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Analyzing the Economic Consequences of an Epidemic Outbreak: Experience from the 2014 Ebola Outbreak in West Africa

Mohamed Jalloh
Economic Policy Analysis Unit (EPAU), Macroeconomic Policy Department,ECOWAS Commission River Plaza Central Area, PMB 401 Abuja, Nigeria
*Email of corresponding author: medjal99@yahoo.com

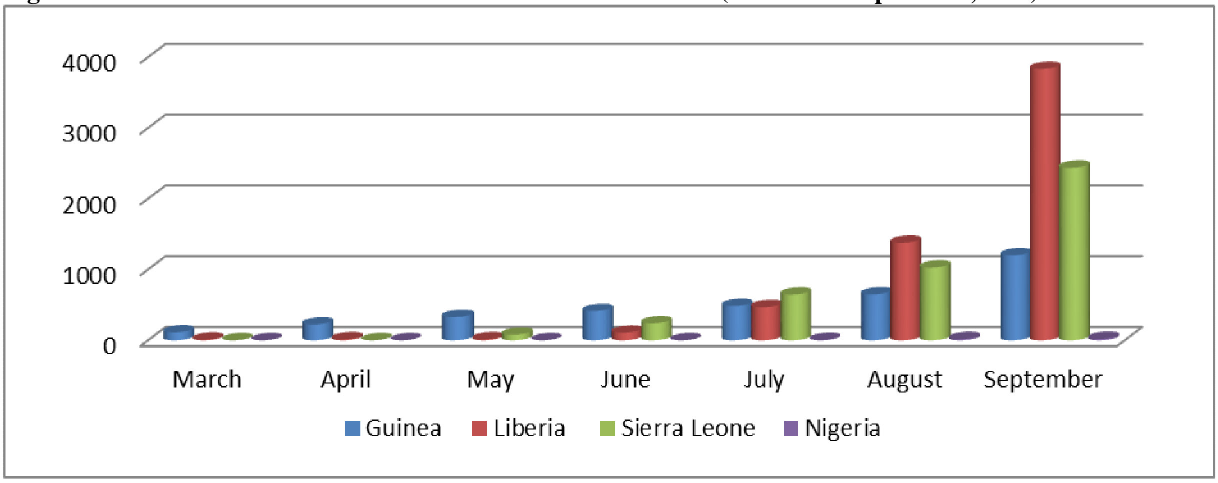
Abstract
The Ebola virus disease has been infection countries in Africa since its first emergence in Zaire in 1976. However, the 2014 Ebola outbreak in West Africa has been unanimously described as the World's most devastating outbreak in history and the first ever witnessed in West Africa. The devastating nature of the 2014 Ebola epidemic made the international community becoming increasing worried as the disease continued to spread across borders. This stud therefore, aimed at evaluating the economic impact of the epidemic in West African countries affected by the outbreak. The study adopted an innovative methodology that scientifically captures the contemporaneous impact of the outbreak on key socioeconomic variables of interest. The results from the study revealed that in addition to the adverse impact of the Ebola outbreak on economic growth, commodity prices and government budget deficits, the isolation of countries hardest hit by the epidemic contributed significantly in worsening the socioeconomic conditions faced by these countries. By way of policy recommendations, the study noted the need to strengthen health care systems in the region, training of more health care workers, and avoidance of actions restriction the movement of persons and goods from epidemic affected areas and the need for regional coordination efforts for the effective combating of epidemic outbreaks in the future.
Keywords: Ebola, epidemic, outbreak, devastating, West African, health care, growth

1. Introduction.

The Ebola virus disease has been on the rampage since August 1976 when it first emerged in Zaire (WHO; 1978). Heymann et al.(1980) shows that the virus re-emerged in June 1977 at Tandala Hospital in northwestern Zaire where it infected a nine-year-old girl who died of acute hemorrhagic fever. In Southern Sudan, 284 infection cases, including 151 deaths were recorded between June and November 1976 (WHO; 1979). Between 31 July and 6 October 1979, 34 cases of the Ebola virus disease re-emerged amongst five families in Southern Sudan resulting to 22 deaths (Baron et al (1983). Many other studies, including Hayes et al (1992), Georges et al (1999), Khan et al (1999) , Okware et al (2002) , Hayes, et al (1992)." have reported Ebola virus disease outbreaks in the United States of America, Gabon, Democratic Republic of Congo , Uganda and The Philippines, respectively.

The 2014 Ebola outbreak is one of the most devastating outbreaks in history and the first ever witnessed in West Africa. As of end August 2014, the World Health Organization (WHO) reports that a total of 3,685 cases of Ebola virus infections cases, including 1,841 deaths from the four West African States of Guinea, Liberia and Nigeria and Sierra Leone. What is more scaring is that a high proportion of those infected by the Ebola outbreak in West Africa included health workers who are even grossly inadequate to handle the increasing number of cases across the affected countries. The acute shortage of protective equipment as well as their improper use amounted to the high death toll amongst health workers, particularly Doctors and Nurses. WHO also reported that as of end August 2014, more than 240 health care workers have developed the Ebola virus disease in Guinea, Liberia, Nigeria, and Sierra Leone, and more than 120 eventually died (i.e. 50% death rate). As of September 30, 2014 the Center for Disease Control and Prevention (CDC) reports that a total of 7,470 infection cases, including 3.431 deaths were recorded in the four affected West African countries as follows: Guinea (1,199 infection cases and 732 deaths), Liberia (3,834 infection cases and 2,069 deaths), Sierra Leone (2,437 infection cases and 623 deaths) and Nigeria (20 infection Cases and 8 deaths). Figure 1 below shows the evolution of the disease since March to September 2014.

Figure 1: Evolution of the Ebola virus infection in West Africa.(March to September,2014)



Source: World Health Organization (WHO) and the Center for Disease Control and Prevention (CDC)

On account of the increasingly devastating effects of the Ebola virus outbreak, mining activities in Sierra Leone has significantly declined, resulting in the reversal of projections of 2014 economic growth rate from 11.3% to 7.1%. In Liberia and Guinea the World Bank revised its projections of 2014 economic growth rate from 5.9% and 4.5% to 2.5% and 2.4% respectively. In all the three hardest hit countries, whilst fiscal revenues are declining, government spending has significantly increased in trying to contain the spread of the disease. This resulted in widening the fiscal deficits of governments in these countries. This development has raised some level of skepticism as to whether the region's good growth prospects will be maintained as earlier projected. In view of this ugly development, the general objective of this study, therefore, aims at evaluating the economic consequences of the 2014 Ebola outbreak in West Africa, most particularly those hardest hit by the outbreak. The specific objectives are to assess the relative effects of the 2014 Ebola outbreak on economic growth, commodity prices and the fiscal deficits of those countries affected by the outbreak.

2. Materials and Methods

As the epidemic is ongoing at the time of carrying out the study, it is extremely difficult to tell exactly by how much government revenues, government spending, commodity prices and economic growth have fallen or risen. On account of this difficulty, the study utilizes various national publications in the affected countries, the International Monetary Fund (IMF), the World Bank, Reuters, BBC, CNN, the World Health Organization (WHO) , the West African Health Organization (WAHO) and the Center for Disease Control and Prevention (CDC) in assessing general opinions on the perceived impact of the Ebola epidemic on key economic variables such as economic growth, inflation, and budget deficits . On the basis of these opinions, we generate qualitative or binary response data for the key variables of interest.

A review of econometric techniques indicate that , in qualitative response models, the variables to be explain , y , is a random variable taking on a finite number of outcomes . The leading case occurs when y is a binary response taking on the values zero and one, which indicate whether or not a certain event has occurred. Regardless of the definition of y , it has been a common practice to refer to y = 1 as a success and y = 0 as a failure. In this type of models, the general interest lies primarily in estimating the response probability:

$$P(X) \equiv P(y = 1 \mid X) = P(y = 1 \mid x_1, x_2 \ldots, x_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

The probit model is a special case of binary response models with a cumulative distribution function (CDF) that takes the form: $G(z) = \varphi(Z) = \int_{-\infty}^{z} \emptyset(v)\, dv$. Where $\emptyset(z)$ is the standard normal density $\emptyset(z) = (2\pi)(2\pi)^{-\frac{1}{2}} \exp(-z^2/2)$. Similarly, the logit model is another special case of equation (1) with a cumulative density function (CDF) that tales a standard logistic distribution of the form; $G(z) = \theta(z) \equiv \exp(z) / [1 + \exp(z)]$.

Logit and probit models are most suitable for such analysis. This is because they are both useful when we want to fit a linear regression model to a binary response variable. For a detail discussion of these models, see Wooldridge (2000a, 2000c, 2000d) , Albert and Chi (1993) , Bliss .(1935 and 1938), McCullagh and Nedler.(1989) , Goldberger (1991) and Greene (1997). Table 1 below shows a description of both the dependent and explanatory variables.

Table 1 : Description of Variables

Variable	Definitions
Dependent Variables	
Economic growth (Growth)	= 1 if growth is adversely affected by the outbreak, 0 otherwise.
Commodity Prices (COMPR)	= 1 if Commodity prices rise following the outbreak, 0 otherwise.
Budget deficits (BUDEF)	= 1 if budget deficit is adversely affected by the outbreak , 0 otherwise
Explanatory Variables	
Ebola Severity Index (ESI)	This index takes values between 0 and 10 depending on the severity of the outbreak. It is calculated taking several factors into consideration as shown in the Table A in the Appendix
Index of Fatality (IOF)	= 0 if no death occur, = 1 if the death rate is less than 30%, = 2 if the death rate is between 30% and 70%, = 3 if the death rate is more than 70%.
International Isolation (ISOL)	= 0 if there is no kind of restriction affecting the free movement of persons from that country, 1 if the country's citizens face some form of discrimination when crossing borders to neighbouring countries, 2 if the country's citizens are severely harassed when crossing borders to neighbouring countries, 3 if land borders are completely closed down thereby deterring free movement of persons and goods across borders in neighbouring countries, 4 if international airlines stop or cancel flights from going to the Ebola virus infected country
EBOINF	Cumulative number of confirmed Ebola virus infection cases in that country as updated by WHO.

Source: Author's generation of variables based on certain criteria and public opinion

Estimation issues

The study pooled data from the four West African Countries of Guinea, Liberia, Sierra Leone and Nigeria over the period March to September, 2014 to form a panel data. This, therefore, requires panel data estimation procedures. Consequently, the specified model as presented in equation (1) will now take the form:

$$P(y_{it} = 1 \mid x_{it}) = G(x_{it}\beta), \quad t = 0, 1, 2, \ldots, T \ldots\ldots\ldots\ldots 2$$

In this formulation, we can obtain a consistent estimator of β by maximizing the partial log likelihood function $\sum_{i=1}^{N}\sum_{t=1}^{T}\{y_{it}\log G(x_{it}\beta) + (1 - y_{it})\log[1 - G(x_{it}\beta)]\}$ using pooled estimation technique. A robust variance matrix estimator is needed to account for serial correlation in the scores across t. In the event the model represented in equation (2) above turns out to be dynamically complete (i.e. , $P(y_{it} = 1 \mid x_{it}, y_{i,t-1}, x_{i,t-1}, \ldots) = P(y_{it} = 1 \mid x_{it})$), all the usual statistics from a probit or logit model that pools observations and treats the sample as a long independent cross section of size NT are valid, including likelihood ratio statistics. In its simplest form, dynamic completeness implies that the scores are serially uncorrelated across t, a key condition for the standard inference procedures to be valid (see Wooldridge ;2000a)

To test for dynamic completeness, we added a lagged dependent variable and possibly lagged explanatory variables. For concreteness, we focus on the probit case since other indexed models are handled in a similar fashion. Suppose we define $u_{it} \equiv y_{it} - \Phi(x_{it}\beta)$, so that under the assumption of dynamic completeness, $E(u_{it} \mid x_{it}, y_{i,t-1}, x_{i,t-1}, \ldots) = 0$, for all t. It therefore implies that u_{it} is uncorrelated with any function of the variables $(x_{it}, y_{i,t-1}, x_{i,t-1}, \ldots)$, including u_{it-1}. Thus, it can be observed that it is serial correlation in u_{it} that makes the usual inference procedures invalid. In practice, we employ a simple test using pooled probit to estimate the artificial model;

$$P(y_{it} = 1 \mid x_{it}, u_{i,t-1}) = \Phi(x_{it}\beta + \gamma_1 u_{i,t-1}) \ldots\ldots\ldots\ldots 3.$$

From the above formulation, the null Hypothesis is $H_0: \gamma_1 = 0$. If H_0 is rejected, then the assumption of dynamic completeness does not hold. This is a case where under the null hypothesis, the estimation of β required to obtain $u_{i,t-1}$, does not affect the limiting distribution of any of the usual test statistics , that is the Wald , LR or LM , of $H_0: \gamma_1 = 0$. The Wald statistics (i.e. the t statistics on γ_1) , is the easiest to obtain amongst them. For the LM and LR statistics, it requires the dropping of the first time period in estimating the restricted model ($\gamma_1 = 0$). This study will therefore employ the Wald test to check the estimated model for dynamic completeness as a way of addressing potential problems associated with serial correlation.

3. Results

Summary Statistics

We start by presenting the summary statistics. As shown in Table 2, the study used 100 observations pooled across the affected countries of Guinea, Liberia, Sierra Leone and Nigeria. As can be observed in Table 2, there is a mean time period of 23.38 with a standard deviation of 10.53, implying that the panel data is unbalanced. For a balanced panel, the standard deviation of the time variable is 0, implying equal time period across the cross-sectional units. The summary statistics also indicate that the mean number of Ebola virus infection cases (EBOINF) is 326.87 with a standard deviation of 350.87. The high standard deviation implies that the number of cases significantly differ from country to country. For instance, whilst Liberia recorded 1698 infection cases as of 31August, 2014 Nigeria only recorded 21 cases. As for the Index of Fatality (IOF), the mean value for the four countries is 52.3% with a standard deviation of 16.396.

Table 2: Presentation of Summary Statistics

Variables	No. Obs	Mean	Std. Dev	Minimum	Maximum
ID	100	1.99	0.969171	1	4
Time	100	23.38	10.53113	1	39
EBOINF Deaths	100	326.87	350.8793	8	1698
IOF	100	181.2	184.6327	1	871
ISOL	100	52.32%	16.39638	7.4%	78.8%
COMPR	100	1.31	1.331021	0	3
Growth	100	0.72	0.451261	0	1
BUDEF	100	0.61	0.490207	0	1
	100	0.84	0.368261	0	1

With regards the binary response variables, the summary statistics as shown in Table 2 indicates that Commodity Prices (COMPR) has a mean value of 0.72 with a standard deviation of 0.45126. This implies that 72% of general opinions strongly support the fact that the Ebola outbreak will have an adverse effect on commodity prices particularly in those countries hardest hit be the virus. The Economic growth variable (Growth) has a mean of 0.61 with a standard deviation of 0.490207. This implies that 61 % of perceptions strongly support the fact that the outbreak will adversely affect economic growth in countries hardest hit by the disease. Finally, the budget deficit variable (BUDEF) has a mean of 0.84 with a standard deviation of 0.36826, implying that about 84% of the views are in support of the fact that the outbreak will adversely affect budget deficits in those countries hardly hit by the epidemic.

Estimates from the Logit and Probit Models

Table 3: Estimation Results from the Logit and Probit Models.

Variables	Logit Model Growth (1)	Logit Model COMPR (2)	Logit Model BUDEF (3)	Probit Model Growth (1)	Probit Model COMPR (2)	Probit Model BUDEF (3)
Constant	-3.443	-------	-1.2091	-1.7482	-1.4981	---------
EBOINF	(-1.73)		(-0.88)	(-1.96)**	(-1.72)	
IOF	0.02116	0.02015	0.01265	0.011204	0.01179	0.00597
ESI	(2.62)***	(5.85)***	(2.11)**	(2.77)***	(2.61)*** .	(2.66)***
ISOL	0.0395	0.02948	- 0.03701	0.01938	-0.14282	-0.009245
	(1.06)	(0.73)	(-1.22)	(1.09)	(-0.82)	(-0.58)
	0.8112	--------	0.91225	0.42403	0.29804	0.11845
	(1.38)		(1.15)	(1.41)	(0.69)	(0.45)
	2.8944	1.0755	1.6875	1.5346	1.04899	0.75311
	(3.08)***	(1.65)	(1.15)	(3.30)***	(2.39)***	(1.78)
No of Obs	100		100	100		100
Wald Test	100			100		
Chi2(4) =	17.0	14.41	55.69	21.68		20.53
Prob>Chi2 =	(0.0019)		(0.0061)	59.49		
	(0.0000)			(0.0002)		(0.0004)
				(0.0000)		

Note that a positive coefficient means the explanatory variable adversely affect the dependent variable based on the definition of our binary response variables, and Where (***) , (**) and (*) implies parameter significance at the 1%, 5% and 10% level respectively.

Table 3 shows the estimation results from both the Logit and Probit models. As shown in Table 3, we estimated three different equations numbered 1 to 3 for both the Logit and Probit models.

The coefficients of equations 1, 2 and 3 show the relatives effects of the explanatory variables on the binary response variables representing economic growth (Growth) ,Commodity prices (COMPR) and budget deficits (BUDEF) respectively. For each of the estimated equations, we present the results of the Wald test to evaluate the dynamic completeness of the model. The results from the Wald test as shown in the lower panel of Table 3 indicate that all the estimated equations are dynamically complete, implying the absence of serial correlation in each of the estimated equations. This is a guarantee that inferences made from the estimated equations are valid.

4. Discussion of findings

As presented in Table 3, the coefficients of one two of explanatory variables representing Ebola infection cases (EBOINF) and the index of International Isolation (ISOL) are consistently significant in all the equation. The other explanatory variables - the Index of Ebola Severity (ESI) and Index of Fatality (IOF) have appropriate signs but rather insignificant. As can be observed in both the Logit and the Probit models, the variables representing Ebola virus infection (EBOINF) has a significantly adverse impact on economic growth (Growth) , Commodity prices (COMPR) and budget deficits (BUDEF) in the countries hardest hit by the outbreak. This result is consistent with that of the general perception that the outbreak of the Ebola virus epidemic will adversely affect economic growth, commodity prices and budget deficits in countries hardest hit by the Ebola outbreak . The coefficients of the Isolation variable (ISOL) are also significant in both the Logit and Probit equations, implying that the act of isolating countries hardest hit by the epidemic contributed significantly in worsening the adverse effects of the outbreak on economic growth, commodity prices and budget deficits. This result is consistent with WHO's warning that isolating countries suffering from the Ebola epidemic will be detrimental to countries suffering from the outbreak.

From the above analysis, it is thus important to note that the key factors contributing to worsening the economic conditions of countries hardest hit by the 2014 Ebola outbreak in West Africa were the soaring number of infection cases and the international isolation of these countries at a time when they needed other countries most for possible assistance in combating the outbreak. The international isolation which came in the form of land border closure as well as stopping of airlines from going to the affected countries resulted in hindering the transportation of the requisite health care equipment, medicines and medical experts from other parts of the world to help combat the outbreak, thereby creating an avenue for worsening the spread of the disease . Furthermore, the isolation made it difficult to make available requisite commodities like petroleum products, imported food stuff and other necessities, contributing to putting pressure on commodity prices as existing stock continues to dwindle. The international isolation also resulted in squeezing out government revenues sources as tax revenues from imports continues to fall at a times when government spending on health to combat the disease is skyrocketing. These and many other factors constituted the key channels through which the act of isolating countries hardest hit by the outbreak adversely impact on the economic conditions of those countries.

5. Conclusion

The Ebola virus disease has been affecting countries in Africa since its first emergence in Zaire in 1976. However, the 2014 Ebola outbreak in West Africa has been unanimously described as the World's most devastating outbreak in history and the first ever witnessed in West Africa. By end September, 2014 a total of 7,470 infection cases, including 3.431 deaths were recorded in the four affected West African countries of Guinea, Liberia, Sierra Leone and Nigeria. Owing to the devastating pace at which the 2014 Ebola epidemic wreaked havoc West African countries, the world became increasing worried as the disease continued to spread across borders. This study, therefore, aimed at assessing the economic impact of the Ebola epidemic in West African, particularly in those countries hardest hit by the outbreak. In addition to providing an overview of the evolutionary trend of the 2014 Ebola outbreak in the four West African countries affected by the disease, the study utilizes an innovative methodology that scientifically captures the contemporaneous impact of the Ebola outbreak on key economic variables of interest. The results from the study revealed that in addition to the adverse impact of the Ebola outbreak on economic condition of those countries, the isolation of these countries by their immediate neighbors as well as other countries outside the West African region contributed immensely in further worsening the economic conditions faced by these countries during the epidemic outbreak.

On account of the aforementioned findings that stem from this study, the following policy recommendations are aimed at providing effective strategies for combating similar outbreak of epidemics in the future. Firstly, there is an urgent need for West African countries to strengthen their health care systems by increasing the allocation of the fiscal budget towards improving the health sector. Secondly, there is a strong need to increase the training of more health workers, particularly in the area of epidemiology to enhance capacity in the handling of future outbreaks of epidemics. Thirdly, there is a strong need for West African countries to strictly adhere to the ECOWAS protocol of Free Movement of Persons and goods so that when there is an outbreak of an epidemic in a member country, isolating of that member state would not result in aggravating the socioeconomic impact of the outbreak as experienced in the current Ebola. Fourthly, there is a stronger need for West African States to establish an epidemic emergency fund through the West African Health Organization (WAHO) to enhance the region's preparedness in combating similar outbreaks in the future. Fifthly, the West African region should establish a rapid response Health Task Force that can be immediately deployed in any member state that experiences an epidemic outbreak with a view to containing the spread of the outbreak to other member states. Finally, there is a strong need for a similar study to be carried out to assess the full economic impact of the 2014 Ebola outbreak in West Africa after the current outbreak is declared over (i.e a post Ebola outbreak study) .

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Appendix

Table A : Calculation of the Ebola Severity Index (ESI) for the Period February to September 2014

Country	Month	Ebola Outbreak	CFR	Border Closure	Regional Quarantine	Flight Cancellation	Declaration of an emergency	Closure of Educational Institutions	Country closure	Total Score (ESI)
Guinea	Feb	1	1	0	0	0	0	0	0	**2**
Guinea	March	1	2	0	0	0	0	0	0	**3**
Guinea	April	1	2	0	1	0	0	0	0	**4**
Guinea	May	1	2	0	1	0	0	0	0	**4**
Guinea	June	1	3	0	1	0	0	0	0	**5**
Guinea	July	1	3	1	1	1	1	1	0	**9**
Guinea	August	1	3	1	1	1	1	1	0	**9**
Guinea	September	1	3	1	1	1	1	1	0	**9**
Liberia	Feb	0	0	0	0	0	0	0	0	**0**
Liberia	March	1	2	0	0	0	0	0	0	**3**
Liberia	April	1	2	0	0	0	0	0	0	**3**
Liberia	May	1	2	0	0	0	0	0	0	**3**
Liberia	June	1	2	1	1	0	0	0	0	**5**
Liberia	July	1	2	1	1	1	1	1	0	**8**
Liberia	August	1	2	1	1	1	1	1	1	**9**
Liberia	September	1	3	1	1	1	1	1	1	**10**
Sierra Leone	Feb	0	0	0	0	0	0	0	0	**0**
Sierra Leone	March	0	0	0	0	0	0	0	0	**0**
Sierra Leone	April	1	0	0	0	0	0	0	0	**1**
Sierra Leone	May	1	1	0	0	0	0	0	0	**2**
Sierra Leone	June	1	2	0	0	0	0	0	0	**3**
Sierra Leone	July	1	2	1	1	1	0	1	0	**7**
Sierra Leone	August	1	2	1	1	1	1	1	0	**8**
Sierra Leone	September	1	2	1	1	1	1	1	1	**9**
Nigeria	Feb	0	0	0	0	0	0	0	0	**0**
Nigeria	March	0	0	0	0	0	0	0	0	**0**
Nigeria	April	0	0	0	0	0	0	0	0	**0**
Nigeria	May	0	0	0	0	0	0	0	0	**0**
Nigeria	June	0	0	0	0	0	0	0	0	**0**
Nigeria	July	1	1	0	0	0	0	1	0	**3**
Nigeria	August	1	1	0	0	0	0	1		**3**
Nigeria	September	1	1	0	0	0	0	1	0	**3**

Source : Author's calculation from WHO updates