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Economic Impact of the Western Africa Ebola Outbreak--A Holistic Approach

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Abstract

The 2014 Western Africa Ebola Epidemic was one of the most severe epidemics in the region's history, creating considerable health and economic burdens on the affected countries. The first part of this paper relies on several macroeconomic databases from 2009 to 2019 to evaluate the aggregate economic impact of Ebola both in the short- and medium-run. We also use household surveys to assess the microeconomic effects of Ebola on employment and household non-farm enterprises (HNFE) at different phases of the outbreak in Sierra Leone. Our primary estimation method is the Difference-in-Differences approach with the canonical specification where we compare outcome variables between Ebola affected and non-affected countries. To address the recently raised concerns about the Difference-in-Difference approach with multiple periods, we apply the nonparametric approach proposed by Callaway and Sant'Anna (2020) and calculate the summary measures proposed by de Chaisemartin & D'Haultfoeuille (2020) as robustness checks. We find a significantly negative effect of Ebola on Foreign Direct Investment inflows in the short-run and a persistently negative effect on iron exports during the sample periods but no noticeable impact on GDP and inflation rate. Ebola also decreased the probability of being employed at an early stage and continuously depresses the HNFE's revenue toward the end of the epidemic. Our results suggest that the Ebola outbreak should be considered as a nationwide economic shock with limited long-run macro effect.

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1. Introduction

The Western Africa Ebola virus disease (EVD) outbreak is one of the most severe epidemics in the region's history. In December 2013, the first case was reported in Guinea. Then, the disease spread to neighboring Western African countries, Liberia and Sierra Leone. As of May 8, 2016, there were a total of 28,646 suspected cases with 11,323 deaths. The epidemic was finally declared over by World Health Organization (WHO) on June 9, 2016 (WHO, 2016). Apart from the loss of life, the Ebola epidemic also caused a significant socioeconomic disruption in Guinea, Liberia, and Sierra Leone. According to the World Bank's estimate, the overall economic loss due to the epidemic was around $2.8 billion. The shock has been worsened by the significant decline in the global price of iron ore, especially for Sierra Leone, whose iron ore mining industry contributes over 20% of its national GDP (World Bank, 2016).

The Ebola outbreak represents a pattern of increasingly frequent epidemics. Epidemiologists and public health scientists have warned that there will be an increased likelihood of pandemics or local epidemics over time due to globalization, urbanization, and climate changes (Jones et al., 2008; Bloom and Cadarette, 2019). In the future, policymakers will have to confront more frequent epidemics and significant economic losses. It will require them to design prudent policies to facilitate economic recovery. This task is more demanding for policymakers in developing countries. Since there is a significant gap in global pandemic preparedness between developing and developed countries, they have to confront a much higher socioeconomic impact of the epidemics than their counterparts in developed economies. Despite improvements in recent years, many developing countries have been unable to meet basic requirements listed in the International Health Regulation (IHR) proposed by the WHO (Fischer and Katz, 2013). The Ebola outbreak is just a notable example that exposed these gaps (Pathmanathan et al., 2014). The outbreak also reveals that the welfare impact of the epidemics is far beyond its epidemiological implications (Government of Republic of Liberia, 2016; Government of Sierra Leone, 2016). Its scope is further determined by the ability of the economy to cope and recover as well as the society's risk-sharing mechanism and the distribution of losses, i.e., macroeconomic resilience and microeconomic resilience.

The goal of this paper is to provide a systematic evaluation of the impact of the Ebola outbreak at both macro and micro levels, using the difference-in-difference appraisal method. At the macro level, our focus is on identifying any short- and long-term impact of the outbreak. With 5-year post-Ebola macro data, we are able to distinguish the potential effect in different time periods and evaluate them individually. Given that the affected countries are all dependent on natural resources, we analyze if the Ebola has any effects on its foreign direct investment (FDI) inflow and the exports of iron-related products. We also examine the Ebola's effect on the price level and economic growth measured by Gross Domestic Product (GDP) per capita. At the micro-level, we concentrate on the employment outcomes and the performance of small household non-farm enterprises (HNFEs) in Sierra Leone. Given that we have data on multiple rounds of household surveys during the outbreak, we can identify the evolution of microeconomic impact at different epidemic phases. By comparing the effect on districts with fewer Ebola cases and those with more cases, we determine if the impact correlates with the Ebola severity and whether the direct or indirect effects dominates.

The paper contributes to the current state of knowledge on the socioeconomic impact of Ebola epidemics and economic resilience in multiple ways. Firstly, to the best of our knowledge, it is the first study that provides a systematic empirical understanding of the macroeconomic impact of Ebola with a long time dimension. Although there is unequivocal evidence that epidemics have a significant socioeconomic impact on the livelihoods of individuals, households, and communities, the empirical literature is largely fragmented, and none of them evaluates the impact in a holistic approach. In the previous macro-level studies (e.g., Bartsch, Gorhan, and Lee (2015), Kirigia et al. (2015), Costa (2020), UNDG (2015)), researchers have proposed different kinds of models and estimates of the nationwide economic loss of Ebola based on limited available data. However, their focus was predominately on the immediate or short-run effect of Ebola with little sector-level analysis.

Also, different from the mainstream public health articles about the Ebola epidemic, our main variables of interest are all economic variables, such as FDI and unemployment. Public health scientists have consistently shown that lower socioeconomic groups had more exposure to the Ebola virus (Grepin et al., 2020; Krauer et al., 2016; Fallah et al., 2015) and were more affected during the outbreak in terms of food consumption and other general welfare estimates (Ordaz-Nemeth et al., 2017; Stanturf et al., 2015). On the other hand, we are more interested in the impact of Ebola in *economic* terms rather than general *welfare* or *health* measures.

In addition, this study will also contribute to the sparse literature about the contribution of household non-farm enterprises (HNFEs) to the local economy at different phases of the outbreak. Although a plethora of literature focused on formal small-to-medium enterprises during an epidemic (e.g., Basuno et al., 2010; Beck and Demigruc-Kunt, 2006; Batrik et al., 2020; Fairlie, 2020), most of it focused on developed countries, and the literature on business performance mostly focused on either formal or manufacturing enterprises (e.g., Frazer, 2005; Shfieraw, 2009; and Klapper and Richmond, 2011). As one of the few existing studies, Nagler and Naude (2017) provide a comparative overview of HNFEs in rural Sub-Saharan Africa using LSMS-ISA survey data. However, they employ a narrow classification of shocks and are unrelated to an unanticipated epidemic shock. Bowels et al. (2015) and Glennerster et al. (2017) are two closely related firm-level studies of Ebola. However, both only evaluated the formal sector (i.e., registered firms) rather than informal employment and HNFEs, which accounted for more than 90% of employment.

Our main finding is that Ebola has a significantly negative effect on FDI inflows and monthly iron exports, while their medium-run impacts are ambiguous. We do not find substantial impact on GDP and inflation rate during the studied period. For the employment outcome, the probability of a household head being employed significantly decreases during the early phase of the epidemic. However, this effect disappears when we approach the end of the outbreak. For the HNFE activities, the probability of a household to operate an HNFE does not change at any stage of the epidemic, but the revenue of those operating businesses significantly decreased compared to the pre-Ebola periods. Interestingly, we notice that HNFEs operating in the capital city, Freetown, are associated with higher revenue compared to their baseline periods. Outside of Freetown, we do not detect a significant correlation between Ebola severity and the impact.

The rest of the paper proceeds as follows: section 2 provides some background information about the epidemiological facts about the Ebola Virus Diseases (EVD) and the pre-Ebola conditions for these affected countries. Section 3 provides a literature review. Section 4 elaborates our data sources and the difference-in-difference method for our macro and micro-level evaluation. Section 5 discusses our main results, while section 6 provides robustness checks for our macro-level analysis. Section 7 briefly discusses the role of Ebola experiences during the current Covid-19 pandemic, followed by concluding remarks in section 8.

2. Background: Ebola Epidemic and the Affected Countries

In this section, we provide background information about the Ebola virus disease (EVD). Section 2.1 illustrates epidemiological facts and the history of EVD. We focus on the 2014-16 Western Africa Ebola outbreaks in section 2.2 and a by-country description of pre-Ebola situations in section 2.3.

2.1 Epidemiological Facts about Ebola Virus Disease (EVD)[1]

Ebola virus disease, also known as Ebola hemorrhagic fever, is a highly fatal hemorrhagic fever of humans and non-human primates. It is a member of the Filoviridae family, which was defined in 1982 (Kiley et al., 1982). Nowadays, EVD frequently refers to the specific member virus of the species *Zaire ebolavirus* in the genus ebolavirus (Feldman et al., 2020). To date, researchers have identified five different types of ebolavirus: Zaire virus (ZEBOV), Sudan virus (SEBOV), Tai Forest virus (TEBOV), Reston virus (REBOV), Bundibugyo virus (BEBOV). The genus *Ebolavirus* was named after the Ebola River, which is close to the first recognized outbreak in D.R. Congo (Johnson et al., 1977).

Similar to other hemorrhagic fever viruses in Africa, researchers consider the EVD as zoonotic, but discovering the origin of each Ebola outbreak and understanding its complex ecology is always challenging (Pourrut et al., 2005). Given its zoonotic nature, the epidemic in the human population must start with an entry from an animal reservoir, such as through hunting, bushmeat consumption, and direct contact with the infected animals. The in-person transmissions are caused by the direct contact of infected persons' body fluids and secretions through mucosal surfaces, breaks, and abrasions on the skin (McElroy et al., 2014). After being infected, patients will first display flu-like symptoms, such as fever and headache. Five to seven days later, patients may start bleeding through the eyes, nose, or mouth. Although the case fatality rate varies by different *Ebolavirus* types, it could exceed 80% (Johnson et al., 1977).

Before the 2014 Western African Ebola outbreak, there were 23 laboratory-confirmed outbreaks of EVD since the discovery of the virus in 1976 (excluding laboratory infections and export cases) (Weyer et al., 2013). These outbreaks were all sporadic and across the rural and secluded areas of central, western, and eastern Africa. Before 2013, West Africa only had one single case of EVD due to Tai Forest virus in Cote d'Ivoire (Formenty et al., 1999). Compared to other communicable diseases, such as malaria, tuberculosis, and HIV, EVD has been widely regarded as a low public health priority in Africa due to its relatively low disease burden (Leroy et al., 2011).

2.2 Western Africa Outbreak

Researchers believe that the outbreak's initial case (or index case) was a 2-year-old infant from Guinea who died on December 6, 2013 (Baize et al., 2014). It has been suspected that the

[1] Goeijenbier et al (2014), Feldman et al (2020), and Yadav and Mohite (2020) offered comprehensive reviews on EVD's virology, epidemiology, treatments, and preventions. Barrette et al (2011) provides a review on different types of ebolavirus.

index case occurred after contacted with an infected bats near the village (Saez et al., 2014). Through unsafe burial, the dead infant then infected several family members and health workers, which triggered the spread of the virus to at least three other districts of Guinea. The EVD stayed hidden for the next three months and was carried into the capital city, Conakry, in February by the dead infant's extended family. The virus was not identified until March 13, 2014. The World Health Organization (WHO) was officially notified of a "rapidly evolving" EVD outbreak on March 23, 2014, when 49 cases and 29 deaths were reported (WHO, 2015b). The virus then spread to neighboring Liberia and Sierra Leone on March 29 and May 7. With pressure from international agencies working in the affected countries, the WHO declared the epidemic a "public health emergency of international concern" on August 8, 2014. Ebola was also confirmed in Nigeria and Mali in July and October 2014, respectively, but effectively contained (Forlain et al., 2016). As of March 31, 2016, WHO had reported 28,652 suspected, probable, and confirmed Ebola cases, including 11,325 deaths. The Western African Ebola Outbreak became the most severe Ebola outbreak ever, with case numbers far exceeding the combined total of all previous outbreaks.

The reasons for the unprecedented size of this Ebola outbreak are undoubtedly multi-facet, as summarized by Moon et al. (2015) and Baush and Roject (2016). Through a detailed analysis on clinical and demographic information of infected patients, the WHO Ebola Response Team (2014) concluded that the epidemiological facets of the virus are similar to those in previous EVD outbreaks and hence excluded the biological characteristics of the virus as the principal cause. They inferred the attributes of the affected populations and insufficient control efforts as the main reasons for failure in early containment. Particularly, they highlighted the interconnectivity and mobility of residents in Guinea, Liberia, and Sierra Leone with porous borders as well as the easy connections between the rural villages and densely populated national capitals. High population mobility made contact tracing difficult as the outbreak responders could not readily cross the borders as the general population did. High mobility also enables patients from neighboring countries to seek unoccupied treatment beds, reigniting transmission chains. It means that no matter how intense the country's response measures had been, as long as one of its neighboring countries suffered from the intense transmission, it would still be at risk.

Researchers also attribute several economic factors to fueling the epidemic. Dr. Margaret Chan (2014), former Director-General of the WHO, summarized these factors "with a single word: poverty." All three worst impacted countries, Guinea, Liberia, and Sierra Leone have been in poverty for decades and just struggled to end the civil wars and conflicts. With limited physical and human capital in healthcare, the outbreak far exceeded their capacity to respond. Also, as mentioned in 2.1, the EVD outbreak only took place at once in Western Africa, and hence it is "an old disease in a new context" (WHO, 2015a). As a result, countries were not prepared for this unfamiliar and unexpected disease at all levels. Not only the general population could not understand the epidemics, but the healthcare workers were also not trained to respond to and manage the outbreak.

Cultural factors, especially the unsafe burial practices, also play a crucial role in this unprecedented outbreak. Funerals in Western African countries, functioning as a social connection between and within the communities, are indispensable to their culture and beliefs (Thiaman et al., 2015). For example, according to the Muslim tradition in Sierra Leone, close female relatives would need to travel a long distance to wash their sister's dead body. Such funeral practice had helped the remote communities survive through civil war, but it facilitated the spread of EVD to new geographical areas (Richards et al., 2015). One traditional burial alone could onset an unimaginably huge chain of transmission leading to hundreds of infections (WHO, 2014a). Funeral practices alone could explain about sixty percent of new infections in Guinea during August 2014 and eighty percent in Sierra Leone during November 2014 (WHO, 2015). At the early stage of international intervention, it is also noted that community resistance to conducting safe burial practices with infection controls impeded early prevention measures (Thiaman et al., 2015; Buli et al., 2015).

2.3 Pre-Ebola Situations

In this section, we will provide a brief background on the pre-Ebola conditions of the affected countries. Our primary focus is on the three worst-affected countries, Guinea, Liberia, and Sierra Leone, but we also briefly discussed other less affected Western African countries, including Mali and Nigeria.

2.3.1 Guinea

Guinea achieved independence from France in 1958 but did not hold its first democratic election until 2010. With the advent of a democratically elected political party, the Government has implemented a series of bold economic and political reforms to restore its socioeconomic standing. With effective implementation of these reforms, it regained the macroeconomic stability by reducing the budget deficit (reduced from 13% of GDP in 2010 to 2% in 2012), stabilizing the price level (declined from 21.4% in 2010 to 10.5% in 2013), and realizing higher economic growth (4% in 2012 compared to 1.9% in 2010). With better economic and political conditions, Guinea became attractive to the foreign investors, with over USD 7 billion of investment being committed during the International Conference on Guinea’s Investors and Partners in November 2013 (Republic of Guinea, 2013).

In spite of its promising economic prospect, with a human development index (HDI) of 0.445 (rank 180 out of 189), more than 40% of its population had an income of less than USD 1.25 per day in 2013, and around 20% has access to basic sanitation facilities (World Bank, 2022). Due to its abundant natural resources of iron, diamond, gold, and bauxite, the economy of Guinea heavily relies on natural resources. The mineral sector contributed around 15% of its annual GDP and 90% of its export earnings in 2012 (Guinea Institut National de la Statistique, 2014). There was also a significant amount of foreign direct investment in mining. Notably, in May 2014, the Simandou North iron ore investment plan was signed with an estimated inflow of USD 20 billion (The Guardian, 2014).

2.3.2: Liberia

By the 1970s, Liberia was politically stable and a lower-middle-income country, but the civil wars between 1989 and 2003 destroyed much of its physical and social infrastructure. The war led to over 200 thousand deaths (or 8% of the population) and over 700 thousand displacements (Bruce, 2004). The economy was in ruins, with a contraction of GDP by 90% and an unemployment rate of 80%, but most schools and health facilities were also destroyed (World Bank, 2011). After the civil war, the economy entered a decade of economic recovery with a significant improvement in education, health services, energy, and other social infrastructure.

However, more than half of its population was still in poverty, with a human development index of 0.477 in 2013 (rank 173 out of 189) (LISGIS, 2016). The service sector dominated the economy, which contributed 46.7% of annual GDP in 2013 (Central Bank of Liberia, 2014). Over 70% of the workforce is employed in the informal sector. Most of those worked in subsistence agriculture, small-scale cash crop farming (in rural), and petty trade (in urban). The economy was also heavily reliant on natural resource production, such as diamond and iron ores. Although its production was halted due to the civil war and international sanctions, it resumed after the end of the war (United Nations Security Council, 2007). As of 2013, the mineral sector contributed to over 10% of its annual Gross Domestic Product (GDP) (CBL, 2014).

2.3.3: Sierra Leone

Similar to Liberia, Sierra Leone also suffered from political instability in the 1990s. After gaining independence from the United Kingdom in 1961, it experienced two phases of brutal civil wars, which formally ended in 2002. Civil wars have destroyed most of its formal economy and resulted in about fifty thousand deaths with hundreds of thousands of displacements. After a decade of economic recovery, Sierra Leone achieved a double-digit real GDP growth rate of 15.2% and 20.1% in 2012 and 2013. It also considerably improved the macroeconomic stability with a single-digit inflation rate and low official interest rates.

Nevertheless, Sierra Leone remained a low-income country. Although the poverty rate decreased from 66.4% in 2003, more than 50% of its population was still below the national poverty line. Only 16% of the population had access to essential sanitation services in 2013 (World Bank, 2020; Statistics Sierra Leone, 2013). Due to its abundant natural resources, the economy was heavily reliant on the mining sector. In 2012, the mineral sector contributed 12% of the annual GDP and 70% of the export earnings. Driven by the growth of iron ore mining, the mineral sector accounted for around 23% of GDP in 2013 (Bank of Sierra Leone, 2014).

2.3.4: Nigeria and Mali

Although Nigeria gained its independence in 1960, it took three decades to achieve a stable democracy in 1999 after several rounds of military dictatorship and coups. Since then, the Nigerian economy has boomed and became the largest economy in Africa in 2013 (World Bank, 2022). With the continent's largest manufacturing and service sectors, it undertook an economic diversification program to encourage production and exports in non-oil sectors, including agriculture and mining. Despite its large-size economy, Nigeria had a human development index of 0.523 in 2013 (rank 161 out of 189) with more than 40% of its population living under the poverty line (World Bank, 2022).

After declaring independence in 1960, Mali suffered continuous military conflicts even after establishing a democratic multi-party state. Due to the armed conflicts throughout 2012, its real GDP growth decreased from 3.2% in 2010 to -0.8% in 2012. It kept a single-digit inflation rate throughout the 2010s (IMF, 2022) As a fragile state with an HDI of 0.413 (rank 184 out of 189), around 47% and 35% of its population lived under the poverty line and had access to basic sanitation facilities in 2013, respectively (World Bank, 2022). The economy was heavily reliant on the agricultural and mining sectors (CIA Fact Sheet, 2022), which attracted significant amounts of FDI inflow.

Overall, the EVD outbreak was an unexpected shock in countries with prolonged histories of social unrest and economic disruptions. Among the three worst-affected countries, they shared the experience of economic recoveries from the previous civil wars and had the promising economic prospect. However, their socioeconomic development needs remained significant even with decade(s) of economic growth, with a low HDI, high poverty rate, and limited access to sanitation facilities. All of the affected countries were also dependent on the natural resources exports, contributing to a significant fraction of their GDP and attracting considerable amounts of foreign investment.

3. Literature Review

3.1 Socioeconomic Impacts of Ebola[2]

The economic literature on the Ebola outbreak predominately focused on estimating the cost of the epidemic, following the framework proposed by Jonas (2013). Under this framework, the economic impact of an epidemic is classified as i) avoidance reactions and ii) direct and indirect costs of diseases. For example, Bartsch, Gorhan, and Lee (2015) measured the total direct costs of Ebola by using lifetime lost wages as a proxy for lifetime productivity losses. Kirigia et al. (2015) calculated the value of statistical life-years by focusing on the non-health component of GDP. Huber, Finelli, and Stevens (2018) criticized previous estimates for not incorporating the social costs and concluded that the 2014 epidemic caused an economic and social burden of USD 53.19 billion. Costa (2020) estimated the individual willingness-to-pay (WTP) to avoid increasing age-specific mortality rates associated with the Ebola outbreak.

UNDG (2015), on the other hand, provided an econometric method to estimate the macro epidemic impact. To calculate the coefficient of a variable that captures the potential impact of the Ebola prevalence on an economy, they established a cross-sectional model using nonlinear two-stage least square techniques. Considering the significance of the informal sector, they also designed a two-sector macro-Ebola model in the context of the Solow-Swan growth model. After defining the production functions in formal and informal sectors, researchers simulated a scenario with and without Ebola.

FEWS NET (2017) provided a general overview of the outbreak's impact on household livelihoods and food security based on informant interviews and a literature review. They concluded that the largest economic impact of the EVD was not direct costs but the resulting behavior changes due to the government-imposed aversion measures and fear of households. Since they observed no permanent loss of household food or income sources, they suggested no apparent change in the fundamental pattern of rural livelihoods. They also highlighted that the food security

[2] There also existed a non-negligible grey literature. Many international NGOs and governments of Western African countries have published their own assessment of impact of Ebola (e.g. World Bank, 2015b, 2015c, Government of Sierra Leone, 2016; Government of Republic of Liberia, 2016). However, they are largely descriptive with little empirical analysis.

problems during the outbreak are not a food availability issue but an accessibility one, driven by households' lower purchasing power.

Rather than focusing on the macroeconomic consequences using pure modeling, another stream of literature focused on micro-level analysis. Some literature highlighted the negative effect of the EVD outbreak upon the social capital, such as institutional trust. Gatiso et al. (2018) investigated the epidemic's impact on the livelihoods of Liberian households using the Sustainable Livelihood Framework (SLF) based on randomly sampled household survey results. They found that the respondents who reported the incidence of EVD in/near their community held lower trust toward Liberian institutions and village chiefs compared to those who reported no EVD cases. Similarly, based on the survey data collected through a random walk procedure, Tsai et al. (2015) and Blair et al. (2017) found that respondents who experienced hardships are less likely to trust the government. They also noted that the low trust in government would lead to less compliance and support to the aggressive control policies but not affect their understanding of the EVD symptoms and transmission pathways. The negative effect of the outbreak on the trust in local institutions can also render future recovery efforts as citizens may no longer follow the state's recommendations. Moreover, distrust in state institutions may raise the risk of future social conflicts and crimes.

Others were concerned about the distribution of EVD impact against various socioeconomic statuses (SES). In brief, the literature noted a significant cross-country variation but the population with lower income and living in urban areas were more vulnerable. They had higher exposure to the Ebola outbreak. These findings support the need for targeted response measures to account for the differential risk of EVD arising from socioeconomic heterogeneity at the subnational level. Grepin, Poirier, and Fox (2020) used the sixth wave of the Afrobarometer Survey results in Liberia and Sierra Leone to explore the distribution of the exposure to EVD during the outbreak. Using whether an individual knows a close friends/family member infected with Ebola as a measure of EVD exposure, they found a cross-country difference in distribution, where higher SES means more exposure in Sierra Leone but less exposure in Liberia. Krauer et al. (2016) also noted similar heterogeneity across countries by re-calculating the basic reproduction factor (R0) for each affected district and country. Ordaz-Nemeth et al. (2017) identified the effect of the EVD outbreak on the bushmeat (i.e., wild animal meats) consumption and food safety in Liberian households based on a survey conducted before and during the Ebola outbreak. They found that bushmeat consumption in wealthier families decreased more significantly than in poorer households (but decreased at all household levels). Daily meal frequency decreased in all SES groups during the crisis, and the diversity of food items and preferences for bushmeat species remained constant. Fallah et al. (2015) used stochastic simulations to quantify the role of poverty in the transmission chains of EVD in Liberia's capital city Monrovia from February to December 2014. They found that cases from middle and low SES communities had 1.5 and 3.5 times more contacts and transmission of cases compared to the high SES communities. Their findings also prove that cases tended to be exported from poverty areas and explain most EVD cases in Montserrado County. Stanturf et al. (2015) used the 2008 Liberian census data to construct a county-level social vulnerability classification. They noted that cultural factors and population density are two crucial factors determining the transmission of EVD.

There is also evidence that females suffered more from the outbreak than males did. Korkoyah and Wreh (2015) used survey data and interviews with community leaders and residents. They found that although more cumulative cases of EVD infection have been reported among males, females have been disproportionally affected by the socioeconomic consequences of the epidemics due to their engagement in vulnerable occupations, reliance on less stable sources of loans, and limited access to routine maternal health services. Similarly, WANEP (2020) highlighted that women suffered more from the epidemic since they were the primary caregivers with less access to capital and justice and prosecution support. UNFPA (2017) also mentioned that women and girls had limited access to maternal health and family planning services during the outbreak.

As one of the few studies with baseline and post-outbreak firm-level data, Bowels et al. (2015) used a quarterly panel dataset of registered firms in Liberia. In a difference-in-difference model, they compared the economic activities, as measured by firm closure, the number of employees per firm, won contracts, across more versus less Ebola-affected counties. They found a nationwide decrease in economic activity during the Ebola outbreak, while there was little association between the Ebola severity and economic burden outside the capital. On the other hand, the county of Montserrado has been hit significantly harder compared to other regions. There was also heterogeneity in sectoral analysis inside and outside the capital. Outside of the capital, the restaurant sectors suffered the most, while the food and beverages sector experienced a significant decline

In a similar firm-level study, Glennerster et al. (2017) focused on the formal sector in Sierra Leone. Sampling large-size tax-paying firms from administrative data provided by the National Revenue Authority (NRA), they collected data through a series of in-person interviews with managers of firms. Apart from the record-keeping information, they asked firms to disclose detailed monthly figures in revenues, costs, imports and exports, and liquidity from April 2014 to January 2015. To control for seasonality effects, they also collected comparable data for the period one year prior, i.e., April 2013 to January 2014. Unlike Bowels et al. (2015), they directly included a monthly average of new weekly Ebola cases in regressions and a dummy variable indicating crisis and post-crisis period. They found that formal sectors suffered falls in sales of about 25% at the height of the Ebola outbreak, while there was no evidence of either changing the number of employees or reducing costs during the crisis.

Glennerster and Suri (2014,2015, 2016) used cellphone market surveys to understand the pattern of commodity prices and agricultural trade activities during the Ebola outbreak. They collected seven rounds of data on food availability, prices, and the number of traders in over 150 markets across Sierra Leone from August 2014 to July 2015. By comparing responses collected from cordon and non-cordon districts to the pre-outbreak data, they found that the number of traders selling essential food items fell by 69% in the cordoned districts. Although there were significantly higher percentages of closed markets in the lockdown area, the food prices remained stable across all surveys, mainly due to the government's efforts to keep food flowing into the cordoned areas. However, there was a price hike in rice in some remote districts in August and September 2014, indicating the need to ensure a good distribution of inflows of imported rice.

Overall, there is unequivocal evidence in the literature that epidemics had a significant socioeconomic impact on the livelihoods of individuals, households, and communities. However, compared to the literature focused on HIV/AIDS and malaria[3], the evidence on the impact of the

[3] See Gallup and Sachs (2001) and Russell (2004) for the review of literature focused on the economic burden of Malaria, tuberculosis, and HIV/AIDS.

Western Africa Ebola outbreak was largely fragmented and scant. In the macro-level studies, there were many models and estimates of the nationwide economic loss of Ebola. However, little industry-level analysis has been done. More importantly, although iron ore industries contributed significantly to the national economies, it is understudied in these worse-affected countries. Bowels et al. (2015) and Glennerster et al. (2017) concentrated on the formal sectors for the micro-level studies. This paper focuses on the general labor market and the informal sector, representing most of the employment in the impacted Western African countries.

3.2 Economic Resilience, Livelihood Diversifications, and Non-Farm Sectors[4]

Previous literature also largely neglected the role of income or livelihoods diversification and the economic resilience during the Ebola outbreak.

Only recently, the concept of resilience has gained attention from regional and spatial economists. Before the Covid-19 pandemic, economic resilience was mainly studied for natural disasters and financial crises (or business cycles) (e.g., Kitsos and Bishop (2018), Rose and Wei (2013)). After the onset of the Covid-19 pandemic, attention is given to economic resilience in response to the pandemic. Asongu, Diop, and Nnanna (2020) constructed a health vulnerability index (HVI) and depicted the link between health vulnerability and economic resilience. By calculating the index for all countries, they found that most African countries exhibit high health vulnerability and low economic resilience. Some researchers also focused on the resilience effect of a specific industry. Pierri and Timmer (2020) discovered the shielding effect of information technology (I.T.) in the U.S. Counties with high I.T. adoption rates can shield the economy from the impact of the pandemic, regardless of gender and race, except those with a lower level of educational attainment.

The resilience studies on African countries, particularly the rural areas, focused on community resilience and livelihood diversification. Individuals and households often possess different combinations of capital assets in their livelihood portfolios. Depending on the circumstances, they may convert one category of assets to another (Stocking and Murnaghan, 2001). Rakodi (1999) suggested that the observed diversifications in livelihood portfolios relate to households' sense of insecurities and sensitivities in changing environments. It was also identified as evidence of vulnerabilities of families due to poverty and hence is a core target of poverty alleviation (Carney, 1999). Another stream of literature considers diversification as the issue of seasonality (e.g., Haggblade et al., 1989). During the non-growing season, rural households pursue employment in the nonfarm economy, where the income generated is in turn to support the later agricultural activities. The flows of labor and finance between farm and nonfarm activities, under this framework, are inseparable and complementary.

Typically, the nonfarm activities are conducted through establishing household nonfarm enterprises (HNFEs), which are small and informal businesses employing less than five workers (Nagler and Naude, 2014). The HNFE offers informal insurance to households by absorbing the unemployed household members' labor supply when limited social security exists (Bridges et al., 2013). For business performance analysis, due to the data availability, most of the literature focused on either formal or manufacturing enterprises, which are primarily urban-based (e.g.,

[4] For a complete review of measurement and definitions of various types of economic resilience, please see Hallegatte (2014). For a closely related concept, community resilinece, please see Kruse et al (2017). Barretta et al (2001) provides a complete summary about the concepts and dynamics of income diversifications.

Frazer, 2005; Shfieraw, 2009; and Klapper and Richmond, 2011). For entrepreneurship, a plethora of literature focuses on formal small-to-medium enterprises in developed countries during an epidemic, such as avian influenza (Basuno et al., 2010) and the current COVID-19 pandemic (Batrik et al., 2020; Fairlie, 2020). As one of the few existing studies, Nagler and Naude (2017) provide a comparative overview of HNFEs in rural Sub-Saharan Africa using LSMS-ISA survey data. They found that enterprises operated by necessity are less productive than those operated due to seeking an opportunity. Female-owned, rural enterprises located in regions with a history of violent conflicts are more likely to have lower productivity levels.

Empirical studies consistently show that diversification to non-farm livelihood strategies rather than relying only on subsistence farming enables households to have better incomes, enhance food security, increase agricultural production by smoothing capital constraints, and better cope with environmental stresses. For example, Reardon et al. (1992) and Webb and Reardon (1992) find that households' capacity to cope with the drought shocks of the mid-1980s in Burkina Faso was strongly associated with the extent of their non-farm diversification patterns. Barrett and Arcese (1998) similarly show that in Tanzania, wildlife poaching responds partly to agroclimatic shocks that affect farm labor productivity. However, predominately, livelihood diversification and community resilience are more frequently evaluated during non-health-related extreme events, such as floods, famine, and droughts. Sparse literature focused on livelihood diversification and HNFE in rural African countries in response to an epidemic. As highlighted by Bordi et al. (2021), while diversified livelihood strategies effectively mitigate many sources of covariant and idiosyncratic risks, such as weather shocks and price spikes, an epidemic is different. Efforts to contain the spread of the virus have led to business closures, restrictions on trade and domestic mobility, and disruptions in markets for agricultural outputs, inputs, and labor, which affect different facets of people's livelihoods (FEWS NET, 2017). The multi-dimensionality of risks and stressors created by the EVD epidemics is unique.

In one of the few existing studies focusing on the Ebola outbreak, Maconachie and Hilson (2018) found that Sierra Leone's rural diamond diggers exhibited considerable resilience during the Ebola epidemic by diversifying their livelihood portfolio. In response to social quarantine policies, diamond diggers and supporters branched out into new economic activities in isolated locations, such as chromite and coltan extraction in remote off-road villages. Others focused on the determinants that constitute community resilience during Liberia's Ebola outbreak. Through key informant interviews with community representatives, Alonge et al. (2019) and Barker et al. (2020) identified strong leadership, tight kinship at the community level, trusted communication channels, and trusted health system stakeholders are the key factors of community resilience in response to the Ebola outbreak in Liberia.

Literature on the Covid-19 pandemic could also shed some light on the effect of the pandemic on the non-farm sectors of rural households. In a comparative cross-country study, Bordi et al. (2021) showed that non-farm businesses are the most frequently cited source of income loss due to the Covid-19 in urban and rural areas, regardless of countries' development status. They also noted a more significant heterogeneity in more advanced food system countries due to their more flexible and diversified non-farm businesses. Similarly, based on a real-time survey shared on Facebook social media platforms in Sub-Saharan countries, Balde et al. (2020) found that workers in the informal economy tend to be more hard hit by the Covid-19 pandemic than their counterparts employed in formal sectors. They are more likely to lose their jobs and experience decreased earnings due to the imposed lockdown policies. Using phone surveys and pre-Covid household surveys, Josephson et al. (2020) also found that the non-farm income sources are the most vulnerable to the lockdown policies. They also noted that rural households are more likely to use extreme coping strategies, such as selling productive assets, in response to the pandemic, which might cause negative long-term consequences.

Overall, economic and community resilience is a crucial topic in development economics. Previous literature primarily focused on the non-health-related crisis or the formal sectors in developed countries. However, virtually no empirical research has been conducted on the non-farm informal sectors of rural households during the Ebola epidemic.

4. Data and Empirical Methods

This section presents our empirical methods to capture the Ebola effect on the affected countries at the national, industrial, and household levels. Since we have both pre-Ebola and post-Ebola data and Ebola is an unexpected exogenous shock, we select the difference-in-difference estimation method as our primary approach. After summarizing the intuition behind the difference-in-difference method in section 4.1, we illustrate specifications at macro and micro levels and their corresponding data sources in sections 4.2 and 4.3, respectively. Section 4.4 discusses the recently raised issues of difference-in-difference with multiple periods by the recent literature and the associated robustness checks.

4.1 Key Empirical Strategy: Difference in Difference (DiD)

The Difference in Difference (DiD) is a quasi-experimental design that applies to sets of group means when certain groups are exposed to the causing variable of interests (i.e., treatment group) and others are not (i.e., control group) (Angrist and Krueger, 2008). The DiD is implemented by taking two differences between group means at pre-treatment and post-treatment periods. The treatment effect is the difference between the pre-treatment and post-treatment differences. By only considering the differences, DiD models remove biases in post-intervention period comparisons between the treatment and control group that could result from time-invariant differences between regions and location-invariant differences between periods. In other words, ideally, it can account for changes due to factors other than the interested intervention. Therefore, the DiD is frequently used in economics and other social science disciplines to investigate the effects of a specific intervention or treatment when individual/country-level randomization is implausible.

To make casual inferences on the estimated treatment effect as the average treatment effect, apart from the assumptions of the OLS models, the DiD model further needs to meet the parallel trend assumption. It requires that the difference between the treatment and control groups is constant over time without intervention. Violation of parallel trend assumption will likely lead to biased estimation of the casual effect, while there is no specific statistical test for this assumption. Typically, researchers choose to compare the outcome trend of both treated and control groups before the onset of the intervention. However, recent literature has suggested that passing the parallel trend test is neither a necessary nor sufficient condition to justify the validity of the difference-in-difference method (Kahn-Lang and Lang, 2018).

In our settings, since we have both pre-Ebola and post-Ebola data at both national and household levels, the difference in difference model will provide a relatively interpretable and reliable estimate of the effect of Ebola on the affected countries.

4.2 Aggregate Effects of Ebola at National and Industrial levels

In our macroeconomics analysis, we use the following two-way fixed effects (TWFE) model to implement the DiD method:

$$Y_{it} = \alpha + \gamma(Outbreak_{it}) + \beta(Post\ Ebola_{it}) + \delta(Outbreak_{it} \times Post\ Ebola_{it}) + \varphi X_{it} + \epsilon_{it}$$
(Equation 1)

where $Outbreak_{it}$ is a categorical variable indicating whether the country is Ebola-affected or not. It equals one if the country i has more than one case of Ebola during 2014 and is zero if otherwise. In our analysis, Guinea, Liberia, Sierra Leone, Nigeria, and Mali have more than Ebola cases during the epidemic and hence are coded as one. $Post\ Ebola_{it}$ is a categorical variable equal to one if time t is after the onset of the Ebola outbreak (i.e., March 2014) and zero if otherwise. X_{it} are covariates, and Y_{it} is our outcome of interests, including iron exports, foreign direct investment (FDI), Gross Domestic Product (GDP), and inflation rate. ϵ_{it} is the residual error term. We use clustered standard errors at the country level in all regressions. Our key coefficient of interest is δ, which should capture the average treatment effect of Ebola on the affected countries (i.e., ATT) if the parallel trend assumption holds.

Equation 1 provides a pooled estimate of the Ebola effect. To distinguish the possible long-run and short-run effects, we estimate another two regression models. To identify short-run effects, we run the regression with observations before the end of 2015. To identify long-run effects, we exclude observations during 2014 and 2015 and run the regression with observations before 2014 and after 2015.

We select the iron industry as our focus for industrial analysis because all Ebola-affected countries possess significant amounts of reserves in iron ores. It is also a commonly exported mineral by all affected countries (USGS Mineral Information, 2015), especially Liberia and Sierra Leone, which are more likely to experience a significant effect of Ebola[5]. We select other non-Ebola-affected African countries that are also leading iron exporters as our control groups. Notably, we select sixteen countries as the control when analyzing GDP, FDI, and iron exports: Algeria, Angola, Cameroon, Central African Rep., Cote d'Ivoire, Dem. Rep. of the Congo, Egypt, Gabon, Libya, Mauritania, Mauritius, Senegal, Tunisia, Uganda, and Zimbabwe. For the inflation rate, since different regions of Africa may experience different time trends, we select the neighboring unaffected Western African countries as the control group: Ghana, Mauritania, and Senegal. Unfortunately, since the inflation rate for Sierra Leone and Mali are mostly missing, we have to exclude them from our analysis of inflation.

4.2.1 Data for Macroeconomic Variables

[5] Admittedly, diamonds and gold are another two commonly-exported minerals by the affected countries. However, since the diamond and gold exports by Sierra Leone and Liberia have been previously sanctioned by the United Nations Security Council (2007), the production and exports of these two products might be different from other African exporting countries. Therefore, we choose not to use diamond and gold as our focus in industrial and national analysis.

United Nations Conference on Trade and Development (UNCTAD) and United Nations Commodity Trade Statistics Database (UN-Comtrade) are two key open-access databases providing outcome variables in our analysis. UNCTAD provides well-harmonized and integrated statistics on its online platform with a unique coverage for countries and products focusing on developing and transition economies. We obtain the following statistics from UNCTAD: annual Foreign Direct Investment (FDI) and annual inflation rates (measured by consumer price indices) from 2009 to 2019. UN-Comtrade is a repository of official international trade statistics collected by the Trade Statistics Branch of the UN Statistics Division. We downloaded the monthly export value of selected twenty-one iron exporting African countries from December 2008 to December 2009 under the HS commodity codes 72 (iron and steel) and 73 (iron and steel articles). We obtain statistics on annual GDP from the International Monetary Fund (IMF).

We select covariates that are widely available across all selected iron exporting countries. We acquired statistics on several institutional indexes from the Heritage Foundation (Economic Freedom Index, Trade Freedom Index, and Investment Freedom Index) and the Swiss Institute of Technology in Zurich (Globalization Index). We also downloaded data on labor market information, such as unemployment rate and percentage of agricultural employment, from UNCTAD.

4.3 Microeconomic Effect of Ebola on Household Income and Small Business Activities in Sierra Leone

In our microeconomics analysis of Sierra Leone, we still adopt a similar design of DiD:

$$Y_{it} = \alpha + \gamma(Ebola\_Severity_{it}) + \beta(Post\ Ebola_{it}) + \delta(Ebola\ Severity_{it} \times Post\ Ebola_{it}) + \varphi X_{it} + \epsilon_{it} \quad \text{(Equation 2)},$$

where $Ebola\ Severity_{it}$ is a categorical variable equal to one if the district individual i located in has more cumulative Ebola cases per 1000 people than the median of all districts, equal to zero if otherwise. $Post\ Ebola_{it}$ has a similar definition as in equation 1, where it is equal to one if the time t is after the onset of the Ebola outbreak in Sierra Leone (i.e., May 2014) and equal to zero if otherwise. X_{it} are individual-level covariates that are commonly used in the literature, including demographic and job/firm-related information. Y_{it} is our outcome of interests, including the household head's income and employment and HNFE activities. We also include a district dummy in the regression to account for district fixed effects, and the SEs are all clustered at the district level in all regressions.

In equation 2, we use districts with relatively fewer cumulative Ebola cases at time t as the control group and districts with above-median cumulative cases as the treatment group. As illustrated in section 2, the capital city of Sierra Leone, Freetown (or Western Urban), became an epicenter during the outbreak. At the same time, it is also an economic and financial center of Sierra Leone. As one of the major cities with the highest population, Freetown is more globalized as its economy revolves around its natural harbor. Therefore, it would be compelling to isolate Freetown from other worst or less affected districts to see how Ebola affects this unique district. Following Bowles et al. (2016), we adjusted equation 2 as follows:

$Y_{it} = \alpha + \gamma(Ebola\ Severity_{it}) + \theta(Freetown_{it}) + \beta(Post\ Ebola_{it}) + \delta(Ebola\ Severity_{it} \times Post\ Ebola_{it}) + \tau(Freetown_{it} \times Post\ Ebola_{it}) + \varphi X_{it} + \epsilon_{it}$ (Equation 3),

where $Freetown_{it}$ will be equal to one if the individual i lived in Freetown as reported in the LFS and equal to zero if otherwise.

Both equations 2 and 3 describe the ordinary least square regression (OLS), which is more appropriate for continuous dependent variables, such as the log-transformed HNFE revenue. For categorical dependent variables such as employment and HNFE operation status, we fit equation 3 into a probit regression model. More formally, we fit:

Pr ($Y_{it} \neq 0 \mid Ebola_{Severity_{it}}, Freetown_{it}, Post\ Ebola_{it}, Ebola_{Severity_{it}} \times Post\ Ebola_{it}, Freetown_{it} \times Post\ Ebola_{it}, X_{it}) = \Phi[\alpha + \gamma(Ebola\ Severity_{it}) + \theta(Freetown_{it}) + \beta(Post\ Ebola_{it}) + \delta(Ebola\ Severity_{it} \times Post\ Ebola_{it}) + \tau(Freetown_{it} \times Post\ Ebola_{it}) + \varphi X_{it}]$ (Equation 4),

where Φ is a standard cumulative normal function. Different from the OLS, we have limited ways to interpret an individual regression coefficient. A positive coefficient means that an increase in the independent variable leads to an increase in the predicted probability of $Y_{it} \neq 0$, i.e., the probability of being employed or the probability for an HNFE keeping active.

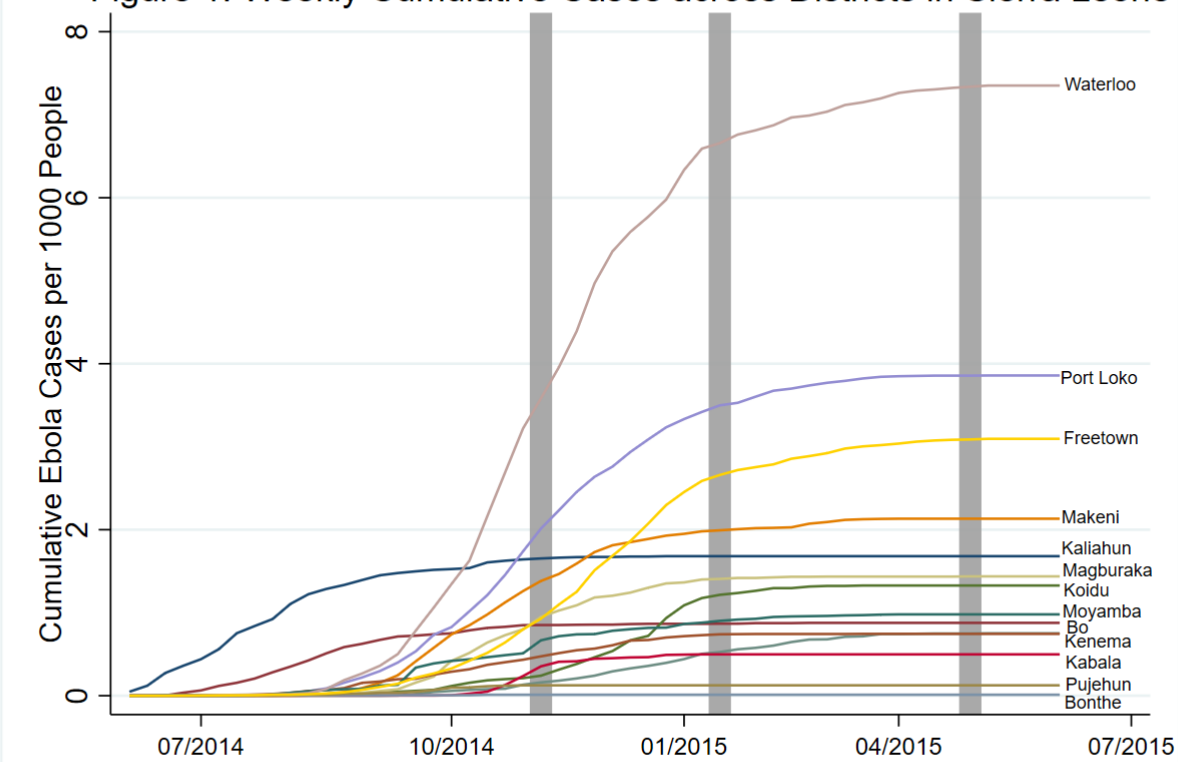
If the parallel trend assumption holds, δ and τ in Equations 2 - 4 will estimate the casual effect of the Ebola outbreak in more affected regions and Freetown relative to the less affected regions, respectively. However, in our settings, this assumption may not be valid. Since high mobility between districts of Sierra Leone is one of the major transmission chains during the epidemic, as highlighted in section 2, districts with fewer Ebola cases are likely less integrated into the regional or global economy, making them have different trends in outcomes. It is also likely that the Ebola outbreak affects each region irrespective of the disease severity measured by cumulative cases. Thus, similar to Bowles (2016), the estimations of δ and τ in our specifications are just comparing the extent of Ebola cases and observed economic outcomes across several districts of Sierra Leone.

4.3.1 Data for Microeconomic Variables

We choose WHO-Global Health Observatory as the source for Ebola case data. It provides weekly case and death reports for Sierra Leone and Liberia at the district/county level. Our household/individual-level data for Sierra Leone are the 2014 Labor Force Survey (LFS) and the High-Frequency Cell Phone Survey on the Socio-Economic Impacts of Ebola 2014-15 (HFCPS). LFS was designed and implemented by Statistics Sierra Leone (SSL) with the support from the WB, International Labor Organization (ILO) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The survey took place during July and August 2014, providing a nationally representative sample of 4124 households from 280 randomly selected Enumeration Areas (EAs). Conducted by the Government of Sierra Leone with the support from the WB, HFCPS consists of three rounds of mobile phone surveys aiming to capture the critical socioeconomic effects of the virus. It used phone numbers previously recorded in the LFS to deliver the surveys to the household head. The three rounds of data collection took place in

November 2014, January-February 2015, and May 2015. Overall, 66% of the 4199 households in the LFS reported a cell phone number. Of those with cell phones, 51% were surveyed in all three rounds, and 79% were included in at least one round. Both LFS and HFCPS use the same identifying variable for each household, which allows us to merge two datasets together. To put the HFCPS into the context of the evolution of Ebola in Sierra Leone, we plotted the weekly cumulative Ebola cases across districts and the survey dates as greyed areas in Figure 1. Round 1 of the HFCPS took place in the mid of explosion phase of Ebola, and Round 2 was undertaken when the Ebola cases largely stabilized. Round 3 was almost at the end of the outbreak, with only sporadic new cases.

Figure 1: Weekly Cumulative Cases across Districts in Sierra Leone



Given the time span of the Ebola outbreak, the LFS 2014 might have been affected by the epidemic, whose data collection continued despite the Ebola outbreak (SSL, WB, ILO, 2015). As a result. Four selected E.A.s (out of 14) in the Kailahun district were under quarantine and were replaced with new E.A.s randomly chosen with the same methodology used to determine the original E.A.s. With a closer look at the data, we note that most data were collected from mid-July to late August of 2014. Therefore, in the subsequent analysis on LFS, we will not use some time-sensitive outcomes, such as hours of work in the last *seven days*. Instead, we will use outcomes consisting of a longer time span, such as whether been employed in the *last 12 months*. In their questionnaire, the "last 12 months" refers to July 2013 to June 2014, with little potential data contamination due to the Ebola outbreak.

Also, as highlighted in the technical report of HFCPS, due to the different characteristics of responding and non-responding households, the sample is descriptive rather than representative of the Sierra Leonean population (SSL, WB, and ILO, 2015). Since the HFCPS was only administered to households with a reported cell phone number, it is likely that our estimation of δ and τ represents only a relatively better-off population. Therefore, our estimates may not represent the general Sierra Leone population.

4.3 Limitations of Two-Way Fixed Effects Model and Robustness Checks[6]

Researchers have long thought that the TWFE estimates of ATT as δ in Equation 1 are equivalent to a difference-in-difference ATT estimate. However, it has recently been shown that this equivalence only holds under several stringent assumptions. TWFE DiD estimates would be biased and even wrong signed without these implausible assumptions. Since then, several remedies have been proposed (e.g., Callway and Sant'Anna, 2018; Abraham and Sun, 2019; Imai and Kim, 2019).

De Chaisemartin and D'Haultfœuille (2020, hereinafter DD (2020)) have shown that to make δ as an unbiased estimate of the ATT in the setting of multiple periods, it would need another two assumptions other than the parallel trend assumption: i) the design is staggered (i.e., the country can only be either affected by Ebola or not and can switch its status at different times) and ii) no variation in treatment timing (i.e., Ebola outbreak starts at all affected countries at the same time). In our settings, assumption (i) holds, while assumption (ii) is not valid. As illustrated in section 2, the affected Western African countries had their first Ebola cases on different days. Although Liberia and Guinea detected their first Ebola cases in late March 2014, it was until May and late August 2014 for Sierra Leone and Mali to find their first cases.

Goodman-Bacon (2018) further showed that the δ is a "weighted average of all possible two-group/two-period DiD estimators in data." Without further assuming no heterogenous treatment effect over time or groups, some of these two-by-two estimates have negative weights and are subtracted from the DiD estimates. It will yield results that could be too small or even wrong-signed. However, treatment effects of Ebola likely vary by country since different countries have different exposures to Ebola. Even in the three most-affected countries, the response of iron ore companies varied (Bermúdez-Lugo and Menzie, 2015). It is also likely that the treatment effects vary across time. Indeed, it is one of the goals of this project to identify whether Ebola has any long-lasting effects. Thus, in our settings, the assumption of constant treatment effect is unlikely to be valid.

Goodman-Bacon (2018) also showed that with different treatment starting times, TWFE estimators would use results based on some forbidden comparisons: (i) the later-treated groups (Sierra Leone, Mali, Nigeria) being used as a control before its treatment begins and (ii) the earlier treated group (Liberia and Guinea) being used as control after its treatment begin.

It is far beyond the scope of this paper to engage in a detailed discussion about which solution recommended by the recent highly evolving literature is superior or how exactly the TWFE model will influence the estimates in our settings. However, it would be worrisome if the applied method in this project might be biased and based on a series of implausible assumptions. Fortunately, for Equations (2) and (3), there are only two periods involved in the regression (i.e., one baseline and one post-Ebola period) and are free from the multiple-period issues. Also, when analyzing the macroeconomic outcomes on an annual basis in equation (1), we could define the post-Ebola periods as years after 2014 and avoid the problem of different timings of Ebola in each

[6] See de Chaisemartin and D'Haultfœuille (2022) for a review of the rapidly evolving literature about this issue.

country. The issue is more disturbing when analyzing the outcome variables, such as export values and inflation rate on the monthly basis. Therefore, we run the regression with aggregated annual data to re-evaluate the effect on export values and inflation rate. In the regressions of equation (1), we also report the summary measures calculated based on DD (2020) for each reported specification.

Summary measures from DD(2020) include the estimated weights attached to the equation (1) as well as the other two measures to check for robustness against the treatment heterogeneity across countries and over time. The first measure corresponds to the minimal value of the standard deviation of the Ebola effect across the affected countries and periods such that δ and ATT of *some* countries and periods have opposite signs. When the first measure is small, they can only have opposite signs even if there is no substantial heterogeneity across countries and periods (i.e., not robust to the treatment heterogeneity). If there is a negative weight, the second measure will be calculated and represents the minimal standard deviation such that δ and ATT of *all* countries and periods have opposite signs. Similarly, suppose the second measure is small. In that case, this indicates our results are not robust to the treatment heterogeneity because δ and all true ATT can have opposite signs even if there is modest heterogeneity. Thus, the summary measures by DD(2020) provide a straightforward method to test whether our results based on equation (1) are robust to the TWFE multiple periods issues as mentioned above, including negative weights problem and treatment effect heterogeneity. If we find that our estimates have negligible negative weight with considerable measures one and two, we would be confident to conclude that the estimation is a robust and accurate estimate of ATT. However, if we notice a considerable magnitude or proportion of negative weights or a small measure of one or two, we would be skeptical toward our estimates and more reliant on alternative regression methods.

To account for the potential biases due to the heterogeneous treatment effect over group and time, we apply a non-parametric method proposed by Callaway and Sant'Anna (2020, hereinafter CS (2020)) as a further robustness check. The basic intuition of CS (2020) is only to use never-treated or not-yet treated as the control group, and each country can be aggregated into cohorts that started experiencing Ebola outbreak in the same period. For the treated group, all estimations of ATT of a group at a post-Ebola period use the last not treated period (i.e., one month/year before the Ebola started) as the baseline and use the current period as the post period. It further relaxes the parallel trend assumption by allowing it to be conditional on covariates. However, it is limited to assuming all covariates are time constant, where only the base-period values are used for estimations. This assumption might not hold given the rapidly evolving African economies in the 2010s. It is also computationally expensive with higher requirements on degree of freedom since it decomposed equation (1) into a series of 2*2 canonical DiD regression. Therefore, we use results from CS(2020) just as a reference for our TWFE estimates.

When all necessary assumptions are met, the average treatment effect for group g at time t is non-parametrically identified as:

$$ATT(g,t) = E\left[\left(\left(\frac{G_g}{E[G_g]}\right) - \frac{\frac{p_g(X)C}{1-p_g(X)}}{E\left[\frac{p_g(X)C}{1-p_g(X)}\right]}\right)\left(Y_t - T_{g-1}\right)\right] \text{ (Equation 4)}$$

where G_g is a categorical variable equal to one when the country is first treated in period g. C is a binary variable to indicate the control group, equal to one for a never-treated country. $p_g(X)$ is the generalized propensity score and equal to $P\left(G_g = 1|X, G_g + C = 1\right)$, which is equivalent to the probability that a country has Ebola cases conditional on having covariates X and conditional on being a member of group g or a control group C. Y_t is the potential outcomes at time t with/without the treatment. T_{g-1} represents the outcome of group g in the last not treated period, $g - 1$.

5. Descriptive Statistics

Table 1 provides the descriptive statistics on macroeconomic variables. We present means and standard deviations for both Ebola-affected countries and selected control groups during pre- and post-Ebola periods. After the Ebola outbreak, the Ebola-affected countries experienced a decline in iron exports and Foreign Direct Investments (FDI), both in terms of their absolute dollar values and percentages relative to the GDP. Their economies keep expanding with a higher GDP per capita after the outbreak. The price levels are also more stable in the post-Ebola periods but still keep two-digit inflation rates.

On the other hand, the selected control groups are more established iron exporters with more developed economies in terms of GDP per capita. The controlled groups attracted fewer FDI inflow than the Ebola-affected counterparts in the pre-Ebola periods, but this relationship reversed after the outbreak. However, they also witnessed a sharp decline in their GDP per capita after the outbreak. The main reason behind this is that the selected countries also rely on the exports of crude oils. The decline of international oil prices severely harmed the economies of these oil exporters, such as Algeria and Angola, making their GDP per capita drop by over 5% during the period 2015 to 2017. In the post-Ebola periods, their price levels are much more stable, reversing the previous deflation trend.

Table 1: Descriptive Statistics on Macroeconomic Variables (on the annual basis)

	Pre-Ebola (2009-2013)				Post-Ebola (2014-2019)			
	Affected Countries		Control Group		Affected Countries		Control Group	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Iron Exports in USD (millions)	628.04	1019.32	1491.17	2497.81	622.30	799.32	1860.17	3049.27
Iron Exports per GDP (%)	4.13	5.62	2.34	0.18	3.70	2.80	2.89	2.22
GDP per capita	967.383	811.16	3514.79	3499.16	1044.71	745.53	3040.01	2688.56
FDI in USD (millions)	1833.32	2862.15	1026.36	1876.01	836.83	1168.91	1205.32	2412.70
FDI per GDP (%)	13.47	18.01	3.16	3.73	5.09	5.91	2.89	3.04
Inflation Rate (%)	26.83	92.09	-7.20	29.7	12.19	5.5	2.20	14.7

Table 2 provides basic summary statistics on microeconomics factors in Sierra Leone for all three rounds of High-Frequency Cell Phone Surveys taken during the Ebola outbreak and their corresponding baseline statistics extracted from the Labor Force Survey. Following the designs in empirical sections, we divide our sample into three groups: Freetown (Capital city), less Ebola-affected districts, and worse Ebola-affected districts. We noticed a gradual improvement in the employment rate as we moved toward the end of the outbreak. In round 3, both employment outcomes and household non-farm enterprises' (HNFE) activities return to their baseline values. For the demographic factors, we noticed that our sample mainly consists of male household heads with an average age of around 45. Across all rounds of surveys, over 70% of the sample are married, and more than half of them cannot read or write.

Regarding the job formality, less than 15% of surveyed respondents have a job with a written contract. Most received no benefits (such as medical insurance and pensions) from their jobs. Most of the employed respondents at baseline are working for the job they used to with a tenure of more than five years. For the HNFEs, more than half of them were unregistered at the baseline with few non-household employees. Households are more likely to operate an HNFE in the trading sector than in the service or production sectors.

Table 2: Microeconomic Factors in Sierra Leone

	Round 1 (November 2014)			Round 2 (January-February 2015)			Round 3 (May 2015)		
	Less Affected Mean	Worse Affected Mean	Freetown Mean	Less Affected Mean	Worse Affected Mean	Freetown Mean	Less Affected Mean	Worse Affected Mean	Freetown Mean
Baseline:									
Employed (%)	84.23	77.60	88.86	83.92	77.78	87.89	83.00	76.70	88.90
HNFE Operation (%)	55.50	56.60	57.90	58.90	56.60	56.90	55.60	57.60	56.00
HNFE Revenue (millions of Leone)	1.68	7.32	1.63	1.94	6.64	1.84	1.96	7.38	1.33
Post-Ebola:									
Employed (%)	69.77	65.20	60.96	71.82	74.18	63.03	82.60	85.40	75.10
HNFE Operation (%)	64.00	61.70	58.50	66.00	71.00	58.30	57.40	60.40	53.80
HNFE Revenue (millions of Leone, if operate at baseline)	0.43	0.43	0.41	0.27	0.54	0.54	0.31	0.57	0.36
Covariates:									
Age	45.46	44.61	45.13	45.51	45.11	45.07	45.05	45.42	44.69
Male (%)	70.23	69.58	69.96	68.18	71.08	71.85	67.18	69.26	69.76
Marital Status									
Married(monogamous) (%)	66.43	67.45	67.54	67.73	64.94	68.70	65.82	63.20	68.44
Married(polygamous) (%)	11.72	8.26	16.45	10.76	10.88	16.39	10.20	11.15	17.77
Informal/Loose Union (%)	0.87	0.34	0.66	0.76	0.69	0.84	0.85	0.56	0.53
Divorced (%)	2.03	0.84	0.88	2.27	0.86	0.84	2.55	0.93	0.27

Separated (%)	2.89	3.88	4.17	2.73	3.80	3.57	3.57	3.90	2.65
Widowed (%)	10.42	10.79	8.55	9.85	11.05	7.56	10.71	13.01	8.49
Never Married (%)	5.64	8.43	1.75	5.91	7.77	2.10	6.29	7.25	1.86
Literacy									
Cannot Read or Write (%)	62.28	51.43	70.18	59.09	53.53	69.12	59.35	54.63	69.76
Yes, read and write (%)	35.84	46.22	27.63	39.24	44.06	27.73	39.29	43.52	27.85
Read only (%)	1.45	2.02	1.54	1.52	1.89	1.89	1.19	1.48	1.06
Write only (%)	0.43	0.34	0.66	0.15	0.52	1.26	0.17	0.37	1.33
Received Formal Education (%)	42.68	54.55	32.18	48.05	52.72	32.96	48.67	51.41	32.12
Received Vocational Training (%)	13.79	17.27	9.15	13.21	17.14	8.79	13.32	16.67	7.48
Jobs Providing Benefits at Baseline (%)	9.54	11.76	4.82	11.36	11.02	3.78	12.41	9.26	3.98
Jobs with a Written Contract at Baseline (%)	10.69	14.12	7.02	12.73	12.91	6.09	13.44	11.85	5.84
Employment Status at Baseline									
Wage Sector (%)	14.02	19.66	8.99	16.82	17.90	7.56	18.20	16.48	8.22
Self-Employed (%)	56.36	48.24	65.35	52.73	49.23	67.65	51.53	49.63	66.58
Household Enterprise (%)	0.00	1.68	8.55	5.00	1.72	7.98	4.59	1.48	9.02
Apprenticeship (%)	5.64	0.84	0.22	0.15	1.38		0.17	1.11	0.27
Unemployed/Unclassified (%)	23.99	29.58	16.89	25.30	29.78	16.81	25.51	31.30	15.92
Job Tenure									
Zero (%)	23.99	29.92	17.11	25.30	29.95	16.81	25.68	31.30	16.18
<1 year (%)	2.60	2.69	1.54	2.58	3.27	1.26	2.72	3.33	1.59
1 year - 3 years (%)	6.65	6.89	5.26	7.42	6.88	5.25	7.48	7.22	4.24
3 years - 5 years (%)	9.83	8.24	7.89	10.15	8.78	6.72	10.71	7.59	6.90
5 years - 10 years (%)	14.60	13.78	15.79	13.48	13.25	16.60	12.93	13.89	18.57
>10 years (%)	42.34	38.49	52.41	41.06	37.87	53.36	40.48	36.67	52.52
Worked in a High-Risk Sector at baseline (%)	24.57	23.70	21.71	24.85	24.10	21.43	23.30	23.70	19.89

Number of non-Household Employees in the HNFE at baseline	0.20	0.21	0.09	0.20	0.24	0.09	0.37	0.42	0.13
HNFE registered (%)	39.90	42.90	47.60	41.70	42.20	47.90	40.60	44.60	47.50
Own at least one HNFE on service sector at baseline (%)	7.70	9.20	7.00	8.30	9.30	6.70	7.80	8.30	6.40
Own at least one HNFE on trading sector at baseline (%)	49.70	47.60	53.10	51.20	49.10	52.50	48.80	51.50	52.00
Own at least one HNFE on production sector at baseline (%)	4.90	5.40	4.80	6.50	4.50	4.80	6.10	4.40	4.80
Total	692	595	456	660	581	476	588	540	377

6. Discussions of Results

We now turn to our main empirical results. Our discussion on macroeconomic variables focuses on the interaction term between Outbreak and Post Ebola dummy variables to assess the effect of the Ebola outbreak on our outcomes of interest in different periods. We report both the coefficient and standard deviations in all regression outputs, and the latter is placed in the parenthesis. Stars are attached next to the standard error if the coefficient estimates are statistically significant at 1%, 5%, or 10%. At the bottom of each regression table, we also report the summary measures of each regression's robustness to heterogeneous treatment effect as proposed by de Chaisemrtin and D'Haultfoeuille (2020, hereafter DD(2020)).

Following the convention, when the dependent variable is in dollar values, we apply the log transformation to reduce the skewness and help us to meet the normality assumption of an OLS regression. However, the log transformation only applies to non-zero values since the log of zero is undefined. In this case, we add one to the meaningful zero-valued observations prior to their transformation (i.e., log(Y+1)). Since our dollar values are usually in millions, adding one to the zero value is unlikely to distort the whole data structure. Although this is one of the most commonly used practices, we acknowledge that this approach might make our estimators not consistent without a strong assumption in the joint distribution of error terms and the transformed variables (Bellego and Pape, 2019)[7].

6.1 Parallel Trend Tests

Table 3 presents the parallel trend test results on macroeconomic variables on an annual basis. The growth of GDP per capita in the constant dollar is not significant except for 2009. However, almost all coefficients are significant for the log-transformed GDP per capita in constant dollars. The inflation rate is mainly insignificant, with only 2011 being weakly significant at the 90% level. All coefficients for log-transformed annual FDI and its percentage as GDP are insignificant, except the percentage term in 2011 being significant only at 90% level. The trade values of iron exports are also only significant for 2009 and 2010.

A significant coefficient in table 3 would indicate that the outbreak-year interaction term is essential for our interested outcomes in pre-Ebola periods, pointing out possible differential trends between Ebola-affected and control groups. So, we are confident that the parallel trend assumptions hold for most of our macroeconomic dependent variables, except for the log-transformed GDP per capita. However, as noted in the previous section, the test is not a necessary nor sufficient justification for the parallel trend assumption. Therefore, a highly significant coefficient is not a fatal error that will preclude us from employing a difference-in-difference method.

[7] We also perform the inverse-hyperbolic sine (HIS) transformation and get qualitatively similar results. Admittedly, when the variable is small, it might bias the estimator (Bellemare and Wichman, 2020).

Table 3: Parallel Trend Tests on Macroeconomic Variables

	GDP per capita	log(GDP per capita)	Inflation Rate	log(FDI)	FDI per GDP	log(Iron Exports)	Iron Exports
	1	2	3	4	5	6	7
Outbreak×2009	-0.8115	-0.1993		-0.0963	-0.0592	-2.4208	-0.0374
	(0.0356)***	(0.0419)***		(0.5891)	(0.0732)	(0.6105)***	(0.0165)**
Outbreak×2010	-0.0162	-0.1577	0.6487	-0.0558	-0.0287	-0.6129	-0.0049
	(0.0327)	(0.0426)***	(1.236)	(0.3236)	(0.0411)	(0.1649)***	(0.0054)
Outbreak×2011	-0.0206	-0.1202	0.0459	0.9198	0.077	-0.0119	0.0235
	(0.0293)	(0.0410)***	(0.0205)*	(0.5544)	(0.0488)	(0.1249)	(0.0194)
Outbreak×2012	0.0086	-0.0556	0.0184	-0.8217	0.0303	-0.1617	0.0116
	(0.0202)	(0.0267)*	(0.0147)	(1.02)	(0.0175)*	(0.1554)	(0.013)
_cons	3.1782	7.4124	-0.264	6.4933	0.0558	5.1138	0.0195
	(1.8715)	(0.0261)***	(0.1647)	(0.1119)***	(0.0096)***	(0.2127)***	(0.0029)***
N	104	0.1395	23	95	104	105	105

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis

6.2 Aggregate Effect of Ebola: GDP growth and Inflation Rate

We begin by evaluating the effect of Ebola on GDP per capita (in constant USD) with results reported in Tables 4 and 5.

Table 4 does not find statistically significant effects on GDP per capita since the interaction term between Outbreak and Post Ebola is insignificant in all periods. However, since part of our control group is also the leading exporters of oil and iron in Africa, the fluctuations in international oil prices would also affect these countries' GDP per capita, masking our estimated effect from Ebola. Therefore, in Table 5, we run the same regression but exclude our control groups' top oil exporters. Particularly, we remove Algeria, Angola, Gabon, Ghana, Libya, and Egypt from the regression. However, we still do not have evidence that Ebola has any effect on either the GDP per capita growth rate or the log-transformed GDP per capita.

Summary measures by DD(2020) warrant our estimation are free from negative-weight problems when including all iron-exporting countries. After excluding the leading oil exporters, the negative-weight problem arises, though neither the proportion nor the magnitude of the negative weights is substantial. The significantly larger summary measure 2, compared to the coefficients of the interaction term, further confirms that the negative weight has a negligible likelihood that the negative weights will make our estimates have opposite signs with all true ATTs. However, summary measure 1 for the growth rate suggests our results may not be robust against the heterogenous treatment effects. Particularly, in table 1, measure 1 for column 1 is less than twice the coefficient of the interaction term, while in columns 2 and 3, measure 1 is even smaller than the coefficients. Measure 1 for the log-transformed GDP per capita in columns 4 to 6 is several times larger than the coefficient, indicating a robust estimate. Similarly, for table 2, measure 1 also suggests that our estimates of the effect on growth rate in columns 2 and 3 are not robust.

Then, in table 5, we analyze the effect of Ebola on the price levels of the affected countries, with neighboring Western African countries as the control group. In columns 1 to 3, our dependent variable is the monthly inflation rate, measured by the monthly consumer price index (CPI) percentage change. In columns 4 to 6, to avoid the issue of differing Ebola onset times in different affected countries, we run the regression on the annual inflation rate. We notice that the coefficients of the interaction term are all statistically insignificant.

Summary measures are not optimistic with the negative weight problems. Except for the short-run periods, there is a non-negligible likelihood that our estimates might be contaminated by the negative weights assigned to some ATTs. Both the proportion and magnitude of negative weights are significant. Particularly, for the medium-run estimates in columns 2 and 5, the sum of negative weights is more than 30% which means our estimates are very likely to underestimate the true ATTs. Summary measure 2 indicates that our estimates might have opposite signs for all true ATTs. Also, measure 1 is less than twice the coefficients in column 2 and smaller than the coefficients in columns 3-6. It suggests that our estimates of the annual inflation rate and the pooled estimates in the monthly inflation rate are not robust to the heterogenous treatment effects.

Overall, we find no evidence for a statistically significant effect of Ebola on annual GDP per capita or price levels in the short run or medium run. The null effect on price level is in line with Glennerster and Suri (2014, 2015, 2016). This also endorses the hypothesis that Ebola's shock influences both the supply and demand sides, and the two effects cancel out each other. However, our finding of no observable effect on GDP is different from all previous estimates by World Bank (2014a, 2014b) and UNDG (2015). One of the possible explanations is that the control group also experienced other external shocks that are not controlled by the included covariates. This would mask the negative effect of Ebola on GDP, but this still could not explain the insignificant coefficient of "Post Ebola." The Summary measures from DD (2020) indicate that our findings on the inflation rate and GDP growth rates based on equation (1) may not be robust for the heterogenous treatment effect across time or countries. These imply we to consider other alternative methods to measure the effect of Ebola on price levels.

Table 4: GDP per capita in Constant USD

	Growth Rate			Log(GDP per capita)		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	-0.0129	-0.0062	-0.0016	0.0298	0.0251	0.0258
	(0.0214)	(0.0179)	(0.0151)	(0.0325)	(0.0389)	(0.0344)
Outbreak×Post Ebola	-0.0385	-0.0144	-0.0247	0.0025	0.0363	0.0295
	(0.0355)	(0.0207)	(0.0235)	(0.0380)	(0.0674)	(0.0504)
UR	-0.0144	-0.0050	-0.0057	-0.0122	-0.0233	-0.0217
	(0.0075)*	(0.0030)	(0.0030)*	(0.0121)	(0.0108)**	(0.0099)**
AG	-0.0069	-0.0005	-0.0003	-0.0141	-0.0135	-0.0136
	(0.0057)	(0.0022)	(0.0021)	(0.0054)**	(0.0031)***	(0.0029)***
TFI	0.0025	-0.0005	-0.0003	0.0048	0.0027	0.0029
	(0.0029)	(0.0005)	(0.0006)	(0.0021)**	(0.0015)*	(0.0016)*
IFI	0.0019	0.0002	0.0002	0.0009	0.0019	0.0017
	(0.0022)	(0.0007)	(0.0008)	(0.0020)	(0.0020)	(0.0018)
EFI	-0.0263	-0.0057	-0.0061	0.0116	0.0072	0.0069
	(0.0175)	(0.0043)	(0.0038)	(0.0087)	(0.0049)	(0.0047)
_cons	1.6043	0.4079	0.4096	7.1198	7.5017	7.4987
	(1.0280)	(0.2291)*	(0.2110)*	(0.5657)***	(0.2538)***	(0.2336)***
R^2	0.0413	0.0131	0.0179	0.2750	0.4239	0.4077
N	118	159	198	139	180	219
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	0 (out of 10)	0 (out of 20)	0 (out of 30)	0 (out of 10)	0 (out of 20)	0 (out of 30)
Measure 1:	0.0721	0.0045	0.0217	0.1716	0.3323	0.2487
Measure 2:	-	-	-	-	-	-

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis

Note: UR stands for Unemployment Rate; AG stands for Percentage of Agricultural Employment; TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 5: GDP per capita in constant USD (excluding main oil exporters)

	Growth Rate			Log(GDP per capita)		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	0.0129	-0.0004	0.0058	0.0191	0.0109	0.0113
	(0.0179)	(0.0224)	(0.0193)	(0.0397)	(0.0479)	(0.0436)
Outbreak×Post Ebola	-0.0547	-0.0331	-0.0424	0.0039	0.0540	0.0404
	(0.0377)	(0.0281)	(0.0311)	(0.0485)	(0.0817)	(0.0605)
UR	-0.0092	-0.0032	-0.0039	-0.0173	-0.0325	-0.0304
	(0.0056)	(0.0037)	(0.0035)	(0.0147)	(0.0142)**	(0.0128)**
AG	-0.0061	-0.0036	-0.0034	-0.0156	-0.0152	-0.0158
	(0.0037)	(0.0022)	(0.0023)	(0.0082)*	(0.0056)**	(0.0054)**
TFI	0.0001	-0.0008	-0.0005	0.0034	0.0022	0.0024
	(0.0025)	(0.0006)	(0.0008)	(0.0032)	(0.0015)	(0.0018)
IFI	-0.0007	-0.0003	-0.0003	0.0007	0.0013	0.0014
	(0.0021)	(0.0005)	(0.0007)	(0.0024)	(0.0025)	(0.0022)
EFI	-0.0125	-0.0039	-0.0046	0.0187	0.0108	0.0100
	(0.0086)	(0.0025)	(0.0028)	(0.0096)*	(0.0060)*	(0.0059)
_cons	1.0754	0.4937	0.5093	6.7100	7.2657	7.3124
	(0.6921)	(0.1962)**	(0.2313)**	(0.5870)***	(0.3706)***	(0.3677)***
R^2	0.1025	0.0632	0.0755	0.4125	0.5404	0.5085
N	91	124	155	107	140	171
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	0 (out of 10)	2 (out of 20)	3 (out of 30)	0 (out of 10)	0 (out of 20)	1 (out of 30)
Sum of negative Weights	-	-0.0105	-0.0321	-	-	-0.0010
Measure 1:	0.1352	0.0343	0.0487	0.1721	0.3161	0.2422
Measure 2:	-	0.4638	0.2535	-	-	19.6536

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis

Note: UR stands for Unemployment Rate; AG stands for Percentage of Agricultural Employment; TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 6: Inflation Rate (Western African countries only)

	Monthly Inflation Rate			Annual Inflation Rate		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	-0.1420		-0.3314	-0.1621	-0.0429	-0.1110
	(0.1796)		(0.1553)*	(0.3291)	(0.3620)	(0.2570)
Outbreak×Post Ebola	-0.0662	0.0212	0.0394	-0.1680	-0.6109	-0.3419
	(0.2324)	(0.3090)	(0.2613)	(0.4794)	(0.3388)	(0.3669)
UR	0.0328	0.1169	0.1293	-0.0413	0.0939	0.0387
	(0.0345)	(0.0566)*	(0.0433)**	(0.0249)	(0.0335)**	(0.0334)
AG	-0.0811	-0.0654	-0.0687	0.0038	-0.0128	-0.0109
	(0.0259)**	(0.0285)*	(0.0238)**	(0.0691)	(0.0308)	(0.0212)
IFI	-0.0075	0.0226	0.0256	0.0041	0.0176	0.0139
	(0.0106)	(0.0141)	(0.0135)	(0.0155)	(0.0061)**	(0.0059)*
EFI	0.0744	0.0473	0.0433	0.0942	0.0383	0.0319
	(0.0261)**	(0.0457)	(0.0419)	(0.1077)	(0.0234)	(0.0226)
TFI	0.0081	0.0244	0.0103	-0.0068	0.0081	0.0042
	(0.0087)	(0.0097)*	(0.0137)	(0.0133)	(0.0037)*	(0.0070)
_cons	-10.3153	24.5672	27.8134	-4.6126	-3.1861	-2.2002
	(11.7879)	(7.2544)**	(8.6739)**	(7.5111)	(1.3458)*	(1.2537)
R^2	0.2240	0.2076	0.2145	0.0709	0.1207	0.0957
N	425	569	713	35	47	59
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of Negative Weights	0 (out of 62)	48 (out of 144)	72 (out of 206)	0 (out of 6)	4 (out of 12)	6 (out of 18)
Sum of Negative Weights:		-0.3248	-0.2103		-0.3431	-0.2768
Measure 1:	0.1565	0.0117	0.0002	0.0804	0.2237	0.1236
Measure 2:	-	0.0267	0.0005	-	0.5222	0.3077

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis

Note: UR stands for Unemployment Rate; AG stands for Percentage of Agricultural Employment; TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

6.3 Aggregate Effect of Ebola: FDI and Iron Exports

Then, we evaluate the effect of Ebola on Foreign Direct Investments and the trade values of Iron Exports. As mentioned at the beginning of this section, we add one to the zero value prior to its transformation to deal with zero values of dependent variables.

Table 7 analyze the effect of Ebola on annual FDI inflow as a percentage of GDP in column 1-3 and the log-transformed FDI inflow in column 4-6. We noticed a significantly negative effect on FDI inflow during 2014 and 2015 (columns 1 and 4). After the Ebola outbreak, the Ebola-affected countries have a 6.74% of decline in FDI per GDP than non-affected countries, significant at a 90% confidence level. In terms of USD in millions at current prices, the FDI inflow of affected countries slumps by 36% during 2014 and 2015, significant at a 95% confidence level. However, when using other longer time spans, the coefficient of interaction term quickly loses significance with no evidence for any medium-run effect on FDI inflow. Therefore, from table 7, we concluded that the Ebola outbreak only has a significantly negative short-run effect on FDI inflow but disappears after the end of the epidemic.

Summary measures from DD(2020) indicate our estimates in Table 7 are robust to the heterogeneous treatment effects, with measure 1 significantly larger than the coefficient of the interaction term. It finds that no individual country-year ATT is attached with negative weight, suggesting no evidence of negative-weight problems.

Table 8 reports the results of using monthly iron exports as the dependent variable. Table 9 aggregates the monthly trade values to the annual level to prevent the issues of different Ebola onset times among affected countries. In Tables 10 and 11, we use the same regression but exclude the non-Western African countries from our analysis. Since there was a constant decline in the demand for iron-related products driven by the recession of the Chinese economies, African iron exporters in different regions might respond differently. Therefore, a more refined control group selection could better expose the Ebola effect on iron exports. Although we do not find any evidence for a significant impact of Ebola on iron exports in any periods in tables 8-10, we notice significantly negative coefficients in columns 5 and 6 in Table 11 at 95% and 90% confidence levels, respectively. These indicate that the Ebola has negatively impacted monthly iron exports during the whole post-Ebola period.

Summary measures indicate that some ATTs are attached with a negative weight when we exclude non-Western African countries from the samples. However, neither the proportion nor the magnitude of those negative weights is significant. Measure 2 in tables 10 and 11 are considerably greater than the corresponding coefficient of the interaction terms, indicating a negligible likelihood that our estimates have an opposite sign with all true ATT. On the other hand, measure 1 is less optimistic in Tables 10 and 11, where measure 1 is considerably smaller than or close to the corresponding coefficients. This indicates that our estimates might have an opposite sign with some true country-time ATTs even with a small heterogeneous treatment effect. Similarly, when including Western African countries in our analysis, although there is no negative weight issue, some of our estimates might not be robust against the heterogeneity.

Overall, we find a significantly negative short-run effect of Ebola on FDI in terms of percentage of GDP and log-transformed values. Those effects disappear after the outbreak's end. This short-run effect is consistent with UNCTAD's report (2015), which found a 10% decline in FDI flows to Western Africa (or $12.8 billion). For the iron exports, we notice a significantly negative impact on its monthly values during the whole post-Ebola period, after excluding non-Western African countries. Summary measures based on DD (2020) indicate that our estimates on both FDI and iron exports are very likely to be free from the issues of negative weight. However, some of our evaluations on iron exports might not be robust against the heterogeneous treatment effects.

Table 7: Foreign Direct Investments Inflow (Annual)

	FDI Inflow per GDP			Log(FDI Inflow in USD, millions)		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	-0.0023	0.0072	0.0044	-0.0894	0.1479	0.0527
	(0.0085)	(0.0141)	(0.0119)	(0.1575)	(0.1406)	(0.1299)
Outbreak× Post Ebola	-0.0660	-0.0743	-0.0722	-0.4481	-0.3553	-0.3522
	(0.0357)*	(0.0489)	(0.0445)	(0.1966)**	(0.6038)	(0.4622)
TFI	-0.0035	-0.0024	-0.0023	-0.0011	-0.0143	-0.0100
	(0.0013)**	(0.0013)*	(0.0011)*	(0.0149)	(0.0090)	(0.0099)
IFI	-0.0008	-0.0015	-0.0013	-0.0077	-0.0047	-0.0014
	(0.0012)	(0.0016)	(0.0015)	(0.0144)	(0.0140)	(0.0115)
EFI	0.0034	0.0026	0.0022	0.1198	0.0369	0.0389
	(0.0020)	(0.0029)	(0.0024)	(0.0383)***	(0.0277)	(0.0266)
_cons	0.1496	0.1504	0.1555	0.4868	5.6585	5.1396
	(0.0833)*	(0.0890)	(0.0783)*	(1.6740)	(1.4770)***	(1.4133)***
R^2	0.1966	0.2306	0.2350	0.0791	0.0267	0.0263
N	127	166	203	127	166	203
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	0 (out of 10)	0 (out of 20)	0 (out of 30)	0 (out of 10)	0 (out of 20)	0 (out of 30)
Measure 1	0.2673	0.7629	0.6059	1.8517	3.6392	2.8942
Measure 2	-	-	-	-	-	-

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

Note: TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 8: Annual Iron Exports

	Iron Exports per GDP			Log(Iron Exports in USD, millions)		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	0.0015	0.0082	0.0053	0.2286	0.4394	0.3492
	(0.0023)	(0.0046)*	(0.0034)	(0.1802)	(0.1537)***	(0.1428)**
Outbreak× Post Ebola	-0.0044	-0.0100	-0.0092	0.0869	-0.0850	-0.0069
	(0.0059)	(0.0098)	(0.0093)	(0.2159)	(0.2813)	(0.2393)
TFI	-0.0015	0.0001	-0.0002	-0.0002	0.0184	0.0105
	(0.0007)**	(0.0006)	(0.0006)	(0.0226)	(0.0114)	(0.0107)
IFI	-0.0001	-0	0	0.0050	0.0110	0.0114
	(0.0004)	(0.0003)	(0.0003)	(0.0228)	(0.0135)	(0.0124)
EFI	0.0008	-0.0001	-0.0002	0.0760	0.0368	0.0360
	(0.0009)	(0.0008)	(0.0007)	(0.0885)	(0.0485)	(0.0463)
_cons	0.0860	0.0310	0.0488	1.5773	2.1932	2.7407
	(0.0457)*	(0.0352)	(0.0367)	(4.0141)	(2.5560)	(2.3844)
R^2	0.0644	0.0387	0.0290	0.0707	0.1844	0.1561
N	139	180	219	139	180	219
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	0 (out of 10)	0 (out of 20)	0 (out of 30)	0 (out of 10)	0 (out of 20)	0 (out of 30)
Measure 1:	0.0110	0.0815	0.0669	1.4193	0.0599	0.6950
Measure 2:	-	-	-	-	-	-

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

Note: TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 9: Monthly Iron Exports

	Iron Exports per GDP			log(Iron Exports in USD, millions)†		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	0.0010		0.0013	-0.8913		-0.6352
	(0.0005)*		(0.0007)*	(0.6808)		(0.7153)
Outbreak ×Post Ebola	-0.0001	-0.0007	-0.0006	1.1143	-0.3661	-0.0131
	(0.0005)	(0.0008)	(0.0008)	(0.9784)	(0.5463)	(0.6035)
TFI	-0.0002	-0.0000	-0.0000	-0.1078	-0.0278	-0.0398
	(0.0001)***	(0.0001)	(0.0001)	(0.0596)*	(0.0272)	(0.0177)**
IFI	-0.0000	-0.0000	-0.0000	0.0038	0.0317	0.0258
	(0.0000)	(0.0000)	(0.0000)	(0.0344)	(0.0291)	(0.0289)
EFI	0.0001	-0.0000	-0.0000	0.1586	0.0469	0.0518
	(0.0001)**	(0.0001)	(0.0001)	(0.0810)*	(0.0452)	(0.0462)
_cons	0.0068	0.0025	0.0038	-2.3916	-2.8050	-2.0587
	(0.0030)**	(0.0026)	(0.0025)	(4.5151)	(3.0578)	(2.9156)
R^2	0.1134	0.0995	0.1045	0.1457	0.1093	0.1230
N	1,668	2,160	2,628	1,668	2,160	2,628
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	0 (out of 96)	0 (out of 240)	0 (out of 336)	0 (out of 96)	0 (out of 240)	0 (out of 336)
Measure 1:	0.0001	0.0070	0.0041	5.4708	3.4632	0.3534
Measure 2:	-	-	-	-	-	-

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

† For the zero-value, we add one prior to its log transformation. Inverse-hyperbolic sine transformation yields a similar result.

Note: TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 10: Annual Iron Exports, only Western African countries

	Iron Exports per GDP			Log(Iron Exports in USD, millions)		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	-0.0007	0.0175	0.0109	-0.4175	0.2988	0.1653
	(0.0135)	(0.0161)	(0.0125)	(0.5981)	(0.4955)	(0.3967)
Outbreak×Post Ebola	0.0023	-0.0147	-0.0089	0.5722	-0.2374	0.0022
	(0.0100)	(0.0131)	(0.0109)	(0.4466)	(0.4065)	(0.3297)
TFI	-0.0034	-0.0017	-0.0022	-0.0689	-0.0271	-0.0304
	(0.0009)***	(0.0008)*	(0.0006)***	(0.0642)	(0.0336)	(0.0294)
IFI	0.0003	-0.0002	-0.0000	0.0549	0.0416	0.0397
	(0.0012)	(0.0011)	(0.0009)	(0.0520)	(0.0388)	(0.0332)
EFI	0.0007	0.0008	0.0003	0.0704	0.0197	0.0049
	(0.0008)	(0.0008)	(0.0003)	(0.0318)*	(0.0326)	(0.0172)
_cons	0.2119	0.1129	0.1688	4.0049	4.5275	5.6244
	(0.0331)***	(0.0587)*	(0.0319)***	(1.7466)*	(2.5643)	(1.4656)***
R^2	0.1370	0.1281	0.1477	0.1805	0.2665	0.2475
N	56	72	88	56	72	88
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights:	1 (out of 10)	2 (out of 20)	3 (out of 30)	1 (out of 10)	2 (out of 20)	3 (out of 30)
Sum of Negative Weights:	-0.0209	-0.0607	-0.0685	-0.0209	-0.0607	-0.0685
Measure 1:	0.0018	0.0196	0.0147	0.8809	0.2802	0.0381
Measure 2:	0.0123	0.0692	0.0441	6.070	0.9896	0.1145

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

Note: TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 11: Monthly Iron Exports, only Western African countries

	Iron Exports per GDP			log(Iron Exports in USD, millions)†		
	2014-15	2016-19	2014-19	2014-15	2016-19	2014-19
	1	2	3	4	5	6
Post Ebola	0.0018		0.0021	0.1490		1.1261
	(0.0012)		(0.0013)	(0.7103)		(0.7605)
Outbreak ×Post Ebola	0.0002	-0.0012	-0.0008	-0.4881	-2.0538	-1.7157
	(0.0008)	(0.0012)	(0.0011)	(0.6588)	(0.8320)**	(0.7553)*
TFI	-0.0002	-0.0001	-0.0001	-0.0287	0.0255	0.0409
	(0.0000)***	(0.0001)*	(0.0000)***	(0.0369)	(0.0334)	(0.0311)
IFI	-0.0000	-0.0001	-0.0001	0.0409	0.0053	-0.0031
	(0.0001)	(0.0001)	(0.0001)	(0.0434)	(0.0407)	(0.0393)
EFI	-0.0000	0.0001	0.0000	0.0599	0.0634	-0.0047
	(0.0001)	(0.0001)	(0.0001)	(0.0575)	(0.0982)	(0.0892)
_cons	0.0197	0.0063	0.0109	-2.4726	-4.7956	-1.8439
	(0.0058)**	(0.0040)	(0.0032)**	(3.2185)	(3.9259)	(3.9882)
R^2	0.2066	0.2156	0.2216	0.2021	0.2237	0.2206
N	672.0000	864.0000	1,056.0000	672.0000	864.0000	1,056.0000
Summary Measures from de Chaisemrtin and D'Haultfoeuille (2020).						
Number of negative weights	12 (out of 96)	24 (out of 240)	36 (out of 336)	12 (out of 96)	24 (out of 240)	36 (out of 336)
Sum of negative weights:	-0.0122	-0.0607	-0.0608	-0.0122	-0.0607	-0.0608
Measure 1:	0.0011	0.0017	0.0007	0.9292	2.8906	2.2305
Measure 2:	0.0141	0.0058	0.0027	12.4600	9.9970	7.9325

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

† For the zero-value, we add one prior to its log transformation. Inverse-hyperbolic sine transformation yields a similar results.

Note: TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

6.4 Microeconomic Effect of Ebola: Employment and Small Business Activities

In this section, we shift our attention toward the microeconomic outcomes. Particularly, our interest is in the employment outcome, the operation status for household non-farm enterprises (HNFEs), and the revenue for the active HNFE at both baseline and Ebola periods. We report the coefficient and standard errors only for the key variables of interest. We indicate whether the specific category of covariates is included by the label "Y" in the table but do not report the coefficient for each covariate. This section presents the results of using all available covariates, including district fixed effects, demographic factors, and baseline job/HNFE-specific factors.

Table 12 reports the results of using employment outcomes as the dependent variable. We notice that the Ebola outbreak has a significantly negative effect on the probability of a person being employed, but this effect disappears in round 3. Since the coefficient for the interaction term $Outbreak \times Ebola\ Severity$ is only weakly significant in round 3, the effect of Ebola on the probability of employment is not correlated with Ebola severity outside the capital city, Freetown. However, for the household head who resides in Freetown, his/her employment outcome significantly worsens after the Ebola outbreak compared to those outside Freetown. This negative effect persists in round 3 with little sign of dissipation.

Table 12: Employment Outcome in Sierra Leone

	Round 1	Round 2	Round 3
Post Ebola	-0.6781	-0.5863	0.1727
	(0.1762)***	(0.2286)**	(0.1905)
Ebola Severity	-0.2622	-0.5831	-0.1260
	(0.1487)*	(0.1725)***	(0.1494)
Freetown	0.0581	-0.0526	0.2325
	(0.1167)	(0.1621)	(0.0998)**
Post Ebola × Ebola Severity	0.1633	0.3298	0.3334
	(0.2342)	(0.2780)	(0.2326)
Post Ebola × Freetown	-0.4427	-0.4631	-0.7101
	(0.1808)**	(0.2324)**	(0.1938)***
District Fixed Effects	Y	Y	Y
Demographic Factors	Y	Y	Y
Baseline Job-Specific Factors	Y	Y	Y
N	3,190	3,132	3,006

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

Table 13 evaluates the HNFE activities during the Ebola outbreak. Column 1 to 3 present the effect upon HNFE operation status, and column 4 to 6 presents the effect upon the log-transformed monthly revenue in millions of Leon. Since no coefficient is significant, we find no significant effect of Ebola on the probability for a household to operate an HNFE. This indicates that opening an HNFE is not a coping strategy adopted by the surveyed households. However, for those operating the HNFE at both baselines and during the outbreak, the Ebola has a significantly negative effect at all rounds. Compared to the baseline periods, their monthly revenue slumped by 59%, 66%, and 62% in rounds 1, 2, and 3. However, among those severely affected districts, their monthly revenue relatively increases in round 2, compared to the less-affected districts. For HNFEs operated in Freetown, their revenue is significantly better off than those not in Freetown at all three rounds.

Table 13: HNFE Activity in Sierra Leone

	Operation Status			Monthly Revenue (log-transformed)		
	Round 1	Round 2	Round 3	Round 1	Round 2	Round 3
Post Ebola	0.1925	0.1859	0.0314	-0.8920	-1.0930	-0.9791
	(0.1560)	(0.1812)	(0.1825)	(0.1198)***	(0.1655)***	(0.1819)***
Ebola Severity	0.1210	-0.1322	0.1661	0.9914	0.7502	1.9552
	(0.0996)	(0.1138)	(0.1250)	(0.1232)***	(0.1228)***	(0.2602)***
Freetown	-0.0055	-0.1256	0.0441	0.6787	0.4295	2.0049
	(0.0911)	(0.1056)	(0.1125)	(0.0843)***	(0.1080)***	(0.1209)***
Post Ebola × Ebola Severity	-0.0864	0.2103	-0.0158	0.2508	0.4290	0.0325
	(0.1844)	(0.1987)	(0.2111)	(0.2331)	(0.2213)*	(0.3296)
Post Ebola × Freetown	-0.2170	-0.1681	-0.1199	0.4948	0.8786	0.8392
	(0.1564)	(0.1818)	(0.1831)	(0.1137)***	(0.1626)***	(0.1932)***
District Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Factors	Y	Y	Y	Y	Y	Y
Baseline Firm-Specific Factors	Y	Y	Y	Y	Y	Y†
N	3,198	3,134	2,750	942	1,020	770

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

† not able to control for number of non-household paid employees due to the degree of freedom problem.

Overall, from Tables 12 and 13, we conclude that the Ebola outbreak has a generally negative effect on the probability of getting employed and HNFE revenue but no observable effect on operating an HNFE. The negative impact on employment probability dissipates at round 3, while the impact on HNFE revenue still persists. Outside of Freetown, the outbreak's effect is generally not correlated with the outbreak severity categorized by the number of cumulative cases at the survey time. For the household heads residing in Freetown, their employment probability significantly deteriorated after the outbreak. On the other hand, for the HNFEs being active during both the baseline and epidemic, operating in Freetown is associated with higher revenue than those outside Freetown.

The observed weak correlation between Ebola severity and employment outcomes but significant coefficients on $Outbreak$ confirms that the impact of the Ebola is dominated by its indirect effects, such as avoidance behaviors (FEWS NET, 2017; Huber et al., 2018). Our findings for the negative effect of Ebola on HNFE monthly revenue are also consistent with two previous studies on formal sectors (Bowels et al., 2015; Glennerster et al., 2017) as well as studies on HNFEs during the Covid-19 pandemic (Bordi et al., 2021; Balde et al., 2020; Josephson et al., 2020). Like Bowels et al. (2015), we noticed a within-country heterogeneity on the Ebola effect, particularly the negative effect of residing in the capital city on employment probability. On the other hand, operating in Freetown is surprisingly associated with higher monthly revenue, different from all known previous studies.

There are several possible explanations for Freetown's positive revenue effect. Firstly, although Freetown is one of the worst-hit districts, it is also the most populated and globalized city in Sierra Leone. These unique characteristics create a relatively favorable condition during the epidemic for the still-active HNFEs. Particularly, when the formal sectors close and fail to satisfy the public demand of households, the relatively more informal HNFEs fill in the gap and gain higher revenue. However, for other HNFEs outside Freetown, due to lower population density and the loss of household incomes due to the outbreak, HNFEs confront a declining demand and hence receive less revenue. Another possible explanation is the seasonality and the limitation of survey designs. The revenue at baseline from the Labor Force Survey (LFS) was a "normally received" monthly value during the past 12-month period, while the revenue during the epidemic from the High-Frequency Cell Phone Surveys (HFCPS) was the revenue received in the previous 30 days. Therefore, it is likely that the respondent in the LFS considers the seasonality and takes a monthly average from a 12-month sum, making it relatively smaller than the reported revenue in HFCPS. However, this cannot explain why the coefficient is negative and significant in all three rounds. Since three rounds of HFCPS span for six months, from November 2014 to May 2015, at least part of the seasonality should have been captured. Therefore, we are more inclined to attribute Freetown's positive revenue effect to its unique characteristics compared to the rest of Sierra Leone.

7. Robustness Check: Alternative DiD Methods by Callaway and Sant'Anna (2020)

This section presents the results of applying an alternative multiple-period difference-in-difference method proposed by Callaway and Sant'Anna (2020, hereinafter CS(2020)). As highlighted in section 4.3, Equation 1 employed in section 6.2-6.3 only estimate the difference-in-difference ATT estimates under several stringent assumptions that might not be held in our case. DD(2020) 's presented summary measures further suggest that our results on GDP growth rates, inflation rates, and iron exports might not be robust against the heterogenous treatment effect across countries and periods. A negative weight issue might exist in the estimates of GDP, inflation rate, and iron exports (only in Western African countries). These prompt us to apply an alternative regression method proposed by CS(2020) to estimate the impact of Ebola on the previously evaluated macroeconomic variables.

However, as acknowledged in section 4.3, CS(2020) also has certain limitations and is not a perfect remedy. Notably, it assumes all covariates as time-invariant and only applies the base-period values of covariates for estimation. Due to its inherent design of decomposing multiple periods into several canonical 2*2 DiD, it also has a higher requirement on the degree of freedom[8]. This sometimes precludes us from including a complete set of covariates in equation 1, leading to potential omitted variable bias. Thus, we only deem the CS(2020) as a robustness check for our main results in sections 6.1-6.2 and is for reference only.

Table 13 presents the CS(2020) results toward the annual macroeconomic variables evaluated in sections 6.1-6.2. The baseline year is 2013, i.e., one year before the outbreak. Each cell represents the average treatment effect on treated (ATT) for all Ebola-affected countries in corresponding years. For example, in column 1 and row 1, -0.10128 means the ATT of Ebola for the affected countries in 2014. The results in table 13 are consistent with most of the conclusions reached in the previous section, except for the FDI and inflation rate. Unlike Table 7 in 6.2, we do not find a significant effect of Ebola on FDI in terms of the percentage of GDP in any period. On the other hand, we notice a possible long-run impact on log-transformed FDI since the coefficients keep negative and significant toward 2019. The ATT is negative and significant for the annual inflation rate from 2017 to 2019, indicating a potential long-run effect. However, given there is no significant short-run effect and no included covariates, the observed long-run effect is likely to be spurious and needs to interpret with considerable caution.

Table 14 evaluates the monthly inflation rate in columns 1 to 2 and iron exports in columns 3 to 10. We report the results for the first 24 months after March 2014, and the entire table is included in the appendix. The baseline is one month prior to the outbreak (i.e., February for Liberia and Guinea, April for Sierra Leone, June for Nigeria, and September for Mali). The ATT on the price level for Liberia and Sierra Leone is not significant since none of the coefficients is significant except for October 2015. However, significant coefficients with different signs scattered across all periods for Nigeria, indicating a mixed-effects of Ebola on the price level. However, again, we must interpret these coefficients with caution since no covariate is included due to the degree of freedom issues.

We notice a negative and significant impact of Ebola on the monthly trade values per GDP in Sierra Leone and Nigeria for the monthly iron exports. The overall ATT quickly loses significance when using the log-transformed dollar value of iron exports. With a closer look at the monthly ATT, we noticed that the coefficients of Sierra Leone are negative and significant immediately after the onset of the outbreak and keep their significance toward March 2016 (Column 4). However, for Liberia and Guinea, the ATT of Ebola is insignificant for the first few months until August 2014 (Column 3).

Overall, the CS(2020) results endorse most of our previous conclusion in 6.1-6.2, except for a slight discrepancy in FDI and inflation rate. Using the canonical method, we find no observable effect on medium-run FDI or the inflation rate in any time period. At the same time, the latter might suffer the heterogeneity problem as indicated by the summary measures from DD(2020). On the other hand, using the CS (2020) method, we found that Ebola has an overall positive effect on inflation rate for the whole post-Ebola years but a negative effect in the first year

[8] For example, if we are using the full sample of African iron exporters, there are 5 Ebola-affected countries and 16 unaffected countries. In this case, CS(2020) only allows for at most 4 covariates to estimate all $ATT(g,t)$ in equation 4 in section 4.3. If we include more than 4 covariates, some or all $ATT(g,t)$ will not be estimated.

(i.e., 2014). Considering the inherent limitations of CS (2020) and the results from DD(2020), we are more inclined to conclude that Ebola has no medium-run effect on FDI but has an ambiguous effect on the inflation rate. Looking at the monthly iron exports, we notice that Sierra Leone and Nigeria have been the worst hit by Ebola. Unlike the instantaneous effect in Sierra Leone, Liberia and Guinea, on the other hand, are less responsive to Ebola at the early stage.

Table 13: Annual Macroeconomic Variables Using Callaway and Sant'Anna (2020)

	FDI Inflow per GDP	Log(FDI Inflow, USD million)	Iron Export per GDP	Log(Iron Exports, USD million)	GDP per capita at constant USD, growth rate	Log(GDP per capita at constant USD)	Inflation Rate
	1	2	3	4	5	6	7
Overall ATT	-0.1083	-0.7813	-0.0061	0.0445	-0.1006	-0.1136	0.0694
	(0.0914)	(0.2896)**	(0.0075)	(0.1477)	(0.2524)	(0.2708)	(0.0344)**
2014	-0.1028	-0.6002	-0.0035	0.0250	-0.1029	-0.0307	-0.0182
	(0.0882)	(0.2224)***	(0.0054)	(0.1119)	(0.2592)	(0.0792)	(0.0109)*
2015	-0.0775	-0.3951	-0.0096	0.1493	-0.1645	-0.1159	0.1633
	(0.0666)	(0.1334)***	(0.0106)	(0.1694)	(0.3286)	(0.2091)	(0.1586)
2016	-0.0970	-0.5433	-0.0103	-0.0764	-0.0774	-0.1182	0.0364
	(0.0810)	(0.3032)*	(0.0090)	(0.1585)	(0.2526)	(0.2781)	(0.0296)
2017	-0.1198	-0.8142	-0.0093	0.0228	-0.0789	-0.1226	0.0556
	(0.0964)	(0.4227)*	(0.0103)	(0.1699)	(0.2398)	(0.3273)	(0.0231)**
2018	-0.1301	-1.3229	0.0016	0.0665	-0.0914	-0.1400	0.1147
	(0.1055)	(0.4904)***	(0.0059)	(0.2706)	(0.2223)	(0.3554)	(0.0539)**
2019	-0.1223	-1.0121	-0.0056	0.0796	-0.0888	-0.1543	0.0644
	(0.1118)	(0.5355)*	(0.0083)	(0.1901)	(0.2144)	(0.3790)	(0.0363)*
UR					Y	Y	
AG					Y	Y	
TFI	Y	Y	Y	Y	Y	Y	
IFI	Y	Y	Y	Y	Y	Y	
EFI	Y	Y	Y	Y	Y	Y	
N	187	187	213	213	193	213	59

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis

Note: UR stands for Unemployment Rate; AG stands for Percentage of Agricultural Employment; TFI stands for Trade Freedom Index; IFI stands for Investment Freedom Index; EFI stands for Economic Freedom Index.

Table 14: Monthly Inflation Rate and Monthly Iron Exports Using Callaway and Sant'Anna (2020)

	Monthly Inflation Rate†		Monthly Iron Exports per Annual GDP				Log(Monthly Iron Exports in USD, millions)			
	Liberia and Guinea	Nigeria	Liberia and Guinea	Sierra Leone	Nigeria	Mali	Liberia and Guinea	Sierra Leone	Nigeria	Mali
	1	2	3	4	5	6	7	8	9	10
Overall ATT	-	-	-0.0023	-0.0017	-0.0003	0.0000	0.4878	0.3825	-0.0654	-0.3280
	-	-	(0.0016)	(0.0004)***	(0.0002)**	(0.0002)	(0.5029)	(0.3374)	(0.5282)	(0.6005)
Mar-14	1.0717		-0.0044				3.3569			
	(1.0400)		(0.0018)**				(1.9250)*			
Apr-14	-0.0650		-0.0021				-0.1919			
	(0.4513)		(0.0019)				(0.3115)			
May-14	-0.5700		0.0039	-0.0019			0.2044	-0.3220		
	(0.6493)		(0.0029)	(0.0003)***			(0.2436)	(0.0807)***		
Jun-14	1.9417		0.0032	-0.0009			0.4665	-0.1333		
	(1.6296)		(0.0031)	(0.0003)***			(0.4281)	(0.1071)		
Jul-14	-0.4883	-	0.0003	-0.0017	0.0004		4.3419	3.3511	-16.0939	
	(0.7075)	-	(0.0040)	(0.0005)***	(0.0004)		(2.0892)**	(1.6956)**	(1.7417)***	
Aug-14	0.3150	-0.4867	-0.0028	-0.0017	0.0002		2.0168	1.7211	2.2944	
	(1.1142)	(0.8914)	(0.0013)**	(0.0006)***	(0.0003)		(1.4345)	(1.1948)	(1.7066)	
Sep-14	0.9650	-0.1967	-0.0016	-0.0023	0.0000		1.5249	1.4081	0.4235	
	(1.2840)	(0.7355)	(0.0013)	(0.0004)***	(0.0003)		(1.6098)	(1.1164)	(0.7355)	
Oct-14	-0.3333	-0.7600	-0.0037	-0.0041	0.0004	0.0003	1.3197	0.4802	3.2157	1.4833
	(0.5318)	(0.3332)**	(0.0013)***	(0.0005)***	(0.0004)	(0.0003)	(1.5695)	(1.1611)	(1.7662)*	(1.5489)
Nov-14	-2.3033	0.2500	-0.0045	-0.0031	0.0003	-0.0001	-6.0193	2.0982	3.4250	2.4951
	(1.6502)	(0.3499)	(0.0009)***	(0.0006)***	(0.0002)	(0.0002)	(6.5538)	(1.4952)	(1.8419)*	(1.9487)
Dec-14	0.9050	0.3333	-0.0039	-0.0030	-0.0001	-0.0004	-0.5203	-0.5253	-0.6519	-1.0474
	(0.6328)	(0.1456)**	(0.0020)**	(0.0004)***	(0.0004)	(0.0003)	(0.2161)**	(0.1325)***	(0.1385)***	(0.5197)**
Jan-15	0.2150	0.1233	-0.0049	-0.0014	-0.0001	-0.0005	0.1128	1.1595	0.0766	0.3564

	(0.8486)	(0.8819)	(0.0024)**	(0.0003)***	(0.0002)	(0.0004)	(0.6837)	(1.1829)	(0.8072)	(1.5636)
Feb-15	-0.6400	0.1933	-0.0021	-0.0016	-0.0001	0.0003	1.3398	1.2828	-0.3349	-0.0335
	(0.5737)	(0.0680)***	(0.0040)	(0.0003)***	(0.0002)	(0.0002)	(1.5586)	(1.0583)	(0.5002)	(0.1342)
Mar-15	1.1050	0.5633	-0.0055	-0.0055	-0.0008	0.0002	3.4121	-2.1919	2.1744	0.4283
	(0.7276)	(0.0936)***	(0.0035)	(0.0005)***	(0.0003)***	(0.0003)	(2.3001)	(1.0567)**	(1.7671)	(0.8859)
Apr-15	0.1117	0.3900	-0.0028	-0.0011	0.0002	0.0003	3.7645	3.2163	3.5839	3.5475
	(0.5977)	(0.4066)	(0.0017)*	(0.0005)**	(0.0003)	(0.0003)	(1.9821)*	(1.5951)**	(2.3039)	(2.0838)*
May-15	-0.4167	0.8767	-0.0045	-0.0026	-0.0000	0.0000	5.6294	3.3242	4.6268	3.3164
	(0.6348)	(0.3790)**	(0.0024)*	(0.0006)***	(0.0003)	(0.0002)	(2.1680)***	(1.6847)**	(2.3191)**	(2.0678)
Jun-15	1.5317	-0.0600	-0.0029	0.0022	-0.0001	0.0007	2.1909	1.5391	0.7564	0.4275
	(1.6416)	(0.0386)	(0.0021)	(0.0005)***	(0.0003)	(0.0003)**	(1.6785)	(0.8371)*	(1.8258)	(0.8643)
Jul-15	0.0450	-0.8967	-0.0023	-0.0026	-0.0003	-0.0002	2.1968	0.5464	0.6526	-0.0694
	(1.1269)	(0.1492)***	(0.0009)**	(0.0005)***	(0.0005)	(0.0003)	(1.6936)	(0.8481)	(1.8186)	(0.8965)
Aug-15	-0.1333	0.5200	-0.0021	-0.0022	0.0007	0.0007	3.7660	2.9511	3.8829	3.6239
	(0.9189)	(0.7165)	(0.0009)**	(0.0006)***	(0.0004)*	(0.0003)**	(2.0771)*	(1.5089)*	(2.2562)*	(2.0029)*
Sep-15	0.8450	0.0533	-0.0036	-0.0034	-0.0000	0.0007	2.4945	1.1825	2.6539	2.2688
	(1.1653)	(0.7598)	(0.0011)***	(0.0004)***	(0.0002)	(0.0004)*	(1.9534)	(1.4232)	(2.1343)	(1.9073)
Oct-15	-1.9367	-1.9333	-0.0019	-0.0013	0.0004	0.0010	2.8746	2.0486	2.7690	2.4629
	(0.4476)***	(0.2152)***	(0.0007)***	(0.0003)***	(0.0003)	(0.0003)***	(1.9444)	(1.3997)	(2.1162)	(1.8803)
Nov-15	-0.3917	0.7167	-0.0030	-0.0039	-0.0001	0.0001	0.4181	-1.0167	-0.5430	-0.3950
	(0.3174)	(0.1932)***	(0.0013)**	(0.0004)***	(0.0003)	(0.0002)	(0.2017)**	(0.1895)***	(0.2222)**	(0.4431)
Dec-15	0.2817	1.0400	-0.0024	-0.0007	0.0001	0.0007	0.2639	0.2593	-0.8145	-0.1431
	(0.2535)	(0.1711)***	(0.0006)***	(0.0005)	(0.0003)	(0.0002)***	(0.1645)	(0.1830)	(0.1337)***	(0.4856)
Jan-16	-0.0633	-0.1400	-0.0038	-0.0038	0.0006	0.0002	-0.2566	-1.4994	-0.4163	-0.7016
	(1.1254)	(1.1172)	(0.0017)**	(0.0004)***	(0.0003)*	(0.0002)	(0.1150)**	(0.1518)***	(0.1149)***	(0.5015)
Feb-16	-0.1983	2.1600	-0.0030	-0.0018	-0.0002	-0.0007	0.2177	-0.2378	-0.7193	-1.3428
	(0.6139)	(0.1466)***	(0.0007)***	(0.0004)***	(0.0002)	(0.0002)***	(0.1885)	(0.2076)	(0.2098)***	(0.5040)***
Mar-16	0.9183	1.5767	-0.0008	-0.0035	-0.0001	0.0007	0.3541	-0.9310	-0.9058	-0.0810
	(0.6630)	(0.1651)***	(0.0008)	(0.0004)***	(0.0003)	(0.0002)***	(0.1553)**	(0.1809)***	(0.1244)***	(0.4971)

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

†Overall ATT is not calculated due to the degree of freedom problem.

Note: We include Investment Freedom Index (0-100) and Trade Freedom Index (0-100) when analyzing monthly Iron Exports. There is no included covariate when analyzing the monthly inflation rate.

8. Ebola and Covid-19 Pandemic: Agenda for Future Research

In this section, we briefly discuss the experience of Ebola and the Covid-19 pandemic in Africa. We also On December 31, 2019, the WHO China Country Office was informed of cases of pneumonia of unknown etiology detected in Wuhan city, Hubei Province. By January 7, 2020, Chinese scientists isolated a novel coronavirus, named SARS-Cov-2 (Covid-19). WHO declared the outbreak as a public health emergency of international concern on January 30, 2020, while the virus quickly spread around the globe. WHO declared it a global pandemic of Covid-19 on March 11 (WHO, 2020a, 2020b). At the time of writing, the African countries have witnessed four waves of the pandemic (WHO, 2022) and are likely entering the fifth wave (Winning and Roelf, 2022).

Although the Ebola virus and Covid-19 have different transmission mechanisms, following the common saying in epidemiology, countries just need to "apply old lessons to new epidemics." With this mindset, a stream of literature concerns the application of the recent Ebola experience to the current Covid-19 pandemic (e.g., Kamorudeen et al. (2020), J Pardo et al. (2020), Leach (2020)). Indeed, there is evidence that the previous experience of Ebola has a positive effect at both macro and micro-levels. Since some Sub-Sarahan countries have experienced the Ebola epidemic, their COVID-19 response has been quicker and more decisive than other parts of the world (Afolabi et al., 2020). The Republic of the Congo directly transformed its Ebola response force into a covid-19 taskforce (Mobula et al., 2020). Maxmen (2020) noted that there had been much anecdotal evidence about officials who experienced the Ebola epidemic taking executive positions in the Covid-19 task force in Western African countries.

Firms and individuals also apply their lessons from Ebola. For example, Lib Solar, an asset-financing firm in Liberia, focused on the solar industry, implemented social distancing and frequent handwashing two weeks before the first reported case of Covid-19 in Liberia. The company also sends non-essential staff home and practices strict health and safety protocols when making necessary travel (Medium, 2020). People are also more accustomed to handwashing. There is anecdote evidence that handwashing has become a common practice in life, and people get used to washing their hands before entering a building (Ahern, 2020). As one of the few positive legacies of the Ebola outbreak, Western African countries, such as Sierra Leone, have kept and even increased their public handwashing facilities after the end of the Ebola outbreak (WHO, 2019).

Initially, all of these beneficial and preventive practices led to a swift and coordinated response, which kept the number of infectious low compared to many other countries. However, constraints related to poverty and scarcity of medical resources were raised (Maxmen, 2020). People were unwilling to visit hospitals due to the belief that hospitals lack medical supplies and cannot provide excellent care. Similar to the Ebola epidemic, medical staff retreat due to the delay of payment for their salary for over two months.

On the other hand, from an economic analysis perspective, there are similarities and differences between the Ebola outbreak and the Covid-19 pandemic. Firstly, although the transmission mechanism and fatality rates are different for the Ebola and the Covid-19, there are similar public health prevention measures: quarantine, sanitation (handwashing and face masking), and vaccinations. Therefore, it is likely that both Covid-19 and Ebola have the same consequences of avoidance behaviors. However, the Covid-19 pandemic lasts much longer than the Ebola outbreaks, leading to potential adaptive behaviors. Economic agents might have initially responded to fast-growing cases with great panic and considerable precautionary measures. After several waves of outbreaks, they might have accustomed to the proliferating cases and react more rationally with less anxiety.

In addition, at the macro level, the Covid-19 pandemic is a global shock with substantial disruptions to the global supply chains (Xu et al., 2020; Javorcik et al., 2020), while Ebola was only a regional shock with limited impact on the international market. As a result, the responses of multi-national companies, such as those in the mining sectors, will be different during Ebola and the Covid-19 pandemic. During the Ebola outbreak, foreign mining companies might redirect their investments to other countries possessing reserves of the same minerals but free from Ebola. However, during the Covid-19 pandemic, as the coronavirus has been spread to almost all countries, it is impossible to hedge against the impact of the pandemic by redirecting investments to nations without covid cases. Even if investors could find a country with desired minerals and free from covid, given the significant influence of Covid-19 on the global supply chain, their investments would still suffer from the impact of the covid. As a result, there is simply "no place to hide" from the Covid-19, and the investors might decide just to retain their current investment without further redirection. Differences in investors' behaviors during the Ebola and Covid-19 pandemic might lead to different post-outbreak patterns of recovery. The Ebola-affected countries may permanently lose the opportunities of receiving investments from some potential foreign investors, while the Covid-affected countries might still attract investments from the same set of potential foreign investors.

Considering the relationship between the Ebola outbreak and the current Covid-19 pandemic, it would be compelling for future research to focus on analyzing the adaptive behavior during the pandemic. The World Bank has released several rounds of high-frequency cellphone surveys that provide nationally representative household-level panel data in 2020 about employment, income loss, knowledge of coronavirus, and resulting coping behaviors. By exploiting multiple-round household-level data, researchers could estimate the economic impact at different waves of the pandemic. By comparing our findings in Sierra Leone and previous relevant studies, researchers could construct a systematic understanding of the relationship between the epidemics and micro behaviors. In addition, although the global nature of the Covid-19 pandemic leaves no perfect control group, given the available household-level data across multiple developing countries, future research could still examine the cross-country heterogeneity and identify possible explanations for the observed heterogeneity (if any).

From a macro perspective, future research could also focus on the foreign direct investment flows during the Covid-19 pandemic. Given the time span of the covid, similar to the microeconomic analysis, researchers could also evaluate the differential trends of FDI during different waves of the pandemic. To examine the redirection of investments, researchers could compare the flows between countries with fewer or more covid cases.

Overall, although the experience of Ebola gives affected countries some advantages in making timely and coordinated responses at the early stage of the pandemic, problems with poverty and weak medical infrastructure persist. These prevent them from further controlling the pandemics. We also recommend the future research on adaptive behaviors and FDI flows during the current Covid-19 pandemic.

9. Conclusion

In this paper, we use the difference-in-difference (DiD) method to evaluate both the macroeconomic and microeconomic impacts of the Western African Ebola Outbreak upon the affected countries.

Different from previous macroeconomic studies on the Ebola's impact, we take advantage of having panel data spanning from 2009 to 2019 to identify both the short-run and medium-run effects of Ebola on all five affected countries. Apart from using the canonical specification of DiD, in the macroeconomic analysis, we calculate the summary measures by de Chaisemrtin and D'Haultfoeuille (2020). We also apply the nonparametric regression method by Callaway and Sant'Anna (2020) as robustness checks to the issues of the heterogenous treatment effect of Ebola across affected countries and periods. We find that the Ebola has an immediate negative effect on FDI and a persistent negative effect on iron exports, but we do not notice any observable effect on GDP. Due to the conflicting results from the canonical method and CS (2020), we are not able to conclude the effect of Ebola on the inflation rate, given the limitation of CS (2020) and the results from DD (2020).

For the microeconomic analysis, by combining three rounds of cell-phone surveys carried out during the Ebola with the baseline pre-Ebola survey data in Sierra Leone, we can analyze the Ebola on employment and the performance of household non-farm enterprises at different phases of the epidemic. Unlike the previous studies focusing on the formal sector, we have a more general focus on formal and informal employment. Our analysis of the HNFEs also contributes to the sparse literature on the performance of the informal sector during an epidemic. We find that Ebola has a negative effect on the probability of getting employed, but this effect diminishes at the end of the epidemic. There is no observable effect on the probability of a household deciding to operate an HNFE or not at any stage of the epidemic. For those operating at both the baseline and during the epidemic, the Ebola significantly reduced revenue. However, for HNFEs operating in the capital city, Freetown, their revenue becomes better than their counterparts in other regions. We also notice that the effect of Ebola is not strongly correlated to the regional severity of the outbreak, as measured by cumulative cases per 1000 people, if outside Freetown.

Our findings have significant policy implications, given that Ebola is only a part of the emerging diseases. In the future, policymakers have to confront more frequent epidemics and the associated health and economic burden. Our macro results indicate that the epidemic is unlikely to have a long-run impact on the country's future macroeconomic performance, such as GDP. Although foreign investors withdraw their capital at the onset of the outbreak, they are very likely to return after the end of the epidemic. However, the persistently negative effect on iron exports should encourage resource-dependent countries to diversify their economic structure. Our micro results indicate that an epidemic like Ebola should be considered as a nationwide economic shock with a limited correlation between the number of cases and the economic burden. Therefore, we recommend that support from the government and international communities during an epidemic focus not only on the epicenter but also on other districts with fewer cases. Considering the performance of previously Ebola-affected countries during the Covid-19 pandemic, we are relieved that the experience of Ebola does have a positive influence on their covid response. However, the later deteriorated situation during the pandemic highlighted the importance of resolving fundamental issues, such as poverty and health infrastructure. Given the difference between Ebola outbreak and the Covid-19 pandemic, we also recommend future research on the adaptive behaviors and FDI flows during the pandemic. This could further help construct a systematic understanding of the economic impact of and recovery from an epidemic.

There are several limitations to our studies. Our microeconomic analysis might suffer from seasonality, and our sample may not represent the general Sierra Leone population. It also highlights the limitations of using difference-in-difference approaches when analyzing subnational variation where both national and local implications exist. Since the Ebola spreads across all the districts of Sierra Leone and each affected district certainly has different confounding characteristics, it leaves us no perfect control group that can be used to establish an ideal counterfactual. We do not sufficiently control the heterogeneity across the affected countries due to the multiple-period issues for the macroeconomic analysis. Although we apply both CS (2020) and DD(2020) with only annual data, we cannot isolate each affected country's treatment effect. Insignificant overall ATT on annual iron exports but significant ATT on monthly iron exports for Nigeria and Sierra Leone further confirm this concern. More research on this is needed. Finally, our industrial analysis only focuses on iron exports, while the affected countries also depend on other minerals, such as bauxite, diamonds, and gold. Future analysis of these non-iron mineral exports may further shed light on the effect of Ebola on those resource-dependent countries.

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Appendix: Monthly Inflation Rate and Iron Exports Using Callaway and Sant'Anna (2020)

	Monthly Inflation Rate†		Monthly Iron Exports per Annual GDP				Log(Monthly Iron Exports in USD, millions)			
	Liberia and Guinea	Nigeria	Liberia and Guinea	Sierra Leone	Nigeria	Mali	Liberia and Guinea	Sierra Leone	Nigeria	Mali
	1	2	3	4	5	6	7	8	9	10
Overall ATT			-0.0023	-0.0017	-0.0003	0.0000	0.4878	0.3825	-0.0654	-0.3280
			(0.0016)	(0.0004)***	(0.0002)**	(0.0002)	(0.5029)	(0.3374)	(0.5282)	(0.6005)
Mar-14	1.0717		-0.0044				3.3569			
	(1.0400)		(0.0018)**				(1.9250)*			
Apr-14	-0.0650		-0.0021				-0.1919			
	(0.4513)		(0.0019)				(0.3115)			
May-14	-0.5700		0.0039	-0.0019			0.2044	-0.3220		
	(0.6493)		(0.0029)	(0.0003)***			(0.2436)	(0.0807)***		
Jun-14	1.9417		0.0032	-0.0009			0.4665	-0.1333		
	(1.6296)		(0.0031)	(0.0003)***			(0.4281)	(0.1071)		
Jul-14	-0.4883	0.0000	0.0003	-0.0017	0.0004		4.3419	3.3511	-16.0939	
	(0.7075)	(0.0000)	(0.0040)	(0.0005)***	(0.0004)		(2.0892)**	(1.6956)**	(1.7417)***	
Aug-14	0.3150	-0.4867	-0.0028	-0.0017	0.0002		2.0168	1.7211	2.2944	
	(1.1142)	(0.8914)	(0.0013)**	(0.0006)***	(0.0003)		(1.4345)	(1.1948)	(1.7066)	
Sep-14	0.9650	-0.1967	-0.0016	-0.0023	0.0000		1.5249	1.4081	0.4235	
	(1.2840)	(0.7355)	(0.0013)	(0.0004)***	(0.0003)		(1.6098)	(1.1164)	(0.7355)	
Oct-14	-0.3333	-0.7600	-0.0037	-0.0041	0.0004	0.0003	1.3197	0.4802	3.2157	1.4833
	(0.5318)	(0.3332)**	(0.0013)***	(0.0005)***	(0.0004)	(0.0003)	(1.5695)	(1.1611)	(1.7662)*	(1.5489)
Nov-14	-2.3033	0.2500	-0.0045	-0.0031	0.0003	-0.0001	-6.0193	2.0982	3.4250	2.4951
	(1.6502)	(0.3499)	(0.0009)***	(0.0006)***	(0.0002)	(0.0002)	(6.5538)	(1.4952)	(1.8419)*	(1.9487)
Dec-14	0.9050	0.3333	-0.0039	-0.0030	-0.0001	-0.0004	-0.5203	-0.5253	-0.6519	-1.0474
	(0.6328)	(0.1456)**	(0.0020)**	(0.0004)***	(0.0004)	(0.0003)	(0.2161)**	(0.1325)***	(0.1385)***	(0.5197)**
Jan-15	0.2150	0.1233	-0.0049	-0.0014	-0.0001	-0.0005	0.1128	1.1595	0.0766	0.3564

	(0.8486)	(0.8819)	(0.0024)**	(0.0003)***	(0.0002)	(0.0004)	(0.6837)	(1.1829)	(0.8072)	(1.5636)
Feb-15	-0.6400	0.1933	-0.0021	-0.0016	-0.0001	0.0003	1.3398	1.2828	-0.3349	-0.0335
	(0.5737)	(0.0680)***	(0.0040)	(0.0003)***	(0.0002)	(0.0002)	(1.5586)	(1.0583)	(0.5002)	(0.1342)
Mar-15	1.1050	0.5633	-0.0055	-0.0055	-0.0008	0.0002	3.4121	-2.1919	2.1744	0.4283
	(0.7276)	(0.0936)***	(0.0035)	(0.0005)***	(0.0003)***	(0.0003)	(2.3001)	(1.0567)**	(1.7671)	(0.8859)
Apr-15	0.1117	0.3900	-0.0028	-0.0011	0.0002	0.0003	3.7645	3.2163	3.5839	3.5475
	(0.5977)	(0.4066)	(0.0017)*	(0.0005)**	(0.0003)	(0.0003)	(1.9821)*	(1.5951)**	(2.3039)	(2.0838)*
May-15	-0.4167	0.8767	-0.0045	-0.0026	-0.0000	0.0000	5.6294	3.3242	4.6268	3.3164
	(0.6348)	(0.3790)**	(0.0024)*	(0.0006)***	(0.0003)	(0.0002)	(2.1680)***	(1.6847)**	(2.3191)**	(2.0678)
Jun-15	1.5317	-0.0600	-0.0029	0.0022	-0.0001	0.0007	2.1909	1.5391	0.7564	0.4275
	(1.6416)	(0.0386)	(0.0021)	(0.0005)***	(0.0003)	(0.0003)**	(1.6785)	(0.8371)*	(1.8258)	(0.8643)
Jul-15	0.0450	-0.8967	-0.0023	-0.0026	-0.0003	-0.0002	2.1968	0.5464	0.6526	-0.0694
	(1.1269)	(0.1492)***	(0.0009)**	(0.0005)***	(0.0005)	(0.0003)	(1.6936)	(0.8481)	(1.8186)	(0.8965)
Aug-15	-0.1333	0.5200	-0.0021	-0.0022	0.0007	0.0007	3.7660	2.9511	3.8829	3.6239
	(0.9189)	(0.7165)	(0.0009)**	(0.0006)***	(0.0004)*	(0.0003)**	(2.0771)*	(1.5089)*	(2.2562)*	(2.0029)*
Sep-15	0.8450	0.0533	-0.0036	-0.0034	-0.0000	0.0007	2.4945	1.1825	2.6539	2.2688
	(1.1653)	(0.7598)	(0.0011)***	(0.0004)***	(0.0002)	(0.0004)*	(1.9534)	(1.4232)	(2.1343)	(1.9073)
Oct-15	-1.9367	-1.9333	-0.0019	-0.0013	0.0004	0.0010	2.8746	2.0486	2.7690	2.4629
	(0.4476)***	(0.2152)***	(0.0007)***	(0.0003)***	(0.0003)	(0.0003)***	(1.9444)	(1.3997)	(2.1162)	(1.8803)
Nov-15	-0.3917	0.7167	-0.0030	-0.0039	-0.0001	0.0001	0.4181	-1.0167	-0.5430	-0.3950
	(0.3174)	(0.1932)***	(0.0013)**	(0.0004)***	(0.0003)	(0.0002)	(0.2017)**	(0.1895)***	(0.2222)**	(0.4431)
Dec-15	0.2817	1.0400	-0.0024	-0.0007	0.0001	0.0007	0.2639	0.2593	-0.8145	-0.1431
	(0.2535)	(0.1711)***	(0.0006)***	(0.0005)	(0.0003)	(0.0002)***	(0.1645)	(0.1830)	(0.1337)***	(0.4856)
Jan-16	-0.0633	-0.1400	-0.0038	-0.0038	0.0006	0.0002	-0.2566	-1.4994	-0.4163	-0.7016
	(1.1254)	(1.1172)	(0.0017)**	(0.0004)***	(0.0003)*	(0.0002)	(0.1150)**	(0.1518)***	(0.1149)***	(0.5015)
Feb-16	-0.1983	2.1600	-0.0030	-0.0018	-0.0002	-0.0007	0.2177	-0.2378	-0.7193	-1.3428
	(0.6139)	(0.1466)***	(0.0007)***	(0.0004)***	(0.0002)	(0.0002)***	(0.1885)	(0.2076)	(0.2098)***	(0.5040)***
Mar-16	0.9183	1.5767	-0.0008	-0.0035	-0.0001	0.0007	0.3541	-0.9310	-0.9058	-0.0810
	(0.6630)	(0.1651)***	(0.0008)	(0.0004)***	(0.0003)	(0.0002)***	(0.1553)**	(0.1809)***	(0.1244)***	(0.4971)
Apr-16	-0.0933	1.1500	-0.0046	-0.0039	-0.0006	0.0007	-0.2617	-1.3495	-1.0820	-0.1831
	(0.2576)	(0.1158)***	(0.0022)**	(0.0005)***	(0.0002)***	(0.0002)***	(0.3078)	(0.1907)***	(0.1692)***	(0.4780)
May-16	-0.2250	2.2733	-0.0036	0.0003	-0.0004	0.0004	-0.0748	-0.0019	-0.7933	-0.3848
	(0.2330)	(0.1221)***	(0.0016)**	(0.0005)	(0.0003)*	(0.0002)**	(0.1464)	(0.1646)	(0.1846)***	(0.4769)
Jun-16	1.9950	0.7433	0.0020	0.0016	-0.0007	-0.0007	0.7204	0.1612	-0.8550	-0.7192

	(1.9677)	(0.2310)***	(0.0011)*	(0.0008)**	(0.0003)**	(0.0006)	(0.2359)***	(0.1630)	(0.1330)***	(0.4779)
Jul-16	0.8017	0.4100	-0.0024	-0.0033	-0.0004	0.0002	0.0278	-1.0749	-1.2636	-0.5478
	(1.1820)	(0.3866)	(0.0009)***	(0.0005)***	(0.0002)*	(0.0001)	(0.0882)	(0.1618)***	(0.1389)***	(0.4847)
Aug-16	-0.0650	0.1533	-0.0030	-0.0016	0.0006	0.0002	1.9338	0.8269	1.0217	0.1097
	(1.1355)	(0.9746)	(0.0027)	(0.0004)***	(0.0005)	(0.0001)**	(1.7197)	(1.0878)	(1.3139)	(0.8081)
Sep-16	-0.3767	-0.2033	-0.0019	-0.0012	0.0001	-0.0003	1.2943	0.7153	0.0579	-0.1637
	(0.9227)	(0.7166)	(0.0007)***	(0.0006)**	(0.0005)	(0.0002)	(1.3103)	(0.8368)	(1.4577)	(0.9104)
Oct-16	0.0717	-0.1500	-0.0055	-0.0034	-0.0004	0.0001	-8.4037	-0.8387	-1.0844	-0.4283
	(0.7880)	(0.1731)	(0.0015)***	(0.0006)***	(0.0002)*	(0.0002)	(5.5247)	(0.2028)***	(0.1874)***	(0.4860)
Nov-16	0.4250	0.7233	-0.0074	-0.0042	-0.0008	0.0004	-9.3721	-1.3391	-1.8105	-0.2334
	(0.4123)	(0.0914)***	(0.0030)**	(0.0004)***	(0.0002)***	(0.0003)	(5.3359)*	(0.1709)***	(0.1223)***	(0.4674)
Dec-16	-0.0233	0.4600	-0.0019	0.0004	-0.0006	-0.0014	0.1734	0.0147	-1.2095	-17.3407
	(0.6585)	(0.3418)	(0.0017)	(0.0006)	(0.0003)**	(0.0003)***	(0.1843)	(0.1809)	(0.1322)***	(0.4768)***
Jan-17	0.1567	0.5900	-0.0031	-0.0041	-0.0005	0.0004	0.1887	-1.5971	-1.1517	-0.2583
	(0.8786)	(0.6044)	(0.0034)	(0.0006)***	(0.0004)	(0.0003)	(0.6114)	(0.1573)***	(0.1223)***	(0.4574)
Feb-17	-0.5100	1.2433	-0.0056	-0.0051	0.0003	0.0008	-6.8287	-16.4043	1.9120	0.5926
	(0.6827)	(0.2126)***	(0.0035)	(0.0003)***	(0.0004)	(0.0002)***	(5.3029)	(0.4689)***	(1.3017)	(0.7320)
Mar-17	0.3850	0.0000	-0.0040	-0.0027	-0.0007	-0.0006	2.0188	0.9928	-16.5335	0.7608
	(0.3464)	(0.0000)	(0.0017)**	(0.0005)***	(0.0003)**	(0.0002)**	(1.2947)	(1.3828)	(1.6642)***	(1.7497)
Apr-17	0.0000	1.2500	-0.0072	-0.0005	-0.0004	0.0005	-15.2418	4.7481	0.4780	6.1228
	(0.0000)	(0.2269)***	(0.0026)***	(0.0009)	(0.0004)	(0.0006)	(1.1551)***	(1.6453)***	(1.2627)	(1.7710)***
May-17	0.0000	1.6367	-0.0071	0.0017	0.0000	0.0011	-15.4360	0.9505	0.7429	0.6829
	(0.0000)	(0.2178)***	(0.0028)**	(0.0005)***	(0.0003)	(0.0004)***	(1.2610)***	(0.7852)	(1.2621)	(0.8080)
Jun-17	1.3667	1.0200	0.0013	0.0004	-0.0006	-0.0001	1.9336	0.6132	0.4555	0.1415
	(1.1715)	(0.2381)***	(0.0004)***	(0.0004)	(0.0003)**	(0.0004)	(1.2574)	(0.7841)	(1.2800)	(0.8155)
Jul-17	0.6583	0.2267	0.0007	-0.0020	-0.0003	0.0001	1.1640	0.6560	0.1100	1.0527
	(1.1347)	(0.5965)	(0.0010)	(0.0005)***	(0.0004)	(0.0004)	(0.7663)	(1.1571)	(0.9687)	(1.5069)
Aug-17	0.6500	0.0833	-0.0012	0.0003	-0.0005	-0.0002	1.6920	0.6799	0.4931	0.1949
	(1.2670)	(0.8202)	(0.0020)	(0.0005)	(0.0005)	(0.0004)	(1.2677)	(0.7887)	(1.2729)	(0.8220)
Sep-17	0.8850	0.4933	-0.0026	-0.0014	-0.0009	0.0001	0.5278	-0.3200	-0.9019	-0.3134
	(0.7091)	(0.4640)	(0.0013)**	(0.0005)***	(0.0006)	(0.0004)	(0.3441)	(0.2119)	(0.1871)***	(0.4574)
Oct-17	0.0883	0.2267	-0.0010	0.0001	-0.0010	-0.0001	2.7010	1.6491	1.6610	1.8608
	(0.5023)	(0.2077)	(0.0016)	(0.0007)	(0.0005)**	(0.0006)	(1.4394)*	(1.2227)	(1.7306)	(1.5688)
Nov-17	0.9633	0.6267	-0.0025	-0.0032	-0.0008	-0.0003	1.3162	-0.2236	0.4231	0.1344

	(0.6778)	(0.2186)***	(0.0026)	(0.0008)***	(0.0004)*	(0.0006)	(1.3094)	(0.7889)	(1.2911)	(0.7940)
Dec-17	0.5617	0.2500	-0.0023	-0.0031	-0.0014	-0.0010	0.1219	-1.0767	-0.6567	-0.8549
	(0.6765)	(0.1020)**	(0.0012)**	(0.0008)***	(0.0005)***	(0.0006)*	(0.2195)	(0.1759)***	(0.1833)***	(0.4468)*
Jan-18	2.1350	1.3633	-0.0043	-0.0021	-0.0005	-0.0004	0.5352	-0.3465	-2.0280	-0.6110
	(1.2409)*	(1.0722)	(0.0028)	(0.0006)***	(0.0004)	(0.0003)	(0.8193)	(0.2882)	(0.2935)***	(0.4414)
Feb-18	0.2383	0.2267	-0.0027	-0.0005	-0.0007	0.0007	1.5329	0.4827	-0.9463	0.4984
	(0.8277)	(0.5858)	(0.0023)	(0.0003)	(0.0003)***	(0.0003)**	(1.2646)	(0.7717)	(1.2656)	(0.8032)
Mar-18	1.6500	0.9133	-0.0011	-0.0016	-0.0015	-0.0012	0.2165	-0.4718	-1.4474	-0.7299
	(0.7649)**	(0.4563)**	(0.0059)	(0.0005)***	(0.0007)**	(0.0008)	(0.9837)	(0.1620)***	(0.1629)***	(0.4674)
Apr-18	0.8933	0.4467	-0.0032	-0.0028	0.0002	0.0023	2.1895	1.6788	0.8726	3.0274
	(0.6211)	(0.2352)*	(0.0027)	(0.0004)***	(0.0005)	(0.0001)***	(1.3741)	(1.5259)	(1.5941)	(1.8079)*
May-18	1.0317	1.1400	-0.0048	0.0022	-0.0000	-0.0005	0.8237	2.8828	0.9401	1.8829
	(0.4752)**	(0.2941)***	(0.0021)**	(0.0008)***	(0.0004)	(0.0004)	(0.9695)	(1.6132)*	(1.3315)	(2.1376)
Jun-18	4.0583	1.0167	-0.0029	-0.0016	-0.0009	-0.0007	-0.1248	-0.5913	-1.1719	-0.7072
	(1.4170)***	(0.3661)***	(0.0026)	(0.0008)**	(0.0005)*	(0.0005)	(0.4254)	(0.1920)***	(0.1894)***	(0.4687)
Jul-18	0.6267	0.2100	0.0005	-0.0044	-0.0011	-0.0007	0.6111	-1.4183	-1.3504	-0.5757
	(2.0364)	(0.7969)	(0.0017)	(0.0006)***	(0.0004)***	(0.0005)	(0.4542)	(0.1615)***	(0.2080)***	(0.4807)
Aug-18	1.0317	0.7300	-0.0002	0.0008	-0.0008	-0.0005	1.2281	0.6100	0.0462	0.1181
	(1.0496)	(0.3967)*	(0.0009)	(0.0007)	(0.0003)**	(0.0004)	(1.3517)	(0.7905)	(1.3016)	(0.8119)
Sep-18	-0.0383	-0.4600	0.0019	-0.0002	-0.0002	-0.0005	1.6595	0.6473	0.1161	-0.0370
	(1.3673)	(1.0737)	(0.0018)	(0.0007)	(0.0004)	(0.0004)	(1.3231)	(0.7808)	(1.2853)	(0.8205)
Oct-18	0.6933	0.7767	0.0032	-0.0005	-0.0003	-0.0002	2.0275	0.5970	0.3336	0.4371
	(0.5362)	(0.2271)***	(0.0005)***	(0.0008)	(0.0005)	(0.0007)	(1.2685)	(0.8569)	(1.4911)	(0.8962)
Nov-18	1.3033	0.7567	-0.0019	-0.0026	-0.0012	0.0004	0.0994	-0.8601	-1.2226	-0.3533
	(0.8620)	(0.2976)**	(0.0008)**	(0.0005)***	(0.0006)**	(0.0003)	(0.1675)	(0.1542)***	(0.1633)***	(0.5059)
Dec-18	0.9417	0.1500	0.0070	0.0004	-0.0012	-0.0023	2.6260	0.8475	-0.0722	-0.5379
	(1.1431)	(0.4203)	(0.0043)	(0.0008)	(0.0007)*	(0.0008)***	(1.7088)	(1.1151)	(1.3472)	(0.8070)
Jan-19	-0.9250	0.4333	-0.0001	-0.0010	-0.0004	-0.0006	2.5952	1.6089	0.8702	1.0931
	(0.5044)*	(0.1486)***	(0.0007)	(0.0004)**	(0.0003)	(0.0002)***	(1.3986)*	(1.3208)	(1.5431)	(1.5923)
Feb-19	-0.0733	0.3900	-0.0019	0.0005	-0.0009	0.0014	0.8919	1.0692	-0.0909	1.7960
	(0.5989)	(0.3492)	(0.0012)	(0.0004)	(0.0004)**	(0.0004)***	(0.8203)	(1.1825)	(1.1685)	(1.7026)
Mar-19	2.9667	0.5900	-0.0011	-0.0000	-0.0001	-0.0010	2.4205	1.9522	1.4875	1.2971
	(1.8320)	(0.1506)***	(0.0015)	(0.0007)	(0.0003)	(0.0006)	(1.4099)*	(1.3335)	(1.5511)	(1.5886)
Apr-19	-0.3567	0.2467	-0.0028	-0.0024	-0.0005	0.0007	1.1598	0.0716	0.1412	0.5756

	(0.8008)	(0.5010)	(0.0009)***	(0.0004)***	(0.0004)	(0.0002)***	(1.2712)	(0.7817)	(1.2783)	(0.8232)
May-19	2.5617	0.5600	0.0003	-0.0002	-0.0009	-0.0007	4.8506	3.4469	4.9502	3.8213
	(2.1185)	(0.1337)***	(0.0007)	(0.0012)	(0.0005)	(0.0012)	(1.9150)**	(1.5913)**	(2.0619)**	(2.0516)*
Jun-19	3.0733	0.3267	-0.0024	-0.0009	0.0003	-0.0005	4.0632	3.5423	2.7800	1.9791
	(2.4366)	(0.2227)	(0.0024)	(0.0004)**	(0.0002)	(0.0005)	(2.0258)**	(1.8051)**	(1.7305)	(1.7258)
Jul-19	1.8083	0.4267	-0.0009	-0.0009	-0.0002	-0.0000	4.1228	1.3747	1.3687	0.5979
	(1.2718)	(0.4476)	(0.0014)	(0.0002)***	(0.0004)	(0.0005)	(1.8878)**	(0.9496)	(1.3057)	(0.8315)
Aug-19	0.7783	-0.1233	-0.0027	-0.0032	-0.0003	-0.0009	2.4541	-0.1119	-0.0112	-0.7597
	(1.6450)	(0.7401)	(0.0013)**	(0.0005)***	(0.0004)	(0.0005)*	(1.5562)	(0.6530)	(0.7132)	(0.5076)
Sep-19	0.7133	0.6467	-0.0043	-0.0024	0.0000	0.0005	2.4813	1.1135	1.5151	0.9731
	(0.7452)	(0.5267)	(0.0026)*	(0.0005)***	(0.0005)	(0.0003)*	(2.1207)	(1.2992)	(1.7733)	(1.0132)
Oct-19	-0.0217	0.5867	-0.0022	-0.0019	-0.0009	0.0002	2.1790	1.3046	1.0610	1.6707
	(0.6600)	(0.3891)	(0.0036)	(0.0004)***	(0.0005)*	(0.0004)	(1.4625)	(1.3306)	(1.5703)	(1.5976)
Nov-19	-0.6300	0.5833	-0.0059	-0.0005	-0.0004	-0.0005	-1.2714	-0.0130	-1.0756	-0.7740
	(0.4699)	(0.2837)**	(0.0033)*	(0.0006)	(0.0003)	(0.0004)	(1.0799)	(0.1904)	(0.1670)***	(0.4594)*
Dec-19	-0.9967	0.9667	-0.0053	-0.0025	-0.0014	-0.0006	-0.6961	-0.9023	-1.4532	-0.8393
	(0.9008)	(0.1899)***	(0.0022)**	(0.0005)***	(0.0004)***	(0.0003)*	(0.3420)**	(0.1189)***	(0.1388)***	(0.4578)*

* p<0.1; ** p<0.05; *** p<0.01; standard error in parenthesis.

†Overall ATT is not calculated due to the degree of freedom problem.

Note: We include Investment Freedom Index (0-100) and Trade Freedom Index (0-100) when analyzing monthly Iron Exports. There is no included covariate when analyzing the monthly inflation rate.