Population's fear and hostility and the Ebola virus epidemic in West Africa

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Abstract

The Ebola virus epidemic in Guinea, Liberia and Sierra Leone has become the most severe outbreak since the virus species was first recognized in 1976. To what extent have population's fear and hostility contributed to the spread of the contagious disease? To address this question, our study attempts to estimate the impact of communities' fearful and hostile reactions towards medical workers and institutions on epidemiological outcomes. Our empirical strategy is to compare virus disease progression in (administrative) areas that faced such incidents with virus disease progression in areas that did not, before and after the incidents. Our results across countries suggest that prior to the incidents the progression of total cases was similar across areas while after the incidents the progression significantly accelerated in areas that faced the incidents compared to areas that did not, and so by 0.76 standard deviations (std. dev.) within six weeks and up to 2.01 std. dev. within twenty-four weeks. Our estimates across countries also suggest that the incidents triggered an increase in total deaths, where the impact is estimated at 0.53 std. dev. within six weeks and up to 2.64 std. dev. within twenty-four weeks. Our results within countries and for specific classifications of cases and deaths are also consistent with the view that population's panic and resistance have aggravated the Ebola virus epidemic in West Africa.

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Contents

1 Introduction

The Ebola virus epidemic in Guinea, Liberia and Sierra Leone has become the most severe outbreak since the virus species was first recognized in 1976, as there have been more reported cases and deaths in this outbreak than in all others combined. To what extent have population's fear and hostility contributed to the spread of the contagious disease? To address this question, our study attempts to estimate the impact of communities' fearful and hostile reactions towards medical workers and institutions on epidemiological outcomes. According to our data sources, by the end of 2014, which marked almost one year into the response to the outbreak, nine such incidents had been reported in six different prefectures of Guinea, while five had been indicated in three different counties of Liberia and four in four different districts of Sierra Leone.

How are such incidents likely to have had substantial impact on epidemiological outcomes? To add insights into our empirical setup, which assumes the incidents as notable epidemiological shocks and administrative areas as relevant observational units, our study documents the main underlying mechanisms. First, our study documents how the incidents, as signs of fear and hostility towards medical workers and institutions, have compromised medical control over virus disease progression. Second, it documents how communities' (micro) reactions are likely to have had notable impact on areas' (macro) epidemiological outcomes.

Our empirical problem is then to determine changes in epidemiological outcomes that can be attributed to the incidents. To this purpose, our method is to use panel observations consisting of cumulative cases and deaths across (administrative) areas and three-week periods, and compare virus disease progression in areas that faced the incidents with virus disease progression in areas that did not, before and after the incidents. The impact of the incidents is identifiable when prior to the incidents the progression of epidemiological outcomes was similar among areas so that potential divergence after the incidents can be distinguished from ongoing tendency anterior to the incidents. The impact is then estimable when after the incidents any departure from the ongoing common trend is notable in terms of timing, magnitude and persistence, so that it can be attributed to the incidents.

Our results across countries suggest that prior to the incidents the progression of total cases was similar across areas while after the incidents the progression significantly accelerated in areas that faced the incidents compared to areas that did not, and so by 0.76 std. dev. within six weeks and up to 2.01 std. dev. twenty-four weeks later. Our estimates across countries also suggest that the incidents triggered an increase in total deaths, where the impact is estimated at 0.53 std. dev. within six weeks and up to 2.64 std. dev. within twenty-four weeks. Our results within countries and for specific classifications of cases and deaths are also consistent with the view that population's panic and resistance have aggravated the

Ebola virus epidemic in West Africa.

The rest of this dissertation will expand as follows. Section 2 will provide background on the Ebola virus disease and population's fear and hostility. Section 3 will present sources used to obtain information on communities' fearful and hostile reactions towards healthcare workers and institutions in Guinea, Liberia and Sierra Leone, and keep track of virus disease progression across administrative areas. Section 4 will detail our empirical method to determine changes in epidemiological outcomes that can be attributed to the incidents. Section 5 will discuss our results and section 6 will conclude.

2 Background

2.1 The Ebola virus disease

The Ebola virus disease is an acute hemorrhagic fever that is initially transmitted to humans by animals. The virus is believed to persist in reservoir species that live in endemic areas. During outbreaks, human infections occur mostly by direct contact with infected individuals. The infection then develops slowly without perceptible symptoms during two to twenty-one days, while fever, chills, malaise, and pain in muscles characterize the sudden onset of the disease. Individuals with fatal virus develop clinical signs early during the infection and die typically in six to sixteen days from multiple organ failures. However, in non-fatal infections, people have fever for several days and improve typically in six to eleven days, as the body develops immune responses (Goeijenbier et al. (2014)).

The Ebola virus species at the origin of the epidemic in West Africa is known as the *Zaïre ebolavirus*[1] and was first recognized in 1976 in the Democratic Republic of the Congo (DRC, named Zaïre from 1965 to 1997), near the Ebola River. Between 1976 and 2014, this species has regularly caused Ebola virus outbreaks in the DRC (five), Gabon (four) and Republic of the Congo (three), in addition to the one in West Africa. However, these separate outbreaks never reached the magnitude of the epidemic that emerged in Guinea, Liberia and Sierra Leone. Table 1 lists for instance these distinct outbreaks, along with reported cases and deaths. One can notice for instance that cases per outbreak ranged from 32 to 319 and deaths from 15 to 281.

According to our data sources, as of December 26, 2014, which marked almost one year since the beginning of outbreak[2], 2670 cases had caused 2367 deaths in Guinea, while 8002 cases and 3417 deaths had been reported in Liberia, and 9339 cases and 2711 deaths in Sierra Leone. The Ebola virus epidemic

[1] Ebola virus species currently recognized to induce disease in humans are: the *Zaïre ebolavirus*; the *Sudan ebolavirus*; the *Tai Forest ebolavirus*, formerly *Ivory Coast ebolavirus*; and the *Bundidugyo ebolavirus* (Goeijenbier et al. (2014)).

[2] The Ebola virus epidemic in West Africa started in Guinea around December 2013 and subsequently spread to neighboring Liberia and Sierra Leone.

in West Africa has thus become the most severe since the virus species was first recognized in 1976, as there have been more reported cases and deaths in this outbreak than in all others combined. Using our data sources, Table 2 display for instance the dramatic progression of total reported cases and deaths in Guinea, Liberia and Sierra Leone, from July 22, 2014 to December 26, 2014.

2.2 Fear and hostility

Which circumstances have contributed to the propagation of the Ebola virus disease in Guinea, Liberia and Sierra Leone? Some analyses have suggested that social factors such as population's fear and hostility have played an important part in the spread of the contagious disease. Months into the response to the outbreak, the director-general of the World Health Organization, Doctor Margaret Chan (August 20, 2014)[3], declared: "*Fear remains the most difficult barrier to overcome. Fear causes people who have had contact with infected persons to escape from the surveillance system, relatives to hide symptomatic family members or take them to traditional healers, and patients to flee treatment centers. Fear and the hostility that can result from it have threatened the security of national and international teams*". During the riposte to the epidemic in Guinea, *The New York Times* (July 27, 2014)[4] also reported that: "*Doctors are fighting the disease and also local populations' fear of medical treatment [...] workers and officials, blamed by panicked populations for spreading the virus, have been threatened with knives, stones and machetes, their vehicles sometimes surrounded by hostile mobs. Log barriers across narrow dirt roads block medical teams from reaching villages where the virus is suspected.*". PBS (July 28, 2014)[5] interviewed for instance the medical advisor for Doctors Without Borders, which had workers on the ground throughout West Africa, about factors, including fear and hostility, that were hindering efforts to stop the outbreak: "**Q***: So how do you treat this?* **A***: So the treatment is not a specific treatment for Ebola. We treat the symptoms, and we do supporting treatment and palliative treatment for the patients [...].* **Q***: [...] What are the special challenges for you in tackling this disease?* **A***: Well, first of all is trying to gain some kind of acceptance from the community, so that we're actually granted access to the communities where we think the disease is happening. [...] We have to isolate the people who are suspected in probable cases, and also, of course, the confirmed cases, and to contact tracing, which means following the contacts of the people who have been in contact with a suspect probable or a confirmed case in the past 21 days, and follow them up on a daily basis to see if they develop any kind of symptoms, so that if they develop any kind of symptoms, they are brought to an isolation facility and are then tested to assess whether or not they have the disease or whether it's something else.* **Q***: It seems one the concerns also for your workers is that they are met*

[3] Chan Margaret. "Ebola Virus Disease in West Africa, No Early End to the Outbreak." *The New England Journal of Medicine*, August 20, 2014.

[4] Nossiter Adam. "Fear of Ebola Breeds a Terror of Physicians." *The New York Times*, July 27, 2014.

[5] Gwen Ifill. "Faced with challenging Ebola outbreak, medical workers use education to combat fear." *PBS*, July 28, 2014.

with hostility, as well as fear in these communities where they're trying to diagnose and treat. How have you been coping with that? **A**: *Well, it's one of the difficult things to cope with. Part of the intervention, part of the response to an Ebola outbreak or hemorrhagic fever outbreak involves pychosocial support, and a part of educating the communities and reaching out to the communities to explain what the disease is. [...] So it's actually very - we keep doing what we usually do in an outbreak, but now it's been extremely challenging, because we're having difficulties in accessing the patients. And what that means is that we are also having difficulty in controlling the spread of the disease."*

To what extent have such circumstances contributed to the spread of the contagious disease? To address this question, our study started with collecting information on communities' fearful and hostile reactions towards medical workers and institutions in Guinea, Liberia and Sierra Leone, and on virus disease progression across administrative areas. The next section is thus devoted to data collection and description.

3 Data

3.1 Collection

Data collection started with an inspection of the *Armed Conflict Location and Event Data* (ACLED) to find well ordered information on population's fear and hostility during the Ebola virus epidemic. The ACLED project is known to collect and code reported information on local conflicts, violence against civilians, isolated violence, rioting and protesting. Raleigh et al. (2010) discuss motives behind this dataset project, which is supported by the Climate Change and African Political Stability Program and the European Research Commission. The dataset essentially uses media coverage (local, regional, national and continental), which is reviewed daily and eventually combined with reports from nongovernmental organizations (NGOs). For each event, the ACLED details the date (day, month and year), location (country, administrative area, city or closest town) and provides contextual notes. Raleigh and Dowd (2015) further discuss methods and content of the ACLED. Version 5 of the dataset is for instance publicly available at the ACLED website[6] and covers all countries on the African continent since 1997. Our essay thus used files for Guinea, Liberia and Sierra Leone covering the entire year 2014. Information contained in the ACLED revealed to be an important piece of evidence to directly address our question. Our analysis of population's panic and resistance focused on reported communities' fearful and hostile reactions towards medical workers and institutions, which is possible because the ACLED provides precise description of each event as contextual notes. More precisely, our ACLED files contained sev-

[6]Country files are available every month at *http://www.acleddata.com/data/version-5-data-1997-2014/*

eral entries, each corresponding to an event. Our study first discarded reported events unrelated to the Ebola virus epidemic and then focused on reported interactions involving medical workers and institutions and local population and then retrieved all reported fearful and hostile reactions. To be specific, Ebola-related interactions involving only security forces and local population were also discarded. Besides being relevant for our purpose, such focus is also an attempt to alleviate potential selection issues due to the reliance of the ACLED on media coverage and NGO's reporting.

Data collection proceeded with *Ebola virus situation reports* to gather precise information on virus disease progression across areas. After the official recognition of the outbreak, situation reports have been published, on an almost daily basis, by the Guinean Ministry of Public Health, the Liberian Ministry of Health and Social Welfare and the Sierra Leonean Ministry of Health and Sanitation, with the support of the World Health Organization. These reports were thus obtained from these institutions' website and from online resources provided by the United Nations Office for the Coordination of Humanitarian Affairs, such as Relief Web or Humanitarian Response. Figures 5, 6 and 7 reproduce for instance specimen of these documents in Guinea, Liberia and Sierra Leone, respectively. Virus disease progression in Guinea is detailed at the prefecture level, while the epidemic is reported at the county level in Liberia and at the district level in Sierra Leone. Guinea is divided into 33 prefectures, plus the national capital city, Conakry, which ranks as a special zone. Liberia is divided into 15 counties and Sierra Leone into 14 districts. Our essay thus selected these reports on a regular basis to construct panel observations consisting of epidemiological outcomes across administrative areas and regular periods. Each time period covers three weeks, which is regarded as the maximum length of the virus disease incubation period. Our choice is for instance based on Goeijenbier et al. (2014) and references to this time period are also recurrent in Ebola situation reports. Moreover, each indicated period p corresponds to 3 x p weeks after the official recognition of the outbreak in the region. As early situation reports were published occasionally, obtaining these documents every three weeks was possible only from July 22, 2014, to December 26, 2014, for Guinea, from June 18, 2014, to December 26, 2014 for Liberia and from August 16, 2014, to December 27, 2014 for Sierra Leone.

3.2 Description

By the end of 2014, which marked almost a year into the response to the epidemic, the ACLED archives had recorded nine communities' fearful and hostile reactions towards medical workers and institutions in six different prefectures of Guinea, while five such incidents had been noted in three different counties of Liberia, and four in four different districts of Sierra Leone. As made explicit in the next section, our empirical strategy is robust to uneven reporting, between say urban and rural areas, as this will not induce an upward bias in our estimates, even though the significance of our results depends on exact reporting. Finally, it is worth noting that media treatment and NGO's reporting, as informational channels, form an integrated part of our study and might constitute potential mechanisms explaining our results. Tables 3 and 4 list for instance all retrieved incidents, along with the date, location and contextual notes. The location corresponds to the administrative area in which the incidents occurred (i.e., prefecture for Guinea, county for Liberia and district for Sierra Leone).

Ebola situation reports were first collected for Guinea to construct a balanced sub-panel with all 33 prefectures, plus the national capital city, Conakry, over 9 three-week periods, which gave us 306 prefecture-period observations[7]. Equivalent reports were also gathered for Liberia to construct a second balanced sub-panel with all 15 counties over 11 three-week periods, which gave us 165 county-period observations[8]. Another series was finally collected for Sierra Leone to construct a third balanced sub-panel with all 14 districts over 8 three-week periods, which gave us 112 district-period observations[9]. Data retrieved for Guinea are cumulative cases and deaths, both classified as confirmed, probable or suspect even though no death was ever classified as suspect during this time period. Reports also contain classifications of prefectures according to four alert levels: i) prefectures which have never notified cases (white); ii) quiet prefectures i.e., without confirmed cases for six weeks (green); iii) prefectures on the alert i.e., with contacts to be followed (yellow); iv) active prefectures i.e., with at least a case in the last three weeks (red). Data retrieved in Liberia are also cumulative cases, which are classified as confirmed, probable or suspect and total cumulative deaths. Finally, information retrieved in Sierra Leone are cumulative cases and deaths, which are both classified as confirmed, probable or suspect, the presence of virus healthcare facility management units in the district, and cumulative admissions and discharges in those units.

How are the incidents likely to have had substantial impact on epidemiological outcomes? Previous sections outlined insights for our empirical setup, which assumes the incidents as notable epidemiological shocks and administrative areas as relevant observational units. First, the background discussion documents how signs of fear and hostility towards medical workers and institutions have compromised medical control over virus disease progression. Second, the data description documents how such communities' (micro) reactions are likely to have had notable impact on areas' (macro) epidemiological outcomes. The next section thus explicits our empirical method to determine changes in epidemiological outcomes that can be attributed to the incidents.

[7]Guinean Ministry of Public Health and World Health Organization - Guinea Ebola Situation Report No. 98, 122, 141, 160, 179, 198, 218, 236 and 255.

[8]Liberian Ministry of Health and Social Welfare - Liberia Ebola Daily Situation Report No. 36, 53, 74, 92, 111, 130, 147, 168, 186, 187, 206 and 225.

[9]Sierra Leonean Ministry of Health and Sanitation - Ebola Viral Disease Situation Report Vol. 80, 99, 118, 129, 137, 145, 156, 175, 194, and 213.

4 Empirical method

4.1 Specification

Our empirical problem is thus to identify and estimate changes in epidemiological outcomes that can be attributed to the incidents, which constitutes the main objectives of our study. To this purpose, our empirical method is to use our panel observations across (administrative) areas and three-weeks periods and compare virus disease progression in areas that faced the incidents with virus disease progression in areas that did not, before and after the incidents. Our empirical design is thus similar in essence to the standard difference-in-differences (dd) design. In the standard dd design, one compares the difference in an outcome after and before an intervention for groups affected by the intervention (treatment group) to the same difference for unaffected groups (control group). In our case, the group of areas affected by the incidents constitutes our treatment group while the group of unaffected areas constitutes our comparison group. If the incidents were not differed across affected areas, one could use the standard dd formulation

$$y_{it} = \alpha + \gamma_1 D_t + \gamma_2 D_g + \gamma_3 D_t D_g + \epsilon_{it} \quad (1)$$

where y_{it} would denote the epidemiological outcome in area i at period t; D_t would assume the value of 0 in all periods t prior to the incidents and 1 in all periods t at and after the incidents; D_g would assume the value of 0 for all areas i in the comparison group and 1 for all areas i in the treatment group; while ϵ_{it} would denote the unobserved error and γ the constant. $D_t D_g$ would indicate epidemiological outcomes for affected areas in the periods after the incidents and the estimated value of γ_3, $\widehat{\gamma}_3$, would be used to inference on the causal impact of the incidents on epidemiological outcomes. However, as the incidents are not simultaneous across affected areas, D_t and the standard formulation in (1) are not well defined for our study. However, one could use the dd formulation

$$y_{it} = \alpha + \eta_i + \lambda_t + \delta D_{it} + \epsilon_{it} \quad (2)$$

where y_{it}, α and ϵ_{it} would be defined as in (1); η_i would denote an indicator variable that captures area i's unobserved explanatory characteristics invariant across periods; λ_t an indicator variable that captures period t's unobserved covariates invariant across areas; while D_{it} would denote an indicator variable for affected areas in the periods after the incidents. D_{it} would for instance assume the value of 0 in all periods t prior to the incidents and 1 in all periods t at and after the incidents if area i belongs to affected areas, and 0 in all periods t if area i belongs to unaffected areas. The estimated value of δ, $\widehat{\delta}$, would be used for inference on the causal impact of the incidents on epidemiological outcomes. However, one challenge with the formulation in (2) remains that, whenever $\widehat{\delta}$ is statistically different from zero, to interpret this result as the impact of the incidents on epidemiological outcomes, one has to argue that changes in the outcomes over periods would have been exactly the same in both affected and unaffected areas in the absence of the incidents (common trend requirement) i.e., that one would have obtained $\widehat{\delta} = 0$ in the absence of the incidents. In our study, one can reasonably assume that whenever $\widehat{\delta}$ is statistically different from zero, then the common trend requirement must hold as epidemiological outcomes are observed for several periods before the incidents. Our preferred dd formulation extends the formulation in (2) to make full use our observations before the incidents and provide evidence on the common trend requirement. Another challenge with the formulation in (2) is that, whenever $\widehat{\delta}$ is statistically different from zero, one obtain no information on the impact of the incidents in terms of timing and persistence, which constitutes important information in our study. With the formulation in (2), the impact of the incidents is implicitly assumed to be immediate and constant over periods. In our study, one can reasonably assume that whenever $\widehat{\delta}$ is statistically different from zero, then the impact of the incidents must have been quite immediate and permanent as outcomes are observed for several periods after the incidents. Our preferred dd formulation also extends the formulation in (2) to make full use our observations after the incidents and provide refined evidence on the impact of the incidents on epidemiological outcomes. Our preferred dd formulation, introduced in Laporte and Windmeijer (2005), thus extends standard dd formulations to

$$
\begin{aligned}
y_{it} &= \alpha + \eta_i + \lambda_t + \delta_{-l}\, P_{i-l} + ... + \delta_{-1}\, P_{i-1} + \delta_0\, P_{i0} + \delta_1\, P_{i1} + ... + \delta_r\, P_{ir} + \epsilon_{it} \\
&= \alpha + \eta_i + \lambda_t + \sum_{j=-l}^{r} \delta_j P_{ij} + \epsilon_{it}
\end{aligned} \tag{3}
$$

where y_{it}, η_i, λ_t and ϵ_{it} are defined as previously, while $(P_{i,-j})P_{ij}$ assumes the value 1 in area i at j periods (before) after the incidents, and 0 everywhere else, where $(l)r$ denotes the furthest observation (before) after the incidents. As some areas have several incidents reported, our specification uses the first to be reported[10]. Our parameter of interest $(\delta_{-j})\delta_j$ can be interpreted as the expected difference in epidemiological outcomes between affected and unaffected areas at j periods (before) after the incidents, taking as the reference the expected difference at $s \neq (-j)j$ and conditional on the area and period fixed effects. The common trend requirement holds and the impact of the incidents is identifiable if, taking as

[10]Suppose for instance that area i faced the first incident at period t, then for all $j = -l, ..., -1, 0, 1, ..., r$

$$
P_j = \begin{cases} 1 & \text{for} \quad \text{area } i \text{ at period } t+j \\ 0 & \text{for} \quad \text{everywhere else} \end{cases}
$$

the reference the estimated value of δ_0, $\widehat{\delta}_0$, (i.e., the estimated difference in outcomes at the period of the incidents), then $\widehat{\delta}_{-j} = 0$ for all $j = 1, ..., l$. The impact of the incidents is thus identifiable when prior to the incidents the progression of epidemiological outcomes was similar across affected and unaffected areas, so that potential divergence after the incidents can be distinguished from any tendency anterior to the incidents. Our choice of $j = 0$ as the reference is only made for expositional purposes, and there no particular reason to prefer $j = -1$ since our periodization is independent from the incidents, and each period covering three weeks one can reasonably assume that incidents happen to pertain to one period t instead of $t \pm 1$. The impact is then estimable if, taking again $\widehat{\delta}_0$ as the reference, $\widehat{\delta}_j$ for some $j = 1, ..., r$ are statistically different from zero. The impact is thus estimable when after the incidents any departure from the ongoing common trend is notable in terms of timing, magnitude and persistence, so that it can be attributed to the incidents. To resume, our preferred formulation allows to provide refined evidence on the common trend requirement while illustrating the timing, pattern and persistence of the impact of the incidents on epidemiological outcomes.

4.2 Estimation

As detailed in the previous section, our data (i, t, y_{it}, x_{it}) for i = 1, ..., M and t = 1, ...,T consist of cumulative cases and deaths y_{it} and covariates x_{it} in area i at period t. Our estimation allows thus for temporally and spatially correlated errors, as well as for panel heteroskedasticity, as discussed in Beck and Katz (1995). The unobserved errors are indeed expected to display contemporaneous correlation, such that at each period t, large errors for area i will often be associated with large errors for area $i' \neq i$. For instance, epidemiological outcomes in the Western Area Urban and Western Area Rural districts of Sierra Leone are likely to be closely related. The errors are also expected to show panel heteroskedasticity such that the variance of the errors is specific to each area, even though it is expected to be constant across periods. The errors are expected to display panel heteroskedasticity as the scale of the epidemiological outcomes differ across areas. Finally, unobserved errors are expected to show serial correlation such that, within each area, the error at period t is potentially related to the error at period $t - 1$ and the degree of serial correlation is expected to differ from area to area. Indeed, as discussed in Bertrand, Duflo and Mullainathan (2004), estimation of the formulation in (3) could be subject to a possibly severe serial correlation problem. Two factors make serial correlation an especially important issue in our study. First, the formulation in (3) relies on long time series (9 periods for Guinea, 11 for Liberia and 8 for Sierra Leone). Second, epidemiological outcomes, the dependent variables, are highly positively serially correlated. These two factors reinforce each other so that the OLS standard error for $\widehat{\delta}$'s could severely understate the standard deviation of δ's. Standard errors are thus corrected for panel heteroskedasticity and contemporaneous correlation and serial correlation. In particular, errors are assumed to follow a first-order autoregressive AR(1) process (i.e., $\epsilon_{i,t} = \rho_i \epsilon_{i,t-1} + \xi_{i,t}$ with area-specific coefficient ρ_i, where $\xi_{i,t}$ are i.i.d. $N(0, \sigma^2)$) and standard errors are corrected for first-order serial correlation using the Prais-Winsten correction.

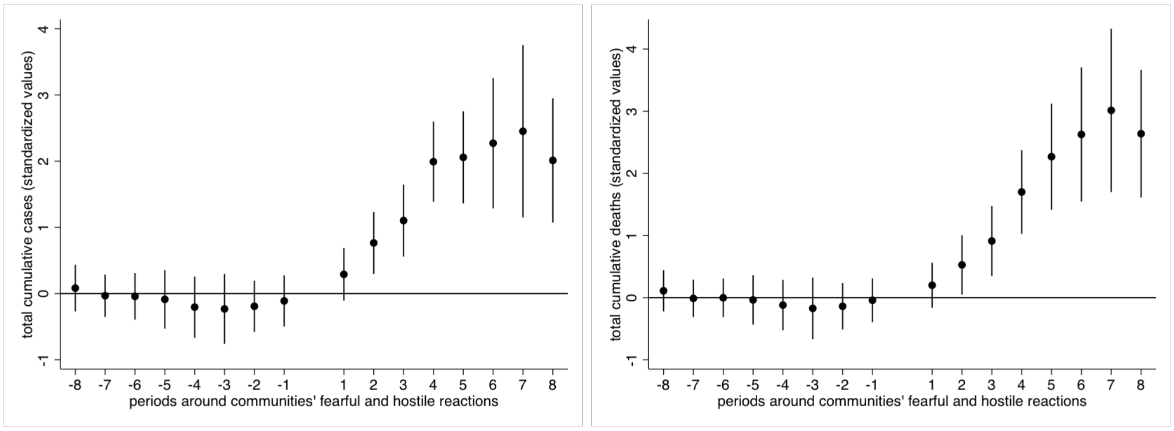
5 Results

5.1 Across countries

Our main panel covers incidents and epidemiological outcomes across all 33 prefectures of Guinea plus for the national capital city, Conakry, and 9 three-week periods between July 22, 2014 and December 26, 2014, which are pooled with observations across all 15 Liberian counties and 11 three-week periods between June 18, 2014 and December 26, 2014, and observations across all 14 Sierra Leonean districts and 8 three-week periods between August 16, 2014 and December 27, 2014. To identify and estimate changes in epidemiological outcomes that can be attributed to the incidents, our estimations then control for the area and period fixed effects. Values are standardized in the sense that each area-period observation is measured in standard deviations (std. dev.) from the sample mean (i.e., mean across areas and periods).

TOTAL CASES Column [1] of Table 5 displays our results for total cases across countries. The total includes (laboratory) confirmed, suspect and probable cases. Controlling for the area and period fixed effects, our results suggest that the impact of the incidents on total cases can be identified and estimated. Taking as the reference the estimated difference in total cumulative cases between areas that faced the incidents and areas that did not at the time of the incidents, $\widehat{\delta}_0$, none of $\widehat{\delta}_{-j}$ for $j = 1, ..., 8$ is statistically different from zero. Our point estimates thus suggest that prior to the incidents the progression of total cases in areas that faced the incidents and in areas that did not remained similar, since the difference in total cumulative cases remained constant. The common trend requirement thus holds and the impact of the incidents is identifiable as potential divergence after the incidents cannot be confounded with ongoing divergence anterior to the incidents. Indeed, $\widehat{\delta}_j$ is increasing in j for $j = 1, ..., 7$ and statistically different from zero (at the one percent level) for $j = 2, ..., 8$. Our results thus indicate that six weeks after the incidents the progression of total cases significantly accelerated in areas that faced the incidents compared to areas that did not, and so by 0.76 std. dev. and up to 2.01 std. dev. twenty-four weeks later. In terms of timing, pattern and persistence, the impact is significant after six weeks, persistent up to twelve weeks after the incidents (from 0.29 to 1.99 std. dev.) and then estimated between 2.01 and 2.45 std. dev.

Figure 1: Total cumulative cases and deaths and periods around communities' fearful and hostile reactions towards medical workers and institutions.



Notes: observations are obtained from a panel across all 33 prefectures of Guinea plus the national capital city, Conakry, and 9 three-week periods between July 22, 2014, and December 26, 2014, across all 15 counties of Liberia and 11 three-week periods between June 18, 2014, and December 26, 2014, and across all 14 districts of Sierra Leone and 8 three-week periods between August 16, 2014, and December 27, 2014. Dependent variables are total cumulative cases and total cumulative deaths. The total aggregates (laboratory) confirmed, probable and suspect epidemiological classifications. Values are standardized so that each area-period observation is measured in standard deviations from the sample mean (i.e., mean across areas and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)j$ for $j = 1, ..., 8$ indicates the estimated difference in the dependent variable between areas that faced communities' fearful and hostile reactions towards medical workers and institutions and areas that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for $j = 0$) as the reference, controlling for the area and period fixed effects. Standard errors are corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with area-specific coefficient). Confidence intervals are reported at the 95% level (see columns [1] and [2] of Table 5).

TOTAL DEATHS Similarly, Column [2] of Table 5 displays our results for total deaths across countries. Controlling for the area and period fixed effects, our results also suggest the incidents triggered an increase in total deaths. Taking again $\widehat{\delta}_0$ as the reference, none of $\widehat{\delta}_{-j}$ for $j = 1, ..., 8$ is statistically different from zero. The impact of the incidents is again identifiable since potential divergence after the incidents cannot be confounded with ongoing divergence anterior to the incidents. Indeed, $\widehat{\delta}_j$ are increasing in j for $j = 1, ..., 7$, and statistically different from zero for $j = 2, ..., 8$. The impact of the incidents on total deaths is estimated at 0.53 std. dev. (at the five percent level) within three weeks and at 2.64 std. dev. (at the one percent level) within twenty-four weeks. Figure 1 displays for instance patterns of point estimates reported in columns [1] and [2] Table 5 to illustrate our analysis.

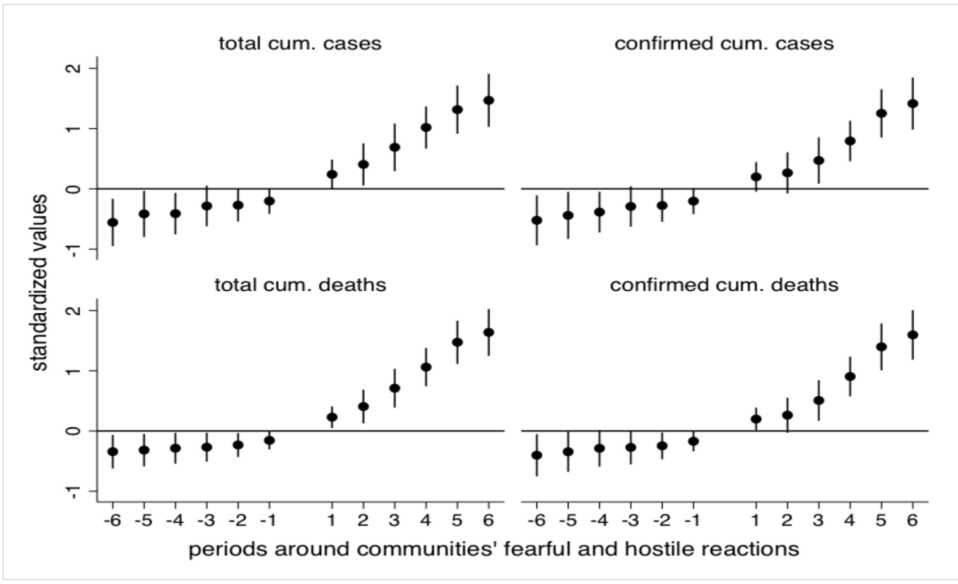
5.2 Within countries

GUINEA Table 6 shows results for the first sub-panel, which covers incidents and epidemiological outcomes across all 33 prefectures of Guinea plus the national capital city, Conakry, and 9 three-week periods between July 22, 2014 and December 26, 2014. Column [1] displays point estimates for total cases, column [2] for confirmed cases, column [3] for total deaths and column [4] for confirmed deaths, controlling for the alert levels, the prefecture and period fixed effects. Results in column [1] suggest however that the impact of the incidents on *total cases* cannot be identified. Indeed, taking $\widehat{\delta}_0$ as the reference, $\widehat{\delta}_{-j}$ for $j = 1, ..., 6$ are decreasing in j, from -0.20 std. dev. (at the ten percent level) to -0.56 std. dev. (at the one percent level), which implies that prior to the incidents the progression of total cases was diverging among prefectures so that the potential impact of the incidents cannot be separated from ongoing tendency anterior to the incidents. Equivalent results in columns [2] also suggest that the impact of the incidents on *confirmed cases*, which account for 77.66% of total cases across observations in Guinea, cannot be identified. Figure 2 displays for instance patterns of point estimates reported in columns [1], [2], [3], and [4] of Table 6 to illustrate our analysis. Our results for *total deaths* and *confirmed deaths* are similar to previous results for total cases and confirmed cases. As illustrated in Figure 2, point estimates reported in columns [3] and [4] of Table 6 also suggest that the impact of the incidents on total deaths and confirmed deaths, which account for 74.36% of total deaths across observations in Guinea, cannot be identified. However, one can notice that the upward trend before the incidents becomes remarkably steeper after the incidents for both cases and deaths.

LIBERIA Table 7 shows results for the second sub-panel, which covers incidents and epidemiological outcomes across all 15 counties of Liberia and 11 three-week periods between June 18, 2014, and December 26, 2014, controlling for the county and period fixed effects. Results in column [1] suggest that incidents in Liberia induced a significant increase in *total cases* nine weeks after the incidents by 0.76 std. dev. (at the one percent level) and up to 1.78 std. dev. (at the one percent level) twelve weeks after. The impact is delayed as $\widehat{\delta}_j$ is not significantly different from zero for $j = 1, 2$ even though it is persistent up to twelve weeks after the incidents. Figure 3 displays patterns of point estimates reported in columns [1], [2] and [3] of Table 7 to illustrate our analysis. Equivalent results in columns [2] of Table 7 suggest that incidents also triggered an increase in *confirmed cases*, which account for 32.58% of total cases across observations in Liberia. The estimated impact is significant twelve weeks after the incidents and persistent up to eighteen weeks after the incidents. As illustrated in Figure 3, results reported in column [3] of Table 7 also suggest also that incidents induced an increase in *confirmed deaths*. The estimated impact is significant nine weeks after the incidents (0.85 std. dev. at the five percent level) and persistent up to eighteen weeks after the incidents (2.24 std. dev. at the one percent level).

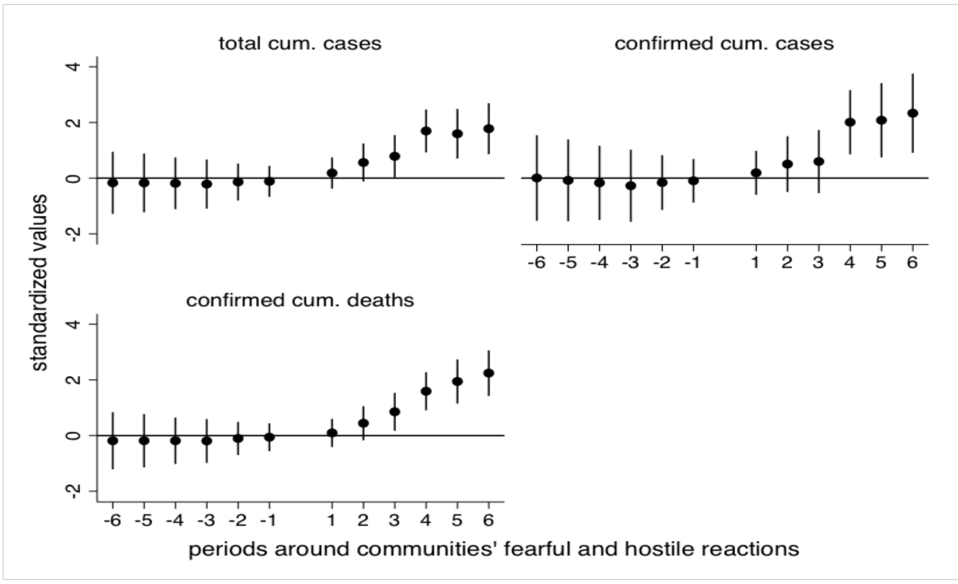
SIERRA LEONE Table 8 shows results for the last sub-panel, which covers incidents and epidemiological outcomes across all 14 districts of Sierra Leone and 8 three-weeks periods between August 16, 2014, and December 27, 2014, controlling for the presence of virus healthcare facility management units and cumulative admissions and discharges in those units, as well as for the district and period fixed effects. Results in column [1] and [2] suggest that the potential impact of the incidents on *total cases* and *confirmed cases*, which account for 78.70% of total cases across observations in Sierra Leone, cannot be distinguished from ongoing tendency anterior to the incidents. However, Figure 4 displays patterns of

Figure 2: Cumulative cases and deaths and periods around communities' fearful and hostile reactions - Guinea.



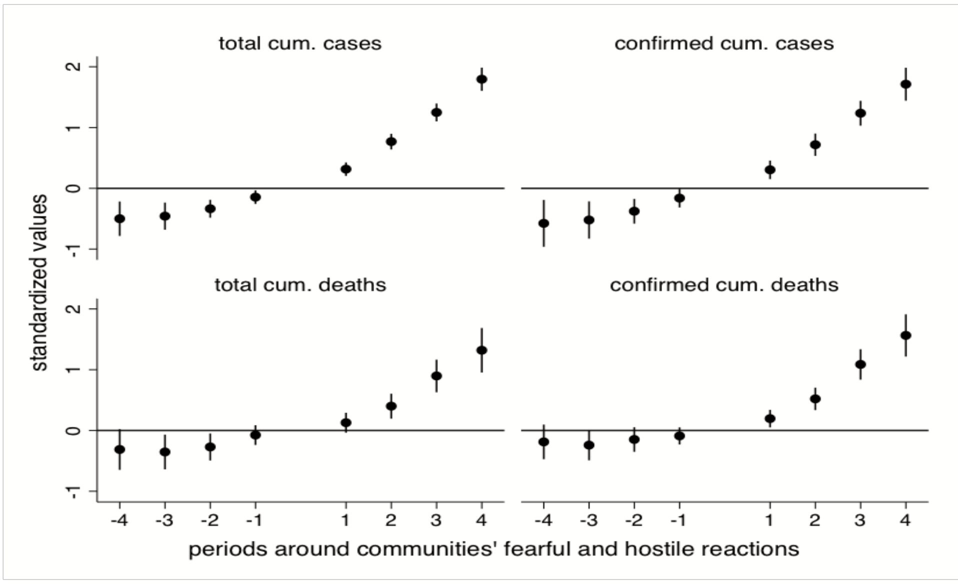
Notes: observations are obtained from a balanced sub-panel across all 33 prefectures of Guinea plus the national capital city, Conakry, and 9 three-week periods between July 22, 2014, and December 26, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases, total cumulative deaths and confirmed cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each prefecture-period observation is measured in standard deviations from the subsample mean (i.e., mean across prefectures and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)$ j for $j = 1, ..., 6$ indicates the estimated difference in the dependent variable between prefectures that faced communities' fearful and hostile reactions towards medical workers and institutions and prefectures that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for j = 0) as the reference, controlling for the prefecture and period fixed effects, in addition to the alert levels. Standard errors are corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with prefecture-specific coefficient). Confidence intervals are reported at the 95% level (see columns [1], [2], [3] and [4] of Table 6)

Figure 3: Cumulative cases and deaths and periods around communities' fearful and hostile reactions - Liberia.



Notes: observations are obtained from a balanced sub-panel across all 15 counties of Liberia and 11 three-week periods between June 18, 2014, and December 26, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases and total cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each county-period observation is measured in standard deviations from the subsample mean (i.e., mean across counties and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)\ j$ for $j = 1, ..., 6$ indicates the estimated difference in the dependent variable between counties that faced communities' fearful and hostile reactions towards medical workers and institutions and counties that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for $j = 0$) as the reference, controlling for the county and period fixed effects. Standard errors are corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with county-specific coefficient). Confidence intervals are reported at the 0.95% level (see columns [1], [2] and [3] of Table 7).

Figure 4: Cumulative cases and deaths and periods around communities' fearful and hostile Reactions - Sierra Leone.



Notes: observations are obtained from a balanced sub-panel across all 14 districts of Sierra Leone and 8 three-week periods between August 16, 2014, and December 27, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases, total cumulative deaths and confirmed cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each district-period observation is measured in standard deviations from the subsample mean (i.e., mean across districts and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)$ j for $j = 1, ..., 4$ indicates the estimated difference in the dependent variable between districts that faced communities' fearful and hostile reactions towards medical workers and institutions and districts that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for j = 0) as the reference, controlling for the presence of virus healthcare facility management units as well as for cumulative admissions and discharges in those units and for the district and period fixed effects. Standard errors are corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with district-specific coefficient). Confidence intervals are reported at the 95% level (see columns [1], [2], [3] and [4] of Table 8).

point estimates reported in columns [1], [2], [3], and [4] of Table 8 and shows that for total cases and confirmed cases the upward trend after the incidents is much steeper than the upward trend before the incidents. As also illustrated in Figure 4, results reported in column [4] of Table 8 suggest that incidents in Sierra Leone led to an increase in *confirmed deaths*, which account for 76.43% of total deaths across observations. Indeed, taking $\widehat{\delta}_0$ as the reference, $\widehat{\delta}_{-j}$ isstatistically different from zero (at the the ten percent level) only for $j = -3$. The impact of the incidents is persistent and estimated at 0.19 std. dev. (at the one percent level) within three weeks and up to 1.56 std. dev. (at the one percent level) within twelve weeks. As also illustrated in Figure 4, equivalent results reported in column [3] of Table 8 suggest that the impact of the incidents on *total deaths* cannot be identified, even though the upward trend before the incidents becomes much steeper after the incidents.

6 Conclusion

In light of analyses suggesting that social factors such as population's fear and hostility have contributed to the spread of the Ebola virus disease in Guinea, Liberia and Sierra Leone, our study attempted to identify and estimate the impact of communities' fearful and hostile reactions towards medical workers and institutions on epidemiological outcomes. Our empirical method was to use panel observations consisting of cumulative cases and deaths across (administrative) areas and three-week periods and compare virus disease progression in areas that faced the incidents with virus disease progression in areas that did not, before and after the incidents. Our results across countries suggested that the incidents induced a significant increase in total cases and deaths within six weeks and continued to have adverse effects on epidemiological outcomes up to twenty-four weeks later. Our results within countries and for specific classifications of cases and deaths are also consistent with the view that population's panic and resistance have exacerbated the Ebola virus epidemic in West Africa.

To conclude, it is worth discussing some insights on the causes of population's panic and resistance, as our analysis was essentially devoted to the epidemiological consequences. In particular, are the disease and epidemic responsible for population's fear and hostility or the causes to be found in more deeply rooted origins? Some observers have suggested that the handling of the epidemic instilled fear and hostility among the population. Glennerster, M'Cleod and Suri (January 30, 2015)[11] argued for instance that *"the early days of the crisis were characterized by a sense of immense fear, anxiety and alarm, regionally and globally [...] Pictures of health workers in full protective suits became a ubiquitous symbol of the panic. Misleading reports, speculation and poor projections from international agencies, government ministries and the media about the Ebola outbreak exacerbated the problem. The fear that was spread by the dramatic reports that accentuated the negative, undermined confidence, made it harder to encourage people to seek care."* Among public authorities, the president of Liberia, Ellen Johnson Sirleaf (March 11, 2015)[12], eventually conceded that the nature of the disease was particularly fearsome: *"We didn't know what we were dealing with [...] It was an unknown enemy. People attributed it to witchcraft. We did not know what to do. We were all frightened. I was personally frightened."* It is also worth pointing out that insights from past outbreaks remain contrasting. Breman and Johnson (October 30, 2014)[13], members of the international emergency team that intervened during the outbreak in Zaire in 1976, recount that: *"People lacked basic commodities and were fearful and agitated. We explained to them that we knew what caused the outbreak [...] People [...] were relieved when we said we'd*

[11] Glennerster Rachel, Herbert M'Cleod and Tavneet Suri, January 30, 2015. "How Bad Data Fed the Ebola Epidemic." *The New York Times*.

[12] Gladstone Rick , March 11, 2015. "Liberian Leader Concedes Errors in Response to Ebola." *The New York Times.*

[13] Joel G. Breman and Karl M. Johnson, October 30, 2014. "Ebola Then and Now." *The New England Journal of Medicine*.

come to stop the disease's spread, treat patients, and meet their families [...] villagers trusted the hospital and the mission staff [...] and credibility was gradually restored [...] we assuaged fear by working closely with national and local leaders, explaining what we knew and didn't know, and promising to remain in the area, treat patients, visit villages, and give evidence-based guidance." However, Feldmann and Geisbert (2011), drawing lessons from previous Ebola outbreaks, asserted that *"the launch of diagnostic support in remote areas of equatorial Africa can be logistically and technically difficult since these regions are austere environments with cultural differences and sometimes hostile behavior."* Can fearful and hostile reactions towards medical workers and institutions be regarded as signs of distrust? Nathan Nunn and Leonard Wantchekon (2011) have suggested that such phenomenon could have deep rooted origins and be traced back to the slave trade, which they argue induced a *"culture of mistrust"* within Africa that is still persistent today.

As the Ebola virus remains chronic in endemic areas and public health authorities outline changes to prevent future epidemics, the aim of our study was to provide empirical evidence on circumstances that could exacerbate future outbreaks.

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[8] Raleigh Clionadh, Caitriona Dowd, 2015. "Armed Conflict Location and Event Data Project (ACLED) Codebook." .

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Table 1: Other reported *Zaire ebolavirus* outbreaks from 1976 to 2014.

date	country	cases	deaths
August - November 2014	Democratic Republic of the Congo	66	49
December 2008 - February 2009	Democratic Republic of the Congo	32	15
2007	Democratic Republic of the Congo	264	187
November - December 2003	Republic of the Congo	35	29
December 2002 - April 2003	Republic of the Congo	143	128
October 2001 - March 2002	Republic of the Congo	57	43
October 2001 - March 2002	Gabon	65	53
July 1996 - January 1997	Gabon	60	45
January - April 1996	Gabon	37	21
1995	Zaire	315	250
1994	Gabon	52	31
1976	Zaire	319	281

Notes: the 2014 *Zaire ebolavirus* outbreak in the DRC is unrelated to the one in West Africa.
Sources: Centers for Disease Control and Prevention - *http://www.cdc.gov/vhf/ebola/outbreaks/history/chronology.html*.

Table 2: Total cumulative cases and deaths across countries and periods.

	Guinea		Liberia		Sierra Leone	
period	total cum. cases	total cum. deaths	total cum. cases	total cum. deaths	total cum. cases	total cum. deaths
6	-	-	28	14	-	-
7	-	-	109	41	-	-
8	416	305	360	82	-	-
9	529	385	834	178	836	326
10	529	621	1870	431	1292	452
11	1048	854	3369	767	1960	554
12	1441	1164	4190	1114	3187	1173
13	1675	1415	6485	2636	4480	1429
14	2055	1769	7084	2975	6190	1606
15	2292	2051	7765	3222	7897	2100
16	2670	2367	8002	3417	9339	2711

Notes: The total aggregates (laboratory) confirmed, probable and suspect epidemiological classifications. Each indicated period p corresponds to 3 x p weeks after the official recognition of the outbreak in the region.
Sources: Guinean Ministry of Public Health and World Health Organization - Guinea Ebola Situation Report No. 98, 122, 141, 160, 179, 198, 218, 236 and 255 (the time period is from July 22, 2014, to December 26, 2014); Liberian Ministry of Health and Social Welfare - Liberia Ebola Daily Situation Report No. 36, 53, 74, 92, 111, 130, 147, 168, 186, 187, 206 and 225 (the time period is from July 22, 2014, to December 26, 2014); Sierra Leonean Ministry of Health and Sanitation - Ebola Viral Disease Situation Report Vol. 80, 99, 118, 129, 137, 145, 156, 175, 194, and 213 (the time period is from June 18, 2014, to December 26, 2014).

Table 3: Communities' fearful and hostile reactions towards medical workers and institutions in Guinea, Liberia and Sierra Leone in 2014 during the response to the Ebola virus epidemic.

Date - Location - Country	Contextual Notes
05/04/14 - Macenta - Guinea	*An angry crowd attacked an isolation centre for people suffering from the Ebola outbreak; some young people threw rocks at the aid workers (MSF) working there; it's believed misinformation about the treatment process and a rumor that Ebola was brought over on purpose motivated the attack.*
02/07/14 - Gueckedou - Guinea	*The Red Cross has suspended operations in southeast Guinea after a group of naked men wielding knives surrounded a marked Red Cross vehicle and threatened the passengers.*
10/07/14 - Lofa - Liberia	*Residents of some villages in Lofa County have chased away doctors attempting to screen communities for Ebola with knives and stones.*
13/07/14 - Nzerekore - Guinea	*Residents of villages in Guinea's southeast region have shut out medical workers by blocking roads and bridges in some cases due to fears over Ebola.*
25/07/14 - Kenema - Sierra Leone	*Thousands of protesters marched on the main Ebola hospital in Kenema and threatened to burn it down and remove the patients after a rumor spread about "cannibalistic rituals" occurring there; police fired tear gas to disperse the crowd, and allegedly hit a young boy in the leg with a bullet.*
26/07/14 - Lofa - Liberia	*Residents of Popalahun community staged a roadblock and attacked Liberian health workers employed by Samaritan's Purse. They smashed the windshield of the jeep they were traveling in, slashed the tires with machetes and beat one worker with a hammer before they escaped.*
01/08/14 - Montserrado - Liberia	*Members of the Duport Road community chased away an Ebola burial team.*
16/08/14 - Montserrado Liberia	*Unidentified young attackers armed with clubs and some guns attacked and looted an Ebola isolation centre in West Point. During/after the attack between 17 and 20 patients left the centre, or were taken away by family members. No injuries were reported.*
28/08/14 - Nzerekore - Guinea	*A crowd of young men, some armed with clubs and pistols, set up barricades and threatened to attack the hospital following rumors that Ebola had been purposefully spread in the city. Security forces intervened, the rioters fired gunshots, and at least 55 people were injured.*
17/09/14 - Nzerekore - Guinea	*At least 21 members of a government outreach team were injured when residents of Wome near Nzerekore attacked them with sticks and stones, thinking they were coming to bring Ebola to the village. 6 of the officials and 3 journalists were believed to be captured but 8 bodies have been recovered. Among them were the regional director of health and assistant director of Nzerekore hospital. It is also reported that they've erected barricades and destroyed a bridge to block access to the town.*

Sources: ACLED Version 5 - *http://www.acleddata.com/data/version-5-data-1997-2014/*.

Table 4: Communities' fearful and hostile reactions towards medical workers and institutions in Guinea, Liberia and Sierra Leone in 2014 during the response to the Ebola virus epidemic.

Date - Location - Country	Contextual Notes
19/09/14 - Western Rural - Sierra Leone	*Health workers burying Ebola victims were attacked by youths in the village of Matainkay, 20km east of Freetown. Attack occurred on the second of a three-day Ebola lockdown in the country.*
23/09/14 - Forecariah - Guinea	*A Red Cross team was attacked while collecting bodies believed to be infected with Ebola, one worker wounded in the neck. Family members of the dead attacked 6 volunteers and vandalized their cars, then threw rocks at the regional health office.*
07/10/14 - Grand Kru - Liberia	*Protesters seized a vehicle of health workers traveling to Kanwekan near Grand Kru County. Protesters believe health workers to be more concerned with picking up dead bodies than treating the sick.*
21/10/14 - Kono - Sierra Leone	*A riot took place on Oct. 21 between youth and police in Koidu, after health workers were prevented from taking a blood sample from a 90-year-old woman suspected of having Ebola. Health workers called on police for protection from rioters. Youth wielded machetes and shovels, and attacked buildings, including Eastern Radio station. Riots resulted in two people dead and 10 injured. Identity of victims unavailable.*
27/10/14 - Pork Loko - Sierra Leone	*An ambulance carrying suspected Ebola patients crashed into a ditch in the northwestern district of Port Loko after a mob pelted it with stones. No injuries reported.*
01/12/14 - Conakry - Guinea	*An angry crowd confronted Red Cross workers regarding the burial of an Ebola victim. The police tried unsuccessfully to calm the situation as the rioters burned a Red Cross vehicle.*
04/12/14 - Conakry - Guinea	*Dozens of youth staged an angry protest against a new Ebola treatment centre, halting the construction. They damaged a gazebo and equipment being used for the opening as Doctors Without Borders staff and local officials were evacuated.*
19/12/14 - Kissidougou - Guinea	*Hundreds of youth violently prevented the installation of an Ebola treatment center, setting fires and breaking furniture.*

Sources: ACLED Version 5 - *http://www.acleddata.com/data/version-5-data-1997-2014/*.

Table 5: Total cumulative cases and deaths across countries and periods around communities' fearful and hostile reactions towards medical workers and institutions.

j	total cumulative cases (standardized values) [1]	total cumulative deaths (standardized values) [2]
-8	0.083	0.11
	(0.18)	(0.17)
-7	-0.032	-0.012
	(0.16)	(0.15)
-6	-0.042	-0.0023
	(0.18)	(0.16)
-5	-0.087	-0.037
	(0.23)	(0.20)
-4	-0.20	-0.12
	(0.24)	(0.21)
-3	-0.23	-0.17
	(0.27)	(0.25)
-2	-0.19	-0.14
	(0.20)	(0.19)
-1	-0.11	-0.042
	(0.20)	(0.18)
1	0.29	0.20
	(0.20)	(0.19)
2	0.76***	0.53**
	(0.24)	(0.24)
3	1.10***	0.91***
	(0.28)	(0.29)
4	1.99***	1.70***
	(0.31)	(0.34)
5	2.06***	2.27***
	(0.36)	(0.44)
6	2.27***	2.63***
	(0.50)	(0.55)
7	2.45***	3.01***
	(0.66)	(0.67)
8	2.01***	2.64***
	(0.48)	(0.52)
Area FE	yes	yes
Period FE	yes	yes
Observations	583	583
R^2	0.56	0.60

Notes: observations are obtained from a panel across all 33 prefectures of Guinea plus the national capital city, Conakry, and 9 three-week periods between July 22, 2014, and December 26, 2014, across all 15 counties of Liberia and 11 three-week periods between June 18, 2014, and December 26, 2014, and across all 14 districts of Sierra Leone and 8 three-week periods between August 16, 2014, and December 27, 2014. Dependent variables are total cumulative cases and total cumulative deaths. The total aggregates (laboratory) confirmed, probable and suspect epidemiological classifications. Values are standardized so that each area-period observation is measured in standard deviations from the sample mean (i.e., mean across areas and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)j$ for $j = 1, ..., 8$ indicates the estimated difference in the dependent variable between areas that faced communities' fearful and hostile reactions towards medical workers and institutions and areas that did not, at *j* periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for j = 0) as the reference. Standard errors are reported in parentheses under point estimates and corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with area-specific coefficient). Significance levels are reported at 10% (*), 5% (**) and 1% (***).

Table 6: Cumulative cases and deaths and periods around communities' fearful and hostile reactions towards medical workers and institutions - Guinea.

j	total cum. cases (standardized) [1]	confirmed cum. cases (standardized) [2]	total cum. deaths (standardized) [3]	confirmed cum. deaths (standardized) [4]
-6	-0.56***	-0.52**	-0.34**	-0.40**
	(0.20)	(0.21)	(0.14)	(0.18)
-5	-0.42**	-0.44**	-0.32**	-0.35**
	(0.20)	(0.20)	(0.14)	(0.17)
-4	-0.41**	-0.39**	-0.29**	-0.29*
	(0.18)	(0.17)	(0.13)	(0.16)
-3	-0.28*	-0.29*	-0.27**	-0.27*
	(0.17)	(0.17)	(0.12)	(0.14)
-2	-0.27**	-0.28**	-0.23**	-0.25**
	(0.14)	(0.14)	(0.10)	(0.11)
-1	-0.20*	-0.20*	-0.16**	-0.17**
	(0.11)	(0.11)	(0.08)	(0.08)
1	0.24*	0.20	0.23**	0.20**
	(0.13)	(0.13)	(0.09)	(0.10)
2	0.41**	0.26	0.41***	0.26*
	(0.18)	(0.17)	(0.14)	(0.15)
3	0.69***	0.47**	0.71***	0.51***
	(0.20)	(0.20)	(0.16)	(0.17)
4	1.02***	0.79***	1.06***	0.90***
	(0.18)	(0.17)	(0.16)	(0.17)
5	1.32***	1.25***	1.47***	1.40***
	(0.20)	(0.20)	(0.18)	(0.20)
6	1.47***	1.42***	1.64***	1.60***
	(0.22)	(0.22)	(0.20)	(0.21)
Prefecture FE	yes	yes	yes	yes
Period FE	yes	yes	yes	yes
Control Variable	yes	yes	yes	yes
Observations	306	306	306	306
R^2	0.78	0.68	0.86	0.74

Notes: observations are obtained from a balanced sub-panel across all 33 prefectures of Guinea plus the national capital city, Conakry, and 9 three-week periods between July 22, 2014, and December 26, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases, total cumulative deaths and confirmed cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each prefecture-period observation is measured in standard deviations from the subsample mean (i.e., mean across prefectures and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)$ j for $j = 1, ..., 6$ indicates the estimated difference in the dependent variable between prefectures that faced communities' fearful and hostile reactions towards medical workers and institutions and prefectures that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for $j = 0$) as the reference. Control variable is an indicator variable that uses reported classifications of prefectures according to four alert levels. Standard errors are reported in parentheses under point estimates and corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with prefecture-specific coefficient). Significance levels are reported at 10% (*), 5% (**) and 1% (***).

Figure 5: Guinea Ebola Situation Report No. 255.

Guinée - Epidémie de la Maladie à virus Ebola

Organisation mondiale de la Santé

Données épidémiologiques, Ebola_Guinée 26/12/2014																													
Description	Totaux	Conakry	Gueckedou	Macenta	Dabola	Kissidougou	Dinguiraye	Telimele	Boffa	Kouroussa	Siguiri	Pita	Nzérékoré	Yomou	Dubréka	Forécariah	Kerouane	Coyah	Dalaba	Beyla	Kindia	Lola	Boke	Mamou	Faranah	Kankan	Fria	Labe	Koundara
Nouveaux cas enregistrés ce jour*																													
Nouveaux Cas suspects	**5**			1									1					1				2							
Nouveaux Cas Probables	**0**																												
Nouveaux Cas confirmés	**8**	3						2					1		1			1											
Total des nouveaux cas enregistrés ce jour	13	3	0	1	0	0	0	2	0	0	0	0	2	0	1	0	0	2	0	0	0	2	0	0	0	0	0	0	0
Cumul des cas																													
Total des Cas suspects	28	5	1	4	0	4	0	0	0	0	0	0	2	0	0	1	0	2	0	0	3	2	0	2	1	1	0	0	0
Total des Cas Probables	275	16	112	27	3	5	1	3	7	2	7	1	38	0	2	2	1	5	0	0	21	0	0	0	22	0	0	0	0
Total des Cas confirmés	2367	344	269	714	7	90	0	38	19	17	22	7	208	11	53	44	160	150	9	45	45	46	1	0	41	27	0	0	0
Cumul (des cas confirmés, probables et suspects)	2670	365	382	745	10	99	1	41	26	19	29	8	248	11	55	47	161	157	9	45	69	48	1	2	64	28	0	0	0
Décès																													
*Nouveaux décès confirmés ce jour **	**13**	2	1			3									2			4			1								
*Nouveaux décès probables ce jour **	**0**																												
Total des décès suspects	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total des décès probables	**275**	16	112	27	3	5	1	3	7	2	7	1	38	0	2	2	1	5	0	0	21	0	0	0	22	0	0	0	0
Total des décès confirmés	**1417**	149	203	467	7	54	0	12	11	10	11	3	137	5	26	26	95	76	2	26	25	29	0	0	27	16	0	0	0
Cumul des deces (suspects, probables et confirmés)	**1692**	165	315	494	10	59	1	15	18	12	18	4	175	5	28	28	96	81	2	26	46	29	0	0	49	16	0	0	0
Taux de letalité des cas confirmés et probables	63%	45%	82%	66%	100%	60%	100%	37%	69%	63%	62%	50%	71%	45%	51%	60%	60%	52%	22%	58%	67%	60%	0%	0%	77%	57%			

Sources: Guinean Ministry of Public Health and World Health Organization.

Figure 6: Liberia Ebola Daily Situation Report No. 225.

Ebola Case and Death Summary by County

County	DAILY EMAIL REPORT New[1] suspected and probable cases (Alive and Dead)			Laboratory[2] Confirmed Cases (Alive and Dead)	Confirmed Cases on Contact List	Cumulative[3] cases 23 May-December 26th 2014				Cumulative deaths[2]
	Total	Suspect	Probable			Total	Suspect	Probable	Confirmed	
Bomi	[redacted]			0	0	296	90	67	139	167
Bong	2	2	0	0	0	562	379	33	150	137
Gbarpolu	0	0	0	0	0	34	15	3	16	12
Grand Bassa	0	0	0	0	0	177	52	71	54	79
Grand Cape Mount	1	1	0	0	0	199	68	45	86	107
Grand Gedeh	0	0	0	0	0	11	8	0	3	6
Grand Kru	0	0	0	0	0	36	14	18	4	27
Lofa	0	0	0	0	0	649	171	146	332	387
Margibi	8	8	0	0	0	1244	413	441	390	572
Maryland	0	0	0	0	0	23	17	2	4	19
Montserrado	4	3	1	0	0	4329	1767	797	1765	1795
Nimba	0	0	0	0	0	330	83	131	116	57
River Gee	0	0	0	0	0	19	7	4	8	8
River Cess	0	0	0	0	0	43	9	10	24	26
Sinoe	3	2	1	0	1	50	26	7	17	18
NATIONAL	18	16	2	0	1	8002	3119	1775	3108	3417

[1] From daily email county reports of aggregated data for that day
[2] Laboratory confirmed cases of suspects and probable cases identified during the preceding days
[3] From individual-level data from the Case Investigation form; cases may be reclassified according to surveillance case definitions
↑Increase in daily reported cases by county

Sources: Liberian Ministry of Health and Social Welfare.

Figure 7: Ebola Viral Disease Situation Report Vol. 213.

Table 2: National Cumulative summary of Ebola Cases 23 May – 26 December,2014

Name of district	District population	Number of cases on 26 Dec 2014				Cumulative cases as of 23 May - 26 Dec 2014				Cumulative deaths			CFR
		Non-Case	Suspected	Probable	Confirmed	Cumulative Non-Case	Suspected	Probable	Confirmed	Suspected	Probable	Confirmed	
Kailahun	465,048	0	0	0	0	366	18	67	565	4	35	228	40.4
Kenema	653,013	10	0	0	0	1,319	148	0	496	5	0	262	52.8
Kono	325,003	0	2	0	21	232	118	20	175	2	19	82	46.9
Kambia	341,690	0	0	0	0	179	35	9	108	6	9	44	40.7
Koinadugu	335,471	7	2	0	4	166	35	64	97	0	32	42	43.3
Bombali	494,139	23	1	0	2	1,144	125	25	960	22	19	261	27.2
Tonkolili	434,937	6	0	0	1	439	90	25	426	4	21	121	28.4
Port Loko	557,978	13	0	0	9	1,291	307	2	1164	74	1	328	28.2
Pujehun	335,574	5	0	0	0	65	17	2	31	3	2	16	51.6
Bo	654,142	1	0	0	0	823	134	44	303	8	43	103	34.0
Moyamba	278,119	0	0	0	0	432	78	21	179	9	20	55	30.7
Bonthe	168,729	25	0	0	0	155	10	1	5	1	1	5	100.0
Western area urban	1,040,888	27	3	0	13	3,086	440	5	1772	8	4	487	27.5
Western area rural	263,619	8	0	0	5	1,401	222	2	994	12	2	311	31.3
National	**6,348,350**	**125**	**8**	**0**	**55**	**11,098**	**1,777**	**287**	**7,275**	**158**	**208**	**2345**	**32.2**
Total		**125**	**63**			**11098**	**9339**			**2711**			

Sources: Sierra Leonean Ministry of Health and Sanitation.

Table 7: Cumulative cases and deaths and periods around communities' fearful and hostile reactions towards medical workers and institutions - Liberia

j	total cum. cases (standardized) [1]	confirmed cum. cases (standardized) [2]	total cum. deaths (standardized) [3]
-6	-0.17	0.0055	-0.19
	(0.57)	(0.78)	(0.52)
-5	-0.17	-0.080	-0.19
	(0.54)	(0.75)	(0.49)
-4	-0.18	-0.17	-0.19
	(0.47)	(0.68)	(0.43)
-3	-0.21	-0.27	-0.19
	(0.45)	(0.66)	(0.40)
-2	-0.14	-0.16	-0.10
	(0.34)	(0.50)	(0.30)
-1	-0.12	-0.095	-0.061
	(0.28)	(0.40)	(0.26)
1	0.18	0.19	0.094
	(0.29)	(0.40)	(0.26)
2	0.56	0.50	0.44
	(0.35)	(0.51)	(0.31)
3	0.79**	0.60	0.85**
	(0.39)	(0.58)	(0.35)
4	1.69***	2.01***	1.59***
	(0.39)	(0.59)	(0.35)
5	1.59***	2.08***	1.94***
	(0.45)	(0.68)	(0.40)
6	1.78***	2.33***	2.24***
	(0.47)	(0.73)	(0.42)
County FE	yes	yes	yes
Period FE	yes	yes	yes
Control Variables	no	no	no
Observations	165	165	165
R^2	0.50	0.56	0.54

Notes: observations are obtained from a balanced sub-panel across all 15 counties of Liberia and 11 three-week periods between June 18, 2014, and December 26, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases and total cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each county-period observation is measured in standard deviations from the subsample mean (i.e., mean across counties and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)$ j for $j = 1, ..., 6$ indicates the estimated difference in the dependent variable between counties that faced communities' fearful and hostile reactions towards medical workers and institutions and counties that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for $j = 0$) as the reference. Standard errors are reported in parentheses under point estimates and corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with county-specific coefficient). Significance levels are reported at 10% (*), 5% (**) and 1% (***).

Table 8: Cumulative cases and deaths and periods around communities' fearful and hostile reactions towards medical workers and institutions - Sierra Leone

j	total cum. cases (standardized) [1]	confirmed cum. cases (standardized) [2]	total cum. deaths (standardized) [3]	confirmed cum. deaths (standardized) [4]
-4	-0.50***	-0.58***	-0.31*	-0.19
	(0.14)	(0.20)	(0.17)	(0.15)
-3	-0.46***	-0.52***	-0.35**	-0.24*
	(0.11)	(0.16)	(0.15)	(0.13)
-2	-0.34***	-0.38***	-0.27**	-0.15
	(0.08)	(0.10)	(0.11)	(0.10)
-1	-0.15**	-0.16**	-0.076	-0.090
	(0.06)	(0.08)	(0.08)	(0.07)
1	0.32***	0.30***	0.13	0.19***
	(0.06)	(0.08)	(0.08)	(0.07)
2	0.77***	0.72***	0.40***	0.52***
	(0.07)	(0.09)	(0.10)	(0.09)
3	1.25***	1.24***	0.90***	1.09***
	(0.08)	(0.10)	(0.14)	(0.13)
4	1.80***	1.71***	1.32***	1.56***
	(0.10)	(0.14)	(0.19)	(0.18)
District FE	yes	yes	yes	yes
Period FE	yes	yes	yes	yes
Control Variables	yes	yes	yes	yes
Observations	112	112	112	112
R^2	0.82	0.79	0.83	0.86

Notes: observations are obtained from a balanced sub-panel across all 14 districts of Sierra Leone and 8 three-week periods between August 16, 2014, and December 27, 2014. Dependent variables are total cumulative cases, (laboratory) confirmed cumulative cases, total cumulative deaths and confirmed cumulative deaths. The total aggregates confirmed, probable and suspect epidemiological classifications. Values are standardized so that each district-period observation is measured in standard deviations from the subsample mean (i.e., mean across districts and periods). Point estimates are obtained by Ordinary Least Squares after the Prais-Winsten correction. Each point estimate $(-j)$ j for $j = 1, ..., 4$ indicates the estimated difference in the dependent variable between districts that faced communities' fearful and hostile reactions towards medical workers and institutions and districts that did not, at j periods (before) after the incidents, taking the estimated difference at the period of the incidents (i.e., for $j = 0$) as the reference. Control variables consist of the presence of virus healthcare facility management units as well as cumulative admissions and discharges in those units. Standard errors are reported in parentheses under point estimates and corrected for panel heteroskedasticity, contemporaneous correlation and serial correlation (i.e., AR(1) process with district-specific coefficient). Significance levels are reported at the 10% (*), 5% (**) and 1% (***).