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The Impact of the 2014-2015 West African Ebola Outbreak on Fertility in Sierra Leone

Note to organizer: In addition to adding references, I am in the process of refining the interpretation of the results and modifying the conclusion. Thank you for your consideration.

Abstract (150 words):

The 2014 West African Ebola outbreak was the largest ever in terms of number of cases. The long term demographic consequences of the epidemic are still being studied. The theoretical impact of Ebola on fertility is potentially twofold. First, during the outbreak, people were encouraged to modify their behavior to avoid physical contact with others because Ebola is transmitted most easily through contact with bodily fluids. On the other hand, with the state of emergency declared, people were more limited in their social interactions outside of the home. Using data from a nationally-representative sample of women in Sierra Leone, I estimate the effect of the Ebola outbreak on district level fertility changes using difference-in-difference models and on individual timing of births using event history analysis models. Preliminary results suggest that fertility at the district level increased during the outbreak and the length of the birth interval for individuals decreased.

Introduction

The news of Ebola Virus Disease (EVD or Ebola) spreading through West Africa gripped the world media in late 2014 and early 2015. The zoonotic virus results in severe hemorrhagic fever and spreads rapidly between humans from contact with bodily fluids (Gatherer 2014). The three main countries affected by the outbreak— Guinea, Liberia, and Sierra Leone— reported approximately 29,000 cases and 11,000 deaths attributed to Ebola (World Health Organization 2016). While Liberia reported more overall deaths, Sierra Leone reported the highest number of cases - 14,124 cases and 3,956 reported deaths across all parts of the country. While the case fatality rate was not as high as in other Ebola outbreaks (Kucharski and Edmunds 2014), the 2014 West African Ebola outbreak was the largest ever in terms of number of cases and the long term consequences of the Ebola epidemic are still being studied.

This paper examines trends in fertility specifically in Sierra Leone before and after Ebola using newly-released micro data. The total fertility rate in Sierra Leone has declined from over 6 children per women in 1960 to just over 4 children per women currently (World Bank 2017). The impact of Ebola on fertility is potentially twofold. First, the Ebola virus was detected in the sperm of men who had recovered from Ebola (Mate et al. 2015; Deen et al. 2015). Researchers are uncertain of risks of sexually-transmitted Ebola or long term medical complications on survivors' fertility. These findings suggest a potential for long term impacts on fertility. Second, in the time during the outbreak, people were encouraged to modify their behavior to avoid physical contact with others because Ebola is transmitted most easily through contact with bodily fluids. These social modifications could affect the timing of fertility by reducing sexual activity and by limiting opportunities for socialization when potentially-infected people were quarantined (Fairhead 2014). I hypothesize that these behavioral modifications during the Ebola outbreak did not indefinitely impact fertility but instead couples postponed births. Using data from a nationally-representative sample of women in Sierra Leone, I estimate the effect of the Ebola outbreak on district level fertility changes using difference-in-difference models and on individual timing of births using event history analysis models.

Background

Ebola Virus Disease (EVD) and the 2014-2015 Outbreak in Sierra Leone

The first outbreak of Ebola was reported in 1976 in the Democratic Republic of Congo. Since then there have been about a dozen outbreaks generally contained to central Africa (ref.). The main symptoms of Ebola are headache, muscle pain and fever followed by vomiting, diarrhea, and profuse internal and external bleeding (WHO 2017). Ebola is transmitted person to person via contact with body fluids, thus creating high risks for people caring for infected people as it is difficult to avoid contact with blood. The virus had a terrifyingly high case fatality rate; up to 90 percent of infected individuals perished in past epidemics. Moreover, there were high rates of transmission between people with contact with any bodily fluids (Gatherer 2014; Kucharski and Edmunds 2014). High mortality and thus relatively few survivors resulted in little being known about the long-term health impacts among survivors. In the 2014 West African outbreak, there were many more survivors than in past outbreaks. Much of the public health messaging encouraged people to avoid touching potentially-infected people and to wash off bodily fluids with soap and water. Additionally, potentially infected individuals and their households were quarantined for 30 days (World Health Organization 2017). These measures reduced the social contact people had during the peak of the outbreak. More recent evidence about Ebola is described here, but there continues to be a need for more research on the sexual transmission of Ebola. [1]

The spread of EVD in Sierra Leone in 2014

The 2014-2015 West African Ebola epidemic started in Guinea in early 2014. In May of 2014, a nurse who attended a funeral in Guinea returned to her village in Kailahun district in Eastern Sierra Leone, where she infected six other nurses at the small clinic (WHO 2014). Several of these women were transported to a hospital in Kenema--the largest city in the east of Sierra Leone.[2] In a brief period of time, Ebola cases were reported spreading west along major road networks and in major cities. Just a few weeks after the first case was reported, the capital city of Freetown reported a rapidly increasing number of cases. In the densely-packed capital, the virus was transmitted quickly, and soon all of Sierra Leone's 14 districts had reported cases. The speed of the outbreak led to a high level of uncertainty and fear about the dangers, severity, and risks of Ebola. People in Sierra Leone and around the world raced to gather information.

By June 11, 2014, schools were closed and borders to Guinea and Liberia were shut to trade (Staff 2014). On July 30, Sierra Leone President Ernest Bai Koroma issued a state of emergency for the country (Barbash 2014). This included a massive public health response that included a quarantine of areas that were infected, restrictions on public meetings and gatherings,

[1] In Sierra Leone, a women reported contracting Ebola from sexual intercourse with a survivor, and the virus was found in the survivor's sperm (Mate et al. 2015). Additional studies found that 25 percent of men had detectable Ebola in sperm after being discharged and cleared of Ebola (Deen et al. 2015). The World Health Organization (WHO) recommends survivors refrain from unprotected sexual activities until receiving negative results twice, which in many cases this took up to one year (WHO 2017). These WHO recommendations for sexual behavior modification for survivors were made partially due to incomplete information on how Ebola could impact fetal development (Jamieson et al. 2014; Mupapa et al. 1999). If a women is infected while pregnant, there is evidence of the virus in the placenta, amniotic fluid, and fetus; if a women is infected while breastfeeding, the virus can be found in breastmilk (WHO 2017).

[2] Information from personal field notes of interviews 2017 and from unpublished research conducted by Professor Claudena Skran at Lawrence University. Also, similar to the reported pathways in Richards et al. 2015.

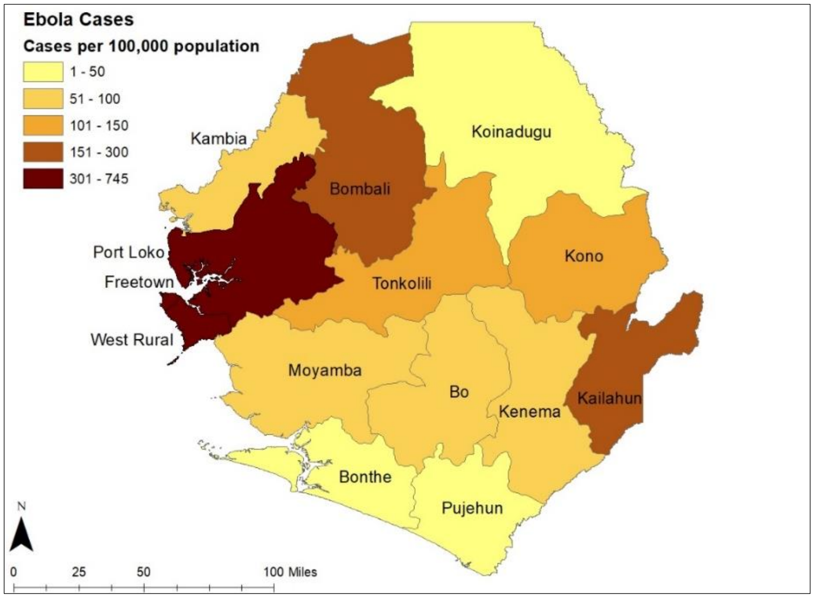
and active surveillance and searches for victims and potentially-infected persons. Negative and hostile social responses to these public health measures included conflicts between traditional burial practices and health workers (Richards et al 2015; Leach 2015). Stories of kidnapping of loved ones from hospitals and the continuation of traditional burial practices hindered efforts (ref.). It is not fully known how effective these measures were in preventing or containing the outbreak or how well they were implemented (Calain 2015).

The rapid and geographically uneven spread of Ebola throughout Sierra Leone allows for visual representation of the spatial impact. As shown by Figure 1, the severity of Ebola cases varied by districts. Spatial analysis must also account for significant cultural, ethnic, religious, and social differences between districts and between urban and rural areas within districts[3].

Figure 2 shows the timeline of the spread of Ebola cases by each of the 14 districts in Sierra Leone. There is variation in timing in the maximum number of cases and their rate of growth. This can be explained by the transmission patterns from the east of Sierra Leone to the western districts. Kailahun district, in the east where the first case was reported, shows many cases early in the epidemic but trails off near the middle of the outbreak. The capital city, Freetown, located in the Western Area Urban district, accounted for the highest number of cases. Nearby districts of Port Loko and Western Area account for the next highest number of cases with major cities of Port Loko and Waterloo located in those districts respectively.

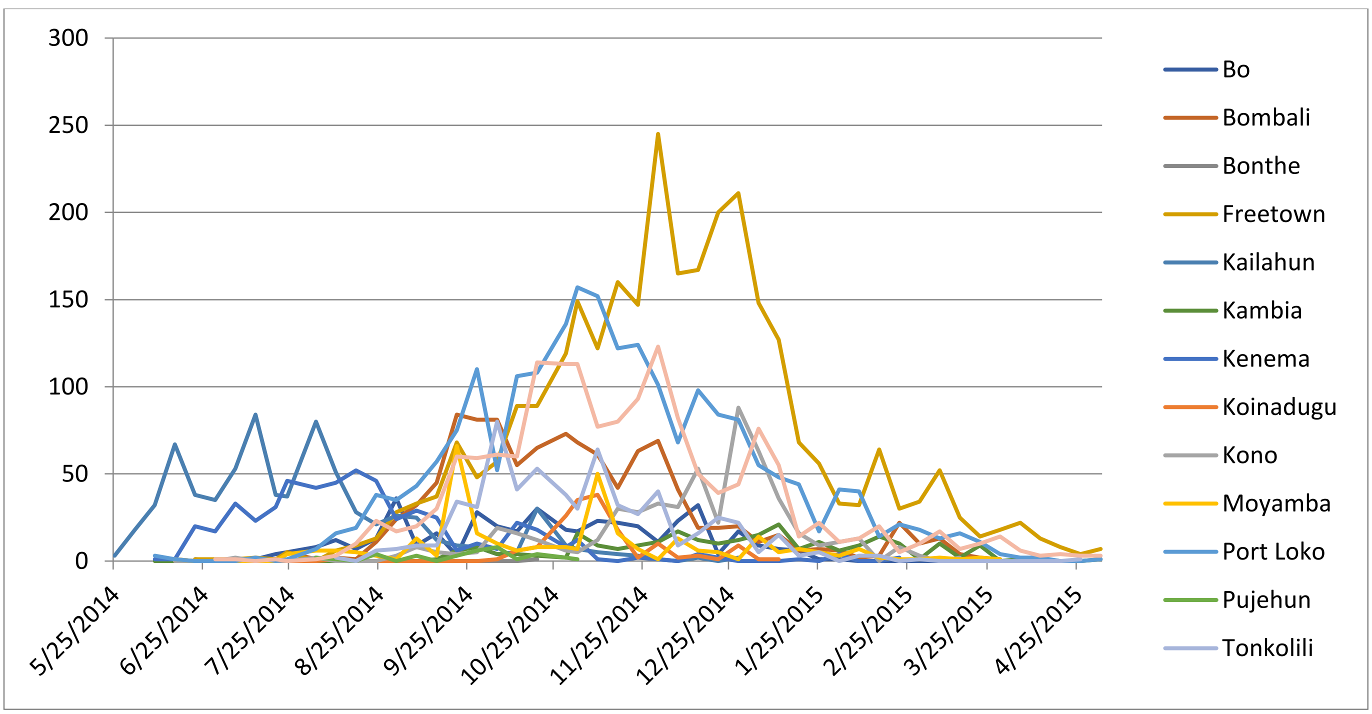
[3] These differences can impact fertility but there is limited data reported at the district level. However, this is not included in this analysis at this point.

Figure 1: Total Ebola cases in Sierra Leone by district December 2013 and June 2015



Source: Author's calculations using data from Backer and Wallinga (2016), Minnesota Population Center shapefile (2018)

Figure 2: Number of cases reported in each district in Sierra Leone between May 2014, and April 2015.



Source: Author's calculations using data from Backer and Wallinga, 2016

Literature: Infectious disease, exogenous shocks, and fertility behavior modification

Little has been documented about the impact of Ebola on long term fertility trends. The relationship between the Ebola public health campaign and fertility are the foundation for the hypothesis that Ebola will impact fertility. Other theoretical frameworks reviewed here include looking at the relationship between other disease outbreaks and fertility and between exogenous shocks and fertility.

Fertility and Other Disease

Shortly after the 2014 West African Ebola outbreak, Zika (ZIKV) was linked to birth deformations such as microcephaly in Latin American countries. This prompted a government recommendation for women to postpone childbearing until more was known (ref.). A working paper by Marcia Castro suggests that this public health announcement resulted in a decline in the number of births in several regions in Brazil (2017). Zika presents a useful compliment to an Ebola study because the impact of Zika on birth outcomes is known and severe.

Other contemporary diseases such as severe acute respiratory syndrome (SARS) in 2003 in southern China, West Nile Virus in the United States since 1991, and the 2001 anthrax attacks have been reported on by obstetrician-gynecologists as impacting pregnant women and neo-natal development (Jamieson et al. 2006). At the population level, the HIV epidemic in Sub Saharan Africa has reduced births by infected women (Carpenter et al. 1997). There are also historic demographic examples of the outbreak of diseases whose mortality impacted fertility and population growth for future generations (Boyd 1999; Underwood 1984).

Fertility during social upheaval

Declines to fertility occur at times of social upheaval or shock (Caldwell 2004). When people are uncertain about the future, the fertility rates of a population may decline. There are also arguments for the opposite effect (Frantsuz 2017). Other examples of fertility change in a time of a short term exogenous shock include the 2007 Indonesian Tsumani (Nobels et al 2015), Oklahoma City Bombing (Rodgers et al. 2005), September 11, 2001 (Morin 2002; Scelfo 2002), and power outages (Burlando 2014).

The fertility response to longer term exogenous shocks has been found to take two major forms. Some shocks initiate long-term fertility declines. Others can cause couples to postpone fertility, with fertility levels eventually returning to the pre-shock level or trend. Total fertility declines occur alongside large demographic shifts happening simultaneously with social transitions. For example, the collapse of the Soviet Union in 1991 lead to fertility declines in Russia and other post-Soviet countries in Eastern Europe and Central Asia (Kohler and Kohler 2002). Fertility postponement can occur in war situations; the Baby Boom in the United States followed World War II (Sobotka, Skirbekk, and Philipov 2011). The impact of war in sub-Saharan Africa has impacted fertility through postponed births (Blanc 2004; Agadjanian and Prata 2002). In Ethiopia, the war and famine of the 1970s and 1980s resulted in elongation of conception intervals due to couples intentionally delaying births with the expectation that conditions would improve in the future (Lindstrom and Berhanu 1999).

Additionally, the disruption of daily routine and situation of quarantine may have also impacted fertility. While conducting field work in Sierra Leone in the summer of 2017, I had several interactions where school children lamented that their fellow female classmates did not return to school when the schools reopened in April 2015 after being closed for nine months. From my understanding, there were a number of girls that would have returned to secondary schools but were forced to drop out because of pregnancy. In Sierra Leone, girls who become pregnant may not return to school (Guilbert 2017). Because of the long period of time without schooling or other activities fill their time, there could be an increase in pregnancy for young women who might have otherwise been in school if it weren't for the Ebola outbreak. This is a theme I would like to further explore in the data.

Fertility behavior modification in married couples

In addition to modifying fertility based on exogenous conditions, the patterns of fertility are being changed by large demographic transitions in behavior and attitude towards childbearing. Ideational theories of fertility transition suggest that information and social norms diffuse throughout a society, and fertility behaviors changes as a result (Mason 1997). Theories of fertility transition have not been able to predict the only minor declines in fertility in African countries in the context of culture, religion, and community (Caldwell and Caldwell 1987; Bongaarts and Casterline 2012). In sub-Saharan Africa, there are strong cultural expectations of motherhood and bearing many children (ref.). Findings show that African women make fertility decisions differently than other Euro-centric theories of fertility transitions differently. Despite evidence of fertility behavior modification during times of social upheaval, conception intentions in Sierra Leone may be different than expected based on theories of fertility in Western or other African contexts. It is unknown how the diffusion of information about Ebola and its impact on fertility modified or changed behaviors in the short or longer term.

Research Question

My research question asks what effect the 2014 West African Ebola outbreak had on fertility rates in Sierra Leone during and shortly after the outbreak. Fertility decisions at the individual level may have an impact on fertility changes at the national level. In order to fully understand how Ebola impacted fertility rates in Sierra Leone, I use difference-in-difference analysis of the aggregated measure of fertility at the district level. Using the same data, I present an event history analysis, to look at changes in the patterns of individual fertility behaviors within married women.

Based on the theories of fertility decline during social upheaval and the highly contagious nature of Ebola, I hypothesize that the high risk for Ebola transmission during the epidemic in Sierra Leone led people to delay or postpone fertility. This would be supported by results in the event history analysis showing increased birth intervals during the outbreak.

Alternatively, if people actually have more children in times of fertility upheaval and people might be having more children with there was limited social interaction (aka quarantine), an alternative hypothesis would be that there would be an increase in children conceived during the months of the Ebola outbreak in Sierra Leone. This might be supported by the difference-in-difference results showing an increase in the fertility rate during the time of Ebola compared to times without cases of Ebola.

Data

Fertility Data

Data were obtained from the 2016 Sierra Leone Demographic and Health Malaria Indicator Survey (SL16 MIS) conducted by the National Malaria Control Program (2016). This is a household survey that is representative of women at the national, regional, and district levels. My analysis at the district level and at the individual level are both weighted using the provided mother weights. The SL16 MIS has a complete birth history of each woman in the five years prior to the survey, 2011-2016, which includes the 2014 Ebola outbreak.

There are 8501 married women who were surveyed in the SL16 MIS; they report a combined 6890 births in the five years prior to the survey. The DHS samples representatively at the district level. As Table 1 shows, motherhood is common in Sierra Leone from a young age. Education level for women in Sierra Leone is still low despite universal primary education since the early 2000s (universal primary education was made free in 2004) (ref.). Over half of the women in the DHS sample report no education. Of the women in the DHS sample, the average number of children is 3.2 children per woman and 80% of the sample is a mother. Over half (57%) of the woman in the sample report a birth in the five years prior to the survey (between 2011-2016). Of these births, half were male and 96% were single births. Most of these births survived until the time of survey (96% reported to be still living at the time of survey).

Table 1: Sample Size and descriptive statistics of the Sierra Leone 2016 Demographic and Health Malaria Indicator Survey.

	All women	Mothers with a birth in last 5 years	Mothers without a birth in last 5 years	Non mothers
Sample size (N)	8501	4887	3614	1589
Proportion of sample	1	0.57	0.43	0.19
Mean age	28.01	28.16	27.89	18.95
Education				
No Education	0.52	0.59	0.42	0.17
Primary	0.14	0.14	0.13	0.16
Secondary	0.33	0.26	0.43	0.66
Higher	0.01	0.01	0.02	0.02
Mean children ever born	3.37	3.86	2.71	-
Births in the last 5 years				
No births	0.43	-		
1 birth	0.37	0.65		
2 births	0.17	0.31		
3 births	0.02	0.04		
4 births	0.00	0.00		
Single Birth		0.96		
Male		0.50		
Still alive		0.96		

Ebola Data

For data on the timing and intensity of Ebola, Backer and Wallinga (Backer and Wallinga 2016) compiled the number of cases from the WHO case reports published between December 2013 and June 2015. The data was produced by week and counts the number of new reported cases in each district. To match the data to the months in the DHS, I have matched the weeks based on the initial May 25, 2014 report of the first case in Kailahun. If the week fell between two months, the month was assigned based on which month had the majority of the days of that particular week. Because of the treatment and recovery period of Ebola, Sierra Leone was not determined to be clear of the outbreak until March 2016, but the majority of the cases and the high of the outbreak itself are included in the data.

Difference-in-Difference

The aggregate impact of the 2014 West African Ebola Outbreak on fertility is tested by comparing districts where Ebola was present with districts that had no reported cases of Ebola within given time using a multi-period difference-in-difference model.

These births are aggregated to the district level to form a weighted count of the number of births in the district per month from 2011 to mid-2016. As the outcome of interest, generalized fertility weight (GFR) is the aggregate measure of fertility. The GFR is the number of births in a district, *d*, in month, *m*, over the total number of women of reproductive age (15-49) in a district. The denominator is constructed from the weighted number of women surveyed in the SL16 MIS and assumed to be constant over time within the district[4].

$$GFR = \frac{Weighted\ Births\ in\ district\ in\ month}{Weighted\ women\ (15-49)\ in\ district}$$

The dates of birth reported in the SL16 MIS represent the month of birth. However, I am interested in how fertility changed as a result of the Ebola outbreak. I account for the time of conception by lagging the month of birth by nine months. This would represent children conceived during months of the Ebola outbreak and born nine months later. This conception lag is indicated as a “nine-month lag” throughout. I have also constructed a time variable that creates a twelve-month lag in births. My purpose in doing this is to incorporate and explore if there was any fertility modification as a result of information from public health campaigns. Because the

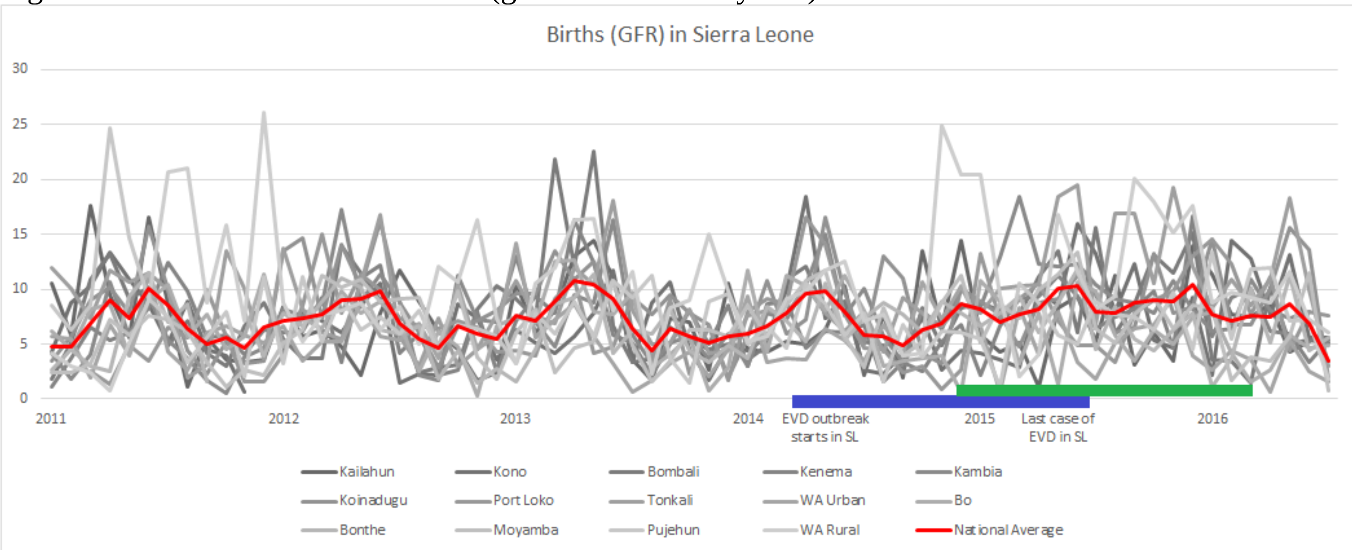
[4] There is not a good measure of migration in the DHS MIS and thus it would be difficult to construct measures that reflected only women in the district for the whole period surveyed.

outbreak lasted for most of a year, some women may have been exposed to information about Ebola that impacted their fertility decisions some months before conceptions[5].

One underlying assumption about difference-in-difference estimation is the assumption of parallel trends. Figure 3 shows the patterns of the weighted generalized fertility rate in Sierra Leone by district. The red line represents the national average fertility rate during the same period. There is an overall birth seasonality effect; all districts show trends that roughly align with the peaks and valleys of the seasonality as shown by the red line (ref). Seasonality is accounted for by the inclusion of the month fixed effects in the difference-in-difference estimations. The blue bar on the X-axis represents the 2014 West African Ebola Outbreak. The green bar represents a nine-month conception delay to show the time that babies would be born if they were conceived during the months of the Ebola outbreak.

[5] The decision to only do 9 and 12 months prior to birth is because of precedent (ref).

Figure 3: Birth trends in Sierra Leone (generalized fertility rate) from the SL16 MIS



I measure the variables indicating Ebola in a district in three ways. First, I present a binary variable where 1 is equal to at least one case of Ebola reported in a district in the 9 months and 12 months prior to a birth event, and 0 otherwise. Second, I include the specific counts of the Ebola reports in a district in a given month 9 or 12 months prior to a birth event. Finally, I scale the number of Ebola reports to the rate of Ebola in the population of a district (also lagged 9 and 12 months). As the Ebola counts and Ebola rates are highly collinear, they are included in separate models.

Based on the number of cases, I create three treatment timing parameters: start, peak, and last. I identify the first week that there were reported cases of Ebola in a particular district; this is labeled as "start". The week with the maximum number of cases in that district was identified as the peak. The final time point was the last week that reported any cases. These three time points were used to create separate estimates as I hypothesize people will have different fertility reactions to different time points. At the start of the epidemic, there is much more uncertainty and thus people may be modifying their fertility behavior more than at other points.

The unit of analysis is the district level. As every district eventually reports cases of Ebola, this treatment is a roll out or multi period treatment. I have adjusted for differences in geography between the SL16 MIS and the Backer and Wallinga data[6]. The number of cases reported in each district shows that some districts were impacted harder by the epidemic. Some districts also had an earlier peak. For example, there were only a handful of cases reported in Bonthe and no deaths. Districts in the east were more impacted earlier in the epidemic while the west had higher peaks as the cities of Freetown and in Port Loko had a high number of cases.

The Ebola outbreak eventually impacted every district in Sierra Leone. As a result, I will use a multi period difference in difference estimator (shown in equation 1).

$$GFR_{dm} = \alpha + \delta D_{dm} + \lambda_m + \eta_d + \varepsilon_{dm} \qquad \text{(Equation 1)}$$

GFR_{dm} is the outcome variable of the generalized fertility rate for a district *d* at month *m*. $\delta D_{d,m}$ is the indicator for the treatment in district *d* at month *m*. λ_m and η_d are the time- and district-fixed effects respectively. ε_{dm} is the error term. This model was run separately using the nine-month and the twelve-month lag for each of the treatment timings (start, peak, and last).

The formula above shows the difference-in-difference estimation for fixed effects for month and district. In the analysis, I provide estimates for comparison based on ordinary least

[6] For geographic consistency, the labels “Western Area Urban” and “Freetown” are the same. As there is a high level of urbanization of the entire Western Area Peninsula, the division between “Western Area Rural” and “Western Area Urban” blurs in regards to where the end of Freetown start and end.

squares (OLS), difference-in-difference with just the month fixed effects, and difference-in-difference with just district fixed effects.

Difference in difference results

The four models included a basic OLS model, a difference-in-difference model with month fixed effects, a difference-in-difference model with district fixed effects, and a difference-in-difference model with month and district fixed effects. Each model was run using both the twelve-month and nine-month fertility lag and models were also separated by timing of Ebola cases in each district to account for differences in the first reported case of Ebola (start), the maximum number of cases (peak), and the final case (last). Results for the estimates are presented in Table 2. Each cell provides the estimate from the separate regression (robust standard errors in parenthesis) with the model R^2 reports in grey italics. The sample size remained constant (n=932).

Table 2: Impact of the 2014 West African Ebola outbreak on fertility in Sierra Leone

Lag time	Timing	OLS	Difference-in-difference model with **month fixed effects**	Difference-in-difference model with **district fixed effects**	Difference-in-difference model with **month and district fixed effects**
Nine	Start	0.1514**	0.1856***	0.1866***	-0.4051*
		(-0.07)	(-0.06)	(-0.06)	(-0.24)
		0.005		*0.012*	*0.204*
	Peak	0.1550*	0.1392***	0.1389**	-0.00901
		(-0.08)	(-0.05)	(-0.05)	(-0.21)
		0.004		*0.006*	*0.201*
	Last	0.1234	0.0104	0.0069	-0.25674
		(-0.10)	(-0.08)	(-0.08)	(-0.16)
		0.002		*0.000*	*0.204*
Twelve	Start	0.0803	0.1200**	0.1212**	-0.4146*
		(-0.08)	(-0.05)	(-0.06)	(-0.24)
		0.001		*0.004*	*0.204*
	Peak	0.0830	0.0633	0.0629	-0.2256*
		(-0.09)	(-0.07)	(-0.07)	(-0.12)
		0.001		*0.001*	*0.203*
	Last	0.1792	0.0087	0.0036	0.0178
		(-0.13)	(-0.08)	(-0.09)	(-0.26)
		0.002		*0.000*	*0.201*

The above table uses robust standard errors. Only the coefficients of interest are presented here. Fixed effect coefficients are omitted. The sample size (n=932) remains constant across all estimates. (stars indicate * .1 **.05 ***.001).

The OLS naïve estimations produced coefficients that were indicative of an increase in fertility. Models using a nine-month lag at the start and peak times are significant. The difference-in-difference estimates that only use fixed effects by month or fixed effects by district are very similar. All coefficients for this model suggest increases in fertility in all timing of

Ebola. In addition to the nine-month lagged start and peak times, the estimates with a twelve-month lag at the starting time are also significant[7].

The final column in table 2 represents the equation 1. The difference-in-difference incorporated both month and district fixed effects. The coefficients for the difference show a decrease in fertility for the starting time at the nine and twelve-month lag significant at the p<.1 level. The coefficient estimates and standard errors are very similar. Additionally, the peak timing within the twelve-month lag is also significant.

Preliminary Results

The interpretation of these results suggests that when using fixed effects for both district and month, the reports of the first cases of Ebola in a district decrease the generalized fertility rate by .4 in months following the start of the outbreak. This result suggests a reduction of the fertility rate by half of a birth per month for the women of reproductive age in a district. These results are convincing as the first reported cases of Ebola were occurring when there was a high level of uncertainty about the scale and risk of the epidemic. As the epidemic continued and more information was known about the risk factors, treatment, and prevention, people may have returned to normal behavior if they perceived their risk to be low.

Heterogeneity in Treatment Effects

The significant results for the nine-month lag and the twelve-month lag suggest that there may be heterogeneity in the treatment effect. Using equation 2, I test for heterogenous treatment effects for the difference-in-difference estimates with district η_d and month λ_m fixed effects, with *k* periods and *j* time intervals. Table 3 shows the results of the estimated effect for 1 year prior

[7] These models would did not produce R^2 statistics.

and 1 year after treatment along with the 6 months prior and 6 months after treatment. Only the coefficients of interest were reported and the robust standard errors are in parenthesis.

$$GFR_{dm} = \sum_{j=0}^{k2} \delta D_{dm} + \lambda_m + \eta_d + \varepsilon_{dm} \qquad \text{(Equation 2)}$$

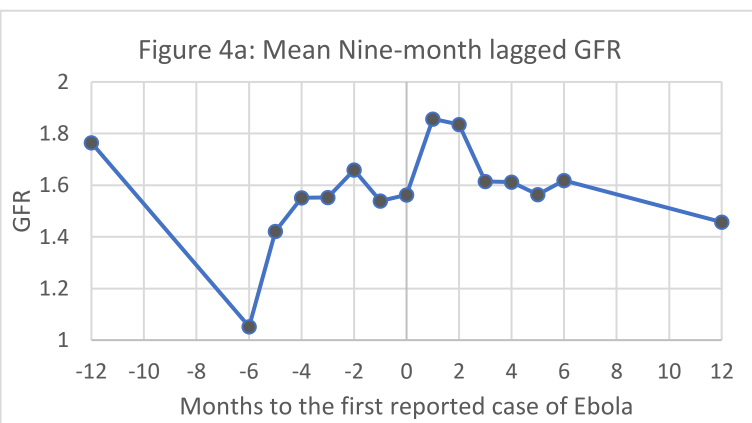
Table 3: Impact of EVD outbreak on fertility rates showing effects over time

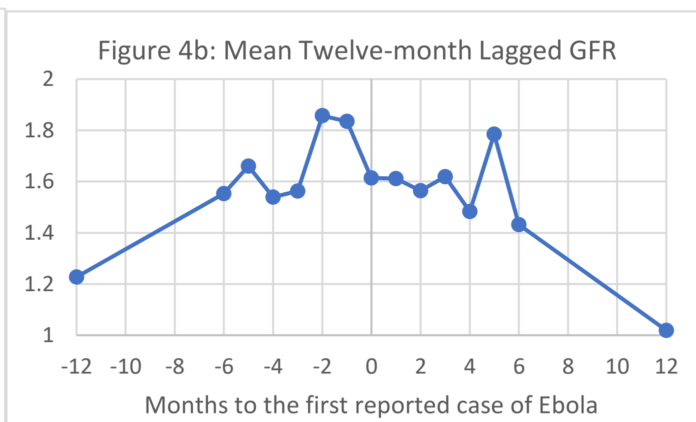
		Lagged Nine			Lagged Twelve		
		Start	Peak	Last case	Start	Peak	Last case
12 months	Prior	0.15	0.06	-0.15	-0.18	-0.25*	-0.08
		(-0.25)	(-0.19)	(-0.20)	(-0.19)	(-0.14)	(-0.11)
6 months		0.07	-0.11	-0.20	0.03	-0.10	-0.07
		(-0.24)	(-0.27)	(-0.28)	(-0.17)	(-0.20)	(-0.17)
5 months		0.44*	-0.06	0.21	0.12	0.07	-0.20
		(-0.21)	(-0.33)	(-0.25)	(-0.36)	(-0.28)	(-0.20)
4 months		0.58*	0.36	0.13	-0.08	-0.02	-0.18
		(-0.28)	(-0.35)	(-0.30)	(-0.46)	(-0.35)	(-0.34)
3		0.50	-0.02	-0.01	-0.30	-0.06	-0.33*
		(-0.31)	(-0.34)	(-0.30)	(-0.54)	(-0.37)	(-0.18)
2		0.61	0.17	-0.13	-0.13	0.28	-0.36
		(-0.36)	(-0.40)	(-0.36)	(-0.50)	(-0.35)	(-0.25)
1		0.41	0.09	-0.10	-0.26	0.24	-0.48***
		(-0.37)	(-0.43)	(-0.46)	(-0.55)	(-0.44)	(-0.15)
Point (start, peak, end)		0.18	0.04	-0.26	-0.53	-0.11	-0.35
		(-0.46)	(-0.41)	(-0.28)	(-0.57)	(-0.32)	(-0.21)
1 month	After	0.35	0.38	-0.29	-0.36	0.22	-0.48***
		(-0.39)	(-0.39)	(-0.34)	(-0.50)	(-0.37)	(-0.15)
2		0.21	0.34	-0.39	-0.42	0.28	-0.08
		(-0.39)	(-0.46)	(-0.29)	(-0.42)	(-0.35)	(-0.23)
3		-0.06	-0.02	-0.24	-0.41	0.13	-0.72**
		(-0.44)	(-0.32)	(-0.20)	(-0.46)	(-0.29)	(-0.29)
4		0.10	0.31	-0.40	-0.58*	-0.14	-0.20
		(-0.33)	(-0.38)	(-0.25)	(-0.28)	(-0.26)	(-0.43)
5		0.04	0.36	0.00	-0.14	0.13	0.53*
		(-0.26)	(-0.31)	(-0.19)	(-0.39)	(-0.15)	(-0.30)
6		0.02	0.21	-0.62***	-0.44	-0.29	-1.06***
		(-0.28)	(-0.24)	(-0.20)	(-0.30)	(-0.26)	(-0.26)
12 months		-0.14	0.07	0.01	-0.08	0.19	NA
		(-0.26)	(-0.25)	(-0.14)	(-0.21)	(-0.16)	
R2		0.209	0.212	0.215	0.210	0.212	0.221

The above table uses robust standard errors. Only the coefficients of interest are presented here. Fixed effect coefficients are omitted. The sample size (n=932) remains constant across all estimates. (stars indicate * .1 **.05 ***.001)

For the estimates start time and peak time, which were the estimates of interest in the difference-in-difference, there is only minor trends of significant patterns in heterogeneity of treatment effect over time. For the models at the last time point particularly in the twelve month lagged models, there are significant differences in the models. This can be interpreted that as the epidemic lasted longer, people did not continue to limit fertility. It likely suggests there is not a permanent decline in fertility, but rather people postponing fertility decisions for several months or a year through the worst of the epidemic before returning to normal fertility patterns. Figure 4 shows the patterns of the mean GFR across the time periods constructed (1-6, 12 months before and after the month) for the timing variable "start" that signals the start of the Ebola outbreak[8]. This representation accounts for the variation in the exact month of the first case of Ebola reported in districts while also accounting for month fixed effects.

Figure 4a and 4b: Heterogeneity in treatment effects on GFR for the starting month of the Ebola outbreak on average.





[8] It can be seen that Figure 4b is Figure 4a but shifted 3 months later. No calculations were made between months 9 and 12.

Figure 4a suggests that there is not actually a decrease in fertility rates after the point of first Ebola with a nine-month lag. The twelve-month lag in Figure 4b has a lag in births for several months before there is another increase of fertility 5 months after the Ebola epidemic started. This can be interpreted that the longer the epidemic continued, people returned to normal fertility patterns such that babies conceived 3 months after the start of the Ebola outbreak were also being conceived at rates that were on par with fertility before the Ebola outbreak[9].

Event History Analysis

Preliminary Model

To examine the impacts of the West African Ebola outbreak on individual fertility, I rely on event history analysis to examine how the timing and severity of Ebola in different districts impacts the timing of births.

To account for censuring data in the event history analysis, I limited my analysis to mothers who were age 15 or older. I also restricted my sample to fecund women who have had a first birth (n=6,912 mothers). This limited my ability to look at younger girls and women who might be making a fertility decision for the first time, but it was a necessary precaution due to a lack of information about the timing of marriage or first intercourse in the survey.

The dependent variable in the analysis is likelihood of a woman giving birth in a particular month, controlling for parity and other factors related to fertility, and controlling for the presences and severity of Ebola in the district, lagged 9 months to account for the time

[9] The interpretation of the results from the start of the outbreak are presented here as they may provide insight for the heterogeneity of treatment results. However, these results may also be meaningfully reportable for the "peak" and "last" metrics.

between conception and birth. The control variables were weighted at the individual level and include the mother's age (in 5-year categories) and the number of children she has as time varying variables and the mother's education as a discrete control variable. Also included are controls for district and urban vs. rural areas.

Preliminary Results

Running multiple models using different measures for Ebola, I present the results of the event history analysis in Table 4.

Table 4: Preliminary Results of Event History Analysis Models

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model IIX	Model IX	Model X
Ebola (yes=1, lag 9)	1.316***				1.299***	1.214***	1.319***	1.276***	1.396***	
	-0.052				-0.07	-0.068	-0.073	-0.071	-0.056	
Ebola (yes=1, lag 12)		1.262***			1.114*	1.046	1.170**	1.136*		1.356***
		-0.05			-0.06	-0.058	-0.065	-0.063		-0.055
Ebola Rate per hundred thousand (lag 9)			20.897***			0.433		0.175		
			-17.798			-0.519		-0.206		
Ebola Rate per hundred thousand (lag 12)				158.504***		20.069**		7.668+		
				-126.888		-21.382		-8.205		
Mother age 20-24 (reference group: 15-19)							0.781***	0.781***	0.782***	0.782***
							-0.034	-0.034	-0.034	-0.034
Mother age 25-29							0.597***	0.597***	0.599***	0.599***
							-0.028	-0.028	-0.028	-0.028
Mother age 30-34							0.482***	0.482***	0.483***	0.483***
							-0.025	-0.025	-0.025	-0.025
Mother age 35-39							0.272***	0.272***	0.274***	0.273***
							-0.019	-0.019	-0.019	-0.019
Mother age 40-44							0.142***	0.142***	0.143***	0.143***
							-0.015	-0.015	-0.015	-0.015
Mother age 45-49							0.025***	0.025***	0.026***	0.026***
							-0.008	-0.008	-0.009	-0.009
Education (reference group: none)										
Primary Education							1.078+	1.079+	1.080+	1.080+
							-0.048	-0.048	-0.048	-0.048
Junior Secondary							1.183***	1.183***	1.187***	1.186***
							-0.054	-0.054	-0.054	-0.054
Senior Secondary							1.215**	1.216**	1.219**	1.219**
							-0.077	-0.078	-0.078	-0.078
Vocational training							0.679*	0.679*	0.680*	0.679*
							-0.114	-0.114	-0.114	-0.114
Higher Education							1.084	1.084	1.084	1.086
							-0.251	-0.251	-0.251	-0.252
Number of Children							1.077***	1.077***	1.076***	1.077***
							-0.007	-0.007	-0.007	-0.007
Rural (reference group: urban)							1.089*	1.089*	1.090*	1.090*
							-0.045	-0.045	-0.045	-0.045
N	479740	479740	479740	479740	479740	479740	479740	479740	479740	479740

Exponentiated coefficients ="+ p<0.10 * p<0.05 ** p<.01 *** p<.001"

Preliminary results

The results for the impact of Ebola on the duration of time to the next birth are not as expected. The relative risk of moving to the next birth 9 months after Ebola was present in a district is only a 1% longer birth interval. There is no significant shortening or lengthening of a birth interval of a birth conceived 3 months after Ebola (12-month lag until birth event). However, when the counts of Ebola cases in a district are included, there is a 30% shorter interval to the next birth parity during the month of Ebola presents (9-month lag). This suggests that women are *more* likely to conceive another birth during the time of the Ebola outbreak, rather than less likely. As the sample excludes women who are transition from being childless to their first birth, this model cannot capture the decisions of these mothers.

The control variables behave as expected (ref.). As the age of the mother increases, she has a longer interval before transitioning to a higher parity birth. Additionally, mothers with some education have a shorter interval before transitioning to a higher parity birth than mothers with no education, except mothers with a technical higher education. Mothers with more children also have a shorter duration between births.

Women living in rural areas have a 9% shorter interval before transitioning to a higher parity birth. The relative risks among the districts suggest that mothers in eastern districts (Kenema and Kono) have a lower likelihood of transitioning to a next birth in comparison to mothers from Kailahun (which is also in the east and was the first district where Ebola was reported).

These results suggest that there is a slight increase in fertility during the Ebola outbreak. It may be a result of the data being right-censured, with not enough birth events to report in the 9 to 12 months after Ebola due to the timing of the survey. The sampling weights provided by the DHS are regarded to be accurate and reliable, but there are limitations on the interpretability of results. As is shown in the presentation of fertility trends over time, there are seasonal impacts to the overall trend. The fertility rate in Sierra Leone has been decreasing over the last 50 years and it is not possible to fully separate the small impact of the EVD outbreak on the overall decreasing trend with the limited five-year birth data from the SL16 MIS.

Preliminary conclusion and future directions

With these preliminary results, we can begin to understand how people modify behaviors during a time of disease outbreak. There are differences across district in how severe the Ebola outbreak impacted the people and their reproductive behaviors. The medical impacts of Ebola as a viral disease are still uncertain. The social impact is underemphasized; this includes stigmatization of Ebola survivors, the rebuilding of communities and the structure of health care, and the return to normal life for the countries in West Africa. As with any quantitative analysis, there is a need for a qualitative element to assess the impact on fertility trends and reproductive behaviors from the mothers, survivors, and health care workers in Sierra Leone. These perspectives can offer guidance for future analysis and provide greater understanding at the individual and population level.

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