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# Evaluating the economic effects of the Ebola virus disease in Liberia: A synthetic control approach

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## Abstract

We use the synthetic control method to isolate the impact of the 2014–2016 Ebola virus disease epidemic on the Liberian economy. We find a slight initial decline in the unemployment rate, followed by an increase of roughly 1% ($p$-value ≤5%). The effect on inflation is more substantial (close to a 7% and 18% increase 4 and 5years after the outbreak) but statistically insignificant in the preceding period (2014–2016). We do not identify any other significant income and welfare effects. Synthetic control evidence for Guinea and Sierra Leone suggest even more limited long-term impacts.

**KEYWORDS**
Ebola, income, inflation, synthetic control method, unemployment

## 1 | INTRODUCTION

The spread of infectious diseases can lead to adverse economic consequences and potentially reverse long-established developmental gains. The outbreak of the 2014 Ebola (Ebola virus disease or EVD) epidemic, for instance, made an additional 170,000 people food insecure in Liberia (World Bank, 2014a). This exogenous shock also led to an increase in the prices of essential commodities and an economic slowdown. During the EVD epidemic (2014–2016), many productive sectors experienced a reduction in operations and production, as several workers avoided work out of fear of contracting the virus and the government imposed mobility restrictions (Chuhan-Pole & Ferreira, 2014; IMF, 2016). Beyond such direct short-term implications, there are concerns that such shocks can induce more persistent longer term economic effects; economic growth in Liberia, for instance, remains subdued since the end of the Ebola health crisis (in May 2015, see AfDB, 2017; Omoleke et al., 2016).

The 2014 EVD outbreak in West Africa has been characterised as the deadliest Ebola outbreak (regarding the overall number of fatalities) since the virus was first discovered in 1976 (WHO, 2022). The outbreak started in Guinea in December 2013. The Zaire Ebola virus was officially confirmed in samples sent from Guinea to Institut Pasteur Dakar in Conakry. WHO was notified by Guinea on 23 March 2014 that cases were confirmed for the Zaire Ebola virus. Cases were confirmed in Liberia on 29 March 2014 (WHO, 2014a). Subsequently, it spread to all counties in Liberia, and, in May 2014, cases were reported throughout Sierra Leone. On 28 July 2014, the Government of Liberia closed all its border crossing points, and on 30 July 2014, all schools were shut down to contain infections (World Bank, 2014b).[1] As the crisis worsened, the Liberian government declared a 3-month state of emergency on 6 August 2014 to curtail people's movement.[2] EVD rapidly spread across multiple locations, including densely populated urban cities in the three most affected West African countries (Liberia, Sierra Leone and Guinea) (hereafter referred to as the *core countries*). This prompted WHO to declare the Ebola crisis as an epidemic and a Public Health Emergency of International Concern (PHEIC) as stated under International Health Regulations (WHO, 2014a, 2014b). By May 2015, EVD cases were imported to other countries, such as Nigeria, Senegal, Mali, Italy, Spain, the United Kingdom and the United States (albeit with few cases reported).

Inadequate surveillance procedures to detect early infections and the overall unpreparedness of the health systems in West Africa led to a high death toll (one that surpassed all previous Ebola outbreaks). WHO (2022) reported that the 2014–2016 Ebola epidemic had a mortality rate close to 40% (amongst infected patients), with Liberia (as the most affected country) taking the unfortunate lead with 4810 deaths. Guinea and Sierra Leone recorded 2544 and 3956 deaths, respectively. The corresponding number of infections were 10 668, 14 131 and 3817 for Liberia, Sierra Leone and Guinea, respectively. By the end of the Ebola crisis, a total of 28 616 confirmed cases, and 11 310 fatalities were reported for the three countries (WHO, 2016). The corresponding prevalence rate (per 100 000 people) was approximately 244.8, 202.3 and 34.2 for Liberia, Sierra Leone and Guinea, respectively. The fatality rates as a percentage of infected cases (and per 100 000 people, total population) were approximately equal to 45% (110.3) for Liberia, 28% (56.4) for Sierra Leone and 66.7% (22.8) for Guinea.[3] To put things into a comparative perspective, during the Cholera outbreak of 2012, Sierra Leone reported 22 815 cases and 296 deaths (i.e., a much larger number of infections but a much smaller number of fatalities compared to EVD). This suggests that EVD, being a less easily transmissible disease but with a much higher fatality rate for those infected, is more likely to create short-term macroeconomic effects by generating fear and panic rather than any long-term repercussions associated with the actual health impacts.

Some even fear that the figures on EDV infections and fatalities lack accuracy as many cases remain unreported (Elston et al., 2017) due to poor monitoring and the stigma associated with the disease. Medical personnel, due to the lack of personal protective equipment and the nature of its work, was particularly exposed to these risks—in Liberia alone, about 190 healthcare workers lost their lives due to Ebola complications resulting in a reduction of the overall healthcare workforce by about 8% and weakening the already inadequate healthcare system (Delamou et al., 2017; Nyenswah et al., 2016; WHO, 2015). Huber et al. (2018) also highlight the additional 'hidden' socio-economic losses associated with the Ebola-induced loss of human lives, especially given the high mortality rate observed amongst the working-age population; they refer in particular to orphaned children, whose upbringing is likely to be affected by the loss of one or both parents.

[1]School closures lasted for 7 months (between July 2014 and February 2015, see Government of Liberia, 2015). An estimated 1.2 million children were out of school in Liberia (with about a third of students not returning to schools once they reopened, see UNICEF, 2015).

[2]The outbreak of EVD in Liberia significantly restricted the provision of health services due to the closure of health facilities across the country as part of a preventive health protocol. Strict health measures were enforced in those counties with the highest number of Ebola cases (Montserrado, Margibi, Bomi and Grand Cape Mount). These preventive health measures and recommendations included contact tracing, regular hand washing, nonconsumption of bush meat, avoiding contact with infected persons and dead bodies. In addition, on 30 July 2014, public servants as well as non-essential government workers were sent home (to curb the spread of the Ebola virus). On 6 August 2014, a 90-day state of emergency was declared, a nationwide curfew was announced and a strict quarantine was implemented in parts of Monrovia (particularly in West Point, with all movement blocked in and out of its densely populated slum community).

[3]Reported cases, however, also include suspected cases that should have been reclassified as either non case, probable or confirmed. For this reason, the case fatality ratio is subject to caution.

Our analysis focuses primarily on the impacts of the 2014–2016 Ebola epidemic on the Liberian economy—one of the lowest income and most fragile nations in sub-Saharan Africa despite its precious mineral resources. We make use of the synthetic control method (SCM) to isolate the effect of the Ebola epidemic on key macroeconomic outcomes, namely, unemployment, inflation, GDP and GDP per capita. To the best of our knowledge, this is amongst the first studies to apply SCM in the context of the outbreak of an epidemic. SCM allows to quantify the effect of a shock several years after it has taken place. This approach generates a synthetic counterfactual unit (a weighted basket of other countries) that imitates the behaviour of the Liberian economy prior to the 2014 Ebola outbreak. The strength of the method lies in the fact that the counterfactual is not simply one unaffected country case but a combination of unaffected countries that are selected in a purely data-driven procedure to best match the pre-Ebola trend of Liberia. In the aftermath of the event (i.e., the Ebola outbreak), any gaps between the values for Liberia and its synthetic unit capture the macroeconomic impacts of the Ebola shock. We find a modest initial decline in the unemployment rate, followed by an increase of roughly 1% ($p$-value≤5%). The effect on inflation is more substantial (close to a 7% and 18% increase 4 and 5 years after the outbreak) but statistically insignificant in the preceding period (2014–2016). We do not identify any income (GDP, GDP per capita) effect. Next to these standard macroeconomic indicators, we also assessed impacts on other welfare measures, namely, the Human Development Index (HDI), the prevalence of undernourishment and health expenditures (as share of GDP), to gain a more complete picture of the repercussions of the Ebola crisis for the Liberian society. All three indicators show no significant impact. There is some suggestive increase in the prevalence of undernourishment in 2018 and 2019, but it is only significant at 12.5%.

The remainder of this article is as follows: Section 2 provides a thorough review of the literature on epidemics/pandemics and economics. Section 3 discusses the empirical methodology, and Section 4 describes the dataset used for the empirical analysis. Section 5 presents the results of our analysis for Liberia and also replicates the analysis for Sierra Leone and Guinea, that is, for the other two West African economies that were severely affected by the Ebola epidemic. Section 6 concludes and provides suggestions for future research.

## 2 | REVIEW OF THE LITERATURE

There have been several studies evaluating the economic effects of epidemics—as in the case of influenza and SARS (Brahmbhatt & Dutta, 2008; Burns et al., 2006; Keogh-Brown & Smith, 2008; Meltzer et al., 1999; Smith et al., 2009) and more recently for COVID-19 (Fernandes, 2020; McKibbin & Fernando, 2021).[4] Albeit tempting to compare the results of this literature with the findings of our study, any comparison needs to be carried out with much caution. This is because there are substantial differences across infectious respiratory diseases with respect to prevention, transmission, disease severity and socio-economic disruption. Even with respect to the same infectious disease, impacts are likely to be time and space specific.

### 2.1 | Influenza impacts

Regarding influenza impacts, Meltzer et al. (1999) use Monte Carlo simulations to proxy the size of effects of a future major outbreak for the US economy based on different health scenarios. They predict an estimated GDP loss between US$71.3 to 166.5 billion that correspond to 89 000 (314,000) and 207 000 (734 000) deaths (and hospitalizations), respectively. Burns et al. (2006) simulate the employment/output effects of an avian influenza (bird flu) outbreak and estimate the global GDP loss to be between 1% and 5% depending on the severity of the pandemic (and employment

[4]We made use of the Web of Science and Google Scholar search engines to identify studies for our literature review that meet the following criteria: focus on the socio-economic impacts of infectious diseases (epidemics), contain empirical analysis, are peer-reviewed or have been published by reputable international organisations (e.g., the World Bank, the UNDP etc) within the last 25 years.

losses up to 0.2% of the global workforce). Smith et al. (2009) use computable general equilibrium (CGE) modelling to evaluate the potential effect of an influenza outbreak on the UK economy; they estimated this to be between 0.5% and 1% of GDP under an optimistic scenario, where most costs are attributed to a reduction in the labour supply and between 3.3% and 4.3% in the case of a high-mortality pessimistic scenario. Epidemics can also induce inflationary pressure, especially as consumers hoard products during periods of heightened uncertainty to limit physical contact with others. The inability to adjust supply in the short term and then often results in shortages, panic buying and a rise in the price of consumables. Barro et al. (2020), for instance, make use of historical cross-country panel regressions to confirm a positive effect of the 1918–1920 Great Influenza on inflation rates (close to a 21% higher inflation rate).

## 2.2 | SARS impacts

In the case of the 2003 SARS outbreak in Asia, Hanna and Huang (2004) make use of the Oxford Economic Forecasting model (that takes into consideration cross-country linkages in trade, labour and financial markets) to estimate short-term macroeconomic effects for the Chinese economy. They find that the 2003 SARS led to a 0.5%–1.5% loss of China's GDP (due to reduced demand for service products, as well as a drop in FDI and export orders), although with a quick rebound effect as the virus became contained. Brahmbhatt and Dutta (2008) find similarly that the tourism and service sectors (for the affected Asian economies) were negatively impacted as a result of reduced demand for travelling. They calculate the direct and indirect (opportunity) costs to be close to 1.1% of GDP and attribute this primarily to the negative demand shock as a result of fear of contracting the virus. Keogh-Brown and Smith (2008) also find a relatively modest and short-term effect for Asian economies based on trend comparisons from national statistics data; for example, they attribute an initial $3.7 billion loss to SARS in the case of Hong Kong, with GDP reverting to pre-SARS levels however within a period of a few months.

## 2.3 | COVID-19 impacts

More recently, studies examine the economic impact of the COVID-19 pandemic; Amewu et al. (2020), for instance, rely on the Social Accounting Matrix (Input–Output Modelling) approach that captures transaction flows across all sectors. They find that every week of a lockdown costs the Ghanaian economy about $450 million, suggesting that the developing economies of the Global South might severely suffer from the financial burden of lockdowns (they also forecast a 12.5% rise in the poverty headcount ratio for a 3-week lockdown). Fernandes (2020) makes use of simulations to estimate the effect of COVID-19 lockdowns on GDP for multiple countries (and finds that this ranges between a 3.8% and 14% GDP loss for India and Portugal for a 4.5-weeks lockdown). McKibbin and Fernando (2021) also take a similar methodological approach, forecasting COVID-19 macroeconomic impacts up to a period of 6 years; their estimates show that GDP, consumption and investment fully recover on average after about 2–3 years (although initial GDP losses can be quite substantial, e.g., as high as 8.4, 8.7, 9.9% for the United States, Germany and Japan). Binder (2020) also confirms through her US consumer survey that individuals exhibiting greater fear and concern about (the socio-economic and health effects of) the coronavirus tend to have larger inflation and unemployment expectations (e.g., inflation expectations are 2% and 3.4%, respectively, for the unconcerned vs. very concerned consumers).

## 2.4 | Ebola impacts

Other analyses have looked at the macroeconomic impacts of the 2014–2016 Ebola epidemic. The World Bank (2014a) made use of CGE modelling to predict a GDP loss (in 2014) of about 3.4%, 2.1% and 3.3% for Liberia, Guinea and Sierra Leone, respectively. These losses combined amount to approximately $1.6 billion. Revised estimates (World Bank, 2014b) slightly increased the GDP loss for Liberia to 3.7% (although the economy largely regains the initial losses in 2015). There is also evidence of a negative impact of the Ebola health crisis on employment. Bowles et al. (2016) relied on firm survey data and applied difference-in-difference regressions to compare the decrease in economic activity across sectors and firms. They claim that the economic effect of the Ebola crisis was not felt simultaneously across all businesses in Liberia (with the hospitality, food, beverage and construction sectors worst hit). The authors attribute a 25% and 24% loss of economic activity and employment, respectively, to the Ebola outbreak. Moreover, they identify an almost 70% loss of jobs for restaurants in Ebola-stricken areas due to strict quarantine measures (Bowles et al., 2016). Huber et al. (2018) reviewed selected grey and published literature to determine the cumulative long-term economic effect of EVD through extrapolation. Once including the (monetized) economic value of life lost (as well as post-EVD long-term health impacts), they find the total socio-economic cost of the Ebola crisis for the core countries to amount to $53 billion. Kostova et al. (2019) made use of difference-in-difference regressions to evaluate the effect of the Ebola crisis on US export sectors to Liberia, Sierra Leone and Guinea (as well as the extent of associated job losses). Their results demonstrate a negative impact on US exports to West African Ebola-affected economies (with a $1.08 billion reduction in exports) and a loss of over 12 000 jobs from the corresponding export sectors. There is also evidence pointing to inflationary pressures induced by the West African Ebola outbreak (see the UNDP, 2014, study that relies on cross-country panel regressions and CGE simulations for evidence). Local governments responded to the health crisis by introducing curfews and curtailing human movements. Disruption in local production and cross-border trade, in combination with panic buying, led to shortages (especially in the case of food) and a rise in inflation, which was close to 45% for some staple food commodities, such as rice and cassava (while the overall inflation almost doubled from 8% to 15%, see UNDP, 2014). Table 1 provides summary information for all aforementioned studies.

## 3 | THE SYNTHETIC CONTROL APPROACH

Existing studies (e.g., those based on difference-in-difference estimations) generally provide a short-term assessment of the Ebola impact on Liberia and other affected countries, often with inherent methodological challenges in isolating the effect amongst other confounding factors. Other impact evaluation studies have relied on randomised control trials (RCTs) to determine the effect of interventions—these are more commonly used to assess impacts of shocks and interventions at the micro-level and with a risk of biased estimates in case strong prior assumptions do not hold (see Krauss, 2018; Page et al., 2016). Moreover, RCTs cannot be readily applied to assess the impact of pandemics and epidemics. To overcome the methodological limitations of the existing studies, we make use of a data-driven econometric technique, the SCM, to evaluate the economic effect of the Ebola outbreak in Liberia (Abadie et al., 2010). SCM has gained popularity in recent years as a policy evaluation method (McClelland & Gault, 2017) and has been used for comparative purposes at multiple levels of analysis (macro, meso and micro). It has been recently used to evaluate the impacts of shocks and interventions in the fields of natural disasters (Barone & Mocetti, 2014; Cavallo et al., 2013; Coffman & Noy, 2012), transparency initiatives (López-Cazar et al., 2021) and public health interventions (Bouttell et al., 2018; Kreif et al., 2016; Rieger et al., 2017, 2019). The application of SCM to natural disasters has largely motivated our own study. For example, Barone and Mocetti (2014) analyse the 1976 and 1980 earthquakes that occurred in two different regions in Italy. With their synthetic control model, they show that different patterns of total factor productivity were at play in the two regions resulting in diverging long-term effects on GDP per capita. Cavallo et al. (2013) assess the impact of large natural disasters on economic growth. Importantly, they show that only catastrophic disasters have a negative effect on growth and only when followed by radical political revolutions. Once the latter is controlled for, there is no effect. In turn, Coffman and Noy (2012) estimate the long-term impacts of a 1992 hurricane on the Hawaiian island of Kauai showing that even 18 years after the hurricane the economy has yet to recover and the island's population is smaller than what it would have been in the absence of the event. These findings are also relevant for the context of our analysis, that is, for studying the effects of major health emergencies.

TABLE 1 Summary of literature review

| Study | Duration of estimated impact | Methods | Outcome indicators | Type of virus | Geographic coverage |
|---|---|---|---|---|---|
| Meltzer et al. (1999) | short-term | Monte Carlo simulations | health outcomes (death rates, hospitalizations, illnesses, medical care), GDP | influenza | US |
| Burns et al. (2006) | short-term | simulations | GDP, employment | avian influenza | Global |
| Smith et al. (2009) | short-term | CGE simulations | mortality and morbidity rates, vaccine efficacy, school closures, prophylactic absenteeism, GDP | influenza | UK |
| Barro et al. (2020) | short and medium term | historical cross-country panel regressions | inflation, GDP per capita, growth in consumption, rates of stock returns | influenza (1918–1920 Great Influenza) | cross-country |
| Hanna and Huang (2004) | short-term | Oxford Economic Forecasting model, simulations | GDP | SARS 2003 | China |
| Brahmbhatt and Dutta (2008) | short-term | computation of direct and indirect (opportunity) costs | illnesses, costs of care, loss of output, productivity loss | SARS 2003 | Asian economies |
| Keogh-Brown and Smith (2008) | short-term | trend comparisons based on national statistics data | production, hospitality services and tourism, exports and trade | SARS 2003 | Asian economies |
| Amewu et al. (2020) | short-term | Social Accounting Matrix (Input–Output modelling) | GDP, GDP growth, industrial output, services, food sector, poverty | COVID-19 | Ghana |
| Binder (2020) | short-term | consumer survey | inflation and unemployment expectations | COVID-19 | US |
| Fernandes (2020) | short-term | forecasts, simulations | GDP and GDP growth | COVID-19 | Cross-country |

TABLE 1 (Continued)

| Study | Duration of estimated impact | Methods | Outcome indicators | Type of virus | Geographic coverage |
|---|---|---|---|---|---|
| McKibbin and Fernando (2021) | short and medium term (up to 6 years) | CGE simulations | labour supply shocks, risk premia and finance, output of multiple sectors (energy, mining, agriculture, manufacturing, services) | COVID-19 | Cross-country |
| World Bank (2014a, 2014b) | short and medium term | CGE simulations | GDP, agriculture, mining, forestry, services, manufacturing, public finances, poverty headcount ratio | 2014 Ebola | West Africa |
| UNDP (2014) | short term | cross-country panel regressions, panel data CGE simulations | economic growth, inflation, public revenues, trade | 2014 Ebola | West Africa |
| Bowles et al. (2016) | short term | firm survey, difference-in-difference regressions | employment (total and per sector), number of new contracts | 2014 Ebola | Liberia |
| Huber et al. (2018) | short, medium and long term | extrapolation | death and health impacts, output, health care, school closures | 2014 Ebola | West Africa |
| Kostova et al. (2019) | short and medium term | difference-in-difference regressions | export volumes | 2014 Ebola | West Africa |

The direct health effects of the Ebola outbreak are naturally devastating for the concerned individuals but (possibly) less so from a country perspective (with a death toll of less than a permille of the total population for economies characterised by high population growth).

In what follows, we provide a short synopsis of SCM. The SCM generates a synthetic comparative unit that imitates as closely as possible the behaviour of the actual unit (e.g., Liberia) prior to a shock or an intervention (more details on the method and its merits can be found in Abadie et al., 2015). This synthetic unit is, in effect, a weighted basket of other units (e.g., countries). The weights are automatically chosen as to minimise the overall gap/distance between the values of the actual and synthetic unit prior to the intervention, which can be seen as the 'treated' and 'untreated' units. The minimised distance between the actual and synthetic units is also commonly known as the root mean squared prediction error (RMSPE). The group of units, to which the weights are assigned, are commonly referred to as *donors*; these are units that did not undergo the intervention/shock examined (e.g., the Ebola outbreak) during the period of study. The size of the impact is then estimated based on the gap between the actual and synthetic units in the aftermath of the intervention (Abadie, 2021; Abadie et al., 2010).

More formally, let $D_{jt}$ denote the disease status of country *j* in year *t*, that is, it is equal to 1 for the Ebola outbreak and 0 otherwise. $OUT_{jt}$ is the observed economic or wellbeing outcome (unemployment, inflation, GDP, GDP per capita, HDI, undernourishment and health expenditures), while $OUT_{jt}^{N}$ is the unobserved counterfactual, and $\beta_{jt}$ are annual effects associated with $D_{jt}$ (Galiani & Quistorff, 2017). The observed outcome, $OUT_{jt}$ corresponds to the sum of disease effects and the counterfactual outcome across years:

$$\mathrm{OUT_{jt}} = \beta_{jt}\, \mathrm{D_{jt}} + \mathrm{OUT_{jt}^{N}}$$

where the process generating the counterfactual may be formulated as:

$$\mathrm{OUT_{jt}^{N}} = \alpha_t + \gamma_t Z_j + \delta_t \mu_j + \varepsilon_{jt}$$

where $\alpha_t$ is the unobserved time effect, $Z_j$ contains covariates and their effects $\gamma_t$, $\delta_t$ is a vector of unobservable factors and associated factor loadings $\mu_j$, and $\varepsilon_{jt}$ is the error term. The model accounts for unobserved country-specific predictors such as structural and cultural differences with $\mu_j$. Contrary to a fixed effects model where $\delta_t = \delta$, we even allow them to vary over time. We have one affected unit Liberia (to which we assign $j = 1$). We estimate the disease effects $\beta_{1t}$ by obtaining the missing counterfactual, which is based on a weighted average of the outcome variable in the pool of control countries:

$$\mathrm{OUT_{1t}^{N}} = \sum_{j \geq 2}^{J} w_j\, \mathrm{OUT_{jt}}$$

Weights $w_j$ ranging from zero to one are selected to minimise the pre-disease RMSPE subject to summing up to one. Additional covariates are taken into account as far as they help predict pretreatment outcome variable. We have opted for population, population growth, population density and share of the rural population, as Ebola spreads through contact with body fluids such as touching the body of someone who has symptoms or recently died from the disease.

The optimal sample weights are then administered to post-disease outcomes to extrapolate Liberia's path in the absence of the Ebola outbreak, that is, we create a synthetic Liberia. Put differently, the weights are used to predict Liberia's trajectory had Ebola not hit the country. A good pre-Ebola outbreak fit between Liberia and its synthetic control makes it more plausible to attribute the estimated differences in post-outbreak outcomes to EDV.

The statistical significance of the gap/impact in the post-outbreak period is decided based on falsification exercises with 'placebo effects', which examine the distribution of equivalent synthetic control placebo effects for other units of the so-called donor pool (Galiani & Quistorff, 2017). If the placebo effects for other donor units (i.e. non-Ebola-stricken economies) are comparable in size to the gap identified in the case of Liberia, then the statistical significance of the Ebola effect for the Liberian economy would be relatively low. For our analysis, we adopt an alternative inference method, the so-called adjusted non-restricted donor sample method (Abadie et al., 2010) that divides the size of the Ebola effect in the aftermath of the outbreak by its pre-Ebola RMSPE value. This approach controls for the adequacy of approximations of other synthetic countries and produces adjusted less conservative *p*-values for the estimated Ebola effect.

We use the STATA packages 'synth_runner' for the analysis. For more information about the method and its implementation, see Abadie (2021), Galiani and Quistorff (2017), Abadie et al. (2015, 2010), Cavallo et al. (2013), Abadie and Gardeazabal (2003) and Vanderbei (1999).

## 4 | DATA DESCRIPTION

To evaluate the macroeconomic effects of the Ebola outbreak, we make use of four standard macroeconomic indicators as outcome variables, namely, unemployment, inflation, GDP and GDP per capita. We employ the broadly conceived unemployment indicator from the ILO that considers the share of the labour force that is without work but available for and seeking employment as unemployed. Yet, we acknowledge that this definition disguises the role and scope of the informal sector in Liberia. According to the World Bank (2020), 90% of the workforce are employed in the informal sector and suffer from high levels of poverty and food insecurity. We initially intended to also assess effects on poverty (however, both time and spatial data coverage was poor). In addition, we study inflation as it has received extensive attention in the macroeconomics literature as an undesirable outcome, when at a high rate in the aftermath of a crisis. We also consider GDP and GDP per capita impacts. The overall size of GDP provides an aggregate monetary measure of the production of all goods and services, and its changes are often perceived as a measure of economic progress. GDP expressed in per capita terms is, instead, often seen as a measure indicating the average standard of living (Harvie et al., 2009). To capture welfare and wellbeing along a broader dimension, we also include the HDI, the prevalence of undernourishment and health expenditure (as share of GDP) in the analysis. In particular, undernourishment is included in direct response to the observation that workers in the informal sector suffer from food insecurity (World Bank, 2020). We hope that this indicator allows us to learn about the impacts of the 2014 Ebola outbreak on the most vulnerable.

Data on unemployment is taken from the ILO (2022); information about GDP, GDP per capita, undernourishment and health expenditure comes from the World Bank (2022), while data on inflation are taken from the IMF World Economic Outlook database (IMF, 2020), and the HDI information comes from UNDP (2022). Table A.1 in the Appendix provides a description of all variables used in our analysis and their sources. To predict the behaviour of these seven macro-socio-economic outcome indicators, we rely on a number of selected demographic control variables (population size, population growth, population density and the share of the rural population) since the demographic composition and pressure are considered to be linked to the spread of Ebola.

Our synthetic control analysis covers the period between 2001 and 2019 (with 2014 as the year of the intervention, viz., the onset of the Ebola health crisis). This choice was informed by data availability and the desire to have as long a pre-outbreak timespan as possible.[5] Moreover, we took into account that in 2020 the COVID-19 pandemic hit the globe (and therefore we do not extend the post-treatment period beyond 2019). We expect that our donor pool of African countries was already affected by the COVID-19 pandemic in 2020, even if only indirectly.[6] For our main empirical model, we use other (non-Ebola stricken) African countries as our comparative donor pool. The African countries are the prime candidates for the donor pool not only because of their location and, thus, more comparable climatic conditions but also because of their shared history and arguably their closer cultural proximity, which helps avoid interpolation biases (Abadie et al., 2015). The donor pool consists of a total of 42 African countries. We exclude those countries that have recorded Ebola outbreaks in our pre-outbreak period from 2001 to 2013 and the outbreak year of 2014. We use the history of the Ebola virus disease as reported by the Centers for Disease Control and Prevention (CDC)[7] to identify the excluded countries (year of the last outbreak in brackets): Democratic Republic of Congo (2014), Guinea (2014), Sierra Leone (2014), Mali (2014), Nigeria (2014), Senegal (2014), Uganda (2012), Republic of the Congo (2005), Sudan (2004) and Gabon (2001). The full list of donor countries is presented in the Appendix, Table A.2.

## 5 | RESULTS

We estimate the effect of the Ebola outbreak on Liberia's economy using a donor pool of African countries without Ebola occurrences in previous years. The SCM generates for each outcome variable a counterfactual synthetic unit (synthetic Liberia) based on a weighted average of values assigned to the donor pool countries. Table A.2 in the Appendix presents the weights per donor unit for each macroeconomic outcome variable. A total of 15 countries

[5]We also run models starting only in 2004 to exclude all war-related events. With these models, we come to similar conclusions. Results are available upon request.

[6]Including the 2020 data in our analysis does not alter the results. Results can be made available upon request.

[7]Detailed information can be accessed here: https://www.cdc.gov/vhf/ebola/history/chronology.html. [Last accessed: 5 July 2022].

receives a weight of zero for all outcomes.[8] In turn, Angola is part of the donor pool five times and Madagascar four times. Central African Republic, Djibouti, Equatorial Guinea, Ethiopia, Malawi and Sao Tome and Principe are each part of the donor pool for three of the seven outcomes; Burundi, Cote d'Ivoire, Ghana, Mozambique, Rwanda and Zimbabwe lend themselves as donors for two outcomes. Other countries are only in the donor pool for one outcome. Overall, 27 countries are involved as donors.

Next, we turn to the actual results. Figure 1 depicts the synthetic control results for our macroeconomic variables of interest (unemployment, inflation, GDP and GDP per capita) and the welfare indicators (HDI, undernourishment and health expenditure). The left panels present both the pre- and post-treatment trends (based on the 2014 Ebola outbreak as the cutting intervention point) for Liberia and its counterfactual synthetic unit. The timing of the 'intervention' (the Ebola health crisis that started in 2014) is represented with a vertical dotted line. The left panels demonstrate how the synthetic units for Liberia for all outcome variables follow the actual values of Liberia during the pre-Ebola years. The macroeconomic effect of the Ebola shock is then determined by the deviation (gap) between the synthetic and actual values during the years that follow the outbreak; positive values, hence, represent an increase of the corresponding macroeconomic outcome variable for Liberia in relation to its counterfactual unit. The right panels present the corresponding levels of statistical significance (pseudo $p$-values) based on the placebo tests for 2014 and later years.

Panel A presents results in relation to the unemployment rate. There is a slight initial decline in the unemployment rate, with a gap as small as −0.04 percentage points in 2015 (i.e., a slightly lower unemployment in the presence of the Ebola virus in comparison to the synthetic counterfactual units). This small effect is statistically insignificant and might be seen as a short-term human capital effect of originally unemployed workers replacing other workers who either fell sick or died. Indeed, the unemployment rate increases in the years that follow (in comparison to the synthetic values) with the largest positive unemployment gap being close to 1% in 2016 and statistically significant at the 1% level.[9] Unemployment remains roughly 1 percentage point higher ($p$-value ≤5%) in the ensuing years. This likely captures Ebola-related bottlenecks and disruptions to economic activities as a result of lower demand for goods and services, reduced supply of work due to fear of contracting the virus and adherence to strict government measures. Yet, as discussed above, the official unemployment rate has to be assessed cautiously due to the large size of the informal economy. Therefore, we later also turn to other wellbeing indicators.

Panel B presents the synthetic control results for the inflation rate. The Ebola effect on inflation appears to increase over time, that is, the gap between the synthetic and real Liberia widens over time. The effect on inflation is quite substantial and close to a 7% and 18% increase 4 and 5 years after the outbreak. The effects are statistically significant at the 12.1% and 1% level, respectively. For 2019, the effect amounts even to a 22% rise ($p$-value ≤1%). However, the effects (and corresponding gaps) are statistically insignificant in the period 2014 to 2016, that is, in years one, two and three after the outbreak. These substantial inflationary pressures are possibly attributed to Ebola-related quarantine measures, travel restrictions and the closure of cross-border trade to stop the transmission of the virus. The trade disruption had a particularly large impact on the prices of (imported) food. While these Ebola measures triggered the initial price changes, inflation intensified and became persistent and entrenched as individuals adjusted their expectations.

While Panel C suggests that the economy slowed down in the aftermath of the Ebola outbreak (as evident by the reduced slope of the GDP trend line), the effect does not appear to be statistically significant (for any of the post-intervention years). Panel D shifts attention to GDP per capita, which is often perceived as a measure of average living standards within an economy. Here there are two discernible patterns worth noting. First, the gap in GDP per capita between synthetic and actual Liberia has been widening, reaching a level close to $150 by

[8]The countries are Algeria, Botswana, Cameroon, Egypt, Eritrea, Kenya, Libya, Morocco, Mauritius, Namibia, Eswatini, Tunisia, Tanzania, Seychelles and Zambia.

[9]The precise $p$-values can be found in the Appendix, Table A.3.

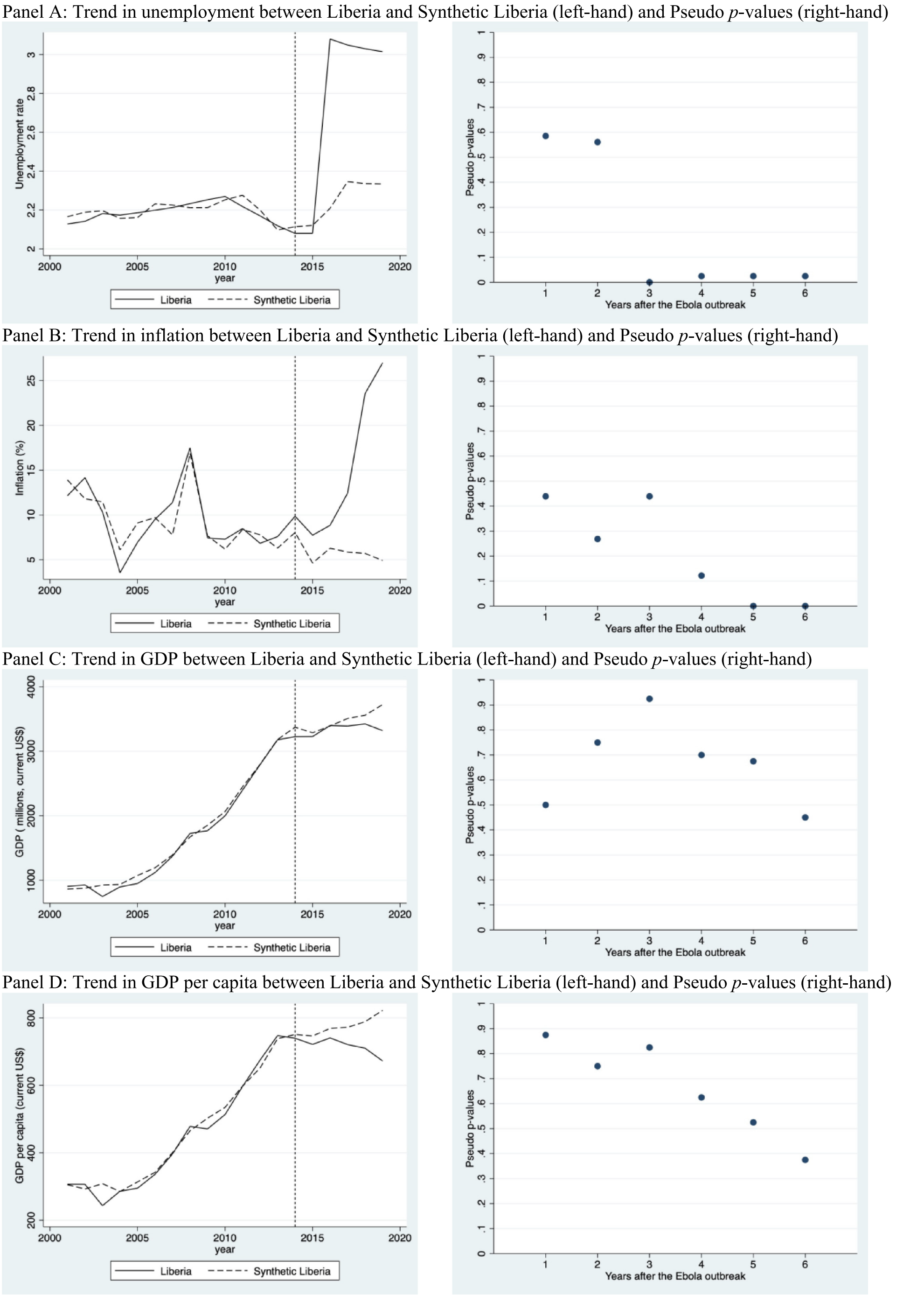
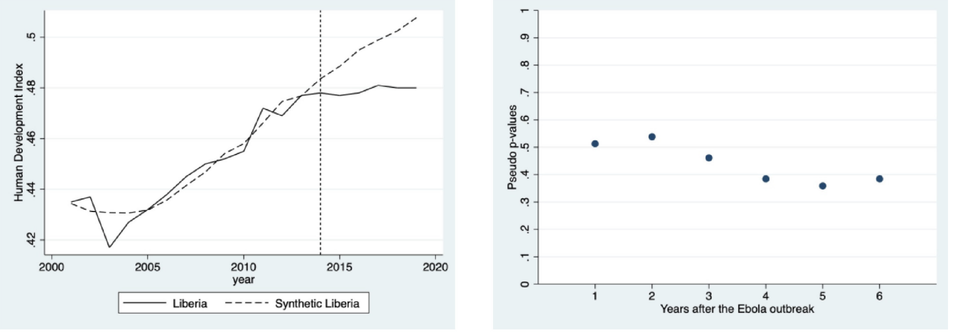


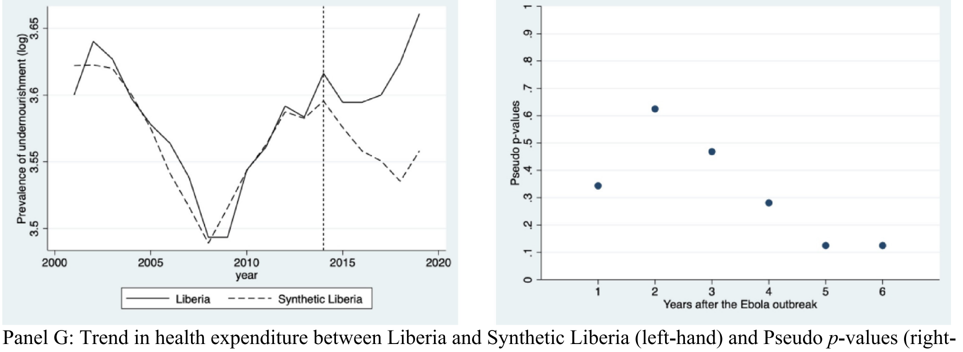

**FIGURE 1** Impacts of Ebola (Liberia) *Source*: Authors' compilation.

2019 from just below $11 in 2014. Second, between 2014 and 2016 GDP per capita levels stagnated and started declining thereafter. However, the corresponding *p*-values again suggest that one cannot attribute this gap to the Ebola crisis with statistical certainty. This is suggesting that the disappointing economic performance since 2014 has deeper roots extending beyond the Ebola health crisis. While Ellen Johnson Sirleaf's first term as presi-

Panel E: Trend in HDI between Liberia and Synthetic Liberia (left-hand) and Pseudo *p*-values (right-hand)




Panel F: Trend in undernourishment between Liberia and Synthetic Liberia (left-hand) and Pseudo *p*-values (right-hand)




Panel G: Trend in health expenditure between Liberia and Synthetic Liberia (left-hand) and Pseudo *p*-values (right-hand)

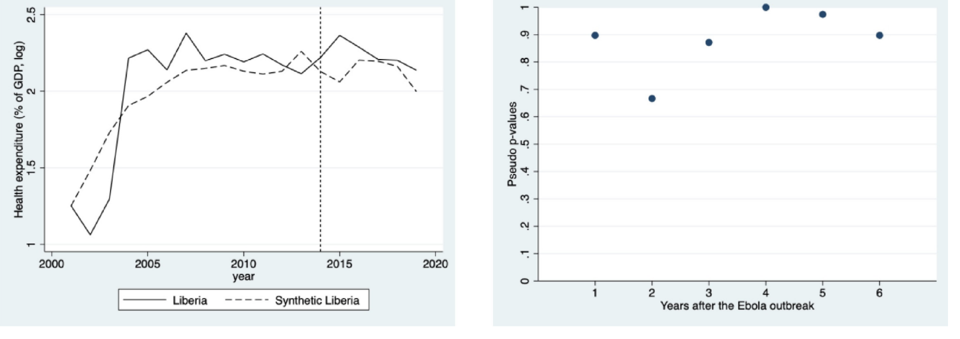



**FIGURE 1** (Continued)

dent (2006–2012) was generally considered successful (especially with respect to boosting growth and attracting foreign investment), her second term between 2012 and 2018 (which coincided with the Ebola outbreak and its immediate aftermath) has been criticised for extensive economic mismanagement (see Pailey & Harris, 2017 for a discussion). Even before the Ebola outbreak, her administration was accused of running budget deficits and failing to curtail inflation (despite the generous inflows of external aid). Procyclical fiscal policies in the aftermath of the Ebola health crisis in the form of raising taxes on basic commodities and services further lowered demand and exacerbated further economic conditions. During her second term, there were also several accusations of corruption and mishandling of public resources that culminated with Charles Sirleaf (her son and deputy governor of Liberia's Central Bank at the time) being charged in 2019 for the unlawful printing of local currency (of a value equal to $75 million). George Weah took over as president in 2018 with his administration, however, facing similar challenges (with members of his cabinet accused of corruption and facing financial sanctions by the United States), a situation that only worsened during 2019–20 by widespread protests as a result of broad public dissatisfaction with Weah's economic policies.

In Panel E, we turn to our first welfare measure, namely, the HDI. For this analysis, our original donor pool is reduced by three countries due to lack of data. As can be seen, the HDI in Liberia is lower after the outbreak of Ebola in 2014, and the gap is widening. Yet, we also note that the corresponding *p*-values are far from statistical significance across the entire post-outbreak period, suggesting that overall wellbeing as measured by this composite indicator has not worsened. In Panel F, we present findings for the prevalence of undernourishment suggesting a deterioration that manifests itself in roughly a 1 percentage point increase and is only significant at the 12.5% level in 2018 and 2019, that is, the last two periods. Note that the percentage change is calculated from the log value (depicted) and that this analysis rests on a donor pool with only 32 countries due to data limitations. Finally, we turn to Panel G that presents health expenditure as share of GDP. We observe that the pre-outbreak fit between Liberia and the synthetic Liberia is weak and the post-outbreak impacts are limited at most, volatile and clearly statistically insignificant. Thus, the welfare indicators point a similar picture as the standard macro-indicators of a rather limited impact of the 2014 Ebola outbreak on the economy and wellbeing.

## 5.1 | The effect of Ebola for Guinea and Sierra Leone

The main focus of this research has been on the economic impact of the Ebola crisis on Liberia, motivated by the fact that Liberia was the worst hit country in West Africa regarding the total death toll. In this subsection, we replicate our synthetic control analysis for the other two West African countries that were also severely affected, namely, Guinea and Sierra Leone.

### 5.1.1 | Guinea

Figure 2 depicts the estimated gap between the actual and synthetic values of Guinea.[10] Panel A presents the results for unemployment, which show an increasing trend that started already prior to the Ebola outbreak. Changes are, however, of very small magnitude—below 0.2 percentage points—and not statistically significant.[11] Panels B, C and D provide the corresponding gaps for the inflation rate, GDP and GDP per capita, respectively. In contrast to Liberia, inflation was not substantially different from the synthetic control in the aftermath of the Ebola outbreak. Similarly, GDP and GDP per capita are largely unaffected, with the latter even showing a positive (albeit statistically insignificant) gap in 2014 and 2015. Turning to the welfare indicators, we observe a perfect overlap in the Guinean HDI before, as well as after the Ebola outbreak, whereas for Liberia, we had identified some decrease, albeit a statistically insignificant one (Panel E). For Guinea, we do not have information on undernourishment, but we can analyse health expenditure (Panel F). It seems that contrary to Liberia, there was a positive response in health expenditure in 2014 and 2015 of 1.2 percentage points (after transformation from log, *p*-value = 12.8%) and 1.4 percentage points (*p*-value ≤2.6%), respectively. Most importantly, for all outcome indicators (expect for the 2015 health and the 2014 unemployment values), the Ebola effect as captured by the gaps in the post-intervention years is consistently statistically insignificant at conventional levels. This suggests that Guinea's economy and society at large were less affected by negative impacts of EDV compared to Liberia.

[10]The list of donor countries and their synthetic weights across outcomes is in Table A.4 in the Appendix.
[11]Precise *p*-values for all outcome variables and periods are in Table A.5 in the Appendix.

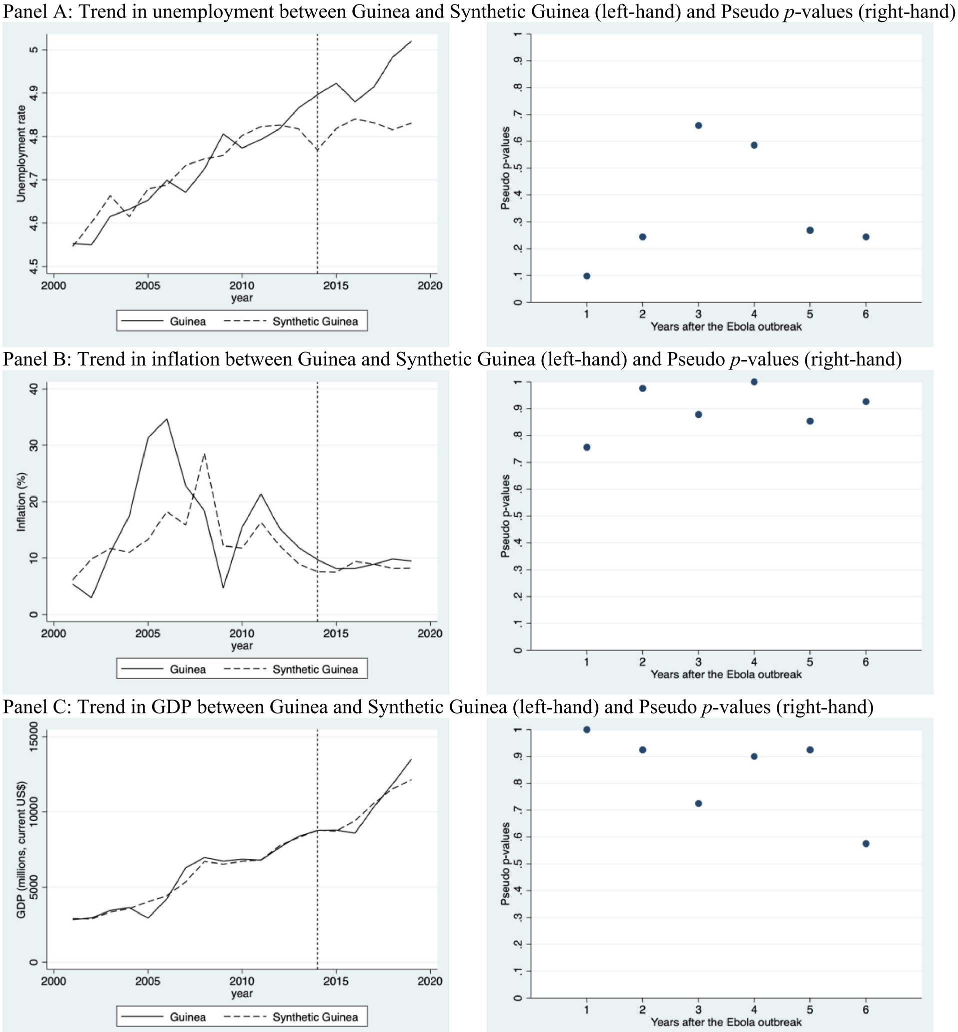



**FIGURE 2** Impacts of Ebola (Guinea) *Source*: Authors' compilation.

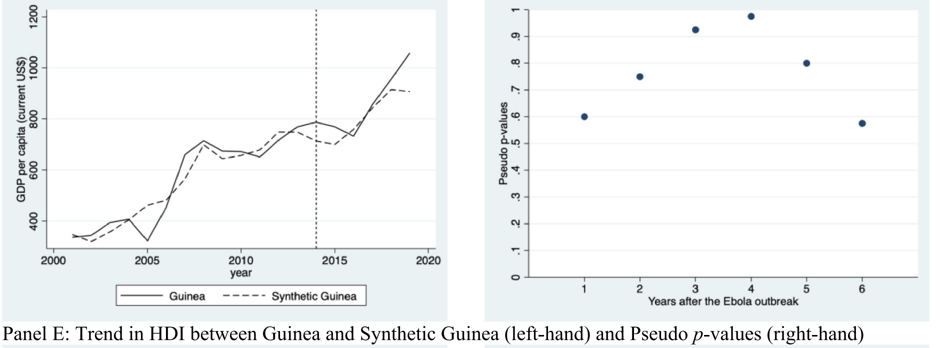
### 5.1.2 | Sierra Leone

Similarly, the left-hand panels of Figure 3 show the trend of the selected macroeconomic and welfare variables of interest during the pre- and post-treatment year of the Ebola crisis for Sierra Leone (SL) and synthetic Sierra Leone.[12] The right panels of Figure 3 depict the corresponding pseudo *p*-values.[13] Panel A presents the results for unemployment, which depict a tiny increase between 0.04 and 0.07 percentage points in 2014 and 2015, respectively, and then smoothly align with the synthetic control. Across all periods, effects are statistically insignificant. Regarding inflation, the Ebola crisis seems to have had a similar impact on Sierra Leone as on Liberia (Panel B). After an initial (slight) dampening effect in 2014, we observe a substantial rise in later years. Yet, effects are smaller in absolute terms as compared to Liberia and not statistically significant. Panel C depicts the gap for GDP values; as in the case of Liberia, the Ebola crisis has an overall negative effect on GDP (with the

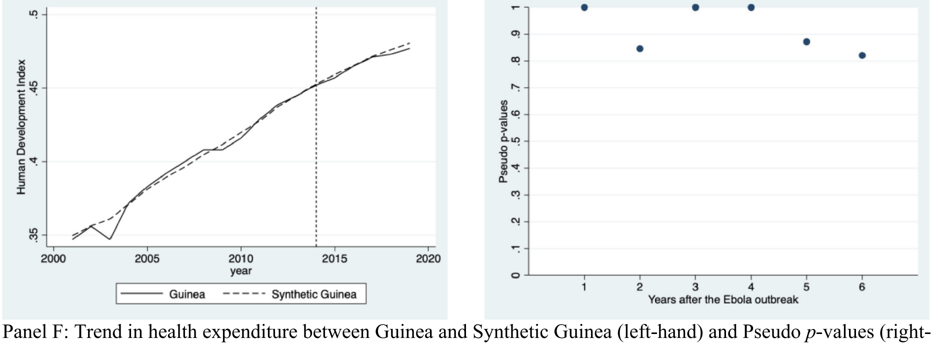
[12]The list of donor countries and their synthetic weights across outcomes is in Table A.6 in the Appendix.

[13]Precise *p*-values for all outcome variables and periods are in Table A.7 in the Appendix.

Panel D: Trend in GDP per capita between Guinea and Synthetic Guinea (left-hand) and Pseudo *p*-values (right-hand)




Panel E: Trend in HDI between Guinea and Synthetic Guinea (left-hand) and Pseudo *p*-values (right-hand)




Panel F: Trend in health expenditure between Guinea and Synthetic Guinea (left-hand) and Pseudo *p*-values (right-hand)

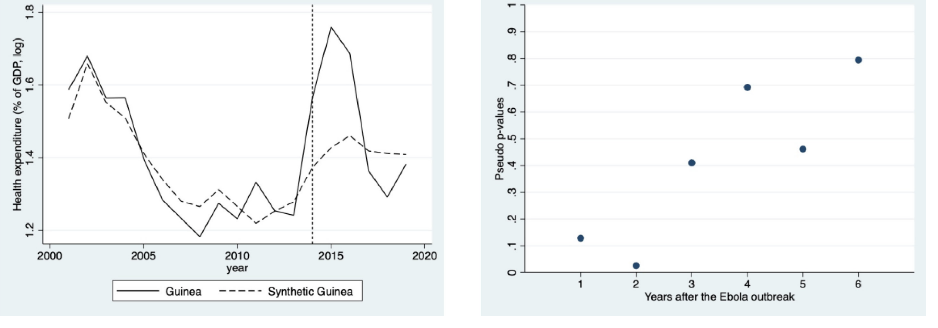
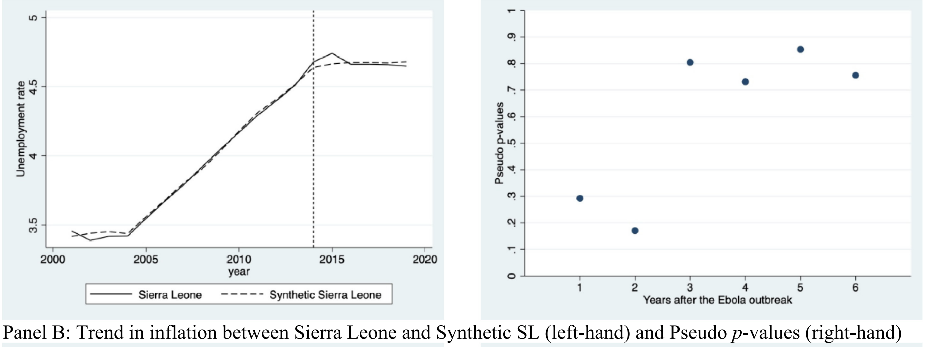



**FIGURE 2** (Continued)

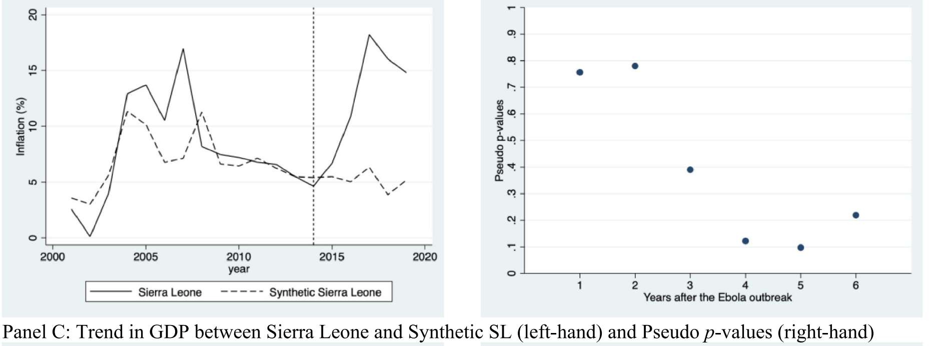
exception of a small rise in 2014). Again, effects are not statistically significant. Akin to Liberia, Panel D depicts a negative gap for GDP per capita and hence a negative effect of Ebola on average living standards; the magnitude of the gap is substantial, namely, close to a reduction of $400 in 2019, although only borderline significant in the years 2015 to 2019 with *p*-values varying between 5% and 12.5%. Next, we turn to the welfare indicators. Similar to Liberia, we observe a (statistically insignificant) decline in HDI after the Ebola outbreak (Panel E). Contrary to Liberia, undernourishment does not seem to be affected in Sierra Leone; the trend line for Sierra Leone and its synthetic counterfactual overlaps considerably throughout (Panel F). Last, we assess health expenditure (Panel G). As in the case of Guinea, there is some indication that health expenditure has significantly gone up right after the Ebola outbreak, but again, we have a fairly poor pre-outbreak fit making it impossible to unreservedly draw conclusions.

In short, the findings for Liberia, Guinea and Sierra Leone largely overlap. Effects seem to be strongest for Liberia that was most affected, but overall, they suggest that there are not long-term effects of the Ebola outbreak on the

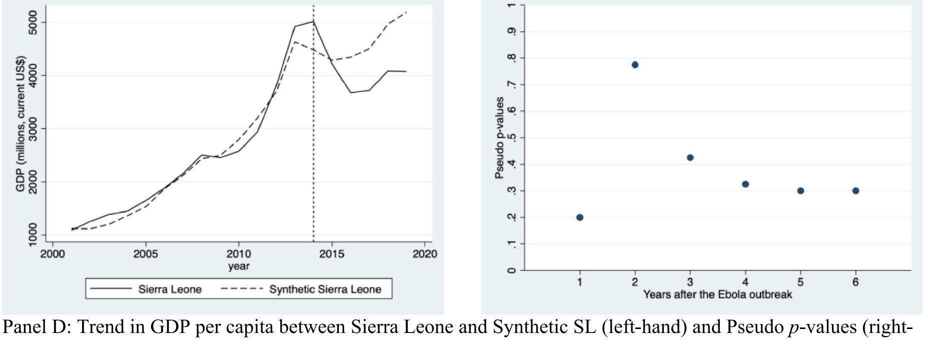
Panel A: Trend in unemployment between Sierra Leone and Synthetic SL (left-hand) and Pseudo *p*-values (right-hand)




Panel B: Trend in inflation between Sierra Leone and Synthetic SL (left-hand) and Pseudo *p*-values (right-hand)




Panel C: Trend in GDP between Sierra Leone and Synthetic SL (left-hand) and Pseudo *p*-values (right-hand)




Panel D: Trend in GDP per capita between Sierra Leone and Synthetic SL (left-hand) and Pseudo *p*-values (right-hand)

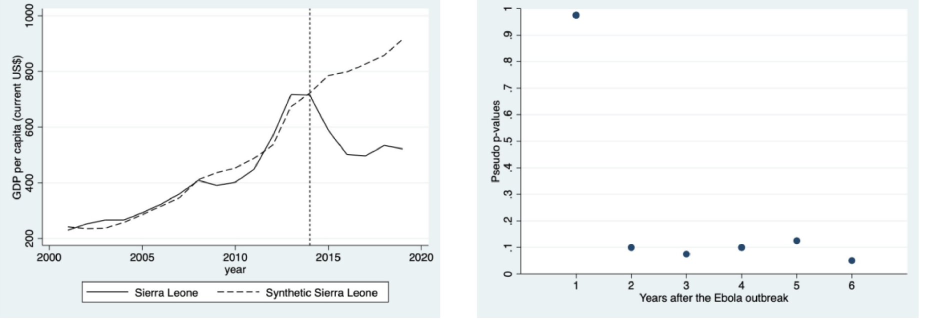



**FIGURE 3** Impacts of Ebola (Sierra Leone) *Source*: Authors' compilation.

macroeconomy and aggregate wellbeing. The more significant negative effect of the EVD on the Liberian economy is possibly attributed to a number of intertwined factors. First, the Ebola crisis was felt more profoundly in Liberia, which experienced the largest number of deaths despite having a much smaller population size in comparison to

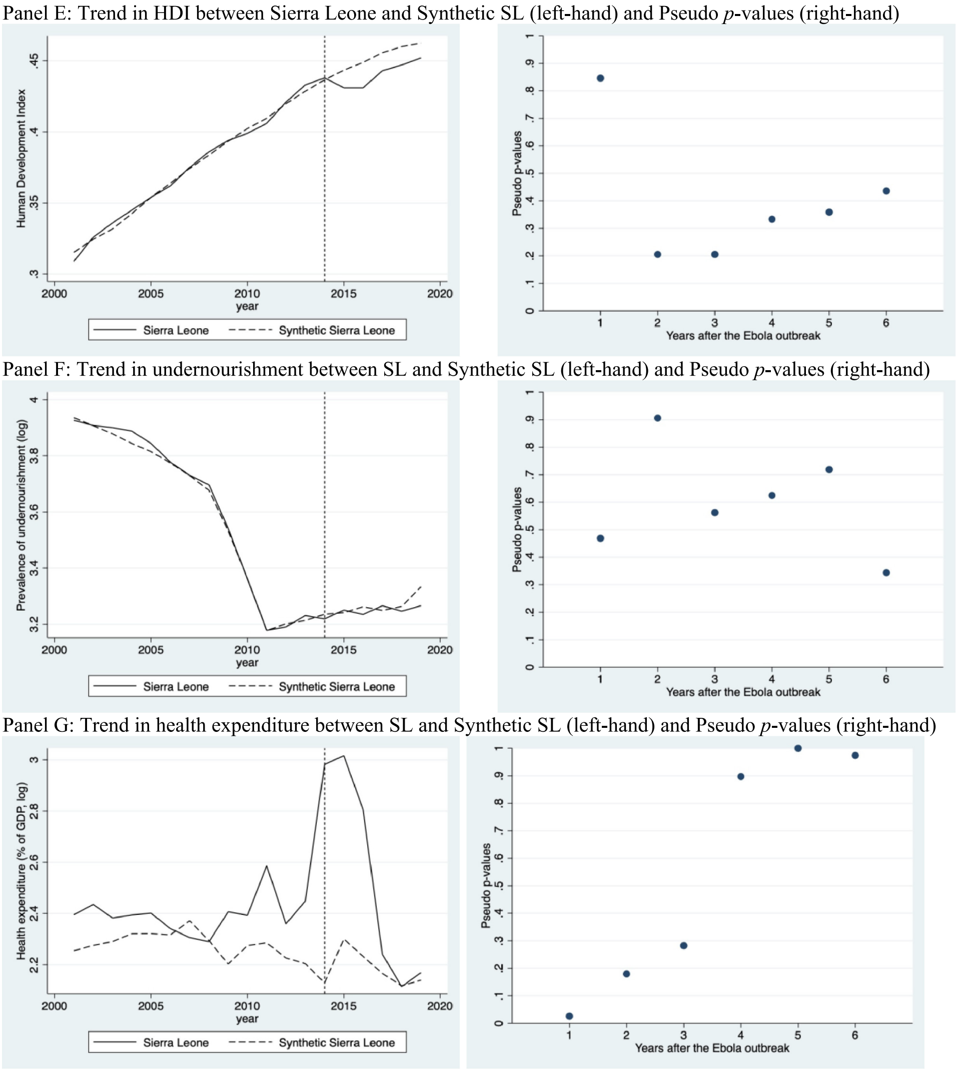



**FIGURE 3** (Continued)

Sierra Leone and Guinea (with per capita Ebola-related deaths in Liberia being approximately two and six times larger compared to Sierra Leone and Guinea). Second, the macroeconomic effects attributed to strict quarantine measures were amplified by simultaneous inflationary pressures and severe disruption to exporting activities. Third, a large share of the Liberian public was sceptical of the official figures reported by the health authorities and responded (within a general climate of distrust, fear and panic) by minimising social contact as much as possible. In Liberia, many of the Ebola deaths were under-reported due to an associated stigma and local officials were even known to provide falsified death certificates (in exchange for bribes) to allow families to perform traditional funerals for their deceased relatives.

We cannot proceed without acknowledging that our empirical analysis is faced with some limitations. Across SCM specifications, our pretreatment fit does not establish a perfect overlap between the situation in the Ebola-stricken country and the synthetic control. This suggests that the predictor variables of the countries in our donor pool are not fully comparable with the characteristics of the three Ebola-stricken countries, which needs to be taken into account when gauging the strength of our findings. Put differently, the availability of a credible donor pool is a challenge. This is why we decided to only include African countries in the donor pool. Note that such restrictions are common in SCM frameworks (Abadie et al., 2015). Moreover, the Ebola-stricken countries should not exhibit any outlier characteristics in the pretreatment period. Yet, knowing the three countries under study, we cannot fully rule it out; for example, Liberia is war affected with the peace agreement only signed in 2003. Further note that a coup took place in Guinea in 2008 and Sierra Leone was in civil war between 1991 and 2001 with the end of war only being declared in 2002. These external circumstances also relate to the fact that small effects are difficult to detect with SCM as well as with other methods, especially in volatile environments. This might further explain why this study as well as others (see Section 2) are unable to find statistically significant effects (if, on national scale, the effect of the Ebola outbreak might have indeed been comparatively small). In turn, we are not concerned about spillovers because the Ebola outbreak was locally contained and we exclude countries that experience Ebola between 2001 and 2014 from the donor pool (Abadie, 2021). Similarly, we are not concerned about anticipation effects, as the 2014 Ebola outbreak hit weak surveillance systems and poor public health infrastructure that were not well-prepared. Furthermore, while the pre-outbreak period is not extremely long, we have opted for the 13 years window 2001 to 2013 to establish a decent pre-outbreak trend. We do not extend the after-outbreak period beyond 2019 to avoid conflated effects that could be attributed to the COVID-19 pandemic. While being aware of the limitations of SCM and their implications for our findings, we find it worthwhile to assess the existing data and to start an informed discussion and knowledge generation about the possible implications of the 2014 Ebola outbreak for the affected countries. We expect that this discussion can also feed into advocacy strategies for more and better (health) data that can then in turn be analysed in even more sophisticated analyses in the long term.

## 6 | CONCLUSION

Following the end of civil war, Liberia transitioned successfully from a failed state to one enjoying peace, political stability and steady economic development. The 2014 Ebola outbreak was largely perceived as a macroeconomic shock derailing this progress and reversing past developmental gains. Earlier literature has probed into the macroeconomic effects of the 2014 Ebola outbreak for West Africa, especially for the most affected countries, Liberia, Guinea and Sierra Leone, although with a focus on the more immediate repercussions for the economy. We contribute to this literature by providing the first empirical study that makes use of the SCM to study the economic impacts of the 2014 Ebola outbreak on longer term macroeconomic and welfare outcomes.

In general, most macroeconomic effects appear to be small, short-term and statistically insignificant. For the case of Liberia, we find a slight initial decline in the unemployment rate, followed by an increase of about 1%. This likely captures Ebola-related bottlenecks and disruptions to economic activities as a result of both reduced demand for goods and services, as well as restrictions in mobility and labour supply due to fear of contracting the virus. The effect on inflation is more substantial, namely, a close to 9% and 18% increase 3 and 4 years after the outbreak but statistically insignificant in the preceding periods. These substantial inflationary pressures are possibly attributed to Ebola-related quarantine measures, travel restrictions and the closure of cross-border trade to stop the transmission of the virus, which increased the prices of imported goods. We hypothesise that while these Ebola measures triggered the initial price changes, inflation intensified and became persistent and entrenched as individuals adjusted their expectations. This can be the result of a price-wage spiral, where workers seek nominal wage increases to compensate for price changes and associated reductions in their purchasing power (also as advanced protection against further inflationary pressures). This can generate a vicious cycle of mutually reinforced price and wage inflation. For instance, monthly minimum wages in Liberia are currently almost twice as high compared to many other sub-Saharan economies of similar GDP per capita levels (e.g., those in Gambia, Malawi and Guinea-Bissau). Lastly, external debt almost doubled in the aftermath of the Ebola outbreak (between 2014 and 2019), which Liberian authorities tried to address through printing more money (which, as a result, exacerbated and prolonged inflationary pressures).

The research has significant policy implications, in particular in light of the current pandemic. While it is still early to assess the medium- and long-term macroeconomic effects of the COVID-19 pandemic on individual economies, our synthetic control analysis sheds light into the duration and intensity of similar impacts in the case of the 2014–2016 Ebola epidemic in West Africa. Importantly, most macroeconomic effects appear to be largely transient. Yet, the case of persistently higher inflation in Liberia in the aftermath of the Ebola outbreak provides a warning signal of how some disruptions can become long-lasting; this is especially relevant in the case of current debates on COVID-19 and macroeconomic management, given that many fear that initial supply chain problems may persist and individuals/firms could adjust their inflationary expectations upwards.

We have several possible extensions of our analysis in mind. Limited data availability prevented us from assessing a range of additional socio-economic impacts, for example, in the context of tourism revenues, aviation volumes, poverty rates and educational outcomes. Even more limited is regional data availability for Liberia and other West African economies. Regional variation in the timing and extent of exposure to the Ebola virus could allow us to probe into the more micro-/meso-socio-economic effects of the Ebola epidemic.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## APPENDIX A

**TABLE A1** Variable description and data sources

| Variable | Description of the data | Source |
|---|---|---|
| Outcome variables | | |
| GDP | Current price—US dollars (million) | World Bank (2022) |
| GDP per capita | Current price—US dollars | World Bank (2022) |
| Unemployment | Total (% of labour force) | ILO (2022) |
| Inflation rate | Average consumer price % change | IMF (2020) |
| Prevalence of undernourishment | Share of the population | World Bank (2022) |
| Human Development Index | Index | UNDP (2022) |
| Health expenditure | Current expenditure as share of GDP | World Bank (2022) |
| Control variables | | |
| Population | Total number of people | World Bank (2022) |
| Population growth | Annual % | World Bank (2022) |
| Population density | People per sq. km of land area | World Bank (2022) |
| Rural population | Share of total population | World Bank (2022) |
| Population, female | Share of total population | World Bank (2022) |

**TABLE A2** Synthetic control country weights for Liberia

| | Synthetic control weights | | | | | | |
|---|---|---|---|---|---|---|---|
| Country | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
| Algeria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Angola | 0.008 | 0 | 0.059 | 0.003 | 0.005 | 0 | 0.009 |
| Benin | 0.091 | 0 | 0 | 0 | 0 | 0 | 0 |
| Botswana | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burkina Faso | 0.001 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burundi | 0 | 0 | 0 | 0.186 | 0 | 0.296 | - |
| Cabo Verde | 0 | 0 | 0.036 | 0 | 0 | 0 | 0 |
| Cameroon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 0 | 0.206 | 0.203 | 0 | 0 | 0 | 0.141 |
| Chad | 0.557 | 0 | 0 | 0 | 0 | 0 | 0 |
| Comoros | 0.052 | 0 | 0 | 0 | 0 | 0 | - |
| Cote d'Ivoire | 0.048 | 0 | 0 | 0 | 0 | 0 | 0.033 |
| Djibouti | 0 | 0 | 0 | 0.046 | 0.202 | 0 | 0.028 |
| Egypt, Arab Rep. | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(Continues)

**TABLE A2** (Continued)

| Country | Synthetic control weights | | | | | | |
|---|---|---|---|---|---|---|---|
| | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
| Equatorial Guinea | 0.028 | 0.173 | 0.082 | 0 | 0 | 0 | - |
| Eritrea | 0 | - | 0 | - | - | 0 | - |
| Eswatini | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ethiopia | 0 | 0 | 0.064 | 0.2 | 0.007 | 0 | 0 |
| Gambia, The | 0 | 0 | 0 | 0 | 0 | 0 | 0.039 |
| Ghana | 0 | 0 | 0 | 0.024 | 0 | 0 | 0.097 |
| Guinea-Bissau | 0 | - | 0 | 0 | 0.055 | 0 | - |
| Kenya | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lesotho | 0 | 0.535 | 0 | 0 | 0 | 0 | 0 |
| Libya | 0 | 0 | 0 | 0 | 0 | - | - |
| Madagascar | 0.05 | 0 | 0 | 0.405 | 0.041 | 0 | 0.202 |
| Malawi | 0 | 0.086 | 0.045 | 0 | 0 | 0.521 | 0 |
| Mauritania | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 |
| Mauritius | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mozambique | 0.014 | 0 | 0.003 | 0 | 0 | 0 | 0 |
| Namibia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Niger | 0 | 0 | 0.171 | 0 | 0 | 0 | - |
| Rwanda | 0.007 | 0 | 0 | 0 | 0 | 0.183 | 0 |
| Sao Tome and Principe | 0 | 0 | 0.224 | 0 | 0.638 | 0 | 0.036 |
| Seychelles | - | 0 | 0 | 0 | 0 | 0 | - |
| Somalia | 0 | - | - | - | - | - | 0.413 |
| South Africa | 0 | 0 | 0.113 | 0 | 0 | 0 | 0 |
| Tanzania | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 0.145 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tunisia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zambia | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Zimbabwe | 0 | 0 | 0 | 0.135 | 0.052 | - | - |

*Note*: Every column represents one synthetic control specification. Weights result from minimising the root mean squared prediction error (RMSPE). '-'indicates missing data for the respective country and outcome indicator.

TABLE A3 Pseudo *p*-values for Liberia

| Year after the Ebola outbreak | Pseudo *p*-values Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
|---|---|---|---|---|---|---|---|
| 2014 | 0.585 | 0.513 | 0.439 | 0.875 | 0.500 | 0.897 | 0.344 |
| 2015 | 0.561 | 0.538 | 0.268 | 0.750 | 0.750 | 0.667 | 0.625 |
| 2016 | 0.000*** | 0.462 | 0.439 | 0.825 | 0.925 | 0.872 | 0.469 |
| 2017 | 0.024** | 0.385 | 0.122° | 0.625 | 0.700 | 1.000 | 0.281 |
| 2018 | 0.024** | 0.359 | 0.000*** | 0.525 | 0.675 | 0.974 | 0.125° |
| 2019 | 0.024** | 0.385 | 0.000*** | 0.375 | 0.450 | 0.897 | 0.125° |

***indicates statistical significance at the 1% level.
**indicates statistical significance at the 5% level.
*indicates statistical significance at the 10% level.
°indicates statistical significance at the 15% level.

TABLE A4 Synthetic control country weights for Guinea

| Country | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure |
|---|---|---|---|---|---|---|
| Algeria | 0 | 0 | 0 | 0 | 0 | 0 |
| Angola | 0 | 0 | 0 | 0 | 0 | 0 |
| Benin | 0 | 0 | 0 | 0 | 0 | 0 |
| Botswana | 0.017 | 0 | 0 | 0 | 0 | 0 |
| Burkina Faso | 0 | 0 | 0 | 0 | 0 | 0 |
| Burundi | 0 | 0 | 0 | 0 | 0 | 0 |
| Cabo Verde | 0.005 | 0 | 0 | 0.001 | 0 | 0 |
| Cameroon | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 0 | 0 | 0 | 0 | 0 | 0 |
| Chad | 0 | 0 | 0 | 0 | 0 | 0.47 |
| Comoros | 0 | 0 | 0 | 0 | 0 | 0 |
| Cote d'Ivoire | 0 | 0 | 0 | 0 | 0.067 | 0 |
| Djibouti | 0 | 0 | 0 | 0.012 | 0 | 0 |
| Egypt, Arab Rep. | 0.005 | 0 | 0 | 0 | 0 | 0 |
| Equatorial Guinea | 0 | 0.034 | 0 | 0 | 0 | 0.063 |
| Eritrea | 0 | - | 0 | - | - | 0 |
| Eswatini | 0.033 | 0 | 0 | 0 | 0 | 0 |
| Ethiopia | 0 | 0.151 | 0.169 | 0.293 | 0.047 | 0 |
| Gambia, The | 0 | 0 | 0 | 0.021 | 0 | 0 |
| Ghana | 0 | 0 | 0 | 0 | 0 | 0 |
| Guinea-Bissau | 0 | - | 0 | 0.646 | 0.719 | 0 |

(Continues)

**TABLE A4** (Continued)

| Country | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure |
|---|---|---|---|---|---|---|
| Kenya | 0 | 0 | 0 | 0 | 0 | 0 |
| Lesotho | 0 | 0 | 0 | 0 | 0 | 0 |
| Libya | 0 | 0 | 0 | 0.012 | 0.013 | - |
| Madagascar | 0 | 0 | 0 | 0 | 0.108 | 0 |
| Malawi | 0 | 0 | 0.083 | 0 | 0.044 | 0 |
| Mauritania | 0 | 0.095 | 0 | 0 | 0 | 0.274 |
| Mauritius | 0.006 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 0 | 0.177 | 0 | 0 | 0 | 0 |
| Mozambique | 0.687 | 0 | 0.202 | 0 | 0 | 0 |
| Namibia | 0.011 | 0 | 0 | 0 | 0 | 0 |
| Niger | 0.028 | 0.543 | 0 | 0 | 0 | 0 |
| Rwanda | 0.018 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0.546 | 0 | 0 | 0 |
| Seychelles | - | 0 | 0 | 0 | 0 | 0.193 |
| Somalia | 0 | - | - | - | - | - |
| South Africa | 0 | 0 | 0 | 0 | 0 | 0 |
| Tanzania | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 0 | 0 | 0 | 0 | 0 | 0 |
| Tunisia | 0 | 0 | 0 | 0 | 0 | 0 |
| Zambia | 0 | 0 | 0 | 0 | 0 | 0 |
| Zimbabwe | 0.19 | 0 | 0 | 0.015 | 0 | - |

*Note*: There is no data available on the prevalence of undernourishment for Guinea.

**TABLE A5** Pseudo *p*-values for Guinea

| | Pseudo *p*-values | | | | | | |
|---|---|---|---|---|---|---|---|
| Year after the Ebola outbreak | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
| 2014 | 0.098* | 1.000 | 0.756 | 0.600 | 1.000 | 0.128 | - |
| 2015 | 0.244 | 0.846 | 0.976 | 0.750 | 0.925 | 0.026** | - |
| 2016 | 0.659 | 1.000 | 0.878 | 0.925 | 0.725 | 0.410 | - |
| 2017 | 0.585 | 1.000 | 1.000 | 0.975 | 0.900 | 0.692 | - |
| 2018 | 0.268 | 0.872 | 0.854 | 0.800 | 0.925 | 0.462 | - |
| 2019 | 0.244 | 0.821 | 0.927 | 0.575 | 0.575 | 0.795 | - |

***indicates statistical significance at the 1% level.

**indicates statistical significance at the 5% level.

*indicates statistical significance at the 10% level.

°indicates statistical significance at thee 15% level.

TABLE A6 Synthetic control country weights for Sierra Leone

| Country | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
|---|---|---|---|---|---|---|---|
| Algeria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Angola | 0 | 0.181 | 0 | 0 | 0 | 0 | 0.467 |
| Benin | 0.017 | 0 | 0 | 0 | 0 | 0 | 0 |
| Botswana | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burkina Faso | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burundi | 0 | 0 | 0 | 0.581 | 0 | 0 | - |
| Cabo Verde | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cameroon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 0 | 0 | 0 | 0 | 0 | 0 | 0.324 |
| Chad | 0.255 | 0 | 0 | 0 | 0 | 0 | 0.171 |
| Comoros | 0.287 | 0 | 0 | 0 | 0 | 0 | - |
| Cote d'Ivoire | 0.001 | 0 | 0 | 0 | 0 | 0 | 0 |
| Djibouti | 0 | 0 | 0 | 0.164 | 0.36 | 0 | 0 |
| Egypt, Arab Rep. | 0 | 0 | 0.11 | 0 | 0 | 0 | 0 |
| Equatorial Guinea | 0.096 | 0 | 0 | 0 | 0 | 0 | - |
| Eritrea | 0 | - | 0.058 | - | - | 0 | - |
| Eswatini | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ethiopia | 0 | 0 | 0 | 0.228 | 0 | 0 | 0 |
| Gambia, The | 0.005 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 0 | 0 | 0 | 0.008 | 0.027 | 0 | 0 |
| Guinea-Bissau | 0 | - | 0 | 0 | 0 | 0 | - |
| Kenya | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lesotho | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Libya | 0 | 0 | 0.077 | 0 | 0.003 | - | - |
| Madagascar | 0.006 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malawi | 0 | 0 | 0.045 | 0 | 0 | 0 | 0 |
| Mauritania | 0 | 0 | 0.607 | 0 | 0 | 0 | 0 |
| Mauritius | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mozambique | 0.333 | 0.148 | 0 | 0.019 | 0.056 | 0 | 0 |
| Namibia | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Niger | 0 | 0.501 | 0 | 0 | 0 | 0 | - |
| Rwanda | 0 | 0.17 | 0.093 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0.451 | 0 | 0 |
| Seychelles | - | 0 | 0 | 0 | 0.058 | 0 | - |
| Somalia | 0 | - | - | - | - | - | 0.038 |

(Continues)

**TABLE A6** (Continued)

| Country | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
|---|---|---|---|---|---|---|---|
| South Africa | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tanzania | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tunisia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zambia | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Zimbabwe | 0 | 0 | 0.01 | 0 | 0.044 | - | - |

**TABLE A7** Pseudo *p*-values for Sierra Leone

| | Pseudo *p*-values | | | | | | |
|---|---|---|---|---|---|---|---|
| Year after the Ebola outbreak | Unemployment | Human Development Index | Inflation | GDP per capita | GDP | Health expenditure | Undernourishment |
| 2014 | 0.293 | 0.846 | 0.756 | 0.975 | 0.200 | 0.026** | 0.469 |
| 2015 | 0.171 | 0.205 | 0.780 | 0.100* | 0.775 | 0.179 | 0.906 |
| 2016 | 0.805 | 0.205 | 0.390 | 0.075* | 0.425 | 0.282 | 0.563 |
| 2017 | 0.732 | 0.333 | 0.122° | 0.100* | 0.325 | 0.897 | 0.625 |
| 2018 | 0.854 | 0.359 | 0.098 | 0.125° | 0.300 | 1.000 | 0.719 |
| 2019 | 0.756 | 0.436 | 0.220 | 0.050** | 0.300 | 0.974 | 0.344 |

***indicates statistical significance at the 1% level.
**indicates statistical significance at the 5% level.
*indicates statistical significance at the 10% level.
°indicates statistical significance at the 15% level.