APPENDIX

Sensitivity analysis: Effect of seasonality on main model

Fig. A-1 and Table A-1 illustrate the time trends and RBF4MNH effect estimates produced by the ITS analysis when conducted exactly as presented in the article, but including a further adjustment for seasonality. Findings are consistent with the primary analysis presented in the article.

The definition of season in our study is based both on literature and on the trends observed in our data. Chikhungu and Madise define four distinct seasons in Malawi: a warm and wet season (December to February) characterized by heavy rains and the beginning of farming; a dry season (March to May); a cool and dry season (June to August); and a hot and dry season (September to November) with the month of November oftentimes already characterized by heavy rains.[1] However, our time series data suggested higher levels of maternal mortality during the period from June to September. We therefore redefined the cool-dry season from June to September and the hot-dry season from October to November. Dummy variables representing these four seasons were added to the ITS model using the hot-wet season as reference.

As shown in Table A-1, only the hot-wet season had a strong positive effect (statistically significant only at a significance level of 0.1) on maternal mortality. Seasonality adjustment led to a steeper upward trend in maternal mortality of 5.4 (vs. 2.3) deaths/100,000 facility-based deliveries per month during the pre-intervention period in the control group. However, inclusion of seasonality affected our main estimates in the first post-intervention period only minimally and not at all in the second post-intervention period.

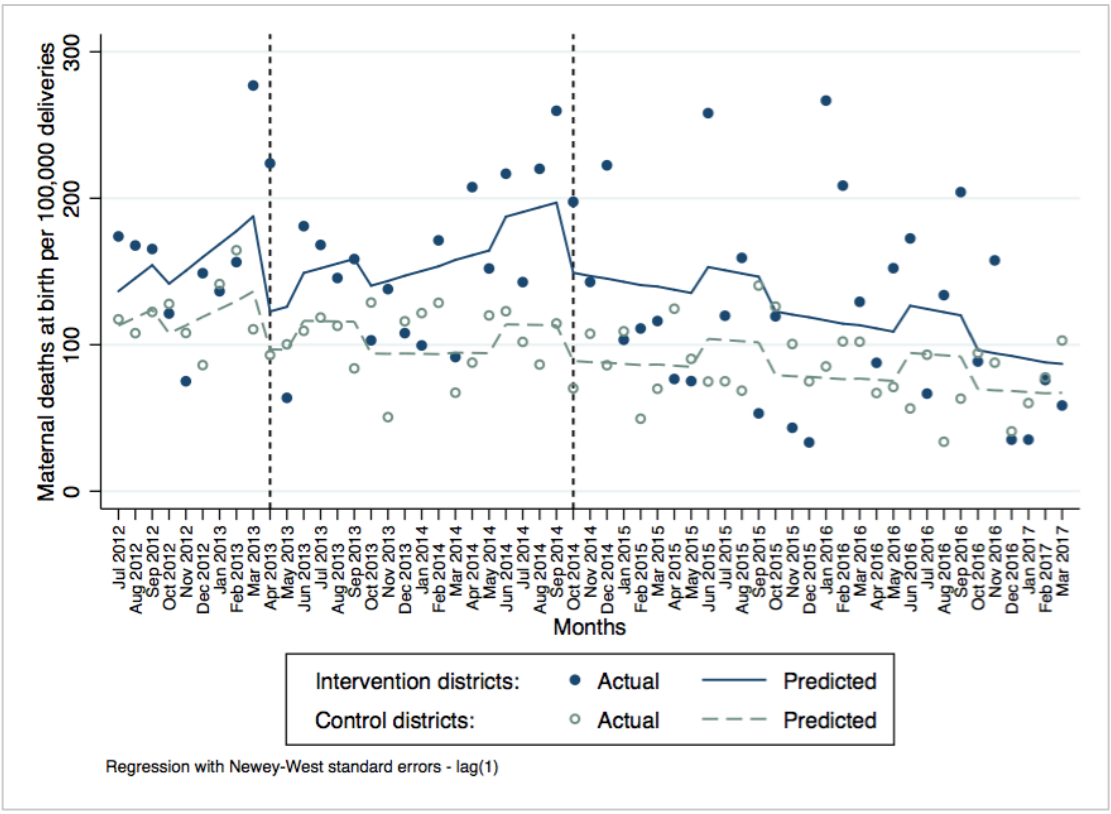

Fig. A-1. Time trends of facility-based maternal mortality by district and months.
Time series adjusted by seasons. Dots represent maternal mortality ratios averaged across facilities within each study arm (i.e. intervention vs. control); lines represent predicted maternal mortality ratio trends for each period based on linear regression.

Table A-1. Effect of the RBF4MNH on facility-based maternal mortality.
Estimates based on interrupted time series analysis adjusted by seasonality.

	Estimated maternal deaths per 100,000 facility-based deliveries (95%-confidence interval)	
Pre-intervention period:		
Control level (July 2012)	113.1	(99.0 – 127.1) ***
Difference in levels intervention vs. control (July 2012)	23.4	(-32.5 – 79.4)
Control monthly trend	5.4	(-27.4 – 11.1) *
Difference intervention vs. control in trend change	3.5	(-11.3 – 18.3)
Effects related to phase 1 (post-intervention period 1):		
Control level change	-45.0	(-84.0 – -5.9) **
Difference intervention vs. control in level change	-28.9	(-112.2 – 54.5)
Control monthly trend change	-5.6	(-11.6 – 0.4) *
Difference intervention vs. control in trend change	-0.1	(-17.5 – 18.0)
Effects related to phase 2 (post-intervention period 2):		
Control level change	-2.7	(-31.0 – 25.7)
Difference intervention vs. control in level change	-26.9	(-88.4 – 34.6)
Control monthly trend change	-0.6	(-2.4 – 1.2)
Difference intervention vs. control in trend change	-4.8	(-10.1 – 0.5) *
Effects of seasons:		
Hot-wet season (December—February)	Reference	
Warm-dry season (March—May)	-21.5	(-44.7 – 1.7) *
Cool-dry season (June—September)	-21.1	(-47.7 – 5.5)
Hot-dry season (October—November)	-19.9	(-42.6 – 2.8) *

*p<0.1, **p<0.05, ***p<0.01

Sensitivity analysis: ITS model using matched controls

In the manuscript, we present effect estimates derived from an ITS model that holds as control districts all other comparable districts in the country. This was deemed to be relevant since it reflected our desire to produce results with minimal manipulation of the data, excluding a priori only districts with substantially non-comparable health system structures. To ensure robustness of our findings to alternative modeling exercises, we also applied an alternative model by matching each intervention district with a single control district. We used the 'itsamatch' Stata package to identify control districts that were not significantly different (alpha = 0.05) from at least one intervention district at baseline based on maternal mortality and facility delivery trends and levels observed during the pre-intervention period.[2] Matching using a higher alpha was not possible for all intervention districts. The matched controls and resulting sample characteristics are presented in Table A-2. The sample including only four matched control districts had lower average mortality rates for each period compared to the sample including all 19 comparable control districts.

Fig. A-2 and Table A-3 display the time series trends and ITS estimates for the matched control model adjusted for seasonality. The matched control districts model is the only model in which the pooled intervention and control district trends differed significantly at baseline, challenging the ability to interpret the control as representing an acceptable counterfactual. In the matched control model the effect estimates were more pronounced in the first and less strong in the second post-intervention period compared to the initial model. There was a statistically significant effect of the cold-dry season on increased facility-based mortality. Inclusion of seasonality minimally reduced the estimated effect sizes compared to the non-adjusted matched control model (data not shown).

The matching process was intended to provide a model with a more comparable baseline level and trend among controls when comparing to intervention districts to aid interpretation of the counterfactual. However, given that this goal was not achieved, we have concluded that the most appropriate model is that which compares the intervention district to all other rural mainland districts, thereby allowing all theoretically comparable districts to serve as the control.

Table A-2. Sample distribution and sample characteristics.

	Total number of districts [a]	Total number health facilities	Total number observations	Monthly facility-based maternal deaths per 100,000 facility-based deliveries per period mean (standard deviation)		
				Pre-intervention period	Post-intervention period 1	Post-intervention period 2
Intervention	4	63	5,242	158.0 (54.0)	158.4 (53.3)	123.5 (66.0)
Controls	4	76	6,496	113.1 (34.6)	67.6 (35.4)	75.1 (39.9)

[a] *Matches: Balaka/Salima, Dedza/Kasungu, Mchinji/Zomba, Ntcheu/Mzimba*

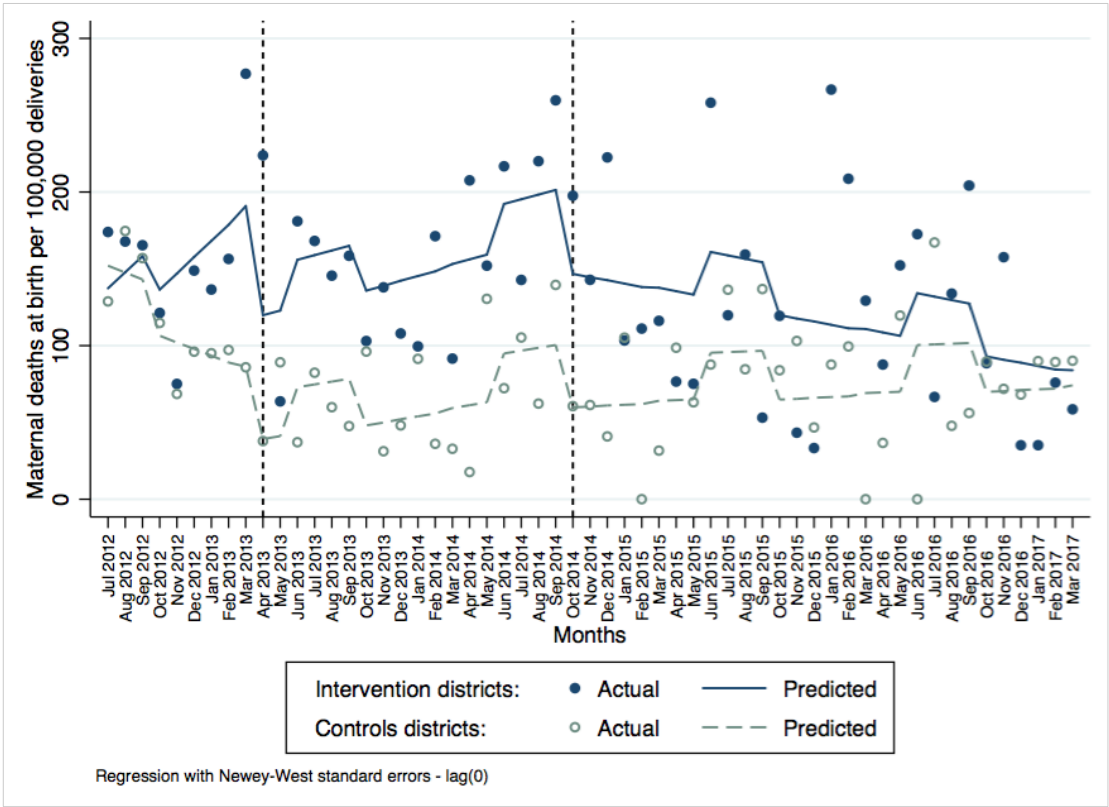

Fig. A-2. Time trends of facility-based maternal mortality by district and months for matched controls.

Time series adjusted by seasons. Dots represent maternal mortality ratios averaged across facilities within each study arm (i.e. intervention vs. control); lines represent predicted maternal mortality ratio trends for each period based on linear regression.

Table A-3. Effect of the RBF4MNH on facility-based maternal mortality. Estimates based on interrupted time series analysis of matched controls adjusted by seasonality.

	Estimated maternal deaths per 100,000 facility-based deliveries (95%-confidence interval)	
Pre-intervention period:		
Control level (July 2012)	152.0	(123.0 – 181.0) ***
Difference in levels intervention vs. control (July 2012)	-14.7	(-69.6 – 40.2)
Control monthly trend	-4.5	(-10.4 – 1.5)
Difference intervention vs. control in trend change	14.9	(0.3 – 29.5) **
Effects related to phase 1 (post-intervention period 1):		
Control level change	-42.6	(-82.2 – -3.1) **
Difference intervention vs. control in level change	-38.9	(-148.9 – 71.1)
Control monthly trend change	6.3	(-0.7 – 13.3) *
Difference intervention vs. control in trend change	-13.7	(-29.6 – 2.2) *
Effects related to phase 2 (post-intervention period 2):		
Control level change	-10.2	(-55.4 – 34.6)
Difference intervention vs. control in level change	-15.3	(-93.4 – 62.8)
Control monthly trend change	-1.4	(-5.0 – 2.2)
Difference intervention vs. control in trend change	-3.9	(-10.6 – 2.9)
Effects of seasons:		
Hot-wet season (December—February)	Reference	
Warm-dry season (March—May)	-32.2	(-56.8 – -7.5) **
Cool-dry season (June—September)	-31.8	(-59.9 – -3.7) **
Hot-dry season (October—November)	-30.0	(-56.6 – -3.4) **

*p<0.1, **p<0.05, ***p<0.01

References

1 Chikhungu LC, Madise NJ. Seasonal variation of child under nutrition in Malawi: is seasonal food availability an important factor? Findings from a national level cross-sectional study. *BMC Public Health* 2014;**14**:1146. doi:10.1186/1471-2458-14-1146

2 Linden A. *ITSAMATCH: Stata module to perform matching in multiple group interrupted time-series analysis*. Boston College Department of Economics 2017. https://ideas.repec.org/c/boc/bocode/s458428.html (accessed 16 Jul 2018).