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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

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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 Agyabeng¹, Kwame Agbeshi², Gabriel Incoom³, Priscilla Nortey⁴, Alfred E. Yawson⁵, Samuel Bosomprah¹

¹ Department of Biostatistics, School of Public Health, University of Ghana, Accra.

² Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.

³Department 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: <u>soothelone@gmail.com</u> Kwame Agbeshi: <u>kagbeshie@gmail.com</u> Gabriel Incoom: <u>gabrielincoomghana@gmail.com</u> Priscilla Nortey: <u>pnortey@gmail.com</u> Yawson Edwin Alfred: <u>aeyawson@yahoo.com</u> Samuel Bosomprah: <u>sbosomprah@gmail.com</u>

Corresponding author: Duah Dwomoh: <u>duahdwomoh@yahoo.com</u>

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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.

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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 UHC³. 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.

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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 ⁶⁷. 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

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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 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 denormalized. 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 (<u>https://ourworldindata.org/</u>). 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

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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

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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: FN	IHCP implementation FMHP % ^b	- Rao-Scot Chi-square
All-cause mortality in the five years preceding				100
he 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	3 5 [3 3-3 6]	3 1 [2 9 3 3]	0.4 [0.3-0.4]	76 70***
preceding the survey [95% CI]	5.5 [5.5-5.0]	5.1 [2.9-5.5]	0.4 [0.3-0.4]	/0./0
All-cause infants deaths in the five years	67[65-70]	7 3 [7 1-7 6]	40[36-43]	168 40***
preceding the survey [95% CI]	0.7 [0.8 7.0]	,	[5.05]	100.10
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)	2.00
Wealth quintile	2(507 (22.2)	102(4(82.0)	7222 (17.1)	2.00
Poorest	20397 (23.3)	19264 (82.9)	/333 (1/.1)	
Middle	23320 (22.7)	16602 (85.5)	6501 (18.6)	
Richer	22913 (19.4)	10412(01.4) 14198(80.7)	6105 (19.3)	
Richest	15409 (16.5)	11251 (82.9)	4158 (17.1)	
Household size	15409 (10.5)	11251 (02.9)	4156 (17.1)	20 26***
1-4	26784 (25.8)	19215 (79.8)	7569 (20.2)	20.20
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)	0.61
Place of residence	22(27(22.2))	25025 (02.0)	7502 (17.1)	0.61
Urban	32627 (32.2)	23035 (82.9)	/592 (1/.1)	
Kuiai Household ownership of bodnet	/8121 (07.8)	34932 (82.0)	23169 (18.0)	1012 52***
No bednet	43000 (46 4)	36880 (92.4)	6015 (7.6)	1013.32
Bednet	68000 (53.6)	43062 (73.6)	24746 (26.5)	
Missing	45 (0.06)	45 (100 0)	0 (0 0)	
Mothers current age	15 (0.00)	15 (100.0)	0 (0.0)	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)	10.10**
Single	110000 (06.4)	77000 (82.4)	30000 (17.6)	10.19**
Single	2004 (2.6)	77000 (82.4)	1244 (20.9)	
withple	Child mortalit	v estimete per country	1244 (20.7)	
	Ciniu mortant	J countate per country		Cumulative incidence rate
Country	Year of survey	NMR per 1000 live births	IMR per 1000 live births	per 1000 person years at risk
	2003	31	81	67.9 [61.9-74.6]
Burkina Faso	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
	2003	43	64	30.0 [24.2-37.7]
Ghana	2008	30	50	28.5 [22.5-36.8]
	2014	29	41	15.1 [11.9-19.4]
	2003	48	100	63.2 [55.6-72.1]
Nigeria	2008	40	75	50.6 [47.7-53.7]
	2013	37	69	36.8 [34.3-39.6]
	2001-2002	37	95	70.5 [63.8-78.2]
Zambia	2001-2002 2007	37 34	95 70	70.5 [63.8-78.2] 44.7 [39.1-51.4]

Abbreviations: FMHP – Free maternal health policy; NMR: Neonatal mortality rate, IMR: Infant mortality rate. P-value notation: ***p<0.001, **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 morta	ality: 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	с <u>э</u>	. ,			
Male		ref		ref	
Female		0.90 [0.73-1.11]		0.89 [0.76-1.03]	
Mothers current age		L J			
<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		1.00 [1.01 0.00]		[1.10 0.20]	
Urban		ref		ref	
Rural		1.35*** [1.14-1.60]		1.29*** [1.14-1.45]	
Household size		[1.17 1.00]		> [1.111.13]	
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		0.45 [0.55 0.52]		0.45 [0.57 0.45]	
Improved		ref		ref	
Unimproved				1 13* [1 01-1 26]	
Access to an improved toilet facility		1.00 [0.92-1.27]		1.15 [1.01-1.20]	
Improved not shared		rəf		rəf	
Improved shared		0.81*[0.66.0.08]		0 76*** [0 66 0 87]	
Unimproved		0.85 [0.72-1.01]		0.86* [0.77_0.97]	
Mothers education		0.05 [0.72-1.01]		0.00 [0.77-0.97]	
None		ref		ref	
Drimary				0.04 [0.83 1.06]	
г ппату ТНS		1.01 [0.64-1.2]		0.74 [0.05-1.00]	
1110 Secondary or higher		0.04 [0.09-1.02]		0.75° [0.05-0.85] 0.55** [0.20.0.79]	
Birth order		0.95 [0.59-1.44]		0.55. [0.59-0./8]	
DI UI OFUEF 1 at hieth		- maf		rof	
Zna olitins		$0.70^{**}[0.57-0.86]$		$0.83^{\circ} [0.71 - 0.98]$	
STO DIFINS		$0./1^{**}[0.55-0.9]$		0.99 [0.84-1.17]	
4th Dirths		1.03 [0.84-1.26]		1.20* [1.04-1.39]	
Multiple births		C		C	
Single		ret		ret	
		5.51*** [4.26-6.62]		5./0*** [5.11-4.40]	
Household ownership of bednet				C	
No bednet		ret		ret	
Bednet		0.91 [0.78-1.05]		0.95 [0.86-1.05]	
Country Fixed Effect	Ves	Yes	Ves Ves	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.

8		,	6							
9		Sensitivity analysis based on different model specification								
10 11 12		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			
13 14		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-		
15		aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β [95% CI]	aRR [95% CI]	aRR [95% CI]		
10	Time									
16	Baseline: 2008	rer 0.92[0.82, 1.03]	ret 0.63*[0.42.0.96]	rei 0.62*[0.42.0.01]	ret 0.50[0.22, 1.07]	-0.35*[-0.690.01]	ret -2 /1**[0 /6 0 81]	ret 0.67**[0.51.0.86]		
17	Intervention	0.52[0.82, 1.85]	0.03 [0.42, 0.90]	0.02 [0.42, 0.51]	0.35[0.35, 1.07]	-0.55 [-0.05, -0.01]	-3.41 [0.40, 0.01]	0.07 [0.51, 0.80]		
10	No FMHP	ref	ref	ref	ref	ref	ref	ref		
10	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]		
19	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]		
20	Sex of nousehold nead Male	ref	ref	ref	ref	ref	ref	ref		
20	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]		
21	Mothers current age			• • •				. , .		
22	<18 years	ref	ref	ref	ref	ref	ref	ref		
าว	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]		
25	35+ Place of residence	0.46 [0.36, 0.59]	0.55 [0.55, 0.86]	1.29[0.85, 1.95]	0.7 [5.12, 14.36]	1.11 [0.07, 1.50]	-5.17 [0.59, 0.8]	0.5***[0.55, 0.72]		
24	Urban	ref	ref	ref	ref	ref	ref	ref		
25	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]		
25	Wealth quintile	rof	raf	rof	rof	rof	rof	raf		
26	Poorest	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]			
27	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]		
20	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]		
28	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]		
29	Household size		,		,	,	,	r.		
20	1-4	ret	ret	ret	ret	ret	ret	ret		
50	5-7	0.42***[0.37, 0.49]	0.40***[0.38, 0.56]	0.55***[0.45, 0.65]	0.49**[0.51, 0.78]	-0.41**[-0.87, -0.15]	8.18 [0.38, 0.55]	0.42***[0.34, 0.51]		
31	Access to improved water	0.55 [0.5, 0.4]	0.41 [0.33, 0.32]	0.40 [0.55, 0.55]	0.55 [0.22, 0.45]	0.04 [0.07, 0.41]	0.07 [0.32, 0.45]	0.50 [0.51, 0.40]		
32	Improved	ref	ref	ref	ref	ref	ref	ref		
52	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]		
33	Access to improved toilet facility	rof	rof	rof	rof	rof	rof	rof		
34	Improved, not 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]		
25	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]		
30	Mothers education	_								
36	None	ref	ref	ref	ref	ref	ref	ref		
27	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]		
57	JHS Secondary or higher	0.94[0.80, 1.10]	0.95[0.69, 1.25]	0.80[0.05, 1.15]	0.02[0.35, 1.10]	-0.25[-0.57, 0.06] -0.92***[-1.440.41]	-1.01[0.72, 1.11]	0.96[0.80, 1.16]		
38	Birth order	011 0 [0100] 1000]	0.01[0.10] 1.11]	017 1[0112, 1121]	(120 [0100, 0117]	0.52 [1.1.1, 0.12]	1.57 [0.15] 1.15]	01/ 5[0115, 1116]		
30	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]		
40	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]		
41	4th births Multiple 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]		
42	Single									
42	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]		
43	Household ownership of bednet									
лл	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. -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

8			a 111				
9 _			Sensitivity ar	alysis based on different r	nodel specification		
10			Cox-proportional hazard Model:	Logistic regression	Probit regression	Modified	Poisson
11	Modified	Poisson	Clustering,	Model: Clustering,	Model: Clustering,	Model: Clustering	, weighting, and
12	Model: Clustering, weighting, and stratification were adjusted		weighting, and	weighting, and stratification	weighting, and stratification	stratific	ation
13			stratification	were adjusted	were adjusted	were ad	justed
14	No Kernel weighting	With Kernel	With Kernel	With Kernel	With Kernel weighting	ATET weighting and	ATE weighting and
л. 1г. –	and PSM	weighting and PSM	weighting and PSM	weighting and PSM	and PSM	PSM- IPTW	PSM-
1 <u>5</u>	aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
16 Ime Baseline: 2008	ref	rof	rof	rof	rof	rof	rof
17 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		[0.10]					
18 NO FMHCP	ref	ref	ref	ref	ref	ref	ref
19 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]
20 Sex of household head	rof	rof	rof	rof	rof	raf	rof
21 Female	ret 0 88*[0 78 0 08]	0 75**[0 61 0 92]	rei 0 81*[0 68 0 98]	ret 0.96[0.79, 1.17]	rer -0.02[-0.13.0.09]	ret 0.87[0.74, 1.02]	ret 0 88[0 75 1 02]
1 Mothers current age	0.00 [0.70, 0.90]	0.75 [0.01, 0.52]	0.81 [0.08, 0.98]	0.50[0.75, 1.17]	-0.02[-0.15, 0.05]	0.07[0.74, 1.02]	0.00[0.75, 1.02]
<18 years	ref	ref	Ref	ref	ref	ref	ref
23 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]
21 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]
2 Place of residence			- /				,
25 Urban	ret	ret	Ref	ret	ret	ref	ret
26 Westth quintile	1.10 [1.05, 1.29]	1.2[0.96, 1.5]	1.19[0.97, 1.40]	1.18[0.96, 1.45]	0.09[-0.03, 0.2]	1.14[0.90, 1.30]	1.15[0.69, 1.45]
	ref	ref	Ref	ref	ref	ref	ref
27 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]
28 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]
20 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]
29 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]
30 Household size	,	,			,	,	,
1-4 21 5-7	ret 0.42***[0.20.0.47]	ret 0.45***[0.38.0.52]	Ret 0.52***[0.45_0.59]	ret 0.54***[0.45.0.65]	ret _0.34***[_0.440.24]	ret 0.46***[0.4.0.52]	ret 0.42***[0.27.05]
31 ⁵⁻⁷	0.35***[0.32, 0.39]	0.45 [0.58, 0.52]	0.52 [0.45, 0.55]	0.43***[0.35, 0.52]	-0.34 [-0.44, -0.24]	0.42***[0.36_0.49]	0.45 [0.57, 0.5]
32 Access to improved water	0.00 [0.02] 0.00]			[0.05] (0.02]	0.15 [0.55, 0.51]	0.12 [0.00, 0.10]	0.50 [0.55, 0.15]
33 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]
34 Access to improved toilet facility							
35 Improved, not shared	ref	ref	Ref	ref	ref	ref	ref
C Unimproved, 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]
30 Mothers education	0.66 [0.61, 0.90]	0.52[0.8, 1.05]	0.95[0.82, 1.05]	0.88[0.75, 1.02]	-0.07[-0.15, 0.02]	0.55[0.62, 1.05]	0.92[0.79, 1.00]
37 None	ref	ref	Ref	ref	ref	ref	ref
20 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]
So ^{IHS}	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]
39 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							
- O ISL DITU	1 03[0 92 1 15]	0 86[0 72 1 02]	101 0 77**[0 65 0 01]	1 er 0 6***[0 5 0 72]	rer 0 27***[-0 28 -0 17]	1 0 0 1 0 0 1 0 0 1 0 0 1	rer 0.84*[0.71_1]
41 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]
42 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	• • • •						
43 Single	ref	ref	ref	ref	ref	ref	ref
44 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	,	,				,	,
4) No bednet	ret	ret	ret	ret 0.0000 0.000	ret	ret	ret
46 Country Fixed Effect	1.00[0.36, 1.14]	0.30[0.00, 1.09]	4 dinetad	0.00, 1.12]	-0.01[-0.08, 0.00]	Adjusted	0.94[0.03, 1.03]
Abbreviation	ns. FMHCP: Free m	aternal healthcare n	olicy DSM: Dronen	sity score matching	aPP: Adjusted Palati	va Diek aHD. Adiue	ted

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<0.05.

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

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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

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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

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robust quasi-experimental design to evaluate the impact of health intervention using crosssectional 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.

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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.

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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)

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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

	Inte	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	FMHCP	FMHCP No FMHCP Standardized	
a	Mean	Mean	Difference	Mean	Mean	Difference
Sex	0.82	0.00	0.10	0.82	0.81	0.06
Fomelo	0.85	0.90	-0.19	0.85	0.81	0.06
Weelth	0.17	0.10	0.19	0.17	0.19	0.00
Poorest	0.23	0.23	-0.02	0.23	0.23	0.02
Poorer	0.23	0.23	-0.02	0.25	0.23	0.02
Middle	0.20	0.19	0.03	0.21	0.21	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	0.00	0.77	0.71	0.00	0.00	0.61
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
ORWKHU¶V DJH DW FKLC	0.02	0.02	0.05	0.02	0.02	0.00
< 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
	0.26	0.25	0.02	0.26	0.24	0.03
None	0.54	0.45	0.10	0.54	0.52	0.02
Primary	0.17	0.43	-0.17	0.17	0.55	0.02
Secondary	0.26	0.24	0.02	0.26	0.27	0.00
Tertiary	0.02	0.25	-0.18	0.20	0.027	0.02
Birth order	0.02	0.05	-0.18	0.02	0.02	0.01
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

2 3 4 5	S1 Tabl (FMNH
7 8	
9	Sex
10	Male
11	Wealt
12	Poores
13	Poorer Middle
14	Richer
15	Riches
10 17	House
18	5 -7
19	8+ House
20	impro
21	Improv Not im
22	House
23	impro
24	Improv Improv
25	Not in
26	Geogr
27	Rural
28	House
29	mosqu No
3U 21	Yes
31 32	0 R W
32	birth < 18
34	18 - 34
35	35+ Educe
36	None
37	Prima
38	Secono
39	Birth
40	First
41	Third
42	Fourth
43	Birth Single
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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).

After matching

Before matching

	FMHCP No FMHCP		Ratio	FMHCP	No FMHCP	Ratio
	Variance	Variance	-	Variance	Variance	
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	0.05	0.17	0.51	0.07	0.07	0.77
improved toilet						
Improved not shared	0.11	0.21	0.53	0.11	0.11	1.02
Improved, not shared	0.23	0.21	1 49	0.23	0.24	0.98
Not improved	0.25	0.10	1.49	0.25	0.24	1.00
Coographic location	0.25	0.23	1.00	0.23	0.23	1.00
Urban	0.21	0.22	0.08	0.21	0.22	0.08
Dural	0.21	0.22	0.98	0.21	0.22	0.98
Kulai Household owns o	0.21	0.22	0.96	0.21	0.22	0.98
moggnite not3						
No.	0.16	0.25	0.64	0.16	0.16	0.08
No	0.10	0.23	0.04	0.10	0.10	0.98
	0.10	0.25	0.64	0.16	0.16	0.98
UKWKHU¶V DJH I						
	0.02	0.02	0.74	0.02	0.02	1.02
< 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	0.05	0.05	1.00	0.05	0.05	1.00
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

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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

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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 Agyabeng¹, Agbeshi Kwame², Gabriel Incoom³, Priscilla Nortey⁴, Alfred E. Yawson⁵, Samuel Bosomprah¹

¹ Department of Biostatistics, School of Public Health, University of Ghana, Accra.

² Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.

³Department 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: <u>soothe1one@gmail.com</u> Agbeshi Kwame: <u>kagbeshie@gmail.com</u> Gabriel Incoom: <u>gabrielincoomghana@gmail.com</u> Priscilla Nortey: <u>pnortey@gmail.com</u> Yawson Edwin Alfred: <u>aeyawson@yahoo.com</u> Samuel Bosomprah: <u>sbosomprah@gmail.com</u>

Corresponding author: Duah Dwomoh: <u>duahdwomoh@yahoo.com</u>

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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.

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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 UHC³. 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.

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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 freely datasets available and could be downloaded at the DHS are 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,

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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 denormalized. 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 (<u>https://ourworldindata.org/</u>). 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

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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

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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.

	T-+-10/	Intervention: FN	<u>AHCP implementation</u>	- Rao-Scot Chi-square
	Total %	NO FMHP % ⁰	FMHP % ⁰	x
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		(1001/001)		121.32***
	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)	0.61
Place of residence	22(27,(22,2))	05005 (00.0)	7502 (17.1)	0.61
Urban	32627 (32.2)	25035 (82.9)	/592 (1/.1)	
Kural	/8121 (67.8)	54952 (82.0)	23169 (18.0)	1012 52***
Household ownership of bednet	12000 (1(1)	2(000 (02 4)	(015 (7.6)	1013.52***
No bednet	43000 (46.4)	36880 (92.4)	6015 (7.6)	
Bednet	68000 (53.6)	43062 (73.6)	24/46 (26.5)	
Missing	45 (0.06)	45 (100.0)	0 (0.0)	11 10***
<18 second	2559 (2.2)	2002 (06.5)	755 (12 5)	11.10***
<18 years	20000 (71.5)	2803 (80.3)	755 (15.5)	
18-34 years	80000 (71.3)	38000 (82.3)	22000 (17.7)	
JJ⊤ Mathara advantian	27000 (23.2)	20000(81.8)	//2/(18.2)	11 09***
None	52000 (46.5)	32000 (79.4)	21000 (20.6)	44.98
Primory	20000 (40.3)	24000 (79.4)	4475(12.0)	
	25000 (25.2)	24000 (80.0)	4475 (15.4)	
1115 Secondary or higher	4241 (4.8)	20000(81.7) 3882(02.4)	350 (7.6)	
Missing	4241(4.0)	11 (64.6)	5 (25 4)	
Birth order	10 (0.01)	11 (04.0)	3 (35.4)	271 20***
lst hirth	24000 (21.1)	16000 (75.8)	8167 (24.2)	271.39
2nd births	21000 (18.9)	14000 (76.1)	7351 (23.9)	
3rd births	17000(15.2)	12000 (83.1)	4386 (16.9)	
4th hirths	49000 (44.8)	38000 (87.7)	11000 (12.3)	
Multiple births	4,000 (44.0)	50000 (07.7)	11000 (12.5)	10 19**
Single	110000 (96.4)	77000 (82.4)	30000 (17.6)	10.19
Multiple	3994 (3.6)	2750 (79.1)	1244 (20.9)	
(dutiple)	Child mortali	ty estimate per country	1211(20.5)	
		NMR per 1000 live		Cumulative incidence rate
Country	Year of survey	births	IMR per 1000 live births	1000 person years at risk
	2003	31	81	67.9 [61.9-74.6]
Burkina Faso	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
	2003	43	64	30.0 [24 2-37 7]
Ghana	2008	30	50	28.5 [22.5-36.8]
	2014	29	41	15.1 [11.9-19.4]
	2003	48	100	63.2 [55.6-72.1]
Nigeria	2008	40	75	50.6 [47.7-53.7]
<i></i>	2013	37	69	36.8 [34.3-39.6]
	2001-2002	37	97	70.5 [63 8-78 2]
Zambia	2001-2002 2007	37	95 70	70.5 [63.8-78.2] 44.7 [39 1-51 4]

Abbreviations: FMHP – Free maternal health policy; NMR: Neonatal mortality rate, IMR: Infant mortality rate. P-value notation: ***p<0.001, **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 timefixed 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.

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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 morta	ality: 2000-2008	Infant mortali	ity: 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		0.15 [0.55 0.52]		[0.07 0.17]	
Improved		ref		ref	
Unimproved		1 08 [0 92-1 27]		1 13* [1 01-1 26]	
Access to an improved toilet facility		1.00 [0.92 1.27]		1.15 [1.01 1.20]	
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		0.00 [0.72 1.01]		0.00 [0.77 0.77]	
None		ref		ref	
Primary		1 01 [0 84-1 2]		0.94 [0.83-1.06]	
IHS		0.84[0.69-1.02]		0 73*** [0 63-0 83]	
Secondary or higher		0.93 [0.59_1.02]		0 55** [0 39_0 78]	
Birth order		0.75 [0.57-1.44]		0.55 [0.57-0.76]	
1st birth		ref		ref	
2nd hirths		0 70** [0 57-0 86]		0.83* [0.71_0.98]	
3rd hirths		0.71** [0.55_0.0]		0.00 [0.71 - 0.76]	
4th hirths		1 03 [0.84 1 26]		1.29 [0.04 - 1.17] $1.20 \times [1.07 - 1.20]$	
Multiple hirths		1.05 [0.04-1.20]		1.20 [1.04-1.59]	
Single		ref		ref	
Multinla		5 31*** [4 26 6 62]		101 3 70*** [3 11 / /0]	
Household ownership of hadnet		5.51 [4.20-0.02]		5.70*** [5.11-4.40]	
No hodpot				rof	
Padnat		0.01 [0.79 1.05]			
Country Fired Effect	Var	0.91 [0.76-1.05]	Var	<u> </u>	
	I CS	I CS	LES	res	

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).

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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 ana	lysis based on different mod	el specification		
	Modifiec Model: Clustering, weig were a	Modified Poisson 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	Modifiec Model: Clusterin stratifi were a	l Poisson g, weighting, and cation ljusted
)	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 End-line: 2014 Intervention No FMHP FMHP	ref 0.92[0.82, 1.03] ref 0.66***[0.53, 0.83]	ref 0.63*[0.42, 0.96] ref 0.94[0.74, 1.19]	ref 0.62*[0.42, 0.91] ref 0.96[0.77, 1.19]	ref 0.59[0.33, 1.07] ref 0.95[0.62, 1.47]	ref -0.35*[-0.69, -0.01] ref -0.04[-0.28, 0.2]	ref -3.41**[0.46, 0.81] ref -0.81[0.78, 1.11]	ref 0.67**[0.51, 0.86] ref 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]
5 Male Female	ref 0.85*[0.73, 0.99]	ref 0.73*[0.55, 0.97]	ref 0.81[0.63, 1.04]	ref 1.08[0.67, 1.74]	ref 0.02[-0.24, 0.29]	ref -1.99*[0.65, 1]	ref 0.78*[0.63, 0.95]
3 <18 years 18-34 years 35+	ref 0.43***[0.35, 0.54] 0.46***[0.36, 0.59]	ref 0.51**[0.35, 0.75] 0.55**[0.35, 0.86]	ref 1.01[0.71, 1.43] 1.29[0.85, 1.95]	ref 2.69**[1.4, 5.18] 6.7***[3.12, 14.38]	ref 0.59**[0.21, 0.98] 1.11***[0.67, 1.56]	ref 3.99***[0.39, 0.72] -3.17**[0.39, 0.8]	ref 0.53***[0.39, 0.71] 0.5***[0.35, 0.72]
Place of residence Urban Rural	ref 1.24**[1.08, 1.42]	ref 1.23[0.87, 1.74]	ref 1.2[0.88, 1.64]	ref 1.04[0.65, 1.65]	ref 0.05[-0.22, 0.32]	ref 1.94[1, 1.6]	ref 1.21[0.84, 1.74]
Wealth quintile Poorest Poorer Middle Richer Richest	ref 1.01[0.89, 1.15] 0.86[0.74, 1.01] 0.91[0.75, 1.1] 0.86[0.68, 1.11]	ref 1.04[0.86, 1.27] 0.93[0.73, 1.18] 0.83[0.61, 1.13] 0.95[0.56, 1.61]	ref 1.03[0.86, 1.24] 0.96[0.77, 1.19] 0.87[0.65, 1.16] 1.01[0.62, 1.62]	ref 0.81[0.53, 1.23] 0.93[0.56, 1.54] 0.88[0.43, 1.79] 1.04[0.46, 2.34]	ref -0.1[-0.34, 0.14] -0.03[-0.32, 0.27] -0.06[-0.47, 0.34] 0.05[-0.41, 0.52]	ref 0.72[0.89, 1.28] 0.2[0.82, 1.27] -0.64[0.7, 1.2] -0.87[0.6, 1.22]	ref 0.98[0.79, 1.22] 0.89[0.69, 1.16] 0.86[0.61, 1.2] 0.88[0.55, 1.42]
1-4 5-7 8+	ref 0.42***[0.37, 0.49] 0.35***[0.3, 0.4]	ref 0.46***[0.38, 0.56] 0.41***[0.33, 0.52]	ref 0.55***[0.45, 0.65] 0.48***[0.39, 0.59]	ref 0.49**[0.31, 0.78] 0.33***[0.22, 0.49]	ref -0.41**[-0.67, -0.15] -0.64***[-0.87, -0.41]	ref 8.18***[0.38, 0.55] 8.67***[0.32, 0.49]	ref 0.42***[0.34, 0.51] 0.38***[0.31, 0.46]
Access to improved water Improved Unimproved Access to improved toilet facility	ref 1.06[0.93, 1.21]	ref 1.06[0.87, 1.3]	ref 1.06[0.89, 1.27]	ref 1.28[0.88, 1.88]	ref 0.15[-0.07, 0.36]	ref 0.02[0.82, 1.22]	ref 1.02[0.82, 1.28]
Improved, not shared Improved, shared Unimproved Mathema education	ref 0.84*[0.72, 0.97] 0.84**[0.75, 0.94]	ref 0.97[0.78, 1.22] 0.92[0.76, 1.11]	ref 0.97[0.79, 1.18] 0.92[0.78, 1.10]	ref 1.08[0.72, 1.63] 1.10[0.76, 1.59]	ref 0.04[-0.20, 0.28] 0.05[-0.15, 0.26]	ref -0.43[0.78, 1.17] -1.00[0.77, 1.09]	ref 0.90[0.70, 1.16] 0.86[0.72, 1.04]
None Primary JHS Secondary or higher	ref 1.05[0.93, 1.20] 0.94[0.80, 1.10] 0.75[0.55, 1.03]	ref 0.98[0.78, 1.23] 0.93[0.69, 1.25] 0.81[0.46, 1.41]	ref 0.97[0.78, 1.20] 0.86[0.65, 1.13] 0.71[0.42, 1.21]	ref 0.78[0.52, 1.18] 0.62[0.35, 1.10] 0.20***[0.08, 0.47]	ref -0.14[-0.38, 0.10] -0.25[-0.57, 0.06] -0.92***[-1.44, -0.41]	ref -0.80[0.76, 1.12] -1.01[0.72, 1.11] -1.37[0.45, 1.15]	ref 0.99[0.79, 1.25] 0.96[0.80, 1.16] 0.79[0.43, 1.46]
 Birth order Ist birth 2nd births 3rd births 4th birthe 	ref 0.94[0.82, 1.09] 0.98[0.82, 1.18] 1.32**[1.12, 1.56]	ref 0.69**[0.54, 0.89] 0.89[0.66, 1.2] 1.18[0.90, 1.56]	ref 0.62***[0.49, 0.77] 0.73*[0.56, 0.97] 0.87[0.67, 1, 12]	ref 0.52*[0.30, 0.89] 0.60[0.34, 1.07] 0.46**10.26.0.811	ref -0.38*[-0.67, -0.08] -0.29[-0.61, 0.03] -0.44**[-0.76, -0.12]	ref -2.89**[0.61, 0.91] -0.24[0.75, 1.25] 2.21*[1.03, 1.58]	ref 0.74*[0.59, 0.93] 0.88[0.67, 1.15] 1.29*[1.00, 1.65]
Multiple births Single Multiple Household ownership of bednet	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]
No bednet Bednet Country Fixed Effect	0.98[0.88, 1.09] Adjusted	0.96[0.82, 1.12] Adjusted	0.96[0.83, 1.11] Adjusted	1.01[0.74, 1.37] Adjusted	0.01[-0.16, 0.19] Adjusted	-1.04[0.79, 1.07] Adjusted	0.93[0.78, 1.1] 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

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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.

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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							
6			Cox-proportional	T : /: :	D 1.4			
7			hazard Model	Logistic regression	Probit regression	Modified	Poisson	
/	Modified Poisson		Clustering	Model: Clustering, Model: Cluster		Model: Clustering	weighting and	
Q	Model: Clustering	, weighting, and	Clustering,	weighting, and	weighting, and	Widden. Clustering	, weighting, and	
0	stratification v	vere adjusted	weighting, and	stratification	stratification	stratific	ation	
9	suumeuten (vere aujustea	stratification were adjusted were adjusted			were adjusted		
10	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]	
17 Time								
Baseline: 2008	ref	ref	ref	ref	ref	ref	ref	
13 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	····· [·····]	[,				[]		
14 No FMHCP	ref	ref	ref	ref	ref	ref	ref	
1 F 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]	
16 Sex of household head	- <i>i i i</i>	. / .		· / /	· / ,	L / J	· / ·	
Male	ref	ref	ref	ref	ref	ref	ref	
17 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]	
10 Mothers current age					. , ,	. , ,		
IO <18 years	ref	ref	Ref	ref	ref	ref	ref	
10 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]	
20 Place of residence								
Urban	ref	ref	Ref	ref	ref	ref	ref	
ZI 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	
23 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]	
24 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]	
25 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]	
23 Household size								
26 ¹⁻⁴	ref	ref	Ref	ref	ref	ref	ref	
20 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]	
27 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	c	c		c.	c	c	c	
ZO Improved	rei	rei	Ref	rei	rei	rei	rei	
29 Access to improved toilet facility	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]	
30 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]	
31 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]	
22 Mothers education		0			<i>c</i>	2	0	
JZ None	ret	ret	Ret	ret	ret	ret	ret	
33 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]	0.7/**[0.64, 0.94]	0.54***[0.43, 0.67]	-0.35***[-0.47, -0.24]	0.82*[0.69, 0.97]	0.8/[0.73, 1.03]	
34 Secondary of 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, -0.51]	0.78[0.53, 1.14]	0.69[0.43, 1.11]	
2 Lat hirth	rof	rof	nof	nof	rof	nof	rof	
33 Ist bitti	1 02[0 02 1 15]	0 8610 72 1 021	1CI 0.77**[0.65_0.01]	0 6***[0 5 0 72]			0.94*0.71 11	
36 and hirths	1.05[0.95, 1.15]	1 12[0 01 1 4]	0.06[0.70, 1.17]	0.65***[0.52, 0.73]	-0.2/***[0.26, 0.12]	1 10[1 1 42]	0.64 [0.71, 1]	
Ath birthe	$1.2^{+}[1.03, 1.37]$ 1.50***[1.72, 1.70]	1.15[0.91, 1.4]	0.90[0.79, 1.17]	0.05***[0.52, 0.81]	-0.24***[-0.30, -0.12]	1.17[1, 1.43]	1.00[0.00, 1.34]	
37 Multiple births	1.37 [1.42, 1.79]	1.05 [1.54, 1.96]	1.25 [1.05, 1.5]	0.7 [0.50, 0.60]	-0.2 [-0.32, -0.08]	1.00 [1.42, 1.73]	1.51 [1.25, 1.60]	
numple on uns	ref	ref	ref	ref	ref	ref	ref	
38 Multiple	4 37***[3 86 4 05]	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 20]	
30 Household ownership of bednet		5.75 [5.10, 4.95]	5.57 [2.70, 4.5]	5.57 [2.75, 4.07]	0.72 [0.57, 0.67]		ч.ч. [J./1, J.27]	
No bednet	ref	ref	ref	ref	ref	ref	ref	
40 Bednet	1 06[0 98 1 14]	1001 88 0389 0	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	
41 country inter Enter	7 tujusteta	7103000		rujusicu	/ tujusteu	1 10/05/00	- Augustea	

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<0.05.

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

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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

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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

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robust quasi-experimental design to evaluate the impact of health intervention using crosssectional 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.

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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.

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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)

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Density balancing plot Balancing box plot Unmatched Unmatched Matched Matched 9 Propensity score œ Density 4 9 2 4 0 Ņ 0 .5 .5 0 1 0 Propensity score FMHCP No FMHCP No FMHCP FMHCP Common-support cumulative distribution plots Cumulative distribution balancing plot Cumulative probability 0 .2 .4 .6 .8 1 Unmatched Matched Cumulative probability . ŝ 0 0 .2 .4 .6 .8 1 Propensity score .5 1 ò .5 1 0 Propensity score Total Unmatched No FMHCP FMHCP Matched

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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

	Inte	rvention countrie	s: Implemented f	ree maternal	healthcare	policy	Comparison countries: No free maternal healthcare policy					
		Ghana			Burkina Faso			Nigeria		Zambia		ì
	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).

FMHCP No FMHCP Standardized Mean Male 0.83 0.90 -0.19 Female 0.17 0.10 0.19 Poarest 0.23 0.02 0.02 Poarest 0.23 -0.02 Poarest Poarest 0.23 -0.02 0.03 Richest 0.16 0.17 -0.02 Household size	FMHCP Mean 0.83 0.17 0.23 0.21 0.20 0.20 0.16 0.29 0.40 0.31 0.90 0.10 0.13 0.37 0.50 0.31 0.69 0.20 0.20 0.31	No FMHCP Mean 0.81 0.19 0.23 0.21 0.20 0.21 0.20 0.16 0.31 0.41 0.29 0.90 0.10 0.12 0.39 0.49 0.32 0.68 0.20 0.80 0.02 0.73 0.24	Standardized Mean Difference 0.06 0.06 0.02 0.02 0.01 0.00 0.01 0.01 0.00 0.01 0.01 0.04 0.00 0.01 0.01 0.04 0.02 0.01 0.01 0.04 0.02 0.01 0.03 0.02 0.01 0.01 0.01 0.01 0.01 0.01 0.03 0.03
Near Mean Difference Male 0.83 0.90 -0.19 Female 0.17 0.10 0.19 Wealth 0.23 0.23 -0.02 Poorest 0.23 0.02 -0.04 Middle 0.20 0.18 0.03 Richer 0.20 0.18 0.03 Richer 0.29 0.25 0.10 5 -7 0.40 0.42 -0.03 8+ 0.31 0.33 -0.06 Household size	Mean 0.83 0.17 0.23 0.21 0.20 0.16 0.29 0.40 0.31 0.90 0.10 0.13 0.37 0.50 0.31 0.69 0.20 0.31 0.50 0.31 0.69 0.20 0.80 0.21 0.22 0.23	Mean 0.81 0.19 0.23 0.21 0.20 0.16 0.31 0.41 0.29 0.90 0.10 0.12 0.39 0.49 0.32 0.68 0.20 0.73 0.24	Difference 0.06 0.02 0.02 0.01 0.00 0.01 -0.03 0.01 0.04 0.00 0.01 0.04 0.00 0.01 0.04 0.03 0.02 0.02 0.02 0.01 0.01 0.01 0.01 0.01
Sec Male 0.83 0.90 -0.19 Female 0.17 0.10 0.19 Poorest 0.23 0.02 0.02 Poorer 0.21 0.23 -0.04 Widtle 0.20 0.19 0.03 Kicher 0.20 0.18 0.05 Kichest 0.16 0.17 -0.02 Household size	$\begin{array}{c} 0.83\\ 0.17\\ 0.23\\ 0.21\\ 0.20\\ 0.20\\ 0.20\\ 0.16\\ 0.29\\ 0.40\\ 0.31\\ 0.90\\ 0.10\\ 0.13\\ 0.37\\ 0.50\\ 0.13\\ 0.50\\ 0.31\\ 0.69\\ 0.20\\ 0.80\\ 0.03\\ 0.72\\ 0.26\\ 0.54\\ \end{array}$	$\begin{array}{c} 0.81\\ 0.19\\ 0.23\\ 0.21\\ 0.20\\ 0.16\\ 0.31\\ 0.41\\ 0.29\\ 0.90\\ 0.10\\ 0.12\\ 0.39\\ 0.49\\ 0.32\\ 0.68\\ 0.20\\ 0.80\\ 0.02\\ 0.73\\ 0.24\\ \end{array}$	0.06 0.02 0.02 0.01 0.00 0.01 -0.03 0.01 0.04 0.00 0.00 0.00 0.01 0.02 0.02 0.02 0.02
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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	No FMHCP	Ratio	FMHCP	No FMHCP	Rat	
	Variance	Variance		Variance	Variance		
Sex							
Male	0.14	0.09	1.49	0.14	0.15	0.9	
Female	0.14	0.09	1.49	0.14	0.15	0.9	
Wealth							
Poorest	0.17	0.18	0.97	0.17	0.18	0.9	
Poorer	0.17	0.18	0.95	0.17	0.16	1.0	
Middle	0.16	0.16	1.05	0.16	0.16	1.0	
Richer	0.16	0.15	1.08	0.16	0.16	1.0	
Richest	0.13	0.14	0.96	0.13	0.14	0.9	
Household size							
≤4	0.21	0.19	1.11	0.21	0.21	0.9	
5 -7	0.24	0.24	0.99	0.24	0.24	1.0	
8+	0.21	0.22	0.96	0.21	0.21	1.0	
Household access to an							
improved water source							
Improved	0.09	0.17	0.51	0.09	0.09	0.9	
Not improved	0.09	0.17	0.51	0.09	0.09	0.9	
Household access to	0.09	0.17	0.51	0.09	0.09	0.7	
improved toilet							
Improved not shared	0.11	0.21	0.53	0.11	0.11	1.0	
Improved, not shared	0.23	0.21	1 40	0.23	0.24	0.0	
Not improved	0.23	0.10	1.49	0.25	0.24	1.0	
Coographic location	0.25	0.23	1.00	0.25	0.25	1.0	
Geographic location	0.21	0.22	0.08	0.21	0.22	0.0	
Dibali	0.21	0.22	0.98	0.21	0.22	0.9	
Kulai	0.21	0.22	0.98	0.21	0.22	0.9	
Household owns a							
M-	0.16	0.25	0.64	0.16	0.16	0.0	
INO X	0.16	0.25	0.64	0.16	0.16	0.9	
Yes	0.16	0.25	0.64	0.16	0.16	0.9	
Mother's age at child's							
birth	0.02	0.02	0.74	0.02	0.02	1.0	
< 18	0.02	0.03	0.74	0.02	0.02	1.0	
18 - 34	0.20	0.20	1.00	0.20	0.20	1.0	
35+	0.19	0.19	1.02	0.19	0.18	1.0	
Educational attainment							
None	0.25	0.25	1.00	0.25	0.25	1.0	
Primary	0.14	0.18	0.78	0.14	0.14	1.0	
Secondary	0.19	0.19	1.02	0.19	0.20	0.9	
Tertiary	0.02	0.05	0.39	0.02	0.02	0.9	
Birth order							
First	0.21	0.16	1.31	0.20	0.21	1.0	
Second	0.19	0.14	1.32	0.19	0.19	1.0	
Third	0.12	0.13	0.96	0.12	0.12	1.0	
Fourth or higher	0.21	0.25	0.86	0.21	0.21	1.0	
Birth type							
Single birth	0.04	0.03	1.23	0.04	0.05	0.8	
Multiple birth	0.04	0.03	1.23	0.04	0.05	0.8	

Abbreviation: FMHCP: Free maternal healthcare policy

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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

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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 Agyabeng¹, Agbeshi Kwame², Gabriel Incoom³, Priscilla Nortey⁴, Alfred E. Yawson⁵, Samuel Bosomprah¹

¹ Department of Biostatistics, School of Public Health, University of Ghana, Accra.

² Municipal Health Directorate, Ghana Health Service, Somanya, Eastern Region, Ghana.

³Department 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: <u>soothe1one@gmail.com</u> Agbeshi Kwame: <u>kagbeshie@gmail.com</u> Gabriel Incoom: <u>gabrielincoomghana@gmail.com</u> Priscilla Nortey: <u>pnortey@gmail.com</u> Yawson Edwin Alfred: <u>aeyawson@yahoo.com</u> Samuel Bosomprah: <u>sbosomprah@gmail.com</u>

Corresponding author: Duah Dwomoh: <u>duahdwomoh@yahoo.com</u>

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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 UHC³. 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.

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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 freely datasets available and could be downloaded at the DHS are 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,

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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 denormalized. 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 (<u>https://ourworldindata.org/</u>). 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

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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,

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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: F No FMHP % ^b	MHCP implementation FMHP % ^b	Rao-Scot Chi-square
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)	190.12
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	+1+ (0.+)	527 (61.2)	67 (10.0)	0.61
Urban	32627 (32.2)	25035 (82.9)	7592 (17.1)	0.01
Bural	78121 (67.8)	54952 (82.0)	23169 (18.0)	
Household ownership of bednet	/0121 (07.0)	54752 (62.0)	25107 (18.0)	1013 52***
No bednet	43000 (46.4)	36880 (02 /)	6015 (7.6)	1015.52
Bednet	68000 (53.6)	43062 (73.6)	24746 (26.5)	
Missing	45 (0.06)	45002 (75.0)	0 (0 0)	
Mothers current age	45 (0.00)	45 (100.0)	0 (0.0)	11 10***
<18 years	2559 (2.2)	2002 (06 5)	755 (12 5)	11.10
10 years	20000 (71.5)	2003 (00.3)	22000 (17.7)	
10-54 years	27000 (25.2)	20000(81.8)	22000 (17.7)	
55+ Mathema advantion	27000 (23.2)	20000(81.8)	1127 (18.2)	44.09***
None	52000 (46 5)	32000 (70 4)	21000 (20.6)	44.98***
	20000 (40.5)	52000 (79.4) 24000 (86.6)	21000 (20.6)	
F1111a1 y	29000 (25.2)	24000 (80.0)	44/3(13.4)	
JED Saaandary or higher	23000 (23.3)	20000 (81.7)	4080 (18.5)	
Secondary of higher	4241 (4.8)	3882 (92.4)	339 (7.6) 5 (25.4)	
WISSING Dirth and an	16 (0.01)	11 (64.6)	5 (35.4)	271 20***
BITUI OTACT	24000 (21.1)	16000 (75.9)	91(7(242)	2/1.39***
1st oirth	24000 (21.1)	16000 (75.8)	8167 (24.2)	
2nd births	21000 (18.9)	14000 (76.1)	(351 (23.9)	
STG DIFINS	1/000 (15.2)	12000 (83.1)	4386 (16.9)	
4th births	49000 (44.8)	38000 (87.7)	11000 (12.3)	10 10++
Multiple births	110000 (06.4)	77000 (02.4)	20000 (17.0)	10.19**
Single	110000 (96.4)	77000 (82.4)	30000 (17.6)	
Multiple	3994 (3.6)	2750 (79.1)	1244 (20.9)	
	Child mortal	ity 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
	2003	31	81	67.9 [61.9-74.6]
Burkina Faso	2010	28	65	44.3 [40.5-48.5]
	2014	27.3	61.4	23.9 [21.5-26.7]
CI.	2003	43	64	30.0 [24.2-37.7]

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	2014	29	41	15.1 [11.9-19.4]
	2003	48	100	63.2 [55.6-72.1]
Nigeria	2008	40	75	50.6 [47.7-53.7]
-	2013	37	69	36.8 [34.3-39.6]
	2001-2002	37	95	70.5 [63.8-78.2]
Zambia	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<0.05. %^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 timefixed 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: Risl	c of neonatal and	infant mort	ality prior to fre	ee maternal healthcare	policy imp	lementation
(2001-2008): Modified Poisson model with rob	ist standard error	on the unm	atched sample.			

	Neonatal morta	ality: 2000-2008	Infant mortal	ity: 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*** [0.43-0.5
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*** [0.66-0.8]
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

 Country Fixed Effect
 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.</td>

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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.

10				Sensitivity anal	vsis based on different mode	l specification		
11		Modified	Paisson	Cox-proportional	Logistic regression Model: Clustering	Probit regression	Modified	Poisson
12		Model: Clustering, weig	thing, and stratification	Clustering, weighting,	weighting, and	weighting, and	Model: Clustering	g, weighting, and
13		were ad	djusted	and stratification were adjusted	stratification were adjusted	stratification were adjusted	were ac	ljusted
14		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-
15		aRR [95% CI]	aRR [95% CI]	aHR[95% CI]	aOR[95% CI]	β[95% CI]	aRR [95% CI]	aRR [95% CI]
16	Time							
10	Baseline: 2008	ref	ref 0.63*[0.42, 0.96]	ref 0.62*10.42.0.911	ref 0 59[0 33 1 07]	ref	ref	ref 0.67**[0.51_0.86]
17	Intervention	0.92[0.82, 1.05]	0.03 [0.42, 0.90]	0.02 [0.42, 0.91]	0.39[0.33, 1.07]	-0.55 [-0.09, -0.01]	0.01 [0.40, 0.81]	0.07 [0.31, 0.80]
18	No FMHP	ref	ref	ref	ref	ref	ref	ref
10	FMHP Time#EMUD	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] 0.57***[0.42, 0.77]	0.93[0.82, 1.07]
19.	Sex of household head	0.50 [0.45, 0.75]	0.55 [0.40, 0.70]	0.55 [0.40, 0.74]	0.44 [0.22, 0.00]	-0.41 [-0.77, -0.02]	0.57 [0.42, 0.77]	0.71[0.40, 1.00]
20	Male	ref	ref	ref	ref	ref	ref	ref
21	Female Mothers current age	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]
22	<18 years	ref	ref	ref	ref	ref	ref	ref
22	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]
23	35+ Place of residence	0.46***[0.36, 0.59]	0.55**[0.35, 0.86]	1.29[0.85, 1.95]	6./***[3.12, 14.38]	1.11***[0.67, 1.56]	-3.1/**[0.39, 0.8]	0.5***[0.35, 0.72]
24	Urban	ref	ref	ref	ref	ref	ref	ref
25	Rural Waalth quintile	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]
25	Poorest	ref	ref	ref	ref	ref	ref	ref
26	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]
27	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]
20	Richer	0.91[0.75, 1.1]	0.83[0.61, 1.13]	0.87[0.65, 1.16]	0.88[0.45, 1.79]	-0.06[-0.47, 0.34]	-0.64[0.7, 1.2]	0.86[0.61, 1.2]
28	Household size	0.00[0.00, 1.11]	0.55[0.50, 1.01]	1.01[0.02, 1.02]	1.04[0.40, 2.54]	0.00[0.41, 0.02]	0.07[0.0, 1.22]	0.00[0.00, 1.42]
29	1-4	ref	ref	ref	ref	ref	ref	ref
30	5-7 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, -0.13]	8.67***[0.32, 0.49]	0.38***[0.31, 0.46]
21	Access to improved water							
31	Improved	ref	ref	ref	ref	ref 0 151-0 07 0 361	ref	ref
32	Access to an improved toilet facility	1.00[0.95, 1.21]	1.00[0.87, 1.5]	1.00[0.89, 1.27]	1.20[0.00, 1.00]	0.15[-0.07, 0.50]	0.02[0.82, 1.22]	1.02[0.82, 1.28]
33	Improved, not shared	ref	ref	ref	ref	ref	ref	ref
24	Improved, shared	0.84*[0.72, 0.97] 0.84**[0.75, 0.94]	0.9/[0./8, 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]
34	Mothers education	0.04 [0.75, 0.74]	0.92[0.70, 1.11]	0.92[0.70, 1.10]	1.10[0.70, 1.57]	0.05[0.15, 0.20]	1.00[0.77, 1.07]	0.00[0.72, 1.04]
35	None	ref	ref	ref	ref	ref	ref	ref
36	Primary IHS	0.94[0.80, 1.20]	0.98[0.78, 1.23]	0.97[0.78, 1.20] 0.86[0.65, 1.13]	0.78[0.52, 1.18]	-0.14[-0.38, 0.10] -0.25[-0.57, 0.06]	-0.80[0.76, 1.12]	0.99[0.79, 1.25] 0.96[0.80, 1.16]
37	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]
20	1st birth	ref	ref	ref	ref	ref	ref	ref
38	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]
39	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]
40	Autoriths Multiple births Single	1.52 [1.12, 1.30]	1.16[0.90, 1.20]	0.8/[0.0/, 1.12]	0.401 [0.20, 0.81]	-0.44 ***[-0.70, -0.12]	2.21 [1.05, 1.58]	1.29 [1.00, 1.05]
41	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]
12	Household ownership of bednet No bednet							
42	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]
43	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.

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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

8	in unreferences analy	sis using mountee					
9			Sensitivity a	nalysis based on different m	odel specification		
10 11 12	Modified Model: Clustering stratification v	Poisson g, weighting, and vere adjusted	Cox-proportional hazard Model: Clustering, weighting, and stratification wore adjusted	Logistic regression Model: Clustering, weighting, and stratification were adjusted	Probit regression Model: Clustering, weighting, and stratification were adjusted	Modified Model: Clustering stratific were ad	Poisson , weighting, and ation justed
13	No Kernel matching	With Kernel	With Kernel matching	With Kernel matching	With Kernel matching	ATET weighting using	ATE weighting using
17	aRR [95% C1]	aRR [95% CI]	248 PS	aOR[95% CI]	BI95% CII	285-121 W 288 [95% CI]	28 (95% CI)
15 Time	akk [55/0 C1]	acc [5576 CI]	ame	aorej	p[/5/0 C1]	atti [7576 C1]	akk[JJJ/0Cl]
16 Baseline: 2008 End-line: 2014 17 Intervention	ref 0.79***[0.73, 0.86]	ref 0.62***[0.48, 0.8]	ref 0.62***[0.49, 0.78]	ref 0.45***[0.35, 0.58]	ref -0.45***[-0.59, -0.32]	ref 0.64***[0.53, 0.78]	ref 0.77**[0.64, 0.91]
18 ^{No FMHCP} FMHCP 19 Time*FMHCP	ref 0.72***[0.62, 0.84] 0.49***[0.39, 0.61]	ref 0.87[0.74, 1.03] 0.46***[0.36, 0.59]	ref 0.89[0.77, 1.04] 0.45***[0.35, 0.57]	ref 0.86[0.72, 1.02] 0.43***[0.33, 0.56]	ref -0.09[-0.19, 0.01] -0.49***[-0.64, -0.34]	ref 0.84*[0.74, 0.96] 0.48***[0.37, 0.6]	ref 0.83***[0.76, 0.92] 0.55**[0.39, 0.77]
Sex of household head	c	C C	c	c	c	c	c
ZU Male	ref 0.88*10.78.0.081	ret	ref 0.81*0.68.0.081	ref	ref	ref 0 87[0 74 1 02]	ref 0.88[0.75, 1.02]
21 Mothers current age	0.00 [0.70, 0.70]	0.75 [0.01, 0.72]	0.01 [0.00, 0.90]	0.90[0.79, 1.17]	-0.02[-0.15, 0.07]	0.07[0.74, 1.02]	0.00[0.75, 1.02]
77 <18 years	ref	ref	Ref	ref	ref	ref	ref
22 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]
23 35+ Place of residence	0.49***[0.4, 0.59]	0.4/***[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]
24 Urban	ref	ref	Ref	ref	ref	ref	ref
	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]
25 Wealth quintile							
26 Poorest	ref	ref	Ref	ref	ref	ref	ref
77 Middle	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]
Z/ Middle 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]
28 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]
20 Household size							
	ref	ref	Ref	ref	ref	ref	ref
30_{8+}^{5-7}	0.45***[0.59, 0.47]	0.45****[0.38, 0.52]	$0.52^{***}[0.45, 0.59]$ $0.46^{***}[0.39, 0.54]$	0.54***[0.45, 0.65]	-0.34***[-0.44, -0.24] -0.45***[-0.55, -0.34]	0.46****[0.4, 0.52]	0.43***[0.37, 0.5]
31 Access to improved water	0.55 [0.52, 0.57]	0.4 [0.54, 0.40]	0.40 [0.57, 0.54]	0.45 [0.55, 0.52]	-0.45 [-0.55, -0.54]	0.42 [0.50, 0.47]	0.56 [0.55, 0.45]
22 Improved	ref	ref	Ref	ref	ref	ref	ref
32 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]
33 Access to an improved toilet							
3.4 Improved not shared	ref	ref	Ref	ref	ref	ref	ref
34 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]
35 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]
36 Mothers education	c	c	D.C	c	c	c	c
JU None Primary	ref 0.0*0.02.0.001	ref 0.82*[0.7.0.97]	Ref 0.82**[0.71_0.95]	ret 0.60***[0.58_0.83]	ref	ret 0.81**[0.71_0.03]	ref 0.89[0.76, 1.03]
37 ^{IIIIIIIII}	0.88*[0.78_0.98]	0.82[0.7, 0.97]	0.77**[0.64_0.94]	$0.09^{-1}[0.38, 0.83]$ 0.54***[0.43, 0.67]	-0.35***[-0.47 -0.24]	0.81**[0.71, 0.93]	0.87[0.73, 1.03]
30 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							
39 1st birth	ref	ref	ref	ref	ref	ref	ref
40 3rd births	1.05[0.95, 1.15]	1 13[0 91 1 4]	0.7/***[0.05, 0.91]	0.65***[0.5, 0.73]	-0.2/***[-0.38, -0.1/] =0.24***[-0.36, -0.12]	0.94[0.82, 1.08]	0.84*[0.71, 1]
4 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]
4 I Multiple births		··· [·· , ···]		. []			(· · · · · · · · · · · · · · · · · · ·
42 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	rof	rof	ref	ref	ref	ref	ref
44 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
TJ 11 1.1	EN CULCID E	11 1/1 1/	DOL D	(1' DD	ALC ADD AC D	1 110 4 11 4 111	1

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<0.05.

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

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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

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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 crosssectional 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.

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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.

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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)

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Density balancing plot Balancing box plot Unmatched Unmatched Matched Matched 9 Propensity score œ Density 4 9 2 4 0 Ņ 0 .5 .5 0 1 0 Propensity score FMHCP No FMHCP No FMHCP FMHCP Common-support cumulative distribution plots Cumulative distribution balancing plot Cumulative probability 0 .2 .4 .6 .8 1 Unmatched Matched Cumulative probability . ŝ 0 0 .2 .4 .6 .8 1 Propensity score .5 1 ò .5 1 0 Propensity score Total Unmatched No FMHCP FMHCP Matched

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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

	Inte	rvention countrie	s: Implemented f	ree maternal	healthcare	policy		Co	mparison counti	ies: No free matern	hal healthcare po	olicy
		Ghana			Burkina F	aso		Nigeria			Zambi	ì
	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 Matchin	ng	After Matching			
	FMHCP	No FMHCP	Standardized Mean	FMHCP	No FMHCP	Standardized Mean	
	Mean	Mean	Difference	Mean	Mean	Difference	
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							
<u>≤</u> 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							
mproved, not shared	0.13	0.30	-0.44	0.13	0.12	0.01	
mproved, 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							
Jrban	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	
Zes	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	
8 - 34	0.72	0.71	0.00	0.72	0.73	0.03	
5+	0.26	0.25	0.02	0.26	0.24	0.03	
Educational attainment					·· ·		
Jone	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	
econdary	0.26	0.25	0.02	0.26	0.27	0.02	
ertiary	0.02	0.05	-0.18	0.02	0.02	0.01	
Birth order	0.02	0.00	0.10	0.02	0.02	5.01	
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	
Sourth or higher	0.31	0.48	-0.35	0.31	0.31	0.00	
Sirth type	0.01	0.70	0.00	0.01	0.01	5.00	
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	
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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	No FMHCP Rat		FMHCP	No FMHCP	Rati	
	Variance	Variance		Variance	Variance		
Sex							
Male	0.14	0.09	1.49	0.14	0.15	0.9	
Female	0.14	0.09	1.49	0.14	0.15	0.9	
Wealth							
Poorest	0.17	0.18	0.97	0.17	0.18	0.9	
Poorer	0.17	0.18	0.95	0.17	0.16	1.0	
Middle	0.16	0.16	1.05	0.16	0.16	1.0	
Richer	0.16	0.15	1.08	0.16	0.16	1.0	
Richest	0.13	0.14	0.96	0.13	0.14	0.9	
Household size							
< 4	0.21	0.19	1.11	0.21	0.21	0.9	
5-7	0.24	0.24	0.99	0.24	0.24	1.0	
8+	0.21	0.22	0.96	0.21	0.21	1.0	
Household access to an					•		
improved water source							
Improved	0.09	0.17	0.51	0.09	0.09	0.0	
Not improved	0.09	0.17	0.51	0.09	0.09	0.0	
Household access to	0.09	0.17	0.51	0.09	0.09	0.2	
improved toilet							
Improved not shared	0.11	0.21	0.53	0.11	0.11	1.0	
Improved, not shared	0.11	0.21	1.40	0.11	0.11	1.0	
Not improved	0.25	0.10	1.49	0.25	0.24	1.0	
Coographic location	0.25	0.23	1.00	0.25	0.25	1.0	
Geographic location	0.21	0.22	0.08	0.21	0.22	0.0	
Urban	0.21	0.22	0.98	0.21	0.22	0.9	
Rural	0.21	0.22	0.98	0.21	0.22	0.9	
Household owns a							
mosquito net ³	0.14	0.05	0.64	0.16	0.16	0.0	
No	0.16	0.25	0.64	0.16	0.16	0.9	
Yes	0.16	0.25	0.64	0.16	0.16	0.9	
Mother's age at child's							
birth							
< 18	0.02	0.03	0.74	0.02	0.02	1.0	
18 - 34	0.20	0.20	1.00	0.20	0.20	1.0	
35+	0.19	0.19	1.02	0.19	0.18	1.0	
Educational attainment							
None	0.25	0.25	1.00	0.25	0.25	1.0	
Primary	0.14	0.18	0.78	0.14	0.14	1.0	
Secondary	0.19	0.19	1.02	0.19	0.20	0.9	
Tertiary	0.02	0.05	0.39	0.02	0.02	0.9	
Birth order							
First	0.21	0.16	1.31	0.20	0.21	1.0	
Second	0.19	0.14	1.32	0.19	0.19	1.0	
Third	0.12	0.13	0.96	0.12	0.12	1.0	
Fourth or higher	0.21	0.25	0.86	0.21	0.21	1.0	
Birth type							
Single birth	0.04	0.03	1.23	0.04	0.05	0.8	
Multiple birth	0.04	0.03	1.23	0.04	0.05	0.8	

Abbreviation: FMHCP: Free maternal healthcare policy

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