1.31]	5.74***[3.92, 8.4]	0.96***[0.75, 1.17]	0.46***[0.35, 0.61]	0.52***[0.39, 0.68]
Place of residence							
Urban	ref	ref	Ref	ref	ref	ref	ref
Rural	1.16**[1.05, 1.29]	1.2[0.96, 1.5]	1.19[0.97, 1.46]	1.18[0.96, 1.45]	0.09[-0.03, 0.2]	1.14[0.96, 1.36]	1.13[0.89, 1.45]
Wealth quintile							
Poorest	ref	ref	Ref	ref	ref	ref	ref
Poorer	1.02[0.92, 1.12]	1.01[0.87, 1.17]	1[0.87, 1.15]	0.97[0.81, 1.16]	-0.02[-0.12, 0.08]	1.04[0.91, 1.18]	0.99[0.86, 1.15]
Middle	0.88*[0.79, 0.98]	0.92[0.77, 1.11]	0.95[0.8, 1.12]	0.99[0.8, 1.23]	-0.01[-0.13, 0.11]	0.92[0.79, 1.07]	0.93[0.78, 1.11]
Richer	0.86*[0.75, 0.99]	0.91[0.7, 1.19]	0.95[0.74, 1.21]	0.93[0.68, 1.28]	-0.03[-0.2, 0.14]	0.89[0.72, 1.09]	0.8*[0.64, 1]
Richest	0.69***[0.57, 0.82]	0.78[0.54, 1.12]	0.81[0.58, 1.13]	0.8[0.57, 1.11]	-0.14[-0.32, 0.05]	0.68**[0.52, 0.89]	0.73[0.5, 1.06]
Household size							
1-4	ref	ref	Ref	ref	ref	ref	ref
5-7	0.43***[0.39, 0.47]	0.45***[0.38, 0.52]	0.52***[0.45, 0.59]	0.54***[0.45, 0.65]	-0.34***[-0.44, -0.24]	0.46***[0.4, 0.52]	0.43***[0.37, 0.5]
8+	0.35***[0.32, 0.39]	0.4***[0.34, 0.48]	0.46***[0.39, 0.54]	0.43***[0.35, 0.52]	-0.45***[-0.55, -0.34]	0.42***[0.36, 0.49]	0.38***[0.33, 0.45]
Access to improved water							
Improved	ref	ref	Ref	ref	ref	ref	ref
Unimproved	1.05[0.96, 1.16]	1.03[0.89, 1.19]	1.02[0.89, 1.17]	1.02[0.88, 1.17]	0[-0.07, 0.08]	0.99[0.86, 1.15]	1.05[0.9, 1.22]
Access to an improved toilet facility							
Improved, not shared	ref	ref	Ref	ref	ref	ref	ref
Improved, shared	0.87*[0.78, 0.97]	0.94[0.79, 1.1]	0.94[0.81, 1.09]	0.82*[0.69, 0.97]	-0.11*[-0.2, -0.01]	0.97[0.83, 1.13]	0.94[0.78, 1.13]
Unimproved	0.88**[0.81, 0.96]	0.92[0.8, 1.05]	0.93[0.82, 1.05]	0.88[0.75, 1.02]	-0.07[-0.15, 0.02]	0.93[0.82, 1.05]	0.92[0.79, 1.06]
Mothers education							
None	ref	ref	Ref	ref	ref	ref	ref
Primary	0.9*[0.82, 0.99]	0.82*[0.7, 0.97]	0.82**[0.71, 0.95]	0.69***[0.58, 0.83]	-0.21***[-0.31, -0.11]	0.81**[0.71, 0.93]	0.89[0.76, 1.03]
JHS	0.88*[0.78, 0.98]	0.83[0.67, 1.02]	0.77**[0.64, 0.94]	0.54***[0.43, 0.67]	-0.35***[-0.47, -0.24]	0.82*[0.69, 0.97]	0.87[0.73, 1.03]
Secondary or higher	0.7**[0.56, 0.89]	0.78[0.53, 1.17]	0.71[0.48, 1.04]	0.38***[0.24, 0.58]	-0.55***[-0.78, -0.31]	0.78[0.53, 1.14]	0.69[0.43, 1.11]
Birth order							
1st birth	ref	ref	ref	ref	ref	ref	ref
2nd births	1.03[0.93, 1.15]	0.86[0.72, 1.03]	0.77**[0.65, 0.91]	0.6***[0.5, 0.73]	-0.27***[-0.38, -0.17]	0.94[0.82, 1.08]	0.84*[0.71, 1]
3rd births	1.2**[1.05, 1.37]	1.13[0.91, 1.4]	0.96[0.79, 1.17]	0.65***[0.52, 0.81]	-0.24***[-0.36, -0.12]	1.19[1, 1.43]	1.08[0.88, 1.34]
4th births	1.59***[1.42, 1.79]	1.63***[1.34, 1.98]	1.25*[1.05, 1.5]	0.7**[0.56, 0.86]	-0.2**[-0.32, -0.08]	1.66***[1.42, 1.93]	1.51***[1.23, 1.86]
Multiple births							
Single	ref	ref	ref	ref	ref	ref	ref
Multiple	4.37***[3.86, 4.95]	3.95***[3.16, 4.95]	3.57***[2.96, 4.3]	3.59***[2.75, 4.67]	0.72***[0.57, 0.87]	4.24***[3.58, 5.03]	4.43***[3.71, 5.29]
Household ownership of bednet							
No bednet	ref	ref	ref	ref	ref	ref	ref
Bednet	1.06[0.98, 1.14]	0.98[0.88, 1.09]	0.97[0.88, 1.08]	0.99[0.88, 1.12]	-0.01[-0.08, 0.06]	0.96[0.86, 1.06]	0.94[0.85, 1.05]
Country Fixed Effect	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted	Adjusted

Abbreviations: FMHCP; Free maternal healthcare policy, PSM: Propensity score matching, aRR: Adjusted Relative Risk, aHR: Adjusted Hazard Ratio, aOR: Adjusted Odds Ratio, ATE: Average Treatment Effect, ATET: Average Treatment Effect on the Treated, IPTW: Inverse Probability of Treatment Weighting, P-value notations: ***p<0.001, **p<0.01, *p<0.05.

Discussion

This study quantified the contribution of FMHCP implementation in Ghana and Burkina Faso in the reduction of neonatal and infant mortality rates. Child mortality within the implementation period in these two countries was compared to mortality in Nigeria and Zambia that do not have a significant major health financing reform in the period under consideration. It remains among the few studies to have compared the effectiveness of FMHCP in the four SSA countries using the more rigorous matching procedure with DID. Our impact evaluation found that the implementation of FMHCP led to a substantial reduction in both neonatal and infant mortality. This finding is consistent with what has been reported previously in the literature based on similar analytic technique [21]. Although all the four countries studied did not attain the MDG 4, Ghana and Burkina Faso have seen a tremendous decline in the trend of neonatal and infant mortality rates over the years. FMHCP was associated with substantial statistically significant reductions in infant and neonatal mortality rates when these estimates were compared between Zambia and Nigeria.

It is estimated that the effective implementation of key maternal and child healthcare interventions could prevent up to 70% of neonatal deaths globally [22 23]. The advantages of increasing access to facility delivery, pre-and postnatal care through FMHCP are well documented in the literature [12 24]. FMHC contributes greatly to increased coverage of routine immunization as women who visit and deliver in recommended health facilities were more likely to benefit from early immunization. The policy also promotes early and accurate diagnosis of childhood illnesses after delivery and within the postpartum period. Education on malaria preventive measures after delivery and the administration of intermittent preventive treatment for pregnancy during antenatal are a few of the benefits women derived from the policy. The FMHC is associated with high antenatal care attendance and institutional delivery by skilled

attendants (midwives, nurses, doctors) at the time of delivery which consequently reduced neonatal deaths and to a larger extent infant mortality [25 26]. Increasing access to the skilled birth attendant and emergency obstetric care is accepted as the most crucial intervention for reducing maternal and new-born deaths [27].

Strengths and limitations

This study has several strengths as well as some limitations. The advantages of using DHS as our primary source data have been well documented [28]. Paramount among these several advantages include high response rates, national coverage, high-quality interviewer training, standardized data collection procedures across countries and consistent content over time, allowing comparability across populations cross-sectionally and over time. The use of DID models with Propensity Score Kernel Matching is seen as strong non-experimental study design options when randomization is not feasible and provides more robust inference [19].

The limitation of this study originates from the fact that the DID analytic technique is generally less robust than the randomized design even though the study established that the parallel trend assumption was not violated. Although kernel matching maximizes the chance of matching control to a treated individual, observations outside the range of common support are still discarded which could potentially reduce the sample size.

We highlight the fact that our study could still suffer from the omission of important time-varying unobserved characteristics such as total annual health expenditure could bias our study results if the omitted variables affected Ghana, Burkina Faso, and comparison countries in different ways. The reason is that DID attributes to the FMHCP policy intervention any differences in mortality trends between the Ghana and comparison countries that occur from the time intervention begins (2008). If any other factor is present that affect the difference in trends between the two groups differently, then the estimate from DID could be biased. In particular, health funding sources like the United States President Malaria Initiative (PMI), President's Emergency Plan for AIDS

Relief (PEPFAR) and the Global Fund for HIV, Tuberculosis, and malaria are few of the foreign aid that could have an impact on child mortality [29]. For instance, Ghana and Zambia received funding support from PMI in 2008 but Burkina Faso has never benefitted from PMI and Nigeria only received funding from the PMI in 2011. Three out of the four countries studied continue to benefit from PEPFAR but received the support at different times (Ghana; 2007, Burkina Faso; not at all, Zambia and Nigeria in 2004). Ghana and Zambia still remain the only countries among the countries studied that have had the benefits of the United States President Malaria Initiative since 2008 which also coincides with the year in which FMHCP policy became fully operational. The observed differentials among the four countries relative to foreign aid could impact on child mortality differently and bias the results.

With regards to Zambia and Nigeria, these two countries might not have a nationwide FMHCP but it is possible that there may be country-specific interventions put in place to curb the menace of child mortality. Even among the intervention countries, there may be other specific interventions that are tailored towards child mortality but were not controlled in the current study. For instance, the "Rapid Scale-Up" program in Burkina Faso has a component that focuses on integrated community case management and this policy has been found to reduce neonatal mortality by 6.2% [30]. Other interventions such as user fee exemption, mass radio campaigns have all been found to be associated with an increase in the healthcare utilization among children under five in Burkina Faso which could have a direct positive impact in reducing neonatal mortality rate [31 32]. In addition to the aforementioned interventions, it is worth emphasizing that both Ghana and Burkina Faso receive support from the Global Fund in the fight against malaria, Tuberculosis and HIV since 2003 and this might have contributed to why Burkina Faso and Ghana might be doing better in terms of reducing infant and neonatal mortality rates. Despite the fact that our impact estimate of the policy may be imprecise and should be interpreted cautiously, we emphasized that the introduction of the FMHCP is associated with the reduction

in both neonatal and infant mortality rates which is an encouraging finding and an important contribution to the literature on the colossal benefits of FMHCP. DID still remains one of the robust quasi-experimental design to evaluate the impact of health intervention using cross-sectional time-series data as it was the case in this study.

Policy implications

The findings from the study provide imperative evidence of an accelerated decline in child mortality rates after the introduction of FMHCP in the two West African countries. The additional investments in health tailored towards FMHCP implementation have yielded positive impacts. The implementation of the policy has reduced the financial burden associated with antenatal and postnatal care attendance and institutional delivery. Future studies should explore whether the investments made through FMHCP have spill-over effects beyond the usual benefits associated with the policy, such as women empowerment, higher investment in the private sector, higher school attainment and increase in employment rate which might, in turn, lead to greater economic development. As the population of women keeps increasing geometrically in SSA, Governments should consider an alternative source of financing to sustain the policy.

Conclusion

The motivation of the study is to obtain more reliable evidence of how the implementation of the free maternal healthcare policy (FMHC) in certain countries in the SSA has reduced child mortality compared to countries in the sub-region with no such national policy. Our findings highlight the importance of FMHCP implementation in reducing the risk of neonatal and infant mortalities. We recommend that a similar policy should be implemented in other lower and middle-income SSA countries to reduce the prevalence of neonatal and infants deaths.

Acknowledgments

The authors duly acknowledge the Demographic and Health Survey Program funded by the U.S. Agency for International Development (USAID), other donors and Ghana Statistical Service for making their data available to the public. We do acknowledge all mothers that were interviewed.

Competing Interests

None declared

Author Contributions

DD, KA, PN conceived and designed the study. Data management and data cleaning were done by DD, GI and KA. Statistical methods were drafted by DD, SB, and GI. DD, PN, GI, KA, SB, and AEY revised the draft critically. All authors have read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data sharing statement

All data sets are public data.

Patient consent

Not required.

Supporting information

S1 Table A: The summary trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

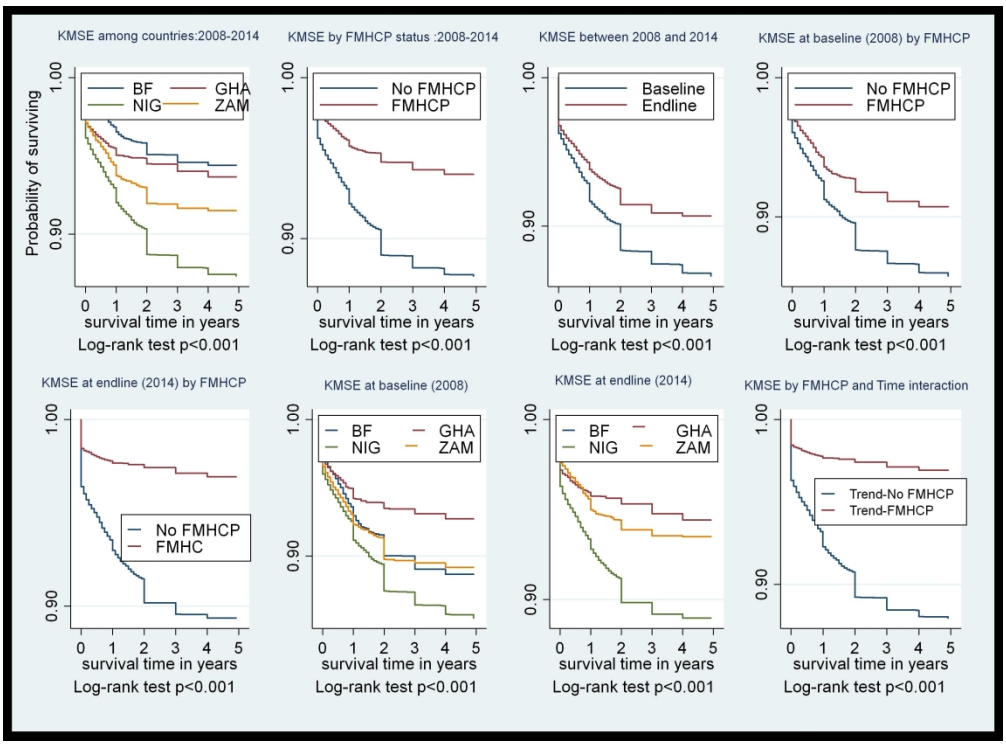
S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMNH and comparison group)

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group)

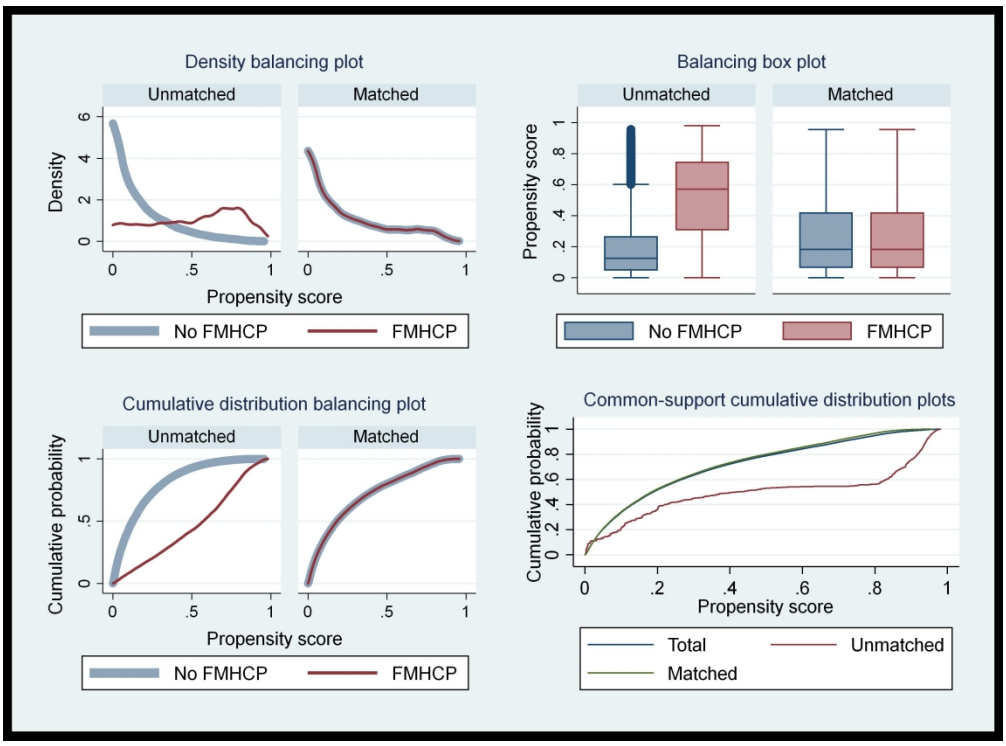
References

1. Peters DH, Garg A, Bloom G, et al. Poverty and access to health care in developing countries. Annals of the New York Academy of Sciences 2008;1136(1):161-71
2. Jacobs B, Bigdeli M, Annear PL, et al. Addressing access barriers to health services: an analytical framework for selecting appropriate interventions in low-income Asian countries. Health policy and planning 2011;27(4):288-300
3. Wang H, Otoo N, Dsane-Selby L. *Ghana National Health Insurance Scheme: improving financial sustainability based on expenditure review*: The World Bank, 2017.
4. Witter S, Arhinful DK, Kusi A, et al. The experience of Ghana in implementing a user fee exemption policy to provide free delivery care. Reproductive health matters 2007;15(30):61-71
5. Organization WH, UNICEF. Trends in maternal mortality: 1990-2015: estimates from WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. 2015
6. Belaid L, Ridde V. An implementation evaluation of a policy aiming to improve financial access to maternal health care in Djibo district, Burkina Faso. BMC pregnancy and childbirth 2012;12(1):143
7. Ridde V, Richard F, Bicaba A, et al. The national subsidy for deliveries and emergency obstetric care in Burkina Faso. Health policy and planning 2011;26(suppl_2):ii30-ii40
8. Okonofua F, Lambo E, Okeibunor J, et al. Advocacy for free maternal and child health care in Nigeria—results and outcomes. Health policy 2011;99(2):131-38
9. Yates R. Universal health care and the removal of user fees. The Lancet 2009;373(9680):2078-81
10. Witter S. Mapping user fees for health care in high-mortality countries-evidence from a recent survey. 2010
11. Leone T, Cetorelli V, Neal S, et al. Financial accessibility and user fee reforms for maternal healthcare in five sub-Saharan countries: a quasi-experimental analysis. BMJ open 2016;6(1):e009692
12. Dzakpasu S, Soremekun S, Manu A, et al. Impact of free delivery care on health facility delivery and insurance coverage in Ghana's Brong Ahafo Region. PloS one 2012;7(11):e49430
13. Ghana Statistical Service GHSG, and ICF International. . Ghana Demographic and Health Survey 2014. 2015
14. Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. Population and development review 1984;10(0):25-45
15. Fuentes R, Pfütze T, Seck P. Does access to water and sanitation affect child survival? A five country analysis: Human Development Report Office (HDRO), United Nations Development Programme …, 2006.
16. Ridgeway G, Kovalchik SA, Griffin BA, et al. Propensity score analysis with survey weighted data. Journal of causal inference 2015;3(2):237-49
17. Jann B. Kernel matching with automatic bandwidth selection. 2017
18. Stuart EA, Green KM. Using full matching to estimate causal effects in nonexperimental studies: examining the relationship between adolescent marijuana use and adult outcomes. Developmental psychology 2008;44(2):395
19. Stuart EA, Huskamp HA, Duckworth K, et al. Using propensity scores in difference-in-differences models to estimate the effects of a policy change. Health Services and Outcomes Research Methodology 2014;14(4):166-82
20. Lunceford JK, Davidian MJSim. Stratification and weighting via the propensity score in estimation of causal treatment effects: a comparative study. 2004;23(19):2937-60

21. McKinnon B, Harper S, Kaufman JS, et al. Removing user fees for facility-based delivery services: a difference-in-differences evaluation from ten sub-Saharan African countries. Health policy and planning 2014;30(4):432-41
22. Adams AM, Madhavan S, Simon D. Women's social networks and child survival in Mali. Social science & medicine 2002;54(2):165-78
23. Darmstadt GL, Bhutta ZA, Cousens S, et al. Evidence-based, cost-effective interventions: how many newborn babies can we save? The Lancet 2005;365(9463):977-88
24. Browne JL, Kayode GA, Arhinful D, et al. Health insurance determines antenatal, delivery and postnatal care utilisation: evidence from the Ghana Demographic and Health Surveillance data. BMJ open 2016;6(3):e008175
25. Lagarde M, Palmer N. The impact of user fees on access to health services in low-and middle-income countries. Cochrane Database of Systematic Reviews 2011(4)
26. Ansah EK, Narh-Bana S, Asiamah S, et al. Effect of removing direct payment for health care on utilisation and health outcomes in Ghanaian children: a randomised controlled trial. PLoS medicine 2009;6(1):e1000007
27. Campbell OM, Graham WJ, group LMSSs. Strategies for reducing maternal mortality: getting on with what works. The lancet 2006;368(9543):1284-99
28. Corsi DJ, Neuman M, Finlay JE, et al. Demographic and health surveys: a profile. International journal of epidemiology 2012;41(6):1602-13
29. Jakubowski A, Stearns SC, Kruk ME, et al. The US President's Malaria Initiative and under-5 child mortality in sub-Saharan Africa: A difference-in-differences analysis. PLoS medicine 2017;14(6):e1002319
30. Munos M, Guiella G, Roberton T, et al. Independent evaluation of the Rapid Scale-Up program to reduce under-five mortality in Burkina Faso. The American journal of tropical medicine and hygiene 2016;94(3):584-95
31. Zombré D, De Allegri M, Ridde V. Immediate and sustained effects of user fee exemption on healthcare utilization among children under five in Burkina Faso: A controlled interrupted time-series analysis. Social Science & Medicine 2017;179:27-35
32. Sarrassat S, Meda N, Badolo H, et al. Effect of a mass radio campaign on family behaviours and child survival in Burkina Faso: a repeated cross-sectional, cluster-randomised trial. The Lancet Global Health 2018;6(3):e330-e41



284x208mm (300 x 300 DPI)



284x208mm (300 x 300 DPI)

Supplemental materials for Impact evaluation of the free maternal healthcare policy on infant and neonatal mortality in four sub-Saharan Africa countries: Difference in Differences with Kernel based Propensity Score Matching Analysis.

S1 Table A: A summary of the trend of neonatal and infant mortality rates among the four comparison and intervention countries in the five years preceding each survey

	Intervention countries: Implemented free maternal healthcare policy						Comparison countries: No free maternal healthcare policy					
	Ghana			**Burkina Faso**			**Nigeria**			**Zambia**		
	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2010 Ref period: 2006-2010	2014 Ref period: 2010-2014	2003 Ref period: 1999-2003	2008 Ref period: 2004-2008	2014 Ref period: 2009-2013	2001/2002 Ref period: 1998-2002	2007 Ref period: 2003-2007	2013/2014 Ref period: 2009-2013
Number of live births in five years preceding the interview	3844	2992	5884	10645	15044	6841	6029	28647	31482	6877	6401	13457
Number of women age 15-49 interviewed	5691	4916	9396	12477	17087	8 111	7620	33385	38948	7658	7146	16411
Total number of women age 15-49 in the country at the time of the survey	4170068	4891557	5655156	2451363	303054 5	3416421	256199 94	28997441	32791677	2143989	2506625	3129094
Survey response rate for eligible women interviewed (%)	95.7	96.5	97.3	96.3	98.4	98.7	95.0	97.0	97.9	96.4	97.0	96.0
NMR per 1000 live births	43	30	29	31	28	27.3	48	40	37	37	34	24
IMR per 1000 live births	64	50	41	81	65	61.4	100	75	69	95	70	45
Cumulative incidence rate per 1000 person years at risk: Infant deaths	30 [24.2-37.7]	28.5 [22.5-36.8]	15.1 [11.9-19.4]	67.9 [61.9-74.6]	44.3 [40.5-48.5]	23.7 [21.3-26.4]	63.2 [55.6-72.1]	50.6 [47.7-53.7]	36.8 [34.3-39.6]	70.5 [63.8-78.2]	44.7 [39.1-51.4]	26.5 [23.2-30.5]

Abbreviations: IMR: Infant mortality rate, NMR: Neonatal mortality rate.

S1 Table B: Assessing the performance of the kernel matching: Balancing test based on standardized mean difference between the two groups (FMHCP and comparison group).

	Before Matching			After Matching		
	FMHCP	No FMHCP	Standardized Mean Difference	FMHCP	No FMHCP	Standardized Mean Difference
	Mean	Mean		Mean	Mean	
Sex						
Male	0.83	0.90	-0.19	0.83	0.81	0.06
Female	0.17	0.10	0.19	0.17	0.19	0.06
Wealth						
Poorest	0.23	0.23	-0.02	0.23	0.23	0.02
Poorer	0.21	0.23	-0.04	0.21	0.21	0.02
Middle	0.20	0.19	0.03	0.20	0.20	0.01
Richer	0.20	0.18	0.05	0.20	0.20	0.00
Richest	0.16	0.17	-0.02	0.16	0.16	0.01
Household size						
≤ 4	0.29	0.25	0.10	0.29	0.31	-0.03
5 -7	0.40	0.42	-0.03	0.40	0.41	0.01
8+	0.31	0.33	-0.06	0.31	0.29	0.04
Household access to an improved water source						
Improved	0.90	0.78	0.34	0.90	0.90	0.00
Not improved	0.10	0.22	-0.34	0.10	0.10	0.00
Household access to improved toilet						
Improved, not shared	0.13	0.30	-0.44	0.13	0.12	0.01
Improved, shared	0.37	0.19	0.40	0.37	0.39	0.04
Not improved	0.50	0.50	0.00	0.50	0.49	0.03
Geographic location						
Urban	0.31	0.32	-0.03	0.31	0.32	0.02
Rural	0.69	0.68	0.03	0.69	0.68	0.02
Household owns a mosquito net						
No	0.20	0.52	-0.71	0.20	0.20	0.01
Yes	0.80	0.48	0.71	0.80	0.80	0.01
Mother's age at child's birth						
< 18	0.03	0.03	-0.05	0.03	0.02	0.00
18 - 34	0.72	0.71	0.00	0.72	0.73	0.03
35+	0.26	0.25	0.02	0.26	0.24	0.03
Educational attainment						
None	0.54	0.45	0.19	0.54	0.53	0.02
Primary	0.17	0.24	-0.17	0.17	0.18	0.00
Secondary	0.26	0.25	0.02	0.26	0.27	0.02
Tertiary	0.02	0.05	-0.18	0.02	0.02	0.01
Birth order						
First	0.29	0.19	0.22	0.29	0.29	0.00
Second	0.26	0.17	0.20	0.26	0.26	0.00
Third	0.15	0.15	-0.02	0.15	0.14	0.01
Fourth or higher	0.31	0.48	-0.35	0.31	0.31	0.00
Birth type						
Single birth	0.96	0.97	-0.04	0.96	0.95	0.03
Multiple birth	0.04	0.03	0.04	0.04	0.05	0.03

Abbreviation: FMHCP: Free maternal healthcare policy

S1 Table C: Assessing the performance of the kernel matching: Balancing test based on the ratio of variances between the two groups (FMNH and comparison group).

	Before matching			After matching		
	FMHCP Variance	No FMHCP Variance	Ratio	FMHCP Variance	No FMHCP Variance	Ratio
Sex						
Male	0.14	0.09	1.49	0.14	0.15	0.92
Female	0.14	0.09	1.49	0.14	0.15	0.92
Wealth						
Poorest	0.17	0.18	0.97	0.17	0.18	0.98
Poorer	0.17	0.18	0.95	0.17	0.16	1.03
Middle	0.16	0.16	1.05	0.16	0.16	1.02
Richer	0.16	0.15	1.08	0.16	0.16	1.00
Richest	0.13	0.14	0.96	0.13	0.14	0.98
Household size						
≤ 4	0.21	0.19	1.11	0.21	0.21	0.98
5 -7	0.24	0.24	0.99	0.24	0.24	1.00
8+	0.21	0.22	0.96	0.21	0.21	1.04
Household access to an improved water source						
Improved	0.09	0.17	0.51	0.09	0.09	0.99
Not improved	0.09	0.17	0.51	0.09	0.09	0.99
Household access to improved toilet						
Improved, not shared	0.11	0.21	0.53	0.11	0.11	1.02
Improved, shared	0.23	0.16	1.49	0.23	0.24	0.98
Not improved	0.25	0.25	1.00	0.25	0.25	1.00
Geographic location						
Urban	0.21	0.22	0.98	0.21	0.22	0.98
Rural	0.21	0.22	0.98	0.21	0.22	0.98
Household owns a mosquito net[3]						
No	0.16	0.25	0.64	0.16	0.16	0.98
Yes	0.16	0.25	0.64	0.16	0.16	0.98
Mother's age at child's birth						
< 18	0.02	0.03	0.74	0.02	0.02	1.02
18 - 34	0.20	0.20	1.00	0.20	0.20	1.04
35+	0.19	0.19	1.02	0.19	0.18	1.04
Educational attainment						
None	0.25	0.25	1.00	0.25	0.25	1.00
Primary	0.14	0.18	0.78	0.14	0.14	1.00
Secondary	0.19	0.19	1.02	0.19	0.20	0.98
Tertiary	0.02	0.05	0.39	0.02	0.02	0.92
Birth order						
First	0.21	0.16	1.31	0.20	0.21	1.00
Second	0.19	0.14	1.32	0.19	0.19	1.00
Third	0.12	0.13	0.96	0.12	0.12	1.02
Fourth or higher	0.21	0.25	0.86	0.21	0.21	1.00
Birth type						
Single birth	0.04	0.03	1.23	0.04	0.05	0.89
Multiple birth	0.04	0.03	1.23	0.04	0.05	0.89

Abbreviation: FMHCP: Free maternal healthcare policy