LUND UNIVERSITY
School of Economics and Management

Master's Programme in Economic Growth, Population, and Development (Economic History)

Socio-Economic Determinants of Ebola Outbreak Intensity and Severity

A study of the West-African Outbreak in 2013-2016

by

Raoul Ilan Ariel Lazar Herbert

ra4774he-s@student.lu.se

Abstract: This study uses a specifically constructed sub-national dataset on Ebola Virus Disease (EVD) outbreak cases, deaths, and CFR in order to look at the question of how important various socio-economic factors were in determining the intensity and severity of the 2013-2016 EVD outbreak in Guinea, Liberia, and Sierra Leone. The results of the OLS model shows that the socio-economic conditions in different regions of the country were important indicators of the number of reported cases and deaths. When looking at the Case Fatality Rate (CFR), the effect of socio-economic conditions becomes blurred as it is also mixed with the actions taken and the effectiveness of the response to the outbreak. The findings are in line with previous findings within the literature which looked at outbreaks of highly infectious diseases across history.

Keywords: Ebola, EVD, public health, SES, Economic History, Epidemics, Disease, Guinea, Liberia, Sierra Leone

EKHS12
Master's Thesis (15 credits ECTS)
June 2020
Supervisor: Abel Gwaindepi
Examiner: Erik Green
Word Count: 12233

Acknowledgements

First of all, a special acknowledgement must go to all the healthcare workers that worked on the frontline of the West African EVD outbreak and who were disproportionately heavily affected by the disease. Their hard work, dedication, and sacrifices helped turn the tide against the virus.

Personally, I would also like to thank my family for supporting me throughout my Master's and being available with help and suggestions whenever it was necessary.

Special thanks also go out to my supervisor, Abel Gwaindepi, for whom this is the second thesis he is helping me with and who continues to provide great comments and guidance when necessary.

Lastly, thank you to Ruth who was stuck by my side throughout the writing of this thesis due to the Corona virus and managed to support and help me despite this.

Raoul Herbert

Lund University

May 2020

Table of Contents

1 Introduction 1

1.1 Research Problem 2

1.2 Aim and Scope... 2

1.3 Outline of the Thesis 3

2 Theory and Literature Review 4

2.1 Background on Ebola Virus Disease and Previous Outbreaks 4

2.2 The Economic History of Epidemics 6

2.3 The Social Determinants of Health... 9

2.4 Summary of the Theory... 11

3 Methodology.. 12

3.1 The Model 12

4 Data 15

4.1 Source Material.. 15

4.2 Descriptive Statistics 16

5 Empirical Analysis.. 20

5.1 Results 20

5.1.1 Number of reported EVD cases 20

5.1.2 Number of reported EVD deaths 23

5.1.3 EVD Case Fatality Rate (CFR)... 26

5.2 Discussion.. 29

6 Conclusion.. 31

6.1 Research Aims and Objectives 31

6.2 Practical Implications... 31

6.3 Future Research 32

List of Abbreviations

CDC – Centers for Disease Control and Prevention

CFR – Case Fatality Rate

ETU – Ebola Treatment Unit

EVD – Ebola Virus Disease

MSF - Médecins Sans Frontières / Doctors Without Borders

NTD – Neglected Tropical Disease

UNFPA – United Nations Population Fund

UNICEF – United Nations Children's Fund

UNMEER – United Nations Mission for Ebola Emergency Response

UN OCHA ROWCA – United Nations Office for the Coordination of Humanitarian Affairs Regional Office for West and Central Africa

WHO – World Health Organization

List of Tables

Table 3-1 - Expected Outcomes of the Econometric Model (Based upon Bowden et al. (2014)) 14
Table 4-1 - Descriptive Statistics 19
Table 5-1 - EVD Cases - Whole Sample 21
Table 5-2 - EVD Cases - Capital Cities Excluded 22
Table 5-3 - EVD Deaths - Whole Sample 24
Table 5-4 - EVD Deaths - Capital Cities Excluded 25
Table 5-5 - EVD CFR - Whole Sample 27
Table 5-6 - EVD CFR - Capital Cities Excluded 28
Table 6-1 - Guinea Descriptive Statistics 37
Table 6-2 - Liberia Descriptive Statistics 38
Table 6-3 - Sierra Leone Descriptive Statistics 39

List of Figures

Figure 1-1 - Overall EVD Cases and Deaths (CDC, 2019) 1
Figure 2-1 - Ebola Outbreaks before 2014 and to Date (Source: HDX, 2015) 5
Figure 4-1 – Prefectures of Guinea (Source: Brinkhoff, 2018) 17
Figure 4-2 – Counties of Liberia (Source: MapUniversal, 2020) 17
Figure 4-3 - Districts of Sierra Leone (Source: Wikimedia, 2020) 17

1 Introduction

Developing countries are generally more vulnerable to shocks and crises than more developed countries. This is in part due to the fact that they frequently struggle to build the right institutions and infrastructure that will allow them to adequately respond in a time of crisis. While developing countries do have a few of these general vulnerabilities, in Africa they also have some geographical challenges that put additional strain on their level of disaster preparedness. This is the disease environment that allows for certain tropical diseases to become endemic and widespread such as malaria as well as causing outbreaks of more infectious and dangerous diseases which can have a devastating impact upon the economies and populations of affected countries.

The West African Ebola Virus Disease (EVD) outbreak brought the previously relatively unknown Ebola virus to the forefront of policy and media attention as its highly infectious spread threatened the lives of people in Guinea, Liberia, and Sierra Leone. The outbreak started in December 2013, was declared a Public Health Emergency of International Concern by the WHO in August 2014 (one of only six such declarations including the current COVID-19 pandemic), and officially ended in June 2016 (WHO, 2014). As it was the largest and most widespread outbreak of EVD in history local governments, the WHO, and international aid organizations struggled to organize an effective response to stem the spread of the disease. As panic and the disease spread, Guinea, Liberia, and Sierra Leone found themselves effectively cut off from the rest of world with flights being cancelled and their economies under huge strain (Walsh and Johnson, 2018). Interestingly, the three main affected countries during the outbreak fared quite differently under the disease as seen in Figure 1 – 1 below:

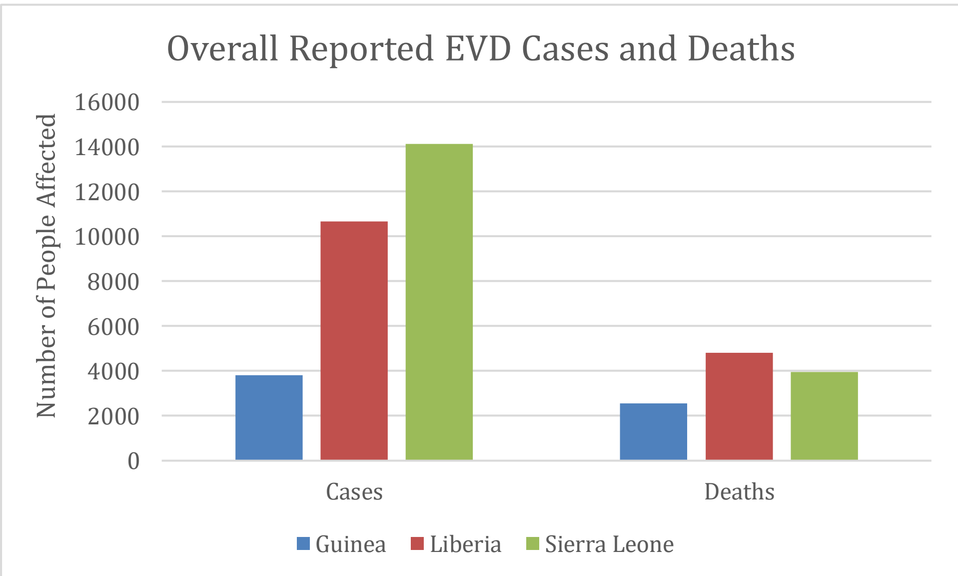

Figure 1-1 - Overall EVD Cases and Deaths (CDC, 2019)

Here we can observe that the number of cases differed drastically between the three nations, and the same goes for the number of deaths. The case fatality rate (CFR – a ratio of the number of deaths to the number of cases) follows the opposite trend to the number of cases with the CFR being highest in Guinea (67%), followed by Liberia (45%), and Sierra Leone (28%). Despite the fact that there appears to be some underestimation and underreporting in these official numbers, there is still significant variation in the severity and intensity with which EVD affected the three different countries during the outbreak (Dalziel et al., 2018). This leads to the question of what determined these differences and whether they can be explained by differences in the response to the EVD outbreak or whether there may be more underlying socio-economic differences between these different countries that contributed to the different outcomes of the EVD outbreak.

1.1 Research Problem

This thesis therefore deals with the problem of why three neighbouring countries were so differently affected by a viral disease of the same strain that hit them simultaneously. An additional challenge is the fact that there is high inequality and regional differences sub-nationally in each of these countries, which means that in order to get a full view on the research problem outlined above a sub-national analysis is necessary to understand fully the internal mechanisms at play as well as the comparative ones between different administrative regions in these neighbouring countries. This research problem is intensified by the fact that this was the largest outbreak of EVD to date and it is unclear what makes this outbreak different from previous outbreaks of EVD in history. It is therefore important to understand the driving factors behind the uncontrolled spread of EVD in West Africa in order also to understand the impact that EVD can potentially have in the future upon other regions or countries.

1.2 Aim and Scope

The aim of this thesis, then, is to look specifically into what factors or pre-conditions in the different administrative regions of Guinea, Liberia, and Sierra Leone were potential key elements that contributed towards the spread and deadliness of EVD. As such it will explore how different socio-economic factors such as working and living conditions, sanitation infrastructure, and health system are related to either the number of EVD cases, deaths, CFR. The idea is that significant differences between Guinea, Liberia, and Sierra Leone can be observed from the topline data on the EVD outbreak and that a further analysis of sub-national data from administrative regions will be able to provide further insight into how different socio-economic pre-conditions may affect the vulnerability of certain groups of the population to a viral disease outbreak such as EVD.

The two main research questions focused on in the econometric modelling for this thesis are:

1. Which socio-economic pre-conditions are significant factors in determining the number of cases, deaths, and CFR of EVD during the West African outbreak?
2. Are the socio-economic factors equally important for the number of cases, deaths, and CFR or does their importance vary for each dependent variable?

In answering these questions, this thesis will aim to contribute towards the literature by providing an analysis of the EVD outbreak that does not yet exist within the literature and also to try and provide indicators for policies that aim towards building the resilience of developing countries towards epidemics and disease outbreaks. It is therefore within the scope of this work to try and define important socio-economic factors that determine how resilient a population may be to an EVD outbreak. It is not, however, within the scope of this work to determine the effectiveness of government or international agency response to the disease once the outbreak has begun which is where a lot of the current research on EVD has focused.

1.3 Outline of the Thesis

The rest of this of thesis will be structured as follows. First, a review of the literature on EVD and the West African outbreak will be presented and analyzed. This will be followed by an in-depth look at how disease outbreaks and epidemics have been researched in the field of economic history which will lead into an analysis of the social determinants of health and how socio-economic pre-conditions may have an effect on epidemic intensity and severity. After this the methodology and econometric model that was employed will be described and explained in detail. The data section will deal with the data quality of the source material that was used as well as descriptive statistics of the variables that were used in the econometric model. This will lead into the chapter on the estimated results of the model and the discussion of what these results mean with regards to the previous literature as well as the aim and research problem defined here. The final chapter will conclude and offer some insight into further necessary research.

2 Theory and Literature Review

This section will present research and background on the West African EVD outbreak and how it is placed in the overall history and research on EVD outbreaks. This will be followed by a discussion of the research in the field of economic history on disease outbreaks and epidemics. And lastly, the theoretical approach and motivation is illustrated by looking at the social determinants of health outcomes and disease outbreaks in order to frame the setting that the data and model of this paper are based upon.

2.1 Background on Ebola Virus Disease and Previous Outbreaks

Ebola Virus Disease (EVD) is a viral haemorrhagic fever whose natural hosts are believed to be fruit bats. “Ebola is introduced into the human population through close contact with the blood, secretions, organs or other bodily fluids of infected animals such as chimpanzees, gorillas, fruit bats, monkeys, forest antelope and porcupines found ill or dead or in the rainforest.” (WHO, 2020). The human-to-human transmission follows similar lines and it is considered a highly contagious disease where the human body remains contagious even after death. People only spread the disease after the incubation period of 2-21 days when they develop symptoms such as fever, fatigue, muscle pain, headache, and sore throat (WHO, 2020). These symptoms are followed by, in the later stages of the virus, vomiting, diarrhoea, rash, impaired liver or kidney function, as well as internal and external bleeding (WHO, 2020). While no official treatment exists for Ebola, “If patients are promptly diagnosed and receive aggressive supportive care – including fluid resuscitation, electrolyte replacement and blood products – the great majority, as many as 90 per cent, should survive” (Farmer, 2014, p. 38-39). While it is not on the official WHO list of Neglected Tropical Diseases (NTDs), the fact that in diagnosis it is frequently confused with malaria, typhoid fever, and meningitis means that it is considered a highly dangerous and underestimated disease and viral haemorrhagic fevers such as Ebola are frequently cited to be a part of the NTDs in academic papers (Hotez and Kamath, 2009). Prior to the West African outbreak, it was largely a sub-national regional problem with cases being restricted to a small geographical area. As Figure 2 – 1 shows, the largest outbreak before 2014 was in Uganda in 2000 with a total reported case number of 425, and reported deaths at 224, with a CFR of 53%. The frightening thing is how these numbers are dwarfed by the West African Outbreak, as seen in Figure 2 – 2. The West African Outbreak was therefore and unprecedented event in the history of this disease and really put EVD into the global spotlight as a disease with terrifying destructive potential.

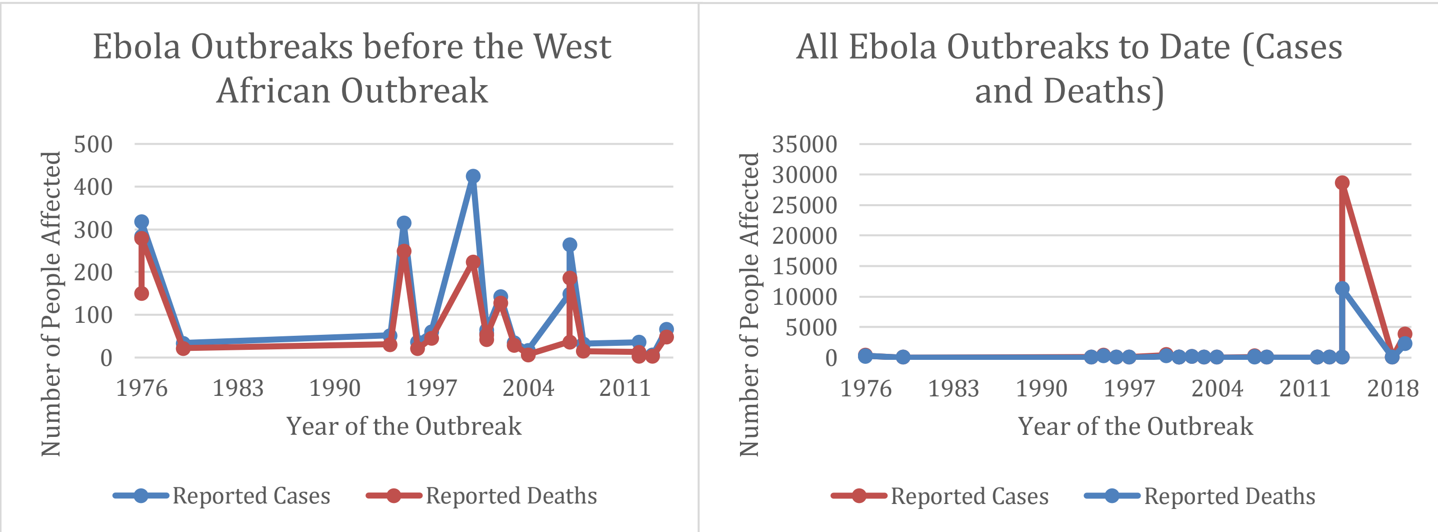

Figure 2-1 - Ebola Outbreaks before 2014 and to Date (Source: HDX, 2015)

With the relatively low impact of EVD prior to 2014, a lot of research on the disease is of a recent nature and based upon this most extreme outbreak. The research on EVD can be divided into the following areas of focus: the impact that the outbreak has had upon the economy and society in the affected countries, the delay in or quality of the response to the outbreak, as well as the potential for increasing outbreaks of this nature in the future due to a number of factors.

The economic and social burden of the outbreak has been immense with the costs being not just economical in nature. Huber et al. (2018) provide an analysis of the hidden costs beyond GDP in terms of social and healthcare losses that shows how wide-ranging and impactful the outbreak was and how long the road to recovery may be. While the official estimates of the cost of the outbreak range from $2,8 to $32,6 billion, Huber et al.'s (2018) estimates bring that number of to $53,19 billion in total cost and losses. The outcome of the crisis is therefore a massive economic to the systems of Guinea, Liberia, and Sierra Leone.

One of the key drivers behind the intensity and size of the West African EVD outbreak appears to have been weak government and international response in the early stages of the outbreak especially. Checchi et al. (2016) point out that EVD transmission began in Guinea in December of 2013 but it was only recognised properly until March 2014 which allowed the outbreak to become as pervasive as it did. In line with this, MSF accused the local governments in Guinea and Sierra Leone of attempting to conceal the outbreak initially and the WHO of not reacting accordingly (O Grada, 2015). The WHO is mandated to coordinate prevention efforts and directly fight the outbreak in cases like these and largely failed to do so until it became a serious issue. As a result, a lot of research has in response to these failures called for a restructuring and evolution of the WHO with a lot of different proposals for such a reform (Checchi et al., 2016; Elmahdawy et al., 2017; Negin and Dhillon, 2016). At the time of writing the WHO is helping to combat another EVD outbreak in the North Kivu region of the

Democratic Republic of the Congo (DRC) so it remains to be seen whether any institutional lessons were learned.

There is also an emerging field of research that is looking into how climate change is changing the population spread of the carriers of infectous diseases such a fruit bats, implying that in the future we could experience EVD outbreaks in a much larger area of countries than previously. Prior to 2014 the only serious EVD outbreaks had been centered around the central African area of the DRC, Uganda, and South Sudan, and it might be that the spread of the disease is increasing with climate change. Daszak et al. (2013) when looking at another virus carried by fruit bats, the Nipah virus, show that the potential habitat for these fruit bats has been steadily expanding in line with changes in the climate throughout Africa and Asia. Similar findings are presented by Epstein et al. (1997) when looking at whether the prevalence of disease-carrying mosquites has changed in line with climatic changes. While these are some indicators of how the underlying disease environment may be changing, Kovats et al. (2001) do acknowledge that much more data and research is needed to be able to definitely confirm these findings.

Thus, there has been a large research output focussing on the West African EVD outbreak predominantly focusing on the economic outcomes of the outbreak, the responses during the outbreak, and on the increasing spread of the EVD but not much focusing on sub-national data and the pre-existing socio-economic factors that might have left regions particularily vulnerable to a virulent disease outbeak.

2.2 The Economic History of Epidemics

Due to the lack of comparable and in-depth research on EVD before the West African outbreak, one if forced to look for comparable cases and incidence of diseases and epidemics across history. Across history, diseases have played an important role in shaping development. As pointed out by Acemoglu et al. (2003), “differences in disease environments had a major impact on the path of institutional development and consequently first-order consequences for economic growth.” (Acemoglu et al., 2003, p. 397). Outbreaks of disease across history have dramatically changed the path that a society was on and had significant long-run effects. The plague for example is frequently cited as having had an important effect upon real wages in Europe and leading to the rise of Europe over the rest of the world in historic development. (North and Thomas, 1973). In trying to understand the relationship between socio-economic factors and the West Africa EVD outbreak, past instances of other severe disease outbreaks can provide a good starting point in understanding the potential mechanisms that are at play in these situations.

The most prominent example across history if intense and deadly disease outbreaks is the plague, or Black Death, which peaked in Europe in the 14^{th} century. And coincidentally, some strong parallels can be drawn between the plague and EVD. “Like plague in the past, the recent Ebola outbreak inspired fear and panic because of its lethality; its long incubation period, and the lack of a medical cure. The elimination of plague as a threat across most of the globe relied on preventative rather than curative measures, and it took centuries for those preventative measures to become fully effective." (O Grada, 2015, p. 23). In terms of how the two diseases are perceived, therefore, there are several similarities that show that historical studies of the plague in Europe may provide some insight into what is important for dealing with Ebola in today's world. Furthermore, Malanima's (2012) analysis shows that the CFR of the plague varied similarly wildly to EVD in different countries with 10% in Austria and up to 50% in Ireland. Given the fact no cure existed for the plague, O Grada (2015) estimates that overall health and nutritional status were important in providing some resistance to the disease and the ability to fight it leading to the different outcomes in CFR and plague intensity in different regions. A number of social factors have come into play in determining these different health and nutritional levels of the population as illustrated by this quote:

> "One of the main lessons from the study of plague is that the characteristics of the pathogen only partly explain the evolution of an epidemic. We need to take into consideration the environment in which the pathogen acts and the institutional context in which the epidemic takes place." (Alfani and Murphy, 2017, p. 326)

This therefore provides a setting for the need to consider social contexts and factors when studying disease outbreaks. Some of the different social contexts that were significant factors in plague outbreaks will be explored below.

Firstly looking at some geographical factors that link to the structure of society, it appears that a regions economic structure and connectedness was an important determinant in how it would be affected by the plague. Europe's trading hubs (Amsterdam, London, Venice) experienced a much higher frequency of plague outbreaks in comparison to other cities (Alfani and Murphy, 2017). Similarly, a high level of integration of commerce with rural regions and interconnectivity can increase the pervasiveness and spread of outbreaks (Curtis, 2016). It seems therefore that highly commercial areas were more susceptible to experiencing a plague outbreak both if they were an international hub and also if they were well connected within their local, national economy. This factor closely interacts with the question of whether the plague was predominantly an urban or a rural phenomenon. While some early waves of plague outbreaks were indeed predominantly urban events, later waves did in fact spread widely in both urban and rural environments (Alfani and Murphy, 2017). Thus, rural populations were affected as well, perhaps due to the fact that they were connected commercially to a regional trading hub as suggested by Curtis (2016). This idea of connectedness also seems relevant in a specific study on Italy which shows that rural populations enjoyed more protection from plague outbreaks, especially if in remote or difficult-to-reach locations (Alfani, 2013). However, despite the fact that trading hubs and very commercially integrated regions did experience a higher frequency of plague outbreaks, it has been found that plague epidemics in the Low Countries were usually more severe in the rural, less-developed regions than in the urban and core commercial regions (Curtis, 2016). Therefore, a higher frequency of outbreaks does not necessarily correlate with the intensity and severity of the outbreak.

There also appears to be a trend in how the plague was affecting different regions depending on their socio-economic status, effectively meaning that the plague predominantly killed the poor, working population. Evidence from across Europe shows that outbreaks of the plague did hit poor communities the hardest, largely due to overcrowding, poor housing, and greater proximity to parasites (Alfani and Murphy, 2017). This would become a self-fulfilling cycle as well where the poor sectors of the cities would be locked down during a plague outbreaks in an attempt to contain it. Evidence from London supports this, with poorer neighbourhoods showing a much higher mortality rates as a result of pandemics (Cummins et al., 2016). It seems that as the plague continued to appear throughout Europe this effect only became stronger over time as the rich started to increasingly self-segregate into more affluent neighbourhoods (Cummins et al., 2016). There they would be able to ensure proper quality of sanitation and care as well as keeping their distance from where most of the plague outbreaks started, in the poorer neighbourhoods.

All of the above research on the plague in rural or urban environments and different socio-economic quarters of the city also supports the choice of using a sub-national administrative regional dataset to study the EVD outbreak in West Africa as there is significant historical evidence not just of differences between different countries but also of different effects internally between different regions.

In an archaeological analysis of epidemic cemeteries it was found that, "people who experienced physiological stressors, and who developed stress markers in response to those stressors … were subsequently more likely to die during the Black Death compared to their peers who lacked the stress markers" (DeWitte, 2014, p.114). This is another social indicator of how plague would affect a population as those not involved in manual labour or living in poor conditions would be less likely to have these stress markers of injury, previous disease, poor nutrition, etc. This argument of linking stressors to poorer health outcomes in times of disease is also repeated by Link and Phelan (1995) with their focus being on modern times and societies and not medieval Europe. It is therefore a studied aspect of the plagued which is similarly relevant in modern times and applicable to modern disease outbreaks.

Lastly, when looking at the plague and preventative measures that were put in place to prevent future outbreaks, it becomes clear that these are of continued relevance today. Actions such as quarantines and restriction of movement were implemented during later plague outbreaks and proved effective, and in large parts are also still the main policy options today when dealing with an epidemic such as Ebola or COVID-19 (Alfani and Melegaro, 2010). There were lockdowns on travel between administrative regions during the West African EVD outbreak and event attempts to lock down different quarters of some of the larger cities. "Quarantine has also been a key weapon against Ebola; a precautionary 21-day quarantine is stipulated for those who have been in close contact with an Ebola victim" (O Grada, 2015, p. 24). The institutional and organisational lessons that were learned from the plague therefore make up the basis of the options for epidemic responses today. However, it does need to be remembered that, "The effectiveness of public health measures depended on being ready, eliminating corruption in the forms of breaching quarantines, concealing deaths, deliberate misdiagnoses of plague cases, and anti-social behaviour in general" (O Grada, 2015, p. 18). While this was relevant for historical plague outbreaks, as we have seen above with regards to the EVD outbreak in West Africa, it still remains relevant today in how to handle institutional response to an epidemic.

Another deadly historical disease with frequent outbreaks was smallpox, which has been effectively eradicated in the modern world. It was highly lethal as well, but survivors would have a life-long immunity to the disease (Davenport et al., 2011). In their study on smallpox in 18th century London, Davenport et al. (2011) show that there were social divides in the mortality levels in different areas and socio-economic classes of London. The different disease outcomes in different social contexts were therefore not isolated to the plague but are relevant to other infectious diseases as well.

It is estimated that today more than 800 million people lack access to clean drinking water and more than twice that number do not have access to proper systems of waste disposal (Gallardo-Albarran, 2020). Yet, these issues of poor sanitation can have significant effect on the spread of infectious diseases if they are water-borne or on the ability to disinfect and keep and environment clean of parasites. Beach et al. (2016) find that investments into water purification and sanitation technologies between 1900 and 1940 were critical in combating the prevalence of typhoid fever in American cities. Gallardo-Albarran (2020) found a similar effect for Germany between 1877-1913 with the added caveat that while investing in better water quality it was also essential to invest in efficient systems of waste removal to ensure an overall higher level of sanitation. Poor sanitation can be a contributing social and infrastructural factor towards a disease outbreak and historically has proven to be a significant factor in keeping disease incidence low.

2.3 The Social Determinants of Health

Social factors have been increasingly linked with overall increases in health, especially through measures of life expectancy and mortality. As Cutler et al. (2006) point out, falling mortality and better health have been linked to economic factors and GDP per capita quite strongly through the use of Preston Curves, which show the diminishing returns to life expectancy at increasingly higher GDP per capita levels. Key factors that had important impacts (positive or negative) on mortality were improved nutrition, public health, urbanization, vaccination, and medical treatments (Cutler et al., 2006). Easterlin (1999) also discusses these relationships and how market forces have actually had negative impacts upon mortality as well due to the massive rates of urbanization and over-crowding in cities that would have led to socio-economic conditions that increased diseases and poor health. There is therefore a lot of data that correlates these factors to different mortality and life expectancy but the main literature on this does not specifically focus on diseases and epidemics and their relationship to socio-economic factors.

The idea of socio-economic factors determining the impact that diseases and epidemics will have upon a population is the primary driving factor behind the theoretical approach of this thesis. Link and Phelan (1995) discuss and define this approach extensively in their paper titled *Social Conditions as Fundamental Causes of Disease*. Their claim is that most research on disease and epidemics focuses on individually-based risk factors such as diet, exercise, and personal habits while neglecting the importance of basic social conditions that actually place the choices made by individuals into context. It is important to provide this context to disease as well as otherwise it is unclear how healthcare interventions and funding change the overall disease impact. Link and Phelan's (1995) approach to the social determinants of health comes in two stages. First, the social conditions they discuss are used to contextualise the individual risk factors that are currently used in research, and second, they push for the recognition of social conditions as a fundamental cause of disease defined by access, or lack of it, to resources. Social inequalities and other imbalances, therefore, can lead to some demographics within the population to lack access to essential resources which would help protect them against the impact of diseases.

In their initial work Link and Phelan (1995) focus on race, socio-economic status, gender, stressful life events, and social support and show how each one of these is correlated with different health outcomes and life expectancies for those at opposite ends of the spectrum. Being aware of the impact of these social factors is important as, “epidemiologists need to contextualise risk factors by asking what it is about people’s life circumstances that shapes their exposure to such risk factors as unprotected sexual intercourse, poor diet, a sedentary lifestyle, or a stressful home life.” (Link and Phelan, 1995, p. 85). Furthermore, by looking at these social factors as fundamental causes of disease helps inform the approach of global health and aid agencies such as WHO and others in their aim to limit the incidence of disease and epidemics in the developing world. It is therefore important to theoretically consider the impact of underlying social conditions upon the disease environment and the health system of a country.

While Link and Phelan (1995) focus mainly upon diseases and healthcare and not so much upon sudden outbreaks of a highly infectious disease such as EVD, the work of Bowden et al. (2014) and Clay et al. (2018) provides a great historical insight into how socio-economic factors played important roles respectively in the severity of tuberculosis in Europe and the 1918 Spanish Influenza pandemic in the United States. Clay et al. (2018) focus on the Influenza pandemic of 1918 and 1919 that infected more than 500 million people worldwide and caused millions of deaths. In their work, they focus on a sub-national dataset by comparing pandemic mortality in different cities and comparing their air pollution level as well as factors related to poverty and public health. They find that air pollution had a significant impact upon mortality and that the other factors related to poverty and public health were also relevant. It therefore shows that looking at the socio-economic preconditions to a severe disease outbreak can be important in helping to determine why that disease was so severe. Bowden et al. (2014), looking at respiratory tuberculosis in post-war Europe, provide an even more insightful look into the relationship between standards of living and socio-economic status and the incidence of disease. They look at a number of important factors such as working conditions, living conditions, nutrition, and medical care in order to try and determine how these social conditions interacted with the case and death rates of respiratory tuberculosis. They show clear results for the importance of these factors in relation to respiratory tuberculosis. Their dataset is also comparable to what is available for the West African EVD outbreak and therefore provides a theoretical and methodological inspiration for the structure of this thesis and its econometric model.

2.4 Summary of the Theory

The theoretical background for this thesis therefore lies in a combination of Link and Phelan's (1995) focus on social factors as the fundamental causes of disease with evidence of important variables form past studies on viral disease outbreaks. EVD to this point has largely been analysed in its own context and been compared to past outbreaks such as the plague but no comprehensive study has been done that applies the theories developed from studies of past diseases to the West African EVD outbreak. From the literature we have seen that certain factors were important drivers in past outbreaks such as urban/rural population, socio-economic status, and health system structure/preparedness in case of the plague in Europe. Furthermore, from further studies of other diseases, sanitation, infrastructure, as well as previous exposure to stresses or diseases are also important factors that interact with how a disease outbreak impacts a population. Link and Phelan's (1995) framework combined with the comparable studies on past outbreaks by Clay et al. (2018) and Bowden et al. (2014) provide the unifying factor that allows for these different potential effects to be combined into one testable model for the case of EVD in West Africa. While it is clear from the literature that observable mechanisms and correlations between social conditions and eventual disease outcomes should exist, no such study has been done for EVD on a sub-national basis thus far. This theoretical approach is therefore unique within the literature on EVD as rather than trying to compare it to a past outbreak of a different disease it is looking to test whether the mechanisms that were important in past outbreaks of different diseases are also relevant and applicable to the case of EVD.

3 Methodology

The methodology that underlies this work is essentially a quantitative, post-positivist one, inspired in its structure by the work of Bowden et al. (2014) related to respiratory tuberculosis in post-war Europe. Given the nature of epidemics and disease outbreaks in their ability to spread panic and hysteria, a lot of reporting of the impact of diseases is made with these emotions in mind and lacks the analytical approach needed to build upon the tragic lessons learnt from a deadly disease outbreak. The study of such outbreaks needs to be based on data and evidence in order to be able to take effective learnings from the history of these diseases and apply them to how we prepare for the future. The methods applied in this thesis are therefore quantitative and econometric in order to be able to estimate correlations that shine some lights upon the socio-economic factors that can be said to be pre-determinants of EVD outbreaks intensity and severity. The design and approach are therefore based in the research design proposed by Creswell (2013).

3.1 The Model

The model used for this study will be a standard ordinary least squares (OLS) model that will take the following three forms for regional EVD cases, deaths, and Case Fatality Rate (CFR):

$$EVD_{cases} = \alpha + \beta_1 population + \beta_2 sanitation + \beta_3 diseases + \beta_4 healthsystem + \beta_5\, controls + \varepsilon$$

$$EVD_{deaths} = \alpha + \beta_1 population + \beta_2 sanitation + \beta_3 diseases + \beta_4 healthsystem + \beta_5\, controls + \varepsilon$$

$$EVD_{CFR} = \alpha + \beta_1 population + \beta_2 sanitation + \beta_3 diseases + \beta_4 healthsystem + \beta_5\, controls + \varepsilon$$

Where β_1, β_2, β_3, β_4, and β_5 represent the parameters that will be estimated in the regression and ε represents the error term. Three different dependent variables will be used, which are the total number of reported EVD cases in a region (EVD_{cases}), the total number of reported EVD deaths in a region (EVD_{deaths}), and finally the ration of EVD_{deaths} over the EVD_{cases}, commonly referred to as the Case Fatality Rate (EVD_{CFR}). The independent variables for the purposes of this model have been grouped into four main groups as well as one control group. The first group, *population*, contains variables that describe the different population characteristics in each region such as total population, population density, urban population, total employment, and percentage of people employed in non-agricultural manual labour. This group of variables should give insight into how the overall structure and distribution of the regional population plays into the outcomes of the EVD outbreak. The second group, *sanitation*, contains variables that deal with the basic sanitary infrastructure that exists within each region such as the proportion of households that have access to a protected water source within their house/compound, the proportion of households with a flushing toilet, the distance to the closest water source, as well as proper garbage disposal practices. These *sanitation* variables will provide an idea of whether basic infrastructure is important as a pre-determinant factor in the intensity of an EVD outbreak. The third group, *diseases*, concerns itself with the prevalence and protection from endemic diseases in the African context as well as vaccinations and nutrition with variables such as childhood vaccination rates, Body Mass Index (BMI), hand washing practices within households, number of mosquito nets owned, and safe practices and knowledge of AIDS. These variables concerning themselves with the current health and disease environment of the population will show whether an overall high level of preparedness within a regional population allowed it to resist better during the EVD outbreak. The fourth group, *healthsystem*, concerns itself with the structure and quality of the health system prior to the EVD outbreak with a variable for the total number of health centres or hospitals in a region, and another one for how far away the closest health centre is from a household. These two should give an indication of whether the structure and reach of the local health system is an important driver of how a region is impacted by an EVD outbreak. Lastly, the *control* group of variables includes the GDP per capita, the Gini coefficient, and the number of intensive care beds that were available in each country or region in 2014 at the start of the outbreak.

Three different models for each dependent variable will be estimated that will based upon different underlying samples. The first is a full sample of all administrative regions within Guinea, Liberia, and Sierra Leone to give an overall idea of the socio-economic factors that played a role in the EVD outbreak. The second focuses only upon those regions which had more than 25 reported EVD cases during the outbreak in order to only look at those regions which were significantly impacted by the EVD outbreak. The sample in the second model is reduced from 63 regions to 44. The last sample cuts out the administrative regions of the capitals in each country but retains the low EVD case regions leaving a sample of 60 regions. The rationale behind this is that the capitals in each country usually have a much higher level of development to the other regions and therefore distort the sample upwards, as shown in the case of Sierra Leone's healthcare system being centred around urban centres such as Freetown (United Nations Development Group, 2015). This third sample should give the most accurate results with regards to what socio-economic factors played a role in the EVD outbreak severity and intensity in most regions within Guinea, Liberia, and Sierra Leone.

Lastly, the focus here is on three different dependent variables because it might be the case that different groups of the outlined independent variables may have different mechanisms of effect and thus while some may impact the number of cases a region suffers, others may either limit the number of deaths or the CFR. In trying to model and understand the impact of socio-economic determinants of health during an epidemic outbreak, it therefore important to focus on these different outcomes in order to get a more complete picture. With this in mind, the following table (Table 3 – 1) predicts the expected directions of impact of each group upon the different dependent variables based upon the findings of Bowden et al. (2014) as well as other studies looking at historic disease outbreaks such as the plague. The expectations therefore are that higher population density and urban populations lead to higher incidences of EVD, while a better sanitary environment leads to lower incidences. The preparedness for other, potentially endemic, diseases is likely negative on case and death rates, but it is unclear whether it will have much of an effect on the actual lethality of this new virus to the region measured in CFR. A better health system may not have much of an effect upon case rates, but should help in driving down the number of deaths and the CFR as well.

Table 3-1 - Expected Outcomes of the Econometric Model (Based upon Bowden et al. (2014))

Variable Group	**EVDcases**	**EVD_{deaths}**	**EVD_{CFR}**
population	+	+	+
sanitation	-	-	-
disease	-	-	no effect
healthsystem	no effect	-	-
control			

4 Data

This section starts with a discussion of the source material that was used to build a sub-national dataset on EVD cases, deaths, and CFR. This will give an understanding of the origin of the data as well as its underlying quality and reliability. After that, some descriptive statistics are presented to show the underlying distributions and characteristics of the different variables that will be used in the econometric model. The dependent variables will be looked into first, followed by detailed summaries of the independent variables.

4.1 Source Material

The main data for the EVD cases, deaths, and CFR that is broken down sub-nationally into regions and prefectures for Guinea, Liberia, and Sierra Leone is taken from a dataset that was compiled by UN OCHA ROWCA with data that was compiled manually from a number of published reports by national and regional governments and health ministry officials (OCHA, 2015). As such it contains all officially reported cases by these state entities and divides them into their respective regions. It is a time-series dataset that covers the progression over the course of the EVD outbreak, but for the purposes of this paper only the final total number was used to get a value for the aggregate number of cases that a sub-national region experienced. Given that it is a manually compiled dataset, there is the possibility of recording errors as the reported numbers are transcribed into this dataset, but given the fact that hundreds of reports are included into the final dataset and only the final total number is used in the data here, the chances of these manual errors having an impact are minimal. The bigger issue with data reporting on EVD cases and deaths is the potential for underreporting which some estimates claim was widespread in the West African outbreak (WHO, 2014). Underreporting and underestimation of EVD numbers could be due to family members hiding infected loves ones or once the epidemic properly struck there simply not being enough manpower in overwhelmed hospitals and health centres to correctly record case figures when being in a daily battle to overcome a deadly viral outbreak. As such, the data that was collected by the UN OCHA ROWCA may suffer from an underestimation bias which might show in the econometric model and it is important to be aware of this. However, no better sub-national data is currently available and since the bias will be structural and uniformly downwards, this dataset on EVD cases and deaths will be used for the econometric model.

The data on the characteristics of the sub-national regions within Guinea, Liberia, and Sierra Leone is taken from the most applicable population census and demographic and health survey in each country from around or just before the time of the EVD outbreak. For Guinea that means the census from 2014 and the demographic and health survey from 2012 (Institut National, 2016)(Institut National, 2014). For Liberia the census from 2008 was used and the demographic and health survey from 2013 (Liberia Institute of Statistics, 2014)(Liberia Institute of Statistics, 2009). In the case of Sierra Leone, the census is from 2015 and demographic and health survey from 2013 (Statistics Sierra Leone, 2016)(Statistics Sierra Leone, 2013). The process of each of these surveys was driven by the national statistical office in each nation and supported by the World Bank, UNFPA, WHO, UNICEF, as well as various national development agencies. The support from these organisations ensures that the methodology and data collected by these surveys is of a comparable standard for the purposes of econometric studies such as this. One issue with using these is that the census from Liberia is a number of years earlier from the other ones and may not reflect the actual conditions of regional development within Liberia before it was hit by the EVD outbreak. Nevertheless, the assumption is made that while the exact figures may have changed, the relative trend and position of the different regions within Liberia has not changed as much and can therefore still provide some insight into the socio-economic conditions before Ebola. In the case of Sierra Leone, sub-national data from the previous (2004) census was unavailable which means that census data from the census during the pandemic (2015) had to be used. The assumption here is that the data used on household sanitation as well as urban population and population density would not have changed drastically during or immediately following the crisis and would be more affected in the long-term. With these limitations in mind, the data was compiled into an overall dataset with the EVD cases and deaths to be used in the econometric model.

Further data on the number of health facilities as well as the control variables was taken from a selection of other sources such as Standby Task Force (2015), the OECD (2020), and the most recent Maddison Project Database (2018).

4.2 Descriptive Statistics

There are 63 total observations within the dataset, each of which corresponds to an administrative region or prefecture of Guinea, Liberia, and Sierra Leone. The 34 prefectures of Guinea, 15 counties of Liberia, and 14 districts of Sierra Leone are shown in Figure 4 – 1 to 4 – 3 below. The UN OCHA dataset contains reports on the number of reported cases and deaths in each of these 63 regions which on aggregate reports 3463 cases and 2339 deaths for Guinea, 8905 cases and 3858 deaths for Liberia, and 11908 cases and 3561 deaths for Sierra Leone. This data on cases and deaths is a little different from the overall numbers that are reported by the WHO and CDC on the outbreak, likely because there were some reports made by ministries that could not be accurately assigned to a specific region and were therefore not included in the dataset (CDC, 2019) However, the national CFR rates that can be calculated for this dataset (Guinea at 67,5%, Liberia at 43,3%, and Sierra Leone at 29,9%) are still similar to the overall reported numbers presented in the first chapter (Guinea at 67%, Liberia at 45%, and Sierra Leone at 28%), which shows that the overall reporting of national statistics and regional statistics appears to be very similar.

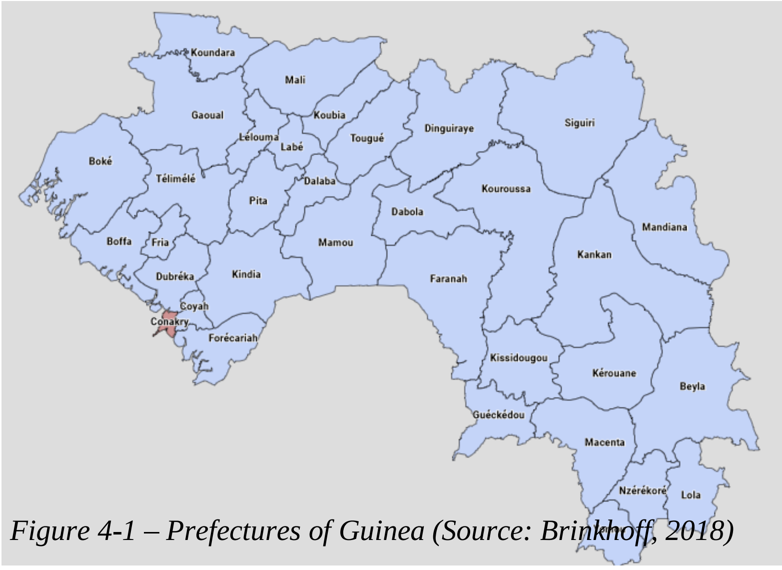

Figure 4-1 – Prefectures of Guinea (Source: Brinkhoff, 2018)

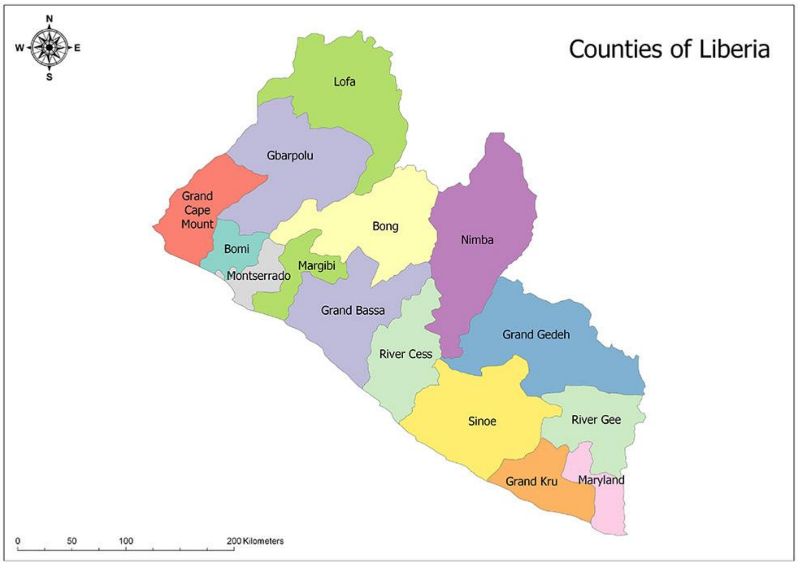

Figure 4-2 – Counties of Liberia (Source: MapUniversal, 2020)

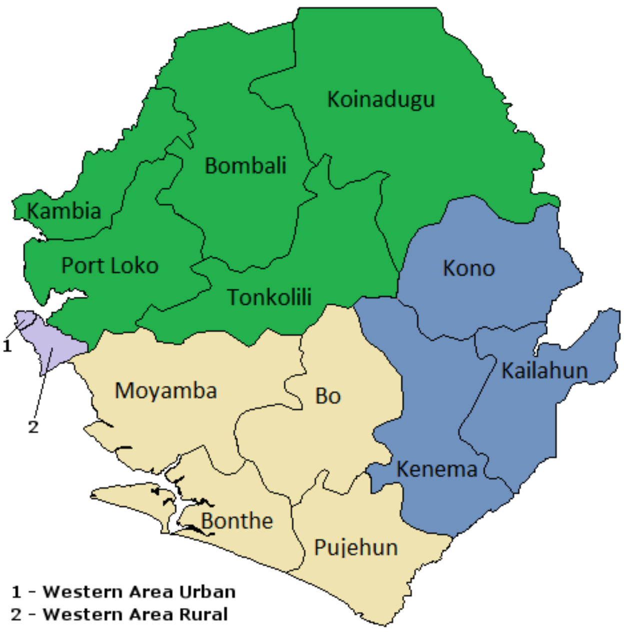

Figure 4-3 - Districts of Sierra Leone (Source: Wikimedia, 2020)

Looking at the independent variables, these have been categorized into five different groups as explained during the methods section and their descriptive statistics can be found in Table 4 – 1. While most of the variables are self-explanatory in how they are laboured, a couple do need to be further clarified here. Manual labour employment is a measure of the amount of people in each region that are employed in manual labour that is not agriculture as a proxy for the amount of people that may be working in simple industrial or similar circumstances as this was found to be significant driver of later disease outcomes by Bowden et al. (2014). Protected water source is defined as having a protected water source such as a tap either inside ones household or within the compound where one lives, flushed private toilets follow the same definition. High distance to water source is the proportion of households whose water source is further away than 1 mile. Safe garbage disposal means the garbage is dumped as part of a proper waste disposal system and not near a water source, on a nearby field, etc. Children with vaccinations refers to the proportion of children that have received all basic vaccinations outlined by the demographic and health survey. Hand washing asked households what proportion regularly washed their hands and had ability to do this at home. Poor AIDS awareness means that survey respondents failed to correctly answer a list of basic questions with regards to how AIDS is transmitted and affects the human body. The distance from a health facility is defined as the proportion of households whose nearest health facility is further than 5 miles away. The control variable of Ebola intensive care beds is a measure taken at the end of 2014 (a year since the first confirmed case in Guinea) to attempt to control for the different responses from the three different countries.

Table 4-1 - Descriptive Statistics

	Total				
	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Population Characteristics					
-Population	63	336260	270015	57913	1667864
-Population Density	63	1411,38	10173,42	8,38	20792,38
-Urban Population	63	27,18	25,87	1,90	100,00
-Total Employment	63	78,32	10,03	55,30	93,70
-Manual Labour Employment	63	24,03	13,16	9,40	74,90
Sanitation					
-Protected Water Source	63	22,92	19,09	3,10	85,40
-Flushed Private Toilets	63	5,29	5,54	1,00	30,18
-High Distance to Water Source	63	0,248	0,159	0,027	0,559
-Safe Garbage Disposal	63	54,76	21,00	6,50	91,40
Diseases					
-Children with vaccinations	63	45,97	16,78	19,30	84,70
-Normal BMI	63	71,14	5,07	54,20	80,80
-Hand Washing Habits	63	22,39	18,83	0,90	58,00
-No Mosquito Nets owned	63	0,379	0,153	0,056	0,604
-Poor AIDS awareness	63	22,57	9,80	4,80	49,70
Health System					
-Total Health Facilities	63	58,19	51,99	12,00	309,00
-Far away from Nearest Health Facility	63	0,399	0,167	0,0607	0,757
Controls					
-GDP per capita (2013)	63	1361	314	827	1684
-Gini Coefficient	63	0,307	0,082	0,050	0,410
-Ebola Intensive Care Beds	63	491	275	250	896

5 Empirical Analysis

In this section the results of the econometric empirical analysis will be presented followed by a discussion of these results. The results are broken down into sections focusing on each dependent variable and the different models that were estimated for each. The discussion then focuses on the overall impact that different socio-economic factors had upon the intensity and severity of the EVD outbreak in West Africa.

5.1 Results

5.1.1 Number of reported EVD cases

Looking first at the number of reported EVD deaths, the results for the whole sample as well as the one where the capital cities are removed are shown in Tables 5 – 1 and 5 – 2. For further detail, the results from the sample only including regions with a case count higher than 25 can be found in the Appendix B. As we can see from model (1) in both the tables below, a higher population density is positively correlated with having a higher number of cases of EVD reported. What is interesting is that this effect becomes larger and more significant when the capital city regions, which also had large, outlying, figures of population density, were removed. This effect remains relevant for model (5) in the second sample, which combines all socio-economic effects in the outlined in the methodology. Having flushed private toilets is positively correlated with EVD cases, but this effect disappears when the capital cities are removed. Having a protected water source is negatively correlated with case numbers in model (5) of the restricted sample, which indicates that it is of some importance in determining regional case rates in the less affluent regions of a country. A strange result is that having higher rates of basic vaccinations is correlated with higher EVD cases in some of the models both in the whole sample as well as the one that excludes capital cities, and some potential reasons for this will be touched upon in the discussion session. There is a correlation between more households not owning mosquito nets and poor AIDS awareness in the different samples as well, where both contribute towards higher reported EVD cases. Lastly, when looking at the two variables for the health system, the total number of health facilities and the number of households that were far away from a health facilities, there does seem to be some evidence of underreporting in the data here. Having a larger number of health facilities is positively correlated with higher EVD case numbers in the whole sample, while more households being further away is negatively correlated with the number of EVD cases in the sample that excludes the capital cities. The reasons behind this, and the mechanisms at play, will be further explored in the discussion section.

Table 5-1 - EVD Cases - Whole Sample

VARIABLES	Dependent Variable: Number of reported EVD cases				
	(1)	(2)	(3)	(4)	(5)
-Population	0.000936 (0.000889)				-6.92e-05 (0.000564)
-Population Density	0.0193* (0.00995)				0.00764 (0.0110)
-Urban Population	6.384 (3.875)				4.886 (3.018)
-Employment	-4.124 (6.195)				4.567 (12.34)
-Manual Labour	3.579 (8.913)				8.915 (11.55)
-GDP per capita	-0.409 (0.463)	0.0519 (0.678)	0.370 (0.375)	-1.108** (0.488)	-0.507 (0.928)
-Gini	-593.0 (1,043)	-1,636 (1,409)	-2,494 (1,996)	567.7 (1,086)	265.6 (1,018)
-ETU beds	0.584 (0.419)	2.002*** (0.709)	1.148 (0.749)	-0.661 (0.531)	0.0215 (0.725)
-Protected Water Source		-11.85 (14.38)			-16.57 (10.72)
-Flushed Private Toilets		124.5*** (44.02)			100.0*** (30.46)
-High Distance to Water Source		1,356 (1,067)			2,061 (1,240)
-Safe Garbage Disposal		-5.376 (7.523)			-1.991 (7.129)
-Children with Vaccinations			1.549 (8.114)		17.19* (8.799)
-Normal BMI			1.116 (16.82)		35.37 (22.58)
-Hand Washing Habits			1.435 (5.485)		-8.206 (8.811)
-No Mosquito Nets			1,603* (833.7)		96.95 (792.7)
-Poor AIDS Awareness			27.18* (15.82)		17.20** (8.426)
-Total Health Facilities				13.39*** (3.414)	8.669** (4.208)
-Far from nearest Health Facility				-1,283 (788.1)	224.9 (866.5)
Constant	558.1 (1,069)	-596.5 (1,539)	-1,322 (1,844)	1,777 (1,081)	-4,403 (3,747)
Observations	63	63	63	63	63
R-squared	0.581	0.577	0.427	0.671	0.841

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5-2 - EVD Cases - Capital Cities Excluded

	Dependent Variable: Number of reported EVD cases				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	0.000826** (0.000349)				0.000754* (0.000422)
-Population Density	2.376*** (0.337)				2.996*** (0.512)
-Urban Population	-1.388 (1.404)				-2.371 (1.517)
-Employment	-4.440 (3.854)				-1.877 (6.660)
-Manual Labour	-4.953 (5.050)				-6.774 (7.587)
-GDP per capita	-0.273 (0.165)	0.0752 (0.470)	0.349 (0.321)	-0.203 (0.254)	-1.590** (0.605)
-Gini	-101.7 (550.5)	-365.3 (922.2)	564.8 (767.0)	439.5 (658.5)	-348.6 (700.6)
-ETU beds	0.519** (0.197)	0.787* (0.395)	0.627 (0.433)	0.409 (0.449)	-0.182 (0.377)
-Protected Water Source		4.775 (6.312)			-13.91* (7.957)
-Flushed Private Toilets		5.493 (22.81)			-5.345 (18.33)
-High Distance to Water Source		355.3 (528.2)			-779.8 (617.6)
-Safe Garbage Disposal		4.374 (4.968)			7.614 (4.615)
-Children with Vaccinations			10.24*** (3.398)		8.536 (5.774)
-Normal BMI			12.97 (11.70)		0.493 (14.28)
-Hand Washing Habits			-2.487 (3.042)		6.569 (4.584)
-No Mosquito Nets			1,037 (709.3)		-559.3 (526.5)
-Poor AIDS Awareness			2.509 (4.960)		8.906* (5.248)
-Total Health Facilities				2.059 (3.429)	-0.336 (2.646)
-Far from nearest Health Facility				-998.1* (502.7)	-790.8 (548.1)
Constant	516.1 (611.5)	-562.9 (1,033)	-2,484** (1,198)	503.3 (539.0)	2,461 (2,223)
Observations	60	60	60	60	60
R-squared	0.681	0.381	0.433	0.425	0.788

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.1.2 Number of reported EVD deaths

The effects for number of reported EVD deaths were expected to be similar to what would happen for the number of reported EVD cases and the results can be seen in tables 5 – 3 and 5 – 4. Population density is again positively correlated with the dependent variable, however only for the sample that excludes the capital cities. Having a higher urban population is also positively correlated with a higher death rate as a result of EVD, although this effect appears to be mainly driven by the densely, and over-populated, capital cities as it does not hold in the reduced sample. Having a higher proportion of the population working in manual labour that is not agriculture is actually negatively correlated with the number of reported EVD deaths. Having a protected water source is negatively correlated with EVD deaths both in the whole and the reduced sample, which means there is a stronger effect here for this variable than there was for the number of reported EVD cases. The same effect for the private flushed toilets holds here as it did above for the number of EVD cases and this will need to be explored further. Better levels of childhood vaccinations are also correlated with higher deaths which is a strange result and will be discussed below. Poor AIDS awareness and not owning mosquito nets are both positively correlated with a higher number of reported EVD deaths although they only show significance in the total sample and the one with cases higher than 25, and not the one where the capital cities are excluded. Lastly, the same underreporting/overreporting issues that existed with regards to the health system variables can be seen here, which is interesting because it means that people were not just underreporting cases of the illness but also the eventual fatalities that would arise out of this.

Table 5-3 - EVD Deaths - Whole Sample

	Dependent Variable: Number of reported EVD deaths				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	0.000368 (0.000354)				-9.42e-05 (0.000193)
-Population Density	0.00205 (0.00386)				-0.00314 (0.00436)
-Urban Population	2.825* (1.603)				2.114 (1.270)
-Employment	-2.186 (2.639)				1.035 (4.732)
-Manual Labour	-0.508 (3.378)				1.554 (4.601)
-GDP per capita	-0.226 (0.191)	-0.136 (0.215)	0.0259 (0.137)	-0.513** (0.223)	-0.339 (0.363)
-Gini	-402.8 (431.4)	-958.2* (537.6)	-1,029 (791.0)	-81.81 (417.7)	-17.29 (400.7)
-ETU beds	0.163 (0.167)	0.534** (0.241)	0.0681 (0.237)	-0.346 (0.225)	-0.274 (0.279)
-Protected Water Source		-7.174 (5.311)			-7.778* (4.138)
-Flushed Private Toilets		49.61** (18.87)			38.08*** (11.82)
-High Distance to Water Source		222.2 (315.6)			540.0 (464.0)
-Safe Garbage Disposal		-2.175 (2.721)			-1.494 (2.919)
-Children with Vaccinations			4.445* (2.629)		7.568** (3.565)
-Normal BMI			2.003 (6.188)		11.04 (8.869)
-Hand Washing Habits			-0.580 (1.845)		-3.043 (3.356)
-No Mosquito Nets			557.3* (312.8)		39.36 (306.7)
-Poor AIDS Awareness			9.047 (6.081)		5.924* (3.468)
-Total Health Facilities				4.289** (1.643)	4.097** (1.631)
-Far from nearest Health Facility				-612.7** (290.1)	-112.6 (322.5)
Constant	486.5 (443.6)	336.8 (479.7)	-347.6 (683.9)	1,044** (493.3)	-865.6 (1,386)
Observations	63	63	63	63	63
R-squared	0.458	0.557	0.363	0.585	0.802

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5-4 - EVD Deaths - Capital Cities Excluded

VARIABLES	Dependent Variable: Number of reported EVD deaths (1)	(2)	(3)	(4)	(5)
-Population	0.000218 (0.000147)				7.70e-05 (0.000167)
-Population Density	0.841*** (0.147)				1.141*** (0.199)
-Urban Population	-0.0148 (0.707)				-0.466 (0.737)
-Employment	-1.889 (1.945)				-0.775 (2.346)
-Manual Labour	-4.026* (2.117)				-4.981** (2.239)
-GDP per capita	-0.126 (0.0820)	-0.00338 (0.191)	0.0598 (0.106)	-0.182* (0.106)	-0.688** (0.263)
-Gini	-130.7 (267.0)	-223.9 (407.1)	248.0 (269.9)	76.44 (255.1)	-26.91 (280.8)
-ETU beds	0.178* (0.0906)	0.131 (0.153)	-0.00224 (0.158)	-0.0255 (0.161)	-0.251 (0.155)
-Protected Water Source		1.849 (2.853)			-6.126* (3.606)
-Flushed Private Toilets		-1.833 (10.05)			-5.310 (7.990)
-High Distance to Water Source		-4.603 (197.4)			-363.8 (235.2)
-Safe Garbage Disposal		1.365 (1.830)			2.600 (1.814)
-Children with Vaccinations			6.764*** (1.842)		5.551** (2.312)
-Normal BMI			7.960 (5.136)		-0.425 (5.167)
-Hand Washing Habits			-1.528 (1.128)		2.506 (1.659)
-No Mosquito Nets			408.5 (253.4)		-89.57 (203.8)
-Poor AIDS Awareness			0.370 (2.064)		3.024 (2.092)
-Total Health Facilities				1.497 (1.221)	0.931 (1.343)
-Far from nearest Health Facility				-429.4** (189.2)	-410.2** (183.8)
Constant	361.1 (304.6)	18.63 (410.6)	-1,054** (465.3)	447.2* (251.7)	1,184 (878.4)
Observations	60	60	60	60	60
R-squared	0.431	0.186	0.341	0.305	0.662

Robust standard errors in parentheses

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

5.1.3 EVD Case Fatality Rate (CFR)

The ratio of the number of reported EVD deaths and the number of reported EVD cases was used as the EVD CFR in an effort to understand whether different socio-economic factors had an impact upon how severe or deadly the outbreak would be in different regions. While there are some trends between the socio-economic factors and the number of EVD cases and deaths, the results for the CFR are much less consistent as seen in tables 5 – 5 and 5 – 6. Having flushed private toilets was significantly correlated with lower CFR, suggesting that proper sanitation can play a factor in how deadly a disease will be. In the reduced sample which excludes the capital cities, proper hand washing techniques was correlated with lower CFR and not owning a mosquito net was positively correlated with a higher CFR. One thing that does stand out throughout the results on CFR is that the control variable for the number of intensive care beds available in ETUs (Ebola Treatment Units) was highly significant in every single model. This control was included in an attempt to include the effects of different responses to the crisis. These results presented here seem to suggest that while socio-economic factors may have some impacts upon the number of cases and deaths in an EVD outbreak, the intensity of the CFR is ultimate a result of the response of the local, regional, and international system to the outbreak and its attempts to control it.

Table 5-5 - EVD CFR - Whole Sample

	Dependent Variable: EVD Case Fatality Rate (CFR)				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	-1.09e-08 (1.83e-07)				3.48e-08 (2.65e-07)
-Population Density	6.13e-07 (1.40e-06)				-5.80e-07 (4.02e-06)
-Urban Population	0.00183 (0.00197)				0.000273 (0.00234)
-Employment	0.00721 (0.00432)				-0.00215 (0.00487)
-Manual Labour	-0.00306 (0.00318)				0.00198 (0.00476)
-GDP per capita	- 0.000165* (8.43e-05)	-0.000309* (0.000177)	-5.14e-05 (0.000168)	-9.70e-05 (0.000106)	-0.000208 (0.000291)
-Gini	0.0664 (0.616)	-0.715* (0.423)	0.137 (0.480)	-0.334 (0.436)	-0.264 (0.522)
-ETU beds	-0.000180 (0.000138)	- 0.000947*** (0.000220)	- 0.000607*** (0.000181)	- 0.000201** (9.62e-05)	- 0.00132*** (0.000344)
-Protected Water Source		-0.00224 (0.00236)			-0.00166 (0.00439)
-Flushed Private Toilets		-0.0190** (0.00866)			-0.0237** (0.00973)
-High Distance to Water Source		-1.497*** (0.442)			-1.736*** (0.544)
-Safe Garbage Disposal		0.000810 (0.00261)			-0.00147 (0.00320)
-Children with Vaccinations			0.00756** (0.00300)		0.00129 (0.00333)
-Normal BMI			0.0154** (0.00699)		0.00542 (0.00967)
-Hand Washing Habits			-0.00544 (0.00337)		-0.00391 (0.00315)
-No Mosquito Nets			0.467 (0.294)		0.313 (0.351)
-Poor AIDS Awareness			0.000737 (0.00321)		-0.00324 (0.00347)
-Total Health Facilities				-2.45e-05 (0.000565)	0.00113 (0.00143)
-Far from nearest Health Facility				0.230 (0.306)	-0.219 (0.477)
Constant	0.218 (0.498)	2.048*** (0.354)	-0.728 (0.619)	0.707** (0.296)	1.871 (1.160)
Observations	63	63	63	63	63
R-squared	0.161	0.327	0.245	0.096	0.408

Robust standard errors in parentheses

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

Table 5-6 - EVD CFR - Capital Cities Excluded

	Dependent Variable: EVD Case Fatality Rate (CFR)				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	-1.97e-07 (2.76e-07)				-2.18e-07 (4.49e-07)
-Population Density	0.000282 (0.000436)				0.000408 (0.000468)
-Urban Population	0.00162 (0.00235)				-0.000229 (0.00273)
-Employment	0.00852* (0.00450)				-0.00154 (0.00549)
-Manual Labour	-0.00602 (0.00437)				-0.00157 (0.00440)
-GDP per capita	-0.000143 (0.000134)	-0.000261 (0.000181)	-7.51e-05 (0.000168)	-0.000148 (0.000167)	-0.000181 (0.000271)
-Gini	0.294 (0.646)	-0.0400 (0.483)	0.643 (0.633)	-0.293 (0.566)	0.255 (0.499)
-ETU beds	-5.90e-05 (0.000174)	- 0.00101*** (0.000239)	- 0.000658*** (0.000205)	-0.000277 (0.000173)	- 0.00107*** (0.000305)
-Protected Water Source		-0.000235 (0.00270)			0.000576 (0.00352)
-Flushed Private Toilets		-0.0416*** (0.0131)			-0.0484*** (0.0166)
-High Distance to Water Source		-1.585*** (0.431)			-1.664*** (0.542)
-Safe Garbage Disposal		0.00181 (0.00275)			0.00114 (0.00317)
-Children with Vaccinations			0.00917*** (0.00319)		0.00355 (0.00367)
-Normal BMI			0.0223*** (0.00811)		0.00537 (0.00802)
-Hand Washing Habits			-0.00639* (0.00334)		-0.00206 (0.00313)
-No Mosquito Nets			0.456 (0.309)		0.551* (0.323)
-Poor AIDS Awareness			0.000284 (0.00359)		-0.00386 (0.00325)
-Total Health Facilities				0.000874 (0.00133)	0.000415 (0.00210)
-Far from nearest Health Facility				0.228 (0.340)	-0.122 (0.403)
Constant	0.0608 (0.543)	1.819*** (0.415)	-1.365* (0.728)	0.757 (0.467)	1.324 (0.992)
Observations	60	60	60	60	60
R-squared	0.173	0.373	0.278	0.090	0.454

Robust standard errors in parentheses

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

5.2 Discussion

Some of the results will need to be discussed in more detail with regards to what they show and how this relates to the literature as well. The original theory on the social determinants of health by Link and Phelan (1995) was structured more as a meta-study that incorporated the findings of multiple studies to determine whether there may be a general link between certain socio-economic pre-conditions and health outcomes within populations, which is why numerous other studies on past outbreaks were also presented in the literature review. From the results above, we can see that there do appear to be some links and correlations between different socio-economic conditions in different regions of Guinea, Liberia, and Sierra Leone and the ultimate number of reported cases and deaths as a result of the EVD outbreak. The key findings to report that are in line with the expectations from the literature are that high population density and urban populations are contributing factors to the scale of an outbreak and the number of fatalities. These findings on EVD and population characteristics are comparable to historic cases of the plague and tuberculosis in Europe (Alfani and Murphy 2017; Bowden et al. 2014). Having a safe and protected water source along with protection against other diseases such as mosquito nets or awareness of AIDS are also important factors in determining how resilient a population will be against an outbreak of EVD. This is in line with the demonstrated past effects of sanitation and disease resistance found by Gallardo-Albarran (2020) and Beach et al. (2016). There is therefore clear evidence that the social determinants of health are important to consider when trying to understand why an outbreak of EVD of this scale could occur. While it does appear that for different diseases different factors may be of more or less importance there is a clear comparable pattern of the correlation between socio-economic factors within society and how it will be affected by a disease outbreak.

While these findings answer the first research question discussed in the Introduction with regards to which socio-economic variables are important with regards to EVD cases, deaths, and CFR, it does not yet address whether all these are equally important in determining each of these dependent variables. Clear comparisons on similar trends can be made with regards to the similarities between the number of reported EVT cases and deaths, but this largely breaks down when looking at the CFR. The social determinants of health therefore appear to be important for the absolute numbers of an outbreak of EVD but are not strongly linked to the ratio between them. EVD has a widely varying CFR, with outbreaks in the past ranging from a 25% fatality rate to 89% (HDX, 2015). With a highly contagious disease like EVD getting control of the spread and doing proper contact tracing are key aspects to properly controlling the situation and the spread (Walsh and Johnson, 2018). This, in line with a properly functioning healthcare system, is the key to controlling the outbreak and the CFR. As already mentioned, with proper medical care and early enough detention the CFR should drop down to about 10% (Farmer, 2014). The CFR therefore might still be dependent upon some socio-economic factors such as the healthcare system, but it does seem that it is primarily determined by the responsiveness of the local government and its ability to organize an effectively response. In the West African outbreak, MSF did accuse the local governments of Guinea, Liberia, and Sierra Leone as well as the WHO of trying to hide or downplay the scale of the outbreak and of not responding quickly and effectively enough (O Grada, 2015). The variations in the regional CFR during the West African outbreak could therefore be due to delays in the local response to the outbreak coupled with inefficiencies, underfunding, and lack of supplies within the local healthcare sector that did not allow for proper treatment to take place.

While it should have been theoretically possible to capture some of these effects of the healthcare sector on CFR, it appears that the controversy with regards to underreporting of EVD numbers is indeed evident within this dataset. This means that we cannot make a clear judgement upon the effect of the healthcare variables as more healthcare facilities being available meant that more cases and deaths would be reported at the location while at the areas that were further away from a healthcare facility the reported cases and deaths were lower. There are some different views with regards to how large the number of underreported cases is, with estimates of the number of unreported cases being between 17 and 70% (McNeil Jr, 2014). It is unclear from the results here how large the underreporting of cases and deaths is in the sub-national dataset that was used but it does appear like there is some downward bias in the data.

There is also an outlying result within the data which is the fact that there appears to be a correlation between higher level of vaccinations for the children in households and higher cases and deaths reported during the EVD outbreak. It is unclear whether this is due to a similar bias as above, where those regions which have more health facilities reporting higher cases and deaths but also being able to provide a higher level of vaccination to their children. More research and clarity are needed with regards to the data and the bias in order to be able to answer this question as well as the ones with regards to the health system.

6 Conclusion

This study has managed to build a sub-national dataset on EVD outbreak cases, deaths, and CFR and use it in order to look at the question of how important various socio-economic factors were in determining the intensity and severity of the 2013-2016 EVD outbreak in Guinea, Liberia, and Sierra Leone.

6.1 Research Aims and Objectives

The results from the econometric model help to answer the first research question of which socio-economic factors are important determinants of the number of cases, deaths, and the CFR in the West African EVD outbreak in 2013-2016. They show us that there are a number of parallels that can be drawn to past outbreaks of infectious diseases in different parts of the world and that there is support for the general theory of socio-economic factors being contributing determinants of health. With regards to the second research question of whether they have the same effect for all three dependent variables of cases, deaths, and CFR, the answer is that the effect is different. The socio-economic variables that were chosen for the model in this thesis appear to be determinants of the number of cases and deaths of the EVD outbreak but are not very clearly correlated with the CFR. It appears that the CFR, or lethality, of EVD is also determined by the responsiveness of local authorities to the outbreak and further research would need to be done to understand the different mechanisms at play here that truly determine the EVD CFR.

6.2 Practical Implications

The results from this work seem to indicate two areas of consideration when looking at their practical implications. First is the overall need to invest in public health infrastructure, sanitation, and disease prevention. This is part of the development agenda of most countries already but as we can see it needs to be priority because when crisis hits, the shortcomings here can really cost the local economy and population. The IMF and World Bank had set goals for the public health infrastructure investments that needed to be done by Guinea, Liberia, and Sierra Leone and all three of them were trailing behind their commitments when the EVD outbreak occurred (Kentikelenis et al., 2015). While this may not necessarily be the fault of the local governments, they need to be aware of these shortcomings and the WHO and other global health organizations also need to be aware of this when an outbreak occurs. Being aware of the socio-economic context in which an outbreak takes place is then an important part of planning the response to the outbreak and how to fight the disease. The West African EVD outbreak was ultimately controlled by taking local social customs into consideration and using them in order to help with contact tracing and disease prevention (Richards, 2016; Walsh and Johnson, 2018). It is therefore key for an effective response to an outbreak to be aware of the local socio-economic conditions as well as the strengths and weaknesses in the system that will allow health officials to combat the disease and its spread.

6.3 Future Research

While this study establishes the fact that socio-economic determinants of health do play a factor in EVD outbreaks when looking at the greatest outbreak to date in West Africa, further research needs to be done to expand upon this base. While it is useful to study a singular outbreak of this size and intensity, it now needs to be compared to other EVD outbreaks that we have sufficient data for in order to understand why the West African one was as large and disastrous as it was and whether the socio-economic determinants of health had a role within this or whether this was more due to the issues with regards to the response to the outbreak by local governments and the WHO. This could then be used to build towards an overall framework of how developing countries can deal with their specific vulnerability to infectious tropical diseases and what measures need to be taken both on a socio-economic level as well as in emergency and disaster response.

References

Acemoglu, D., Johnson, S., & Robinson, J. A. (2004). Disease and Development in Historical Perspective. *Journal of the European Economic Association*, *1*(2–3), 397–405. https://doi.org/10.1038/355590a0

Alfani, G. (2013). Plague in seventeenth-century Europe and the decline of Italy: An epidemiological hypothesis. *European Review of Economic History*, *17*(4), 408–430. https://doi.org/10.1093/ereh/het013

Alfani, G., & Melegaro, A. (2010). *Pandemie d'Italia. Dalla peste nera all'influenza suina: l'impatto sulla societa*. Egea.

Alfani, G., & Murphy, T. E. (2017). Plague and Lethal Epidemics in the Pre-Industrial World. *Journal of Economic History*, *77*(1), 314–343. https://doi.org/10.1017/S0022050717000092

Beach, B., Ferrie, J., Saavedra, M., & Troesken, W. (2016). Typhoid Fever, Water Quality, and Human Capital Formation. *The Journal of Economic History*, *76*(1), 41–75.

Bowden, S., Jalles, J. T., Pereira, Á. S., & Sadler, A. (2014). Respiratory tuberculosis and standards of living in postwar Europe. *European Review of Economic History*, *18*(1), 57–81. https://doi.org/10.1093/ereh/het018

Brinkhoff, T. (2018). *GUINEA: Administrative Division*. City Population. https://www.citypopulation.de/en/guinea/admin/

CDC. (2019). *2014-2016 Ebola Outbreak in West Africa*. Centers for Disease Control and Prevention. https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/index.html

Checchi, F., Waldman, R. J., Roberts, L. F., Ager, A., Asgary, R., Benner, M. T., Blanchet, K., Burnham, G., D'Harcourt, E., Leaning, J., Massaquoi, M. B. F., Mills, E. J., Moresky, R. T., Patel, P., Roberts, B., Toole, M. J., Woodruff, B., & Zwi, A. B. (2016). World Health Organization and emergency health: If not now, when? *BMJ (Online)*, *352*(January), 1–8. https://doi.org/10.1136/bmj.i469

Clay, K., Lewis, J., & Severnini, E. (2018). Pollution, infectious disease, and mortality: Evidence from the 1918 Spanish influenza pandemic. *Journal of Economic History*, *78*(4), 1179–1209. https://doi.org/10.1017/S002205071800058X

Creswell, J. (2013). *Research Design - Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications.

Cummins, N., Kelly, M., & Ó Gráda, C. (2016). Living standards and plague in London, 1560-1665. *Economic History Review*, *69*(1), 3–34. https://doi.org/10.1111/ehr.12098

Curtis, D. (2016). Was Plague an Exclusively Urban Phenomenon? Plague Mortality in the Seventeenth-Century Low Countries. *Journal of Interdisciplinary History*, *47*(2), 1–32. https://doi.org/10.1162/JINH

Cutler, D., Deaton, A., & Lleras-Muney, A. (2006). The determinants of mortality. *Journal of Economic Perspectives*, *20*(3), 97–120. https://doi.org/10.1257/jep.20.3.97

Dalziel, B. D., Lau, M. S. Y., Tiffany, A., McClelland, A., Zelner, J., Bliss, J. R., & Grenfell, B. T. (2018). Unreported cases in the 2014-2016 Ebola epidemic: Spatiotemporal variation, and implications for estimating transmission. *PLoS Neglected Tropical Diseases*, *12*(1), 1–13. https://doi.org/10.1371/journal.pntd.0006161

Daszak, P., Zambrana-Torrelio, C., Bogich, T. L., Fernandez, M., Epstein, J. H., Murray, K. A., & Hamilton, H. (2013). Interdisciplinary approaches to understanding disease emergence: The past, present, and future drivers of Nipah virus emergence. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(SUPPL. 1), 3681–3688. https://doi.org/10.1073/pnas.1201243109

Davenport, R., Schwarz, L., & Boulton, J. (2011). The decline of adult smallpox in eighteenth-century London. *Economic History Review*, *64*(4), 1289–1314. https://doi.org/10.1111/j.1468-0289.2011.00599.x

DeWitte, S. N. (2014). The Anthropology of Plague: Insights from Bioarchaeological Analysis of Epidemic Cemeteries. *The Medieval Globe*, *1*, 97–124.

Easterlin, R. A. (1999). How beneficent is the market? A look at the modern history of mortality. *European Review of Economic History*, *3*(3), 257–294. https://doi.org/10.1017/S1361491699000131

Elmahdawy, M., Elsisi, G. H., Carapinha, J., Lamorde, M., Habib, A., Agyie-Baffour, P., Soualmi, R., Ragab, S., Udezi, A. W., Usifoh, C., & Usifoh, S. (2017). Ebola Virus Epidemic in West Africa: Global Health Economic Challenges, Lessons Learned, and Policy Recommendations. *Value in Health Regional Issues*, *13*, 67–70. https://doi.org/10.1016/j.vhri.2017.08.003

Epstein, P. R., Diaz, H. F., Elias, S., Grabherr, G., Graham, N. E., Martens, W. J. M., Mosley-Thompson, E., & Susskind, J. (1997). Biological and Physical Signs of Climate Change: Focus on Mosquito-borne Diseases. *Bulletin of the American Meteorological Society*, *79*(3), 409–417. https://doi.org/10.1175/1520-0477(1998)079<0409:BAPSOC>2.0.CO;2

Farmer, P. (2014). Diary. *London Review of Books*, *36*(20), 38–39.

Gallardo-Albarrán, D. (2020). Sanitary infrastructures and the decline of mortality in Germany, 1877–1913†. *Economic History Review*, *0*, 1–28. https://doi.org/10.1111/ehr.12942

GHSI. (2019). *Global Health Security Index: Building Collective Action and Accountability*. Global Health Security Index. https://www.ghsindex.org/wp-content/uploads/2020/04/2019-Global-Health-Security-Index.pdf

HDX. (2015). *Ebola Outbreaks before 2014*. Humanitarian Data Exchange. https://data.humdata.org/dataset/ebola-outbreaks-before-2014

Hotez, P., & Kamath, A. (2009). Neglected Tropical Diseases in Sub-Saharan Africa: Review of Their Prevalence, Distribution, and Disease Burden. *PLoS Neglected Tropical Diseases*, *3*(8). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2727001/

Huber, C., Finelli, L., & Stevens, W. (2018). The Economic and Social Burden of the 2014 Ebola Outbreak in West Africa. *Journal of Infectious Diseases*, *218*(1), S698–S704. https://doi.org/10.1093/infdis/jiy213

Institut National de la Statistique de la Guinée. (2016). *Enquête Démographique et de Santé en Guinée à Indicateurs multiples 2012*. 1–530.

Institut National de la Statistique de la Guinée. (2014). *TROISIEME RECENSEMENT GENERAL DE LA POPULATION ET DE L'HABITATION (RGPH3)*. http://www.usaid.gov/sites/default/files/documents/1866/2008 Burundi Population Survey_Status and Structure of Population.pdf

Kentikelenis, A., King, L., McKee, M., & Stuckler, D. (2015). The International Monetary Fund and the Ebola outbreak. *The Lancet Global Health*, *3*(2), e69–e70. https://doi.org/10.1016/S2214-109X(14)70377-8

Kovats, R. S., Campbell-Lendrum, D. H., McMichael, A. J., Woodward, A., & Cox, J. S. H. (2001). Early effects of climate change: Do they include changes in vector-borne disease? *Philosophical Transactions of the Royal Society B: Biological Sciences*, *356*(1411), 1057–1068. https://doi.org/10.1098/rstb.2001.0894

Liberia Institute of Statistics and Geo-Information Services. (2014). *Liberia Demographic and Health Survey 2013*. 1–480. http://dhsprogram.com/pubs/pdf/FR291/FR291.pdf

Liberia Institute of Statistics and Geo-Information Services. (2009). *Republic of Liberia 2008 Population and Housing Census*.

Link, B. G., & Phelan, J. (1995). Social Conditions As Fundamental Causes of Disease. *Journal of Health and Social Behaviour*, *Extra Issue*, 80–94.

Maddison Project Database, version 2018. Bolt, Jutta, Robert Inklaar, Herman de Jong and Jan Luiten van Zanden (2018), "Rebasing 'Maddison': new income comparisons and the shape of long-run economic development", Maddison Project Working paper 10

Malanima, P. (2012). The economic consequences of the Black Death. In E. Lo Cascio (Ed.), *l'impatto della `peste antonina'* (pp. 311–328).

MapUniversal, M. (2020). *No Title*. https://mapuniversal.com/counties-of-liberia/

McNeil Jr, D. G. (2014). *Fewer Ebola Cases Go Unreported Than Thought, Study Finds*. The New York Times. https://www.nytimes.com/2014/12/16/science/fewer-ebola-cases-go-unreported-than-thought-study-finds-.html

Negin, J., & Dhillon, R. S. (2016). Outsourcing: How to reform WHO for the 21st century. *BMJ Global Health*, *1*(2), 2–5. https://doi.org/10.1136/bmjgh-2016-000047

North, D., & Thomas, R. P. (1973). *The Rise of the Western World: A new Economic History*. Cambridge University Press.

O Grada, C. (2015). On Plague in a time of Ebola. *Princeton-Fung Forum on Modern Plagues*, 1–45.

OCHA, R. (2015). *Sub-national time series data on Ebola cases and deaths in Guinea, Liberia, Sierra Leone, Nigeria, Senegal and Mali since March 2014*. HDX. https://data.humdata.org/dataset/rowca-ebola-cases

OECD. (2020). *OECD Statistics*. https://stats.oecd.org/

Richards, P. (2016). *Ebola - How a People's Science Helped End an Epidemic*. Zed Books.

Standby Task Force. (2015). *Health facilities in Guinea, Liberia, Mali and Sierra Leone*. HDX. https://data.humdata.org/dataset/health-facilities-in-guinea-liberia-mali-and-sierra-leone

Statistics Sierra Leone. (2016). *Statistics Sierra Leone 2015 Population and Housing Census Summary of Final Results*. 1–190. http://www.statistics.sl

Statistics Sierra Leone. (2013). *Demographic and Health Survey 2013*. 1–515.

United Nations Development Group. (2015). *Socio-Economic Impact of Ebola Virus Disease in West African Countries*. https://www.undp.org/content/dam/rba/docs/Reports/ebola-west-africa.pdf

Walsh, S., & Johnson, O. (2018). *Getting to Zero: A Doctor and a Diplomat on the Ebola Frontline*. Zed Books.

WHO. (2014). *Statement on the 1st meeting of the IHR Emergency Committee on the 2014 Ebola outbreak in West Africa*. World Health Orgnization. https://www.who.int/mediacentre/news/statements/2014/ebola-20140808/en/

WHO. (2020). *Ebola Virus Disease*. World Health Orgnization. https://www.who.int/news-room/fact-sheets/detail/ebola-virus-disease

WHO. (2014). *Why the Ebola outbreak has been underestimated*. World Health Orgnization. https://www.who.int/mediacentre/news/ebola/22-august-2014/en/

Wikimedia. (2020). *Sierra Leone Colored Provinces with Districts*. https://commons.wikimedia.org/wiki/File:Sierra_Leone_Colored_Provinces_with_Districts.png

Appendix A – Individual Country Descriptive Statistics

Table 6-1 - Guinea Descriptive Statistics

	Guinea				
	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Population Characteristics					
-Population	34	312616,8	268676,1	96527	1667864
-Population Density	34	155,1355	628,6103	19,09068	3706,364
-Urban Population	34	24,23	27,07	1,9	100
-Total Employment	34	77,5	9,49	55,3	89
-Manual Labour Employment	34	16,98	6,62	9,7	38,8
Sanitation					
-Protected Water Source	34	13,91	16,64	3,1	85,4
-Flushed Private Toilets	34	5,3	5,61	1	25,2
-High Distance to Water Source	34	0,359	0,129	0,149	0,559
-Safe Garbage Disposal	34	59,82	11,59	41,6	91,4
Diseases					
-Children with vaccinations	34	34,82	8,29	19,3	43,5
-Normal BMI	34	71,58	4,6	54,2	76,1
-Hand Washing Habits	34	33,19	16,8	1,6	58
-No Mosquito Nets owned	34	0,4485	0,0933	0,303	0,578
-Poor AIDS awareness	34	19	7,4	8,7	32,7
Health System					
-Total Health Facilities	34	35,21	19,54	12	109
-Far away from Nearest Health Facility	34	0,426	0,132	0,1	0,6
Controls					
-GDP per capita (2013)	34	1464	0	1464	1461
-Gini Coefficient	34	0,33	0,083	0,05	0,41
-Ebola Intensive Care Beds	34	250	0	250	250

Table 6-2 - Liberia Descriptive Statistics

	Liberia				
	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Population Characteristics					
-Population	15	231983,6	270835,6	57913	1118241
-Population Density	15	67,19	147,305	8,378177	594,809
-Urban Population	15	27,339	21,4	3,48	91,91
-Total Employment	15	78,44	11,92	57,6	93,7
-Manual Labour Employment	15	29,17	10,24	9,4	42,3
Sanitation					
-Protected Water Source	15	40,77	15,26	9,61	60,75
-Flushed Private Toilets	15	5,91	7,04	1,65	30,18
-High Distance to Water Source	15	0,17	0,032	0,113	0,236
-Safe Garbage Disposal	15	26,81	14,91	6,5	58,7
Diseases					
-Children with vaccinations	15	50,51	13,15	33,1	73,6
-Normal BMI	15	68,22	5,17	60,4	75,7
-Hand Washing Habits	15	2	0	2	2
-No Mosquito Nets owned	15	0,406	0,122	0,218	0,604
-Poor AIDS awareness	15	30,36	9,7	20,3	49,7
Health System					
-Total Health Facilities	15	49,27	44,98	18	198
-Far away from Nearest Health Facility	15	0,521	0,133	0,178	0,757
Controls					
-GDP per capita (2013)	15	827	0	827	827
-Gini Coefficient	15	0,313	0,074	0,13	0,41
-Ebola Intensive Care Beds	15	660	0	660	660

Table 6-3 - Sierra Leone Descriptive Statistics

	Sierra Leone				
	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
Population Characteristics					
-Population	14	505402,9	201638,3	200730	1050301
-Population Density	14	5902,478	21555,69	33,668	80792,38
-Urban Population	14	34,16	27,63	7,1	100
-Total Employment	14	80,18	9,63	61,3	92
-Manual Labour Employment	14	35,64	17,2	17,3	74,9
Sanitation					
-Protected Water Source	14	25,67	13,98	10,52	58,83
-Flushed Private Toilets	14	4,62	3,45	2,23	12,66
-High Distance to Water Source	14	0,0617	0,019	0,027	0,097
-Safe Garbage Disposal	14	72,42	14,78	36,2	89,3
Diseases					
-Children with vaccinations	14	68,2	10,05	51,7	84,7
-Normal BMI	14	73,2	4,86	66,1	80,8
-Hand Washing Habits	14	18,01	13,01	0,9	44,7
-No Mosquito Nets owned	14	0,183	0,137	0,0556	0,504
-Poor AIDS awareness	14	22,87	10,69	4,8	44
Health System					
-Total Health Facilities	14	123,57	60,54	61	309
-Far away from Nearest Health Facility	14	0,204	0,095	0,0607	0,456
Controls					
-GDP per capita (2013)	14	1684	0	1684	1684
-Gini Coefficient	14	0,244	0,056	0,17	0,35
-Ebola Intensive Care Beds	14	896	0	896	896

Appendix B – Regression Tables for Sample with Cases > 25

	Dependent Variable: Number of reported EVD cases				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	0.000743				-0.000104
	(0.00100)				(0.000737)
-Population Density	0.0166				0.00593
	(0.0104)				(0.0119)
-Urban Population	11.68				8.260
	(7.003)				(5.034)
-Employment	-3.632				3.026
	(9.606)				(19.88)
-Manual Labour	1.748				3.072
	(8.672)				(11.02)
-GDP per capita	-0.440	0.623	0.648	-1.351**	-0.182
	(0.560)	(0.727)	(0.581)	(0.573)	(1.021)
-Gini	-602.5	390.5	-1,988	497.9	588.8
	(1,265)	(1,549)	(2,145)	(1,523)	(1,270)
-ETU beds	0.786	3.679**	0.718	-0.670	0.327
	(0.501)	(1.554)	(0.892)	(0.546)	(1.121)
-Protected Water Source		-8.147			-20.62
		(13.56)			(16.98)
-Flushed Private Toilets		160.5***			98.33***
		(43.24)			(30.30)
-High Distance to Water Source		5,553			1,701
		(3,362)			(1,938)
-Safe Garbage Disposal		-8.126			-3.865
		(9.062)			(7.888)
-Children with Vaccinations			22.31		20.73*
			(14.23)		(10.57)
-Normal BMI			14.50		23.68
			(20.84)		(27.52)
-Hand Washing Habits			-3.675		-10.97
			(14.54)		(11.79)
-No Mosquito Nets			3,083**		858.3
			(1,388)		(1,217)
-Poor AIDS Awareness			41.27*		21.11*
			(21.17)		(10.36)
-Total Health Facilities				13.08***	8.143*
				(3.565)	(4.715)
-Far from nearest Health Facility				-1,924*	142.5
				(1,120)	(831.4)
Constant	414.9	-3,812	-4,366*	2,373*	-4,224
	(1,130)	(2,436)	(2,388)	(1,374)	(4,664)
Observations	44	44	44	44	44
R-squared	0.582	0.652	0.514	0.671	0.874

Robust standard errors in parentheses

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

VARIABLES	Dependent Variable: Number of reported EVD deaths (1)	(2)	(3)	(4)	(5)
-Population	0.000272 (0.000406)				-0.000141 (0.000257)
-Population Density	0.00114 (0.00410)				-0.00347 (0.00478)
-Urban Population	4.756 (2.925)				3.433 (2.176)
-Employment	-2.353 (4.178)				1.298 (7.745)
-Manual Labour	-1.096 (3.372)				-1.205 (4.367)
-GDP per capita	-0.226 (0.236)	0.0450 (0.236)	0.162 (0.207)	-0.606** (0.268)	-0.212 (0.398)
-Gini	-436.1 (516.1)	-265.7 (567.6)	-879.8 (841.4)	-117.7 (606.0)	85.05 (492.0)
-ETU beds	0.194 (0.204)	1.015** (0.494)	-0.146 (0.319)	-0.391 (0.234)	-0.194 (0.444)
-Protected Water Source		-6.096 (5.113)			-9.157 (6.441)
-Flushed Private Toilets		61.49*** (18.91)			37.71*** (12.58)
-High Distance to Water Source		1,515 (1,032)			385.9 (745.2)
-Safe Garbage Disposal		-2.823 (3.532)			-1.585 (3.336)
-Children with Vaccinations			12.25** (5.540)		9.190* (4.595)
-Normal BMI			7.192 (7.728)		5.928 (10.51)
-Hand Washing Habits			-3.516 (5.371)		-4.427 (4.584)
-No Mosquito Nets			1,127* (556.8)		371.3 (466.6)
-Poor AIDS Awareness			14.57* (8.200)		7.864* (3.953)
-Total Health Facilities				4.010** (1.674)	3.918** (1.812)
-Far from nearest Health Facility				-904.7** (412.2)	-138.4 (312.7)
Constant	495.2 (484.3)	-663.3 (672.0)	-1,491* (868.1)	1,337** (638.3)	-841.7 (1,738)
Observations	44	44	44	44	44
R-squared	0.441	0.610	0.445	0.582	0.836

Robust standard errors in parentheses

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

	Dependent Variable: EVD Case Fatality Rate (CFR)				
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
-Population	-2.05e-07 (1.35e-07)				-3.73e-07 (2.29e-07)
-Population Density	1.62e-09 (6.05e-07)				-3.86e-06 (3.33e-06)
-Urban Population	-0.000422 (0.00137)				0.000229 (0.00156)
-Employment	-0.00238 (0.00285)				-0.00137 (0.00404)
-Manual Labour	5.32e-05 (0.00209)				-0.000349 (0.00342)
-GDP per capita	-7.25e-06 (6.62e-05)	-0.000153 (0.000185)	5.06e-05 (0.000136)	-1.32e-05 (7.03e-05)	0.000162 (0.000193)
-Gini	-0.268 (0.350)	-0.0557 (0.254)	0.256 (0.255)	0.0920 (0.239)	-0.424 (0.414)
-ETU beds	-0.000525*** (9.39e-05)	-0.000744*** (0.000126)	-0.000596*** (0.000116)	-0.000466*** (6.09e-05)	-0.000974*** (0.000293)
-Protected Water Source		-0.000820 (0.00195)			0.00151 (0.00497)
-Flushed Private Toilets		-0.00747 (0.00663)			-0.0112 (0.00689)
-High Distance to Water Source		-0.559 (0.357)			-0.854 (0.656)
-Safe Garbage Disposal		0.000896 (0.00305)			0.000343 (0.00297)
-Children with Vaccinations			0.000189 (0.00198)		0.000944 (0.00371)
-Normal BMI			0.00133 (0.00457)		-0.00310 (0.00919)
-Hand Washing Habits			-0.00289 (0.00213)		-0.00290 (0.00268)
-No Mosquito Nets			0.0540 (0.221)		0.495 (0.338)
-Poor AIDS Awareness			0.00160 (0.00216)		0.000863 (0.00321)
-Total Health Facilities				-0.000342 (0.000319)	0.00188 (0.00124)
-Far from nearest Health Facility				0.0737 (0.160)	0.234 (0.318)
Constant	1.187*** (0.334)	1.290*** (0.255)	0.612* (0.328)	0.774*** (0.162)	1.220 (0.960)
Observations	44	44	44	44	44
R-squared	0.650	0.632	0.617	0.607	0.712

Robust standard errors in parentheses

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