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Alejandro de la Fuente
Hanan G. Jacoby
Kotchikpa Gabriel Lawin

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Abstract

The 2014–15 Ebola epidemic took a devastating human and economic toll on three West African countries, of which Liberia was perhaps the hardest hit. The pathways through which the crisis affected economic activity in these largely agrarian societies remain poorly understood. To study these mechanisms in the context of rural Liberia, this paper links a geographically disaggregated indicator of Ebola disease mortality to nationally representative household survey data on agricultural production and consumption. The paper finds that higher Ebola prevalence (as proxied by local mortality) led to greater disruption of group labor mobilization for planting and harvest, thereby reducing rice area planted as well as rice yields. Household welfare, measured by per capita expenditures spanning two points before and after the crisis, fell by more in Ebola prevalent areas with more intensive rice farming, precisely those areas that were more adversely affected by agricultural labor shortages.

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Impact of the West African Ebola Epidemic on Agricultural Production and Rural Welfare: Evidence from Liberia[1]

Alejandro de la Fuente[2] Hanan G. Jacoby[3] Kotchikpa Gabriel Lawin[4]

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2 World Bank (adelafuente@worldbank.org)
3 World Bank (hjacoby@worldbank.org)
4 Consultant (kotchigab@gmail.com)

1. Introduction

Between 2014 and 2015, the Ebola Virus Disease (EVD) wreaked havoc across three West African countries. The epidemic killed more than 11,300 people and infected some 28,600 as it swept through Guinea, Sierra Leone and Liberia. Of these countries, Liberia was reported by many organizations as the most severely affected. The first case was identified in Lofa County in March 2014. During the next year and a half, more than 10,670 would become infected and over 4,800 would die from the disease. Although Liberia was finally declared free of Ebola in July 2016, concerns about the epidemic's long-term impacts, as well as its reemergence, remain.

In addition to Ebola's morbidity and mortality toll, there were indirect, yet widespread, economic effects resulting from fear of contagion and from domestic and international disease containment measures. International trade and travel were severely disrupted due to restrictions on individuals from Ebola-affected areas entering many countries. Domestic travel restrictions, including limitations on the movement of people and goods and full quarantines of certain areas, were in place for long periods. Schools and markets were closed. Non-Ebola health services, including maternal health care, declined, as medical facilities were requisitioned to serve as Ebola treatment centers and patients avoided hospitals and clinics for fear of encountering infected persons. Given that Liberia is among the poorest countries in the world, with poverty especially pervasive in rural areas (72% of the rural population is officially classified as poor, compared to 32% in urban areas), limited means were available to cope with a shock of this magnitude.[5]

[5] After an initial delay, hundreds of millions of dollars poured into Liberia as part of the international response effort, widely considered integral to halting the spread of Ebola.

In this paper, we seek to unpack the economic effects of EVD, and epidemics more broadly, in agrarian societies. We focus on the availability of agricultural labor for critical and time-sensitive tasks such as planting and harvesting, which normally require a degree of worker coordination and mobilization. Liberia, for example, has a labor recruitment system known as *kuu* for assembling agricultural workers for seasonal tasks, especially in the production of rice, the principal crop. We consider the hypothesis that fear of congregating in groups disrupted worker mobilization and led to severe labor shortages, thus depressing rice production and, ultimately, rural welfare. To explore this mechanism, we link a geographically disaggregated indicator of Ebola disease mortality with nationally representative household survey data on agricultural production and household welfare.

To preview, we find that higher Ebola prevalence (as measured by local mortality) led to greater disruption of group-labor mobilization for planting and harvest and reduced rice area planted as well as rice yields. Consistent with this evidence, household welfare, measured by per capita expenditures, fell by more in Ebola prevalent areas with more intensive rice-farming, i.e., in precisely those areas differentially affected by agricultural labor shortages.

Other research, produced during and in the immediate aftermath of the EVD crisis in Liberia, also suggests that serious agricultural labor shortages occurred due to contagion fears. However, these findings are based largely on impressionistic or subjective evidence from non-representative samples.[6] Using a simulation model, FAO (2015) estimates that,

6 Among respondents to a World Bank cellphone survey who had already harvested, over 80 percent reported lower production in 2014 than in the previous year, the main reason being the labor disruption due to Ebola (World Bank 2015). This was also the main reason cited by those with crops still in the field as to why the harvest had not been completed. UNDP (2014) finds a decline in the supply of labor due to deaths, the migration of workers to escape the disease, and the unwillingness to engage in collective activities such as land preparation and harvesting.

as a result of labor shortages, rice production declined by 12 percent at the national level, with more precipitous declines (up to 20 percent) in the most affected counties such as Lofa and Margibi; cassava production, which is less labor and input intensive than rice, supposedly experienced a 5 percent drop at the national level.[7] Our study stands apart from this work by providing the first econometric evidence on the Ebola epidemic's impact using nationally representative household survey data combined with administrative records on EVD mortality at the district level.

More broadly, past literature on the economic impact of infectious disease focuses on long-term consequences of early life shocks operating through the mechanism of human capital formation and, ultimately, through the labor market (Almond 2006; Bleakley 2007, 2010; Baird et al., 2016). There is also a small economics literature focusing on aggregate labor supply effects of epidemic disease (e.g., Young 2005; Voigtländer and Voth 2012). To our knowledge, the mechanism explored in this paper -- fear of contagion -- is novel, albeit relevant only to virulent epidemics, where the (perceived) likelihood of contagion from proximity to an infected individual is significant.

The remainder of the paper is organized as follows: Section 2 describes the data and the context of the EVD outbreak in Liberia. Section 3 details the empirical strategy used to assess the Ebola crisis' impacts on labor, agricultural production, and consumption. Section 4 presents the main findings. Section 5 briefly summarizes the paper.

7 Using a market-chain analysis approach, FAO (2016) shows that the Ebola crisis disrupted the collection and transportation of agricultural production to consumption areas, which in turn reduced farmers' incomes (higher costs of inputs and lower negotiating power with collectors whose numbers decreased and producer were forced to sell at lower prices than expected).

2. Data and Context

2.1 Household survey data

Our main data source is the multi-topic Household Income and Expenditure Survey (HIES) collected by the Liberia Institute of Statistics and Geo-Information Services (LISGIS). We use the latest two rounds, 2014 and 2016. Both rounds are representative at the national level and, for rural areas – i.e., localities with population less than 2,000 -- representative at the county level (Liberia is divided into 15 counties). Both surveys also use the same Enumeration Areas (EAs), but fresh households were selected from each EA in each round.

The 2014 round of the HIES was planned for the full calendar year, but only administered from January through July due to the outbreak of EVD in the country. When fieldwork was halted in August 2014, approximately half of the data had been collected. Fortunately, the HIES sample covered during the first two quarters of 2014 was designed to be nationally representative. The HIES 2016 started in January of that year --- after which time only a few cases of Ebola were reported --- and continued through December.

Both the 2014 and 2016 HIES allow us to construct a household consumption aggregate; we use per capita expenditures to proxy household welfare. Consumption expenditures comprise food and non-food components and are reported in Liberian dollars (see LISGIS 2017 for details). To sum up, our analysis of household welfare impacts will effectively use an EA-level panel between 2014 and 2016, focusing, for purposes of comparability, on households surveyed in the first semester (January-July) of each round.

HIES 2016 provides extensive and detailed information on farm labor and agricultural production based on recall of the last completed farming season. The agriculture module also includes questions about the perceived impact of the Ebola crisis

on rice farming. Since HIES 2014 does not include a comparable agricultural module, we cannot construct a 2014-16 panel of EAs for the agricultural production data along the lines of our consumption expenditure data. Instead, our analysis of the impact of the Ebola outbreak on farm labor and production outcomes is purely cross-sectional.

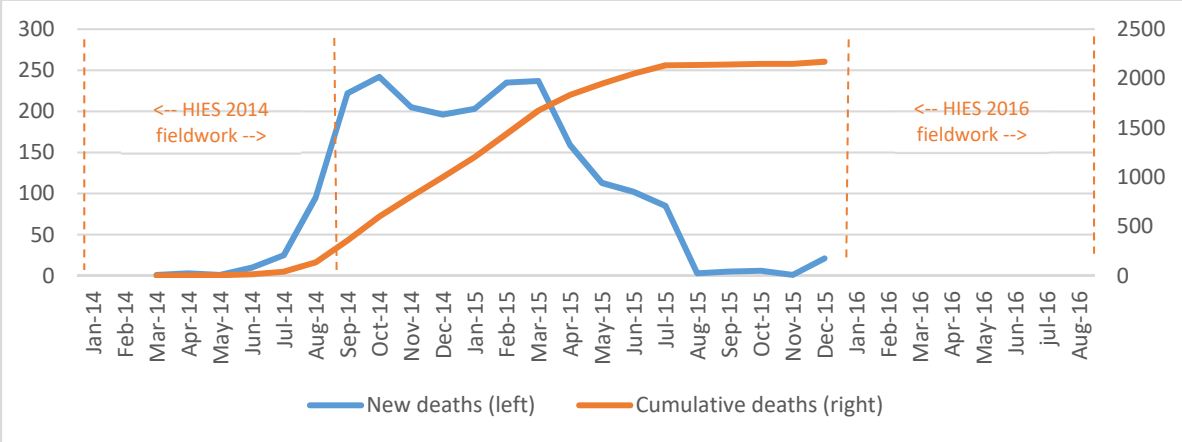
2.2 Mortality during the Ebola Outbreak

On 30 March 2014, Liberia confirmed its first two cases of Ebola virus disease in Foya, Lofa County. By June the first deaths from Ebola occurred in Monrovia when seven patients died from the disease. Although, at the time, only 16 cases were reported in Liberia in total, with the urbanization of the disease the outbreak quickly spiraled out of control, peaking in the first quarter of 2015. By June 2016, when Liberia was (provisionally) declared Ebola-free, 10,678 people had been infected with Ebola, and over 4,800 had died.

Ebola-related burial data obtained from the Ministry of Health up to December 2015 indicate 4,621 total casualties, corresponding reasonably closely to the official figures. Of these deaths, 2,221 were matched to rural areas.[8] In rural Liberia, adult males were the main group of mortal victims from Ebola, but close to a third of the fatalities were under-fives (8%) and adults over 65 (24%) (See table A1.2 in Appendix 1).

[8] The rural classification was done for georeferenced burials (4257/4621) at the locality level using the official cutoff population of < 2,000 as used in the HIES.

Figure 1. Ebola-Related Deaths in Rural Areas, March 2014 – Dec. 2015

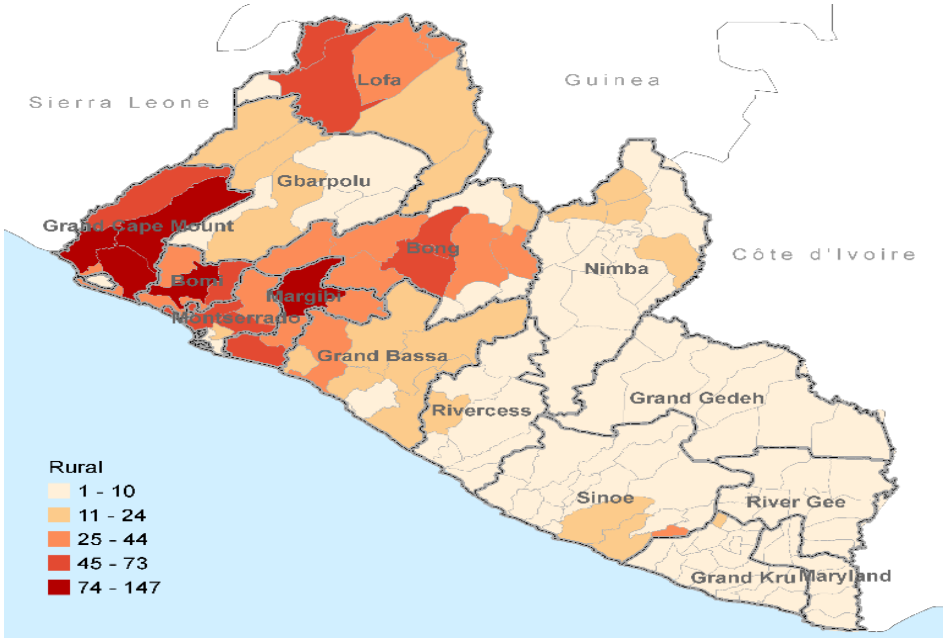


Source: Authors with data from Ministry of Health and Social Welfare.

We use total deaths (burials) suspected to be Ebola-related in a district per 1,000 district population as a measure of Ebola prevalence in the district.[9] Liberia is divided into 130 districts, for which population figures are derived from the (latest available) 2008 Population Census. Based on this measure, Ebola is more prevalent in northern and western Liberia relative to the south and east. FAO (2004) classifies 7 of 15 counties as "severely affected" by Ebola (Bomi, Grand Cape Mount, Lofa and Margibi, Bong, Grand Bassa and Nimba). While, according to our fatality measure (see Figure 2 and Table A1.1 in Appendix 1), Ebola prevalence is not especially high in Nimba nor in Grand Bassa, we will retain the FAO categorization for the purposes of our empirical analysis. Both measures agree that Grand Gedeh and Maryland counties, on the southeast border with Côte d'Ivoire, were by far the least affected by the EVD crisis in relative terms.

[9] In a large subset of these cases, health officials obtained mouth swab tests to confirm Ebola virus. We do not restrict deaths to confirmed Ebola cases because the selection of individuals to test was clearly not random (e.g., testing was probably less likely in more remote areas).

Figure 2: Ebola-related burials in rural areas



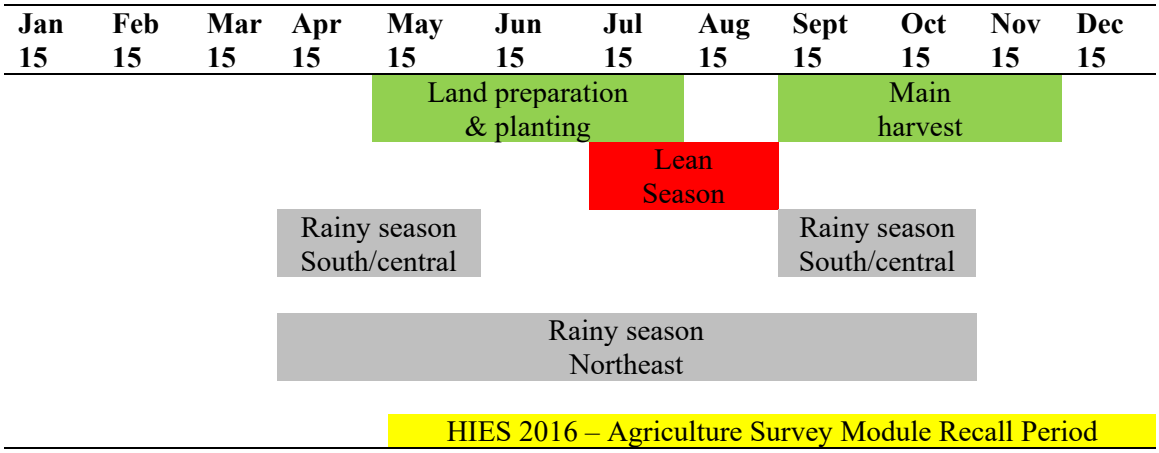
Source: Authors with data from Ministry of Health and Social Welfare.
Note: The rural classification was done for georeferenced burials (4257/4621) at locality level. Following the official definition, any locality with a population equal or greater than 2,000 and all county capitals were classified as urban. The remainder of the localities were classified as rural.

2.3 Ebola and Agriculture

Agriculture constitutes more than a third of Liberia's economy in terms of GDP (38.8%), employing more than 70% of the population. Liberia's major crops are natural rubber, rice, cassava, bananas and palm oil. Rice, alongside cassava, is the main staple crop, grown by about three-quarters of rural households. Given its importance for food security and rural living standards more broadly, this study focuses on rice production.

Ebola struck Liberia at a critical point during the main rice harvest of the agricultural season 2014-15. As figures 1 and 3 show, the epidemic plateaued well into the land preparation and planting activities for the following agricultural season 2015-16, precisely the season recalled by most respondents to the 2016 HIES.

Figure 3. Agricultural Calendar (Rice) and HIES Timeline



Source: The seasonal calendar was adapted from FAO (2016).

Rice production in Liberia uses a labor-intensive, rain-fed system involving team-work at certain crucial production stages, namely planting, maintenance and harvest. The *kuu* system of labor recruitment assembles such work teams, offering members food or labor on their own farms in exchange for work (FAO, 2016). Fear of infection would be expected to reduce farmer willingness to join *kuu* teams and can explain the impact on rice production when and where Ebola raged.

Two channels of impact of the Ebola epidemic on Liberian agriculture are thus as follows: First, there is a direct effect of the Ebola outbreak on the rural labor force through sickness or death, temporarily or permanently removing agricultural workers and thereby disrupting planting and harvesting in agriculture or, more generally, raising farm wages to the extent that a casual labor market exists.[10] However, given the magnitude of Ebola morbidity and mortality relative to the size of the rural population (around two fatalities

[10] This is the mechanism that economists have explored in the context of HIV in Africa (Young 2005) and the Black Death in Europe (Voigtländer and Voth 2012).

out of every thousand), this direct effect is likely to be negligible. Second, agricultural labor force participation could fall indirectly due to measures to contain the virus, such as travel restrictions, and quarantines, but primarily due to the increased fear of congregating in work teams as discussed in the previous paragraph. Lower availability of labor, especially for land preparation and planting, would reduce area devoted to rice and potentially lower yields on rice land that is planted.

Subjective recall data from the 2016 HIES on how Ebola affected rice cultivation in the last completed season lends support to the importance of farm labor availability. A year after the onset of the Ebola outbreak (during the agricultural season 2015/16) many farmers in Liberia were unable to grow or sell their rice. The primary constraint was lack of farm labor for clearing, planting and harvesting. Specifically, 9 percent of rural farming households report not planting rice due to the presence of Ebola in their community. Another 14 percent planted rice, but encountered difficulties during cultivation because of EVD. Of the 48 percent of rural farming households planting rice during the course of the epidemic, 22 percent reported that land clearing and planting were affected, whereas 1 percent did not harvest any of the planted rice and 3 percent did not complete their harvest because of Ebola sickness in their community. While these recall data provide some insights, they are, after all, subjective impressions of farmers. The remainder of this study, therefore, focuses on objective recall data, which are less prone to ex-post rationalization and related biases.

One limitation of the HIES questionnaire is that it does not distinguish the use of *kuu* labor from that of (conventional) hired labor, although we suspect that the former institution is far more widespread than the latter in Liberia's traditional rice farming

communities. At any rate, the use of hired/*kuu* labor is highest in Lofa, Nimba and Bong counties (Table A1.1), known as Liberia's 'breadbasket'. Some of these counties in northern and western Liberia were also Ebola hotspots, implying a *positive* spatial correlation between *kuu* labor and Ebola in the country overall. Indeed, Table A1.3 shows higher shares of hired/*kuu* labor in counties designated by FAO as severely affected by Ebola.

3. Empirical Strategy

3.1 Labor Use and Rice Production

Qualitative and other evidence cited above suggests that, at its height, Ebola caused significant disruption to Liberia's rice production system. The main channel of impact was the shortage of labor for land clearing and harvesting. The agricultural calendar and timeline (fig. 2) show that the Ebola outbreak had not subsided, or at least continued to be disruptive, at the time of the 2015/16 rice season, the earliest for which recall data are available.

Our regression model for rice production outcome Y_{id} of household i in district d is

$$Y_{id} = \delta_1 E_d + X'_{id}\beta + \epsilon_{\mathrm{id},} \quad (1)$$

where E_d is a continuous measure of district-level EVD prevalence based on the total number of Ebola-related burials per 1,000 district population over the course of the outbreak, X_{id} is a vector of household demographic, enumeration area (EA), and district level characteristics., and ϵ_{id} is a random disturbance term. Standard errors are clustered at the district level.

As noted, agricultural production, land and labor use are covered in the 2016 HIES, in a one-year recall format. To ensure that farmers are referring to the 2015 agricultural season, we restrict the sample to agricultural households (rural households engaged in farming) interviewed between January-April 2016; i.e., before the 2016 planting season was underway. Our empirical analysis of agricultural production is by necessity cross-sectional, comparing post-Ebola production outcomes between districts differentially affected by the crisis.

There are two threats to validity of a causal interpretation of our estimates: (1) Omitted variables correlated with both agricultural production outcomes and the incidence of EVD; and (2) Simultaneity between *kuu* labor use and Ebola. In other words, where farmers rely more heavily on *kuu* labor, Ebola could have spread more quickly. Simultaneity bias would lead to a *positive* association between *kuu* labor and Ebola, as suggested by the higher *kuu* share in severely affected counties noted above.

To address these issues, we control for whether the household is in a "severely affected" county as defined by FAO, thus focusing on variation *within* highly affected areas as well as *within* less affected areas. We also control for distance to major roads from the center point of each Enumeration Area (so all the household records within an EA should have the same value), as Ebola may have spread along road networks that are more likely to be placed where agriculture productivity is particularly high. Finally, the production regressions also control for rainfall patterns[11] (total rainfall at Enumeration Area level in 2015) that may have influenced rice planting choices and yields.

[11] The rainfall source data were Climate Prediction Center (CPC) Africa Rainfall Climatology Version 2.0 (ARC2).

3.2 Consumption Expenditures

As noted, the consumption expenditure recall period for the 2014 HIES covers the half-year before the onset of the Ebola epidemic in June 2014, whereas the consumption expenditure recall period for the 2016 HIES (based on the restricted sample of households interviewed in the first semester) covers the half-year starting from January 2016, during which time Liberia was virtually Ebola-free (see figure 1). While the data represent repeated cross-sections of households, for our welfare measure (per capita consumption), we have variation over time, i.e., just before and just after the epidemic. Presumably, household consumption in the first half of 2016 reflects any adverse income shock due to disrupted rice production in 2015.

We estimate an EA fixed effect regression of the form:

$$W_{idt} = \gamma_{EA} + \lambda_{16} \times [\delta_1 E_d + \delta_2 E_d \times R_{EA} + X'_{id}\beta] + \mathrm{u_{idt}}, \quad (2)$$

where W_{idt} is household welfare (varying over two points in time *t*), γ_{EA} is an EA fixed effect, λ_{16} is a dummy for 2016 that multiplies all the time invariant covariates: the Ebola prevalence variable E_d introduced in equation (1), the interaction of Ebola prevalence with a measure of community resilience R_{EA} – i.e., the share of agricultural land in the district planted to rice – and a vector of household demographic characteristics including a constant term.

4. Results

4.1. Labor Use and Rice Production

Table 1 shows that within the counties that were severely affected by Ebola, use of hired/kuu labor was lower in districts with a particularly high Ebola incidence. While the

negative effect is not statistically significant for overall labor use, it is significant for narrower categories of farming activities that are especially hired/kuu labor intensive, namely land clearing and planting. In quantitative terms, multiplying the number of burials per 1,000 population by 10 reduces the intensity of kuu labor in overall labor used for planting by 2.7 percentage points. This disruption in land clearing and planting labor is reflected in a significantly lower share of cultivated land devoted to rice in high Ebola prevalence areas (see Table 2, column 1). Rice yields were also significantly lower in these areas (column 2); a tenfold increase in the number of fatalities per 1,000 population reduces rice yields by 6%.[12]

As a reality check, we run the same specifications in Tables 1 and 2 using the full sample of farming households, which includes households interviewed later in 2016 and who are thus likely to be reporting on 2016 rice production activities. By 2016, the epidemic in rural Liberia had largely run its course. Thus, as expected, the estimated effects of Ebola mortality on the use of hired/kuu labor and on rice cultivation are substantially attenuated (see Appendix Tables A2.1 and A2.2).

[12] A rapid assessment made by Mercy Cops in November 2014 reported an even larger reduction of rice yields, on the order of 10-25% due to the disruption of the *kuu* system.

Table 1. Ebola Mortality and Agricultural Labor

		Hired/Kuu labor per total labor for:			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Hired/Kuu labor per total labor	Clearing	Planting	Management	Harvesting
Log all burials per 1000 population	-0.010	-0.017	-0.027	-0.003	-0.016
	(0.010)	(0.009)**	(0.010)***	(0.012)	(0.011)
Severely affected counties (dummy)	0.140	0.164	0.152	0.124	0.131
	(0.024)***	(0.028)***	(0.026)***	(0.026)***	(0.027)***
Distance weighted to nearest major road (km)	0.000	-0.000	0.000	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Head of household is female	0.033	0.127	-0.010	0.019	-0.022
	(0.030)	(0.033)***	(0.031)	(0.024)	(0.032)
Household head age	-0.000	-0.001	-0.000	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Head education level dummies (ref= no education)					
Household head has primary education	-0.071	-0.050	-0.087	-0.039	-0.043
	(0.031)**	(0.038)	(0.031)***	(0.018)**	(0.032)
Household head has secondary education	-0.034	0.021	-0.049	-0.021	-0.049
	(0.027)	(0.031)	(0.029)*	(0.023)	(0.028)*
Household head has tertiary education	0.080	0.117	0.123	0.129	-0.121
	(0.069)	(0.066)*	(0.081)	(0.131)	(0.094)
Constant	0.328	0.401	0.351	0.119	0.281
	(0.039)***	(0.051)***	(0.040)***	(0.035)***	(0.041)***
Mean of dependent variable	0.389	0.508	0.411	0.195	0.331
Observations	3122	3122	3122	3122	3122
Fstat	7.182	11.900	6.969	3.397	4.987
Prob > Fstat	0.000	0.000	0.000	0.001	0.000
Adjusted R-squared	0.061	0.078	0.057	0.039	0.038

Source: Authors based on HIES 2016.
Note: Standard errors in parentheses clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1. The sample consists of rural farming households interviewed from January to April 2016.

Table 2. Ebola Mortality and Rice Production

	(1) Share of land area allocated to rice	(2) Log rice yield [kg/ha]
Log all burials per 1000 population	-0.014	-0.060
	(0.007)**	(0.024)**
Severely affected counties (dummy)	0.036	-0.177
	(0.025)	(0.074)**
Distance weighted to nearest major road (km)	0.002	0.001
	(0.001)**	(0.002)
Head of household is female	-0.008	-0.202
	(0.016)	(0.065)***
Household head age	-0.001	0.003
	(0.000)*	(0.002)
Head education level dummies (ref= no education)		
Household head has primary education	-0.034	-0.056
	(0.018)*	(0.087)
Household head has secondary education	-0.041	0.002
	(0.016)**	(0.065)
Household head has tertiary education	-0.092	0.069
	(0.040)**	(0.290)
Total Rainfall in 2015		0.000
		(0.000)**
Constant	0.217	6.409
	(0.029)***	(0.172)***
Mean of dependent variable	0.212	6.676
Observations	3122	2387
Fstat	4.122	3.535
Prob > Fstat	0.000	0.001
Adjusted R-squared	0.027	0.027

Source: Authors based on HIES 2016.

Note: Standard errors in parentheses clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1. The sample consists of rural farming households interviewed from January to April 2016.

4.2. Impacts on Welfare

Results reported in columns 1-3 of Table 3 indicate that per capita food consumption and, to a somewhat lesser extent, per capita total consumption fell by more between 2014 and 2016 in areas with higher EVD prevalence, indicating that households did not have the means to completely self-insure against this (income) shock. Recall that our estimation sample consists of two repeated cross-sections of households, which form a panel at the level of the enumeration area. Thus, fixed household characteristics can be included in the EA fixed effect regression. Moreover, the burials variable is assumed to be zero in 2014 (prior to the Ebola outbreak), which is equivalent to interacting burials with a dummy for 2016.

Next, we investigate whether households in districts more involved in rice cultivation, and hence more subject to on-farm labor disruptions, might have experienced larger consumption declines. We do so by adding an interaction term between the share of district land under rice (in 2014) and Ebola mortality (columns 4-6). This term attracts a statistically significant negative coefficient, at least in the case of food consumption, suggesting that rice cultivating areas were indeed more vulnerable to the Ebola outbreak.

5. Conclusions

Consumption growth in rural Liberia was flat between the 2014 and 2016 waves of the HIES (Appendix 1 Table A1.2). Moreover, rural poverty increased from 70% in the first half of 2014 (just before the Ebola crisis) to 82% in the first half of 2016 following the Ebola crisis (LISGIS, 2017). The evidence presented in this paper is consistent with the Ebola outbreak being partially responsible for higher poverty in rural Liberia. The

mechanism is novel: fear of congregating in groups disrupted worker mobilization and led to severe labor shortages, thus depressing rice production and, ultimately, rural welfare.

Table 3. Ebola Mortality and Per Capita Consumption

	Log annual per capita consumption					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Food	Non-food	Total	Food	Non-food	Total
Log (all burials per 1000 population) # Survey year dummy (1 if 2016)	-0.035	-0.025	-0.029	0.036	-0.033	0.016
	(0.019)*	(0.027)	(0.016)*	(0.049)	(0.064)	(0.045)
Log (all burials per 1000 population) # Share of District Land under rice # Survey year dummy (1 if 2016)				-0.322	0.040	-0.203
				(0.184)*	(0.249)	(0.165)
Survey year dummy (1 if 2016)	-0.056	-0.080	-0.059	-0.076	-0.077	-0.072
	(0.028)*	(0.060)	(0.034)*	(0.028)***	(0.063)	(0.035)**
Head of household is male	0.039	0.168	0.075	0.038	0.168	0.074
	(0.020)*	(0.046)***	(0.023)***	(0.020)*	(0.046)***	(0.023)***
Age of Household head	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000
	(0.000)	(0.000)***	(0.000)***	(0.000)	(0.000)***	(0.000)***
Head education level dummies (ref= no education)						
Primary	0.083	0.196	0.105	0.084	0.196	0.106
	(0.025)***	(0.047)***	(0.027)***	(0.025)***	(0.047)***	(0.027)***
Secondary	0.150	0.352	0.204	0.149	0.352	0.204
	(0.025)***	(0.038)***	(0.024)***	(0.025)***	(0.039)***	(0.024)***
College degree	0.112	0.823	0.359	0.109	0.823	0.357
	(0.069)	(0.079)***	(0.070)***	(0.068)	(0.080)***	(0.069)***
Log household size	-0.294	-0.316	-0.320	-0.293	-0.316	-0.319
	(0.020)***	(0.031)***	(0.018)***	(0.020)***	(0.031)***	(0.018)***
Dependency ratio (# hh members aged < 5 / hh size)	-0.247	-0.470	-0.313	-0.245	-0.470	-0.312
	(0.034)***	(0.097)***	(0.035)***	(0.034)***	(0.097)***	(0.035)***
Share of elderly (# hh members aged>64/ hh size)	-0.031	-0.391	-0.128	-0.031	-0.391	-0.128
	(0.053)	(0.085)***	(0.054)**	(0.053)	(0.085)***	(0.054)**

Survey year dummy (1 if 2016) # Counties severely affected by EVD (dummy)	0.077	-0.053	0.043	0.092	-0.055	0.053
	(0.042)*	(0.078)	(0.044)	(0.041)**	(0.079)	(0.043)
Constant	10.609	9.422	10.948	10.609	9.422	10.949
	(0.028)***	(0.066)***	(0.030)***	(0.028)***	(0.066)***	(0.030)***
Mean of dependent variable	5.160	0.426	0.550	0.448	0.230	0.366
Observations	5365	5365	5365	5365	5365	5365
Number of clusters	123	123	123	123	123	123
Fstat	39.942	51.174	90.213	36.386	47.367	82.968
Prob > Fstat	0.000	0.000	0.000	0.000	0.000	0.000
Adjusted R-squared	0.183	0.155	0.231	0.185	0.155	0.232

Source: Authors based on HIES 2014 and 2016.

Note: Standard errors in parentheses clustered at the district level.

*** p<0.01, ** p<0.05, * p<0.1. All models control for Enumeration Area fixed effects and observations are weighted to be representative of the population.

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Appendix 1. Descriptive Statistics

Table A1.1. Descriptive Statistics, by Counties

	County														
	Bomi	Bong	Grand Bassa	Grand Cape Mount	Grand Gedeh	Grand Kru	Lofa	Margibi	Maryland	Montserrado	Nimba	River Cess	Sinoe	River Gee	Gbarpolu
Ebola															
Fatalities	230	298	130	449	20	35	231	261	23	180	106	26	59	96	77
Fatalities per every 1000/district inhabitants	4.42	1.77	0.84	4.86	0.20	1.13	1.72	3.65	0.38	1.73	0.54	1.13	1.17	0.77	1.57
Farm Labor															
Hired/Kuu labor per total labor	0.30	0.49	0.30	0.37	0.36	0.27	0.58	0.35	0.31	0.20	0.44	0.27	0.31	0.25	0.44
Hired/Kuu labor per total labor for clearing	0.44	0.62	0.46	0.46	0.50	0.34	0.65	0.48	0.43	0.28	0.59	0.43	0.39	0.38	0.54
Hired/Kuu labor per total labor for Planting	0.30	0.52	0.35	0.36	0.39	0.30	0.59	0.32	0.34	0.17	0.49	0.31	0.36	0.28	0.43
Hired/Kuu labor per total labor for farm mgmt	0.08	0.29	0.11	0.19	0.09	0.14	0.43	0.16	0.16	0.08	0.20	0.05	0.12	0.10	0.11
Hired/Kuu labor per total labor for harvesting	0.15	0.46	0.25	0.32	0.33	0.24	0.54	0.26	0.20	0.16	0.37	0.21	0.25	0.17	0.43
Rice production															
Share of area devote to rice	0.12	0.30	0.17	0.19	0.33	0.21	0.24	0.18	0.15	0.02	0.24	0.17	0.22	0.29	0.29
Rice yield (kg/ha)	649	1063	1305	865	2222	1229	1218	1187	1439	536	1471	1731	1552	2058	1298

Source: Authors with data from Ministry of Health and Social Welfare for Ebola statistics; and with data from Agriculture Recall Survey from HIES 2016 for labor and production statistics.

Table A1.2. Descriptive Statistics for Rural Samples

	Rural	
	2014 (SE)	2016 (SE)
Dependent variables		
Annual per capita total consumption (LD)	46352	46682
	(29282)	(69672)
Annual per capita total food consumption (LDs)	32487	33057
	(17442)	(18365)
Annual per capita total nonfood consumption (LD)	13865	13625
	(17469)	(61052)
Farm Labor		
Hired/Kuu labor per total labor		0.39
		(0.29)
Hired/Kuu labor per total labor for clearing		0.51
		(0.34)
Hired/Kuu labor per total labor for Planting		0.41
		(0.34)
Hired/Kuu labor per total labor for farm management		0.20
		(0.31)
Hired/Kuu labor per total labor for harvesting		0.33
		(0.33)
Rice production and price		
Share of area devote to rice		0.21
		(0.23)
Rice yield (kg/ha)		1198
		(1414)
Ebola		
Total Ebola-related fatalities		2,221
Age		
0-4		174
5-15		170
16-64		1,330
65 and above		538
Sex		
Female		975
Male		1,245
Ebola-related fatalities per every 1000/ district inhabitants		1.86
Household demographics		
Highest education level attained by household head		
None	0.48	0.50
	(0.50)	(0.50)
Primary	0.17	0.18
	(0.38)	(0.38)

	Rural	
	2014 (SE)	2016 (SE)
Secondary	0.32	0.31
	(0.47)	(0.46)
College degree	0.03	0.01
	(0.17)	(0.12)
Age of household head (years)	49	44
	(73)	(27)
Household head is male	0.76	0.75
	(0.43)	(0.43)
Community/Location Characteristics		
Distance weighted to nearest major road (km)	14	14
	(15)	(15)
Distance to border with Guinea (km)	121	121
	(83)	(83)
Distance to border with Ivory Coast (km)	143	143
	(81)	(81)
Distance to border with Sierra Leone (km)	172	172
	(117)	(117)

Source: Authors based on HIES 2014 and 2016.
Note: LD = Liberian Dollars.

Table A1.3. Descriptive Statistics, Severely Affected and Less Affected Counties from Ebola

	Severely Affected		Less Affected	
	2014 (SE)	2016 (SE)	2014 (SE)	2016 (SE)
Dependent variables				
Annual per capita total consumption (LD)	42,662	44,937	52,989	50,659
	(23,795)	(81,158)	(36,244)	(29,796)
Annual per capita total food consumption (LD)	30,169	31,450	36,656	36,720
	(14,940)	(16,944)	(20,571)	(20,804)
Annual per capita total nonfood consumption (LD)	12,493	13,487	16,333	13,939
	(13,899)	(72,565)	(22,304)	(14,992)
Farm Labor				
Hired/Kuu labor per total labor		0.43		0.29
		(0.29)		(0.28)
Hired/Kuu labor per total labor for clearing		0.55		0.40
		(0.32)		(0.34)
Hired/Kuu labor per total labor for planting		0.45		0.31
		(0.34)		(0.33)
Hired/Kuu labor per total labor for farm management		0,23		0.10
		(0.33)		(0.23)
Hired/Kuu labor per total labor for harvesting		0.37		0.24
		(0.34)		(0.31)
Rice production and price				
Share of area devote to rice		0.22		0.19
		(0.24)		(0.22)
Rice yield (kg/ha)		1,087		1,571
		(1,291)		(1,716)
Imported rice price (LD/kg)	62	68	73	75
	(12)	(15)	(12)	(19)
Local rice price (LD/kg)	61	67	67	64
	(25)	(33)	(10)	(13)
Ebola				
Total Ebola-related fatalities		1,704		516
Age				
0-4		146		28
5-15		138		32
16-64		1015		315
65 and above		404		134
Sex				
Female		753		222
Male		951		294
Ebola-related fatalities per every 1000/district inhabitants		2.15		1.19

	Severely Affected		Less Affected	
	2014	2016	2014	2016
	(SE)	(SE)	(SE)	(SE)
		(2.05)		(1.84)
Household demographics				
Highest education level attained by household head				
None	0.51	0.52	0.44	0.46
	(0.50)	(0.50)	(0.50)	(0.50)
Primary	0.16	0.18	0.18	0.16
	(0.37)	(0.39)	(0.39)	(0.37)
Secondary	0.31	0.28	0.33	0.37
	(0.46)	(0.45)	(0.47)	(0.48)
College degree	0.02	0.01	0.04	0.01
	(0.15)	(0.12)	(0.20)	(0.11)
Age of household head (years)	51	44	45	44
	(83)	(26)	(48)	(29)
Household head is male	0.76	0.74	0.75	0.75
	(0.43)	(0.44)	(0.43)	(0.43)
Community/Location Characteristics				
Distance weighted to nearest major road (km)	13	13	17	17
	(12)	(12)	(19)	(19)
Distance to border with Guinea (km)	88	88	196	196
	(63)	(63)	(72)	(72)
Distance to border with Ivory Coast (km)	149	149	130	130
	(81)	(81)	(78)	(78)
Distance to border with Sierra Leone (km)	131	131	261	261
	(72)	(72)	(146)	(146)

Source: Authors based on HIES 2014 and 2016.
Note: LD = Liberian Dollars

Appendix 2: Ebola-related Burials and Selected Agriculture Labor Outcomes – Full HIES 2016 sample

Table A2.1: Ebola-Related Burials and Selected Agriculture Labor Outcomes – Full HIES 2016 sample

		Hired/Kuu labor per total labor for:			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Hired/Kuu labor per total labor	Clearing	Planting	Management	Harvesting
Log all burials per 1000 population	-0.006	-0.009	-0.017	-0.007	-0.007
	(0.009)	(0.009)	(0.010)*	(0.011)	(0.011)
Severely affected counties (dummy)	0.130	0.146	0.133	0.116	0.111
	(0.023)***	(0.028)***	(0.025)***	(0.023)***	(0.026)***
Distance weighted to nearest major road (km)	0.000	0.000	0.001	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Head of household is female	0.034	0.119	-0.000	0.033	-0.014
	(0.028)	(0.032)***	(0.029)	(0.022)	(0.030)
Household head age	-0.000	-0.001	-0.001	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Head education level dummies (ref= no education)					
Household head has primary education	-0.057	-0.034	-0.071	-0.033	-0.031
	(0.029)**	(0.036)	(0.029)**	(0.017)**	(0.031)
Household head has secondary education	-0.036	0.018	-0.044	-0.017	-0.056
	(0.024)	(0.028)	(0.027)*	(0.021)	(0.024)**
Household head has tertiary education	0.103	0.149	0.190	0.094	-0.146
	(0.059)*	(0.058)**	(0.081)**	(0.122)	(0.084)*
Constant	0.317	0.393	0.348	0.107	0.274
	(0.039)***	(0.052)***	(0.041)***	(0.029)***	(0.041)***
Mean of dependent variable	0.383	0.496	0.404	0.189	0.323

Observations	3389	3389	3389	3389	3389
Fstat	7.227	9.871	6.629	3.854	4.382
Prob > Fstat	0.000	0.000	0.000	0.000	0.000
Adjusted R-squared	0.051	0.060	0.042	0.035	0.028

Source: Authors based on HIES 2016.

Note: Standard errors in parentheses clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1. The sample consists of rural farming households interviewed from January to December 2016.

Table A2.2: Ebola-Related Burials and Selected Agriculture Production Outcomes – Full HIES 2016 sample

	(1) Share of land area allocated to rice	(2) Log rice yield [kg/ha]
Log all burials per 1000 population	-0.011	-0.025
	(0.007)	(0.028)
Severely affected counties (dummy)	0.031	-0.284
	(0.023)	(0.078)***
Distance weighted to nearest major road (km)	0.002	0.001
	(0.001)**	(0.003)
Head of household is female	-0.013	-0.140
	(0.017)	(0.059)**
Household head age	-0.001	0.003
	(0.000)*	(0.003)
Head education level dummies (ref= no education)		
Household head has primary education	-0.037	-0.005
	(0.019)*	(0.073)
Household head has secondary education	-0.049	-0.000
	(0.014)***	(0.063)
Household head has tertiary education	0.027	-0.161
	(0.116)	(0.436)
Total Rainfall in 2015		0.000
		(0.000)
Constant	0.221	6.698
	(0.029)***	(0.225)***
Mean of dependent variable	0.212	6.591
Observations	3389	2560
Fstat	3.080	2.753
Prob > Fstat	0.003	0.006
Adjusted R-squared	0.024	0.022

Source: Authors based on HIES 2016.

Note: Standard errors in parentheses clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1. The sample consists of rural farming households interviewed from January to December 2016.