Behavioral Responses and Economic Impacts in the 2014-16 West African Ebola Epidemic\(^1\)

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October 11, 2019

1. Introduction

Of the 20 severe Ebola outbreaks experienced in Africa since 1976, the West African Ebola crisis of 2014-16 was the largest by far. The WHO estimates that nearly 30,000 people were infected by Ebola Virus Disease (EVD) in Guinea, Liberia and Sierra Leone – referred to below as the EVD-affected countries – between December 2013 and June 2016, over 11,000 of whom died of the disease.\(^3\) We focus in this chapter on the economic impacts of the crisis, which were considerably larger than those directly attributable to illness and death. Our rough estimate is that the crisis reduced the year-to-year growth rate of real GDP per capita in the EVD-affected countries by about 10 percentage points on average in 2014 and 2015. In two of the three affected countries, the implied reduction in the level of real GDP per capita appears to have lasted well beyond 2015. These impacts are large for an outbreak that was ultimately contained with fewer cumulative deaths than those attributable individually to malaria, HIV/AIDS, or non-HIV-positive tuberculosis in the affected countries (see Table 1). They are also large relative to the substantial year-to-year volatility of growth in low-income countries, and by comparison with the typical growth impacts of natural disasters, civil wars, or financial crises (Kellenberg and Mobarak 2011, Collier 1999, Reinhart and Rogoff 2009; see also Sawada, Bhatcharyay and Kotera 2011).

At one level, the disproportionate economic impacts of a deadly infectious outbreak that has no known cure and takes place in a novel context are easy to explain. In contrast to a chronic source of morbidity, the Ebola episode produced a collapse of normal economic life as individuals and local political authorities navigated the challenges of caring for infected individuals and avoiding exposure to the virus. Our aim in this chapter is to develop an analytical account of the key policy tradeoffs policymakers faced in managing and responding to the link between economic activity and disease transmission. Our hope is that economists will develop these themes further and link them more deeply to the data. Our framework illustrates what we see as the economic mechanisms that were at play in

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\(^1\) This chapter is in honor of Olu Ajakaiye on the occasion of his 70th birthday. Our associations with Olu go way back. Steve served as a Resource Person in the AERC’s bi-annual research workshops and collaborated with Olu on numerous AERC research projects including the African Economic Growth Project, which Olu oversaw. Jerry interacted with Olu over a number of years via his work in USAID’s Africa Bureau. We are grateful for helpful comments on an earlier draft by Ayse Kaya. Any errors are our own.

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\(^3\) For a time line of all EVD outbreaks, see https://www.beckershospitalreview.com/quality/timeline-of-global-ebola-outbreaks-1976-present.html (accessed August 25, 2019). We are defining a severe outbreak here as one involving 10 or more deaths from the virus; all severe outbreaks have been in Africa. For the WHO estimates and an overview of the crisis, see https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/index.html. See also Table 1.
West Africa following the declaration of a global health emergency by the World Health Organization in August of 2014. We use it to bring out some economic lessons from the crisis and also (briefly) to interpret the trajectory of the Ebola emergency currently unfolding in the Democratic Republic of Congo.

2. Economic impacts in retrospect

The Ebola crisis had overrun local health systems by the time the World Health Organization belatedly declared a Public Health Emergency of International Concern (PHEIC) on August 8, 2014 (WHO 2014). The WHO’s failure to sound an earlier global alarm may help explain the relatively low profile of the outbreak through the middle of 2014 despite its unusual location within Africa\(^4\) and the evidence of its having crossed at least two national borders. There is no mention of the outbreak, for example, in the International Monetary Fund (IMF)’s July 2014 review of its lending arrangement with Liberia, even though at that point all three countries were involved and Liberia had already experienced 16 cases and 5 deaths by the WHO’s count – with local sources indicating many more.\(^5\)

Figure 1 shows the evolution of real GDP per capita in Guinea, Liberia, Sierra Leone and the other 41 countries of Sub-Saharan Africa (SSA) for which we have data. Each panel shows a set of time-series indexes of real GDP per capita (2013=100) corresponding to different vintages of the IMF’s World Economic Outlook (WEO) database. The WEO April 2019 series provides the most comprehensive retrospective view and is very close in most cases to the real GDP per capita reported in the World Bank’s 2019 World Development Indicators.\(^6\) This series shows that all three countries were growing before the crisis. A dramatic slowdown then took place in 2014 in both Liberia and Sierra Leone, with GDP per capita falling outright in the case of Liberia. There is no obvious break in trend in either Guinea, where the outbreak was much smaller on a per-capita basis than it was in Liberia or Sierra Leone (see Table 1), or the rest of SSA.

Table 2a confirms these visual impressions by showing the annualized growth rates for the two-year periods 2011-2013 and 2013-15 (columns [1] and [2]). In Table 2b we use these growth rates to generate a simple regression-based differences-in-differences test: viewing the rest of SSA as a “no-EVD” counterfactual, by how much did the EVD crisis reduce annualized growth over the 2013-2015 period in the three EVD-affected countries? The answer, in column [7], is that the annual rate of growth fell by more than 11 percentage points. This estimate is highly statistically significant using robust standard errors.

The Ebola crisis coincided with a sharp decline in global commodity prices. If the EVD-affected countries were differentially exposed to these global price movements, our differences-in-differences approach could badly overestimate the separate impact of the Ebola crisis. We control for this possibility in the second row of Table 2b by including the income effect of the terms of trade in the regression. This variable is defined as the increment to real national income (in percentage points)

\(^4\) Of 36 previous outbreaks only 1 was in West Africa, involving a single case with no deaths (Cote d’Ivoire in 1994). The majority by far were in Central Africa, particularly DRC.

\(^5\) In October 2014 the WHO accommodated national sources in its weekly epidemic tracking, leading to a sharp upward adjustment in probable and confirmed cases. See https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/index.html.

\(^6\) Guinea is an exception: the WDI 2019 series for Guinea shows faster growth than the WEO April 2019 series over most of the period.
generated by movements in international prices, holding the volume of merchandise imports and exports constant. The differences-in-differences estimate of the growth impact of the crisis is virtually unchanged in column [7], although it becomes more precise.

The rapid pre-crisis growth of two of the three EVD-affected countries suggests that this simple differences-in-differences comparison may be overstated due to selection bias associated with transitory factors. In the right-hand panel of Table 2a we correct for this possibility by comparing outcomes as viewed in 2016 with what was predicted before the crisis got underway. The IMF’s World Economic Outlook projections released in April 2014 contain the latest data for actual GDP up to that point (through 2012 for most countries), along with estimates and projections through 2019 for all years not covered by actual data. Our examination of contemporary IMF country reports make it clear that as late as July 2014 the relevant IMF staff did not view the Ebola outbreak as affecting their GDP projections for these countries (IMF 2014). We can therefore treat the April 2014 projections as unaffected by the outbreak. On the other hand, these estimates incorporate any country-level information, including about transitory factors, that was viewed as relevant by IMF staff at the time the estimates were made. It is clear from Figure 1 and from column [4] of Table 2a that the IMF expected Liberia and Sierra Leone to grow rapidly in 2014 and 2015, and Guinea to grow at a slower rate more typical of the rest of SSA.

The October 2016 series in Figure 1 shows the IMF’s assessment of real GDP per capita as the Ebola crisis was drawing to a close. Comparing this series with the April 2014 projection, the implied forecast errors isolate the impact of information that was not on the table when the earlier projection was made, including the scope of the Ebola crisis. With the exception of Guinea, it is immaterial whether we use the October 2016 series to reveal the IMF’s forecast errors or rely on the more recent April 2019 series, because the two series are very close to each other. In Tables 2a and 2b, therefore, we use the October 2016 series to compute a difference-in-forecast-errors estimate that is a straightforward counterpart to the differences-in-differences estimate computed earlier. Using the 41 other countries of SSA as the comparator group, we find that as of October 2016, the IMF viewed real GDP per capita in the EVD-affected countries as having grown nearly 10 percent per year more slowly (9.85) in 2014 and 2015 than it would have in the absence of the crisis.

Both of these simple approaches may of course yield an under-estimate of the impact of the outbreak if post-2013 movements in the comparator group include adverse regional spillovers from the crisis. The likelihood of such spillovers was a major concern among policy analysts early in the outbreak, and played a prominent role in regional projections developed by the World Bank in the fall of 2014 (World Bank 2014). The World Bank’s analysis assumed, accurately, that the outbreak would indeed spread to contiguous neighbors, and to other countries linked via air transport. Given the failure of local health systems to contain the outbreak in the three initial countries, the World Bank assumed that if the infection traveled to a new country with a weak health system it would proliferate there, generating an infection trajectory and economic impact proportional to those in Guinea, Liberia and Sierra Leone. In one of the most striking features of the crisis, this assumption proved incorrect. All second-round cross-border infections were effectively contained using the conventional protocol of diagnosis, contact-tracing, and isolation. Senegal and Mali, where the local health systems were not markedly stronger than they had been in the EVD-affected countries before the crisis, were just as successful as Spain and the United States in preventing the local spread of the virus. Nigeria’s experience was particularly

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7 For example, a temporarily favorable shock affecting the three contiguous neighbors, followed by regression to the mean.
important, because the infected individual arrived in the urban environment of Port Harcourt where high population density greatly increased the risk of proliferation.

We return below to the sharp distinction that emerged between first-round and second-round countries. Consistent with this distinction, however, the bottom half of Table 2b does not reveal an economically significant spillover effect of the crisis on GDP per capita among second-round countries in Africa (Mali, Nigeria and Senegal). It also fails to find an impact among contiguous neighbors (Senegal, Mali, Ghana and Niger), where economic impacts might have been expected via channels emphasized below, even in the absence of cross-border infections.

These calculations are very rough, but they are striking. They suggest that the economic impacts of the Ebola crisis were large and confined to first-round countries. There is surely room for more detailed work here using the macro data, particularly to take account of additional covariates whose impacts might otherwise be confounded with those of EVD. Sierra Leone provides a possibly important example of the latter. Its rapid growth before the outbreak and equally precipitous decline in 2015 (Figure 1) were generated mainly by massive fluctuations in the iron ore sector. If the collapse in 2015 was driven in part by factors unrelated to EVD, then the group-wide impact of the crisis is sharply overstated by both methods we have used. The right-side panel of Table 2b shows that estimated impacts fall by more than half when Sierra Leone is eliminated from the comparison, although they remain large and statistically significant. A somewhat different argument could perhaps be made for eliminating Guinea from the comparison, or for allowing for heterogeneity of impacts within the EVD-affected group: as indicated in Table 1, the mortality rate from Ebola was an order of magnitude lower in Guinea than it was in Liberia or Sierra Leone. Judging from Table 2a, removing both “outliers” and focusing on a Liberia-only estimate would yield very similar answers by both of our methods, with an annualized growth impact of roughly 8 percentage points.

3. Rural impacts

The crisis originated in rural areas, as has been the case with all Ebola outbreaks to date. In this section we model the impact of an infectious outbreak on the behavior of rural traders, using the analysis to introduce the concept of social distancing that will play a crucial role in our unified account.

We draw on Fafchamps (2001), who analyzed equilibrium prices in a rural location as a price-setting Nash equilibrium among outside suppliers.8 We generalize the approach of Fafchamps (2001) by allowing traders to move a commodity between two spatially separated markets in which they exploit their local market power as either purchasers or sellers. The model generates simple and intuitive predictions regarding the impact of an infectious outbreak on the number of traders, the level of internal trade, and the spatial variation of prices – implications we can broadly compare with spatial data from the outbreak.

Health risks affect the intensity of arbitrage trade in our analysis, by discouraging physical proximity. We refer to this phenomenon as social distancing.9 Social distancing occurs spontaneously, as traders learn of the risks of human contact and reduce their activity to avoid becoming infected.

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8 For details, see O’Connell (2015).
9 Our concept of social distancing is not a reference to disengagement or what might be called virtual distancing on social networks. In fact, social networks can play a crucial role during an epidemic, not only by conveying information (for better or worse) but by substituting virtual contact for personal contact in supporting economic activity.
Some social distancing may be policy-induced, however, as local or national authorities impose quarantines or other official restrictions on movement. The behavior of traders therefore reflects the joint influence of beliefs and policy restrictions. Policy, in turn, can affect behavior both through restrictions and through beliefs; and beliefs can be influenced either directly, via information campaigns, or indirectly, via the implicit message about disease transmission that individuals perceive as they confront official restrictions on normal activity. The efficacy of these two channels may be highly contextual, depending among other things on the presence or absence of trusted sources of public information.

To clarify these ideas, consider two spatially separated rural market locations $X$ and $M$ in which the price of some staple food reflects a combination of location-specific demand and supply conditions and arbitrage trade. In the absence of trade, prices are given by the random variables $\varepsilon_X$ and $\varepsilon_M$, which reflect local shocks to supply and demand. We focus on a single period\(^{10}\) and assume $\varepsilon_X < \varepsilon_M$, making location $X$ the natural net exporter of the good. With trade in amount $T$ between the two locations, prices are governed by the net supply and demand curves

$$P_X = \varepsilon_X + bT \quad \text{and} \quad P_M = \varepsilon_M - bT.$$  

(1)

We want to determine the intensity of arbitrage trade between the two locations. To move the commodity from the export market to the import market, trader $i$ has to purchase an amount $z_i$ from the export market, transport it to the import market incurring transport costs per unit in amount $c < \varepsilon_M - \varepsilon_X$, and sell it there. Each trader has a two-dimensional decision: first – on the intensive margin -- how much to trade conditional on entering the market; second – on the extensive margin – whether to enter. We model the intensive margin by treating traders as Cournot price competitors. Each trader sets his or her own prices in the two markets in order to maximize profits, taking the amount of arbitrage trade being done by other traders as given and operating as a monopsonist with respect to the residual supply curve in the export market and a monopolist with respect to the residual demand curve in the import market. For a given number of traders, we can solve for a symmetric Nash equilibrium in which a single price prevails in each location and each trader has the same share in total trade. The net revenue earned by each trader in this symmetric equilibrium – before accounting for fixed costs – is given by $\pi(n) = 2bz^2$ where $z(n) = (\varepsilon_M - \varepsilon_X - c)/2b(n+1)$ is the amount each trader transports between the two markets. Holding the number of traders constant, an increase in the marginal cost reduces the volume of trade, both at the individual trader level and in aggregate (total trade being given by $T = n \cdot z(n)$).

Holding the number of traders fixed, equilibrium prices in the two markets depend on the no-trade price gap $\varepsilon_M - \varepsilon_X$, the marginal cost of trade, and the number of traders:

$$P_X(n) = \varepsilon_X + \left(\frac{n}{n+1}\right) \cdot \frac{\varepsilon_M - \varepsilon_X - c}{2} \quad \text{and} \quad P_M(n) = \varepsilon_M - \left(\frac{n}{n+1}\right) \cdot \frac{\varepsilon_M - \varepsilon_X - c}{2}.$$  

(2)

Arbitrage trade increases prices in the surplus location and reduces them in the deficit location, by a larger amount the larger the number of traders and the smaller the marginal cost of trade.

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\(^{10}\) A single-period analysis is more reasonable if the good in question is non-storable, a questionable assumption for many staple commodities including grains.
On the extensive margin, traders decide whether to enter by comparing their operating surplus in the symmetric equilibrium with the fixed cost \(C\) of arbitrage trade between the two markets. Entry occurs if and only if \(\pi(n) \geq C\). Ignoring integer constraints, the equilibrium number of traders is given by the zero-profit condition \(\pi(n) = C\), which yields \(n^* = \sqrt{\frac{2bC}{\epsilon_M - \epsilon_X - c}}\). The equilibrium price gap between the two markets is

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P_M - P_X = \frac{\epsilon_M - \epsilon_X + nc}{n+1} = \min\left[c + \sqrt{2bC}, \, \epsilon_M - \epsilon_X\right].
\]

The no-trade gap of \(\epsilon_M - \epsilon_X\) therefore prevails only if net demand conditions are sufficiently similar in the two locations to prevent profitable entry by even a single trader. Otherwise the price gap is an increasing function of both the transport cost \(c\) and the fixed cost of entry, \(C\).

The welfare gain from cross-location trade is the sum of the profits (after fixed costs) earned by traders and the producers and consumers surplus accruing to residents in the two locations. In a zero-profit equilibrium this is given by \(S = bT^2\). Increases in the fixed cost reduce the number of traders, driving up the equilibrium price gap and reducing total trade despite an increase in the amount transacted by each remaining trader. Welfare therefore falls in both locations. Dollar for dollar, the impact on welfare of a given increment to fixed cost is largest when starting at the no-outbreak baseline, because the initial increases in perceived costs most sharply reduce the number of active traders and the gains from trade. Increases in the marginal cost of trade also reduce the equilibrium number of traders, and across zero-profit equilibria this effect exactly offsets what would otherwise be a reduction in the volume transacted by each trader. Total trade and welfare therefore fall, while the volume transacted by each remaining trader remains constant.

Survey data on trader activity, availability, and prices from Sierra Leone and Liberia paint a complex picture but suggest that the concerns modeled here are empirically relevant. Drawing on survey data from Sierra Leone, the IGC (2014a) reports large reductions in the number of traders selling basic food items in markets that were subject to official quarantine in August and September 2014, by comparison with a 2012 baseline for these months. The October 2014 data (IGC 2014b) show further deterioration in the originally cordoned districts (to 69% of the number of traders in October 2012), along with a substantial deterioration in newly-cordoned areas (to 29%). The October data also show the first evidence of reductions in non-cordoned areas, following the national stay-at-home shutdown of September 19-21.

The separate influences of official restrictions and private perceptions of risk are difficult to disentangle in these data, because the two things are jointly determined. In particular, reductions in trader activity within quarantine districts are not necessarily driven by the quarantine, because private perceptions of elevated risk would reduce activity even in the absence of restrictions. On the other hand, selective quarantines probably operate in part by conveying the authorities’ information in a convincing way to private individuals, thereby exerting a strong influence on private perceptions of risk. Separating these influences requires identifying some independent variation in the official restrictions and private perceptions of risk. The fact that reductions were soon observed outside of the quarantine areas suggests, however, that voluntarily self-protective behavior was at least partially at work.

The IGC data also provide evidence on the market prices of commodities like imported and domestic rice, gari (a local staple), palm oil, and petrol. The model presented here focuses on dispersion rather than levels: it shows that other things equal, a decline in arbitrage trade means larger spatial price differences in equilibrium. Consistent with this, the IGC data show evidence of an increase in high-side “price outliers” during the epidemic, particularly in the cordoned areas (IGC 2014a, 2014b). This analysis could usefully be extended to look directly at price differentials rather than one-way outliers.
An important caveat in interpreting price movements, as emphasized repeatedly in IGC (2014a, 2014b),
is that humanitarian interventions alter local prices and may expressly be designed to mimic the effects
of arbitrage trade, i.e., to provide supplies to deficit areas and thereby reduce the spatial dispersion of
prices.

The qualitative insights from our equilibrium model are likely to be quite general. The authors
of IGC (2014b) point out, for example, that “the decline in activity by traders may be a more general
indicator of reduced informal economic activity outside agriculture due to the fear of infection.” This
concern of course applies to formal as well as to informal activity. The World Bank et al. (2014) report
post-outbreak changes in employment status among households in Liberia, based on a baseline sample
drawn from the national household expenditure survey conducted during the first half of 2014 (the
State of Emergency was declared in Liberia at the end of July 2014, so the first half of the year serves as
a pre-Ebola baseline). Reductions in employment are large, at roughly 50 percent nationally, but the
World Bank reports little correlation between the spatial pattern of employment reductions and the
spatial pattern of the outbreak. This finding is consistent with spatially uniform shocks to demand or
business costs, but also with official restrictions or private risk perceptions that do not vary strongly with
local outbreak intensity. Further scrutiny of these data would be rewarding, with a view to
understanding the drivers of reduced activity and therefore the degree of reversibility of these effects as
specific conditions changed.

4. A unified framework

The first-order economic effects of an epidemic are the direct losses of labor and other resources to
illness, care and death. In this section we propose an analytical framework for understanding the
second-order impacts, defined as the economic consequences of the changes in public and private
behavior that occur due to the outbreak.

Mathematical models of infectious disease predict that for a given biological mechanism of
transmission and pattern of social interaction between healthy and infected individuals, the cumulative
number of cases in a given population follows an S-shaped curve over time. The number of new cases
per week first rises as the outbreak spreads, and then falls gradually to zero as deaths and recoveries
deprive the virus of susceptible hosts (Philipson 2000). Containment is achieved when no new cases are
observed for a period corresponding to twice the interval over which an infected individual can carry
and subsequently transmit the virus. The actual trajectory of an outbreak is of course extremely hard
to predict, not only when the biological mechanisms of transmission are poorly understood but also
when a known virus enters a new and untested context. The pace of transmission depends on behavior,
which in turn depends on beliefs and incentives that may be opaque to policymakers or impervious to

In the case of Ebola, the virus is passed in human populations through direct contact with the
bodily fluids of infected individuals who are either symptomatic or recently deceased. There is no
known cure. The outbreak can therefore spread rapidly if the local health system – which we define
comprehensively to include everything from ordinary home care of the sick and deceased to the formal
protocols and facilities that govern the diagnosis and treatment of Ebola patients – is slow to identify

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11 We are defining containment as a situation in which there are no infected persons. In the epidemiology
literature it is sometimes associated with a reproductive rate below 1, i.e., a situation in which each infected
person infects fewer than 1 other person, so that the number of currently infected persons (the caseload) is falling
over time.
infected individuals or incapable of isolating them safely. In such a situation, self-protective behavior by individuals, communities and governments becomes a crucial determinant of the course of the outbreak. We show in this section that the pattern of this behavior – how individuals and communities interact with each other and with the health system, and how official actors intervene to disrupt transmission of the virus – determines the second-order impacts of the outbreak, both in the short run and over time.

Our framework distinguishes three broad categories of behavior: voluntary exit by individuals and firms to avoid the first-order costs of the outbreak; voluntary or involuntary social distancing by individuals who remain in the local economy and alter their normal interactions either by choice or in response to new public regulations; and health-system improvements that enhance the system’s ability to identify and safely isolate infected individuals. In analyzing the interplay between these elements, we emphasize three central messages. First, in the midst of an outbreak, private and public actors confront a tradeoff between stopping the outbreak and sustaining economic activity. This tradeoff is mild at the outset of an outbreak, and can remain mild if the initial infections are rapidly identified and containment can take place through contact tracing and isolation. But the tradeoff becomes acute once the outbreak gains a foothold. In such a situation, second-order impacts become large, at least in the short run, and mitigating these impacts becomes an important aspect of public policy. Second, ongoing improvements in the health system are crucial not only to containing an ongoing epidemic, but also to limiting its second-order impacts. Third, while many of the secondary impacts of an epidemic are reversible as containment is achieved, perceptions of increased health risks – with attendant costs – may be highly persistent. Restoring employment to its pre-epidemic track is therefore likely to require long-run improvements in the business environment.

4.1 Behavioral responses and economic activity

The responses of governments, communities, and individuals to the perceived risk of infection determine the isolation and transmission outcomes that shape the trajectory of an Ebola outbreak. Our central point in this section is that the same behavioral responses also drive the disproportionate secondary economic impacts of the epidemic.

Figure 2 conveys our analytical framework in summary form. The Figure provides a snapshot, taken in the midst of an Ebola outbreak, of a complex ongoing process. The horizontal axis shows the level of economic activity, as measured by GDP on a seasonally adjusted weekly or monthly basis. The vertical axis measures the rate of transmission of the virus, defined as the weekly or monthly rate of increase of total cases. We use an inverted scale on the vertical axis, so that increases correspond to slower rates of transmission. Points to the northeast in the diagram therefore represent unambiguously higher levels social welfare, in the form of lower transmission rates, higher economic activity, or both.

To capture the public policy problem at a particular point in time, we normalize the vertical scale so that it measures reduced transmission, defined as the difference between the current rate of transmission and the hypothetical rate that the health system would achieve, in its current state, in the absence of behavior changes. This reduction is positive if changes in behavior are working to reduce the

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12 There is no cure for EVD at the time of writing, but as we discuss further in the concluding section an experimental vaccine has proven highly effective in preventing transmission and death in the current Ebola health emergency in the Democratic Republic of Congo.

13 See O’Connell, Chafetz and Wolgin (2015) for details.

14 None of the three first-round countries has reliable high-frequency data on economic activity. Locating the national (or sub-national) economy along the horizontal axis of Figure 1 continues to be a first-order challenge. See Section 5.
transmission rate; it can be negative if behavioral responses are working against the system and exacerbating the outbreak. Points on the horizontal axis correspond to the rate of transmission that would be implied by the current caseload and the current state of the health system, in the absence of outbreak-related changes in public or private behavior.

Point 1 anchors the analysis by showing a pre-Ebola baseline where economic activity is at its normal seasonally-adjusted level. The transmission rate is zero regardless of behavior, because the virus is absent; by definition there is no reduction in transmission due to behavior, so point 1 is on the horizontal axis.

Now consider a situation in which an outbreak is underway. Economic activity is necessarily reduced, because a portion of the community’s labor is lost to illness, death, and the obligations of caretaking and burial. Point 2 shows this first-order impact under the hypothetical of no change in behavior. At point 2, private actors are continuing their normal interactions, even though this exposes them to infection, and the health system is responding according to its pre-existing state of preparedness. The economic loss is proportional to the caseload, which is initially small. But this is just a snapshot in time: if the population is naturally connected, the epidemic will spread and point 2 will move to the left, the distance between points 1 and 2 rising over time.

Three categories of behavioral response can heighten or modify this trajectory. Exit occurs when individuals or firms reduce their in-country presence to avoid heightened health-related risks and costs. Social distancing occurs when individuals, community leaders, or governments respond to transmission risks by imposing voluntary or involuntary restrictions that reduce normal interactions between healthy individuals. Health-system improvement works by modifying interactions between healthy and infected individuals.

These responses have sharply different impacts on the trajectories of the outbreak and the economy. Exit is the simplest: it reduces economic activity, but to a first approximation leaves the within-country transmission rate unchanged. We show it in Figure 2 as a displacement along the horizontal axis, from point 2 to point 3. Exit played a prominent role in the Ebola crisis, with departures by expatriate staff in the private and non-governmental sectors and large reductions in tourism and other discretionary cross-border entries (World Bank 2014a). The early exit of a number of major international airlines undoubtedly encouraged these patterns. Arrival restrictions imposed by outside governments on international travelers from the EVD-affected countries further increased the perceived costs of in-country activity, and reduced discretionary arrivals to very low levels between the global emergency and the middle of 2015.

Exit is also the main source of adverse neighborhood effects of an epidemic (the direct source being cross-border transmission). These occur when an outbreak in one country causes individuals and firms to reassess the health risks of operating in other countries. Contiguous neighbors are obvious targets given their exposure to transmission across land borders, as are countries connected through intensive air links (Gomes et al. 2014). Some sectors are more intensive in discretionary in-country activity than others, including tourism and foreign direct investment outside of the natural resource sector; these are particularly vulnerable to exit-based neighborhood effects.

While exit behavior is readily reversible in principle, the durability of changed risk perceptions is an important empirical question. In our rural trader analysis, the intensity of trader activity returns to baseline only if the perceived costs of trade fall back to pre-epidemic levels. In the urban environment and among enterprises with international personnel, the costs of providing for health risks may have shifted upwards on an essentially permanent basis (e.g., for health insurance, including for medical evacuation). Targeted policies might then be required to mitigate persistent effects on the business environment.

Social distancing comprises both voluntary avoidance behavior and temporary official restrictions like public-sector furloughs, school shutdowns, area quarantines, and border closings.
In our rural trading environment, these changes amount to increases in the fixed and variable costs that govern the intensity of economic interaction and the gains from specialization and exchange. The point illustrated there is much more general: wherever direct interaction is intrinsic to economic activity, the community faces a tradeoff – given the condition of the local health system – between improvements in containment and increases in economic activity. The solid frontier in Figure 1 shows the menu of feasible choices available to public officials at an ongoing stage of the outbreak. The height of this frontier, and the set of policies required to achieve it, depend jointly on the state of the health system and the potentially complex private behavioral responses that are already underway. In the absence of effective social distancing policies, society may end up below this frontier: but for a given state of the health system, it cannot do better. From any point below the frontier, therefore, the two-fold task of official social distancing policies is, first, to achieve the frontier, and second, to strike an appropriate balance on the frontier between containment and economic activity – for example, at a point like 4.

The social distancing frontier may confront society with very unfavorable options if the health system is weak. Divergences between private incentives and public imperatives are a feature of many public health problems, but are particularly acute when information about the virus is contested and/or the local health system is not trusted. Healthy individuals may reject information about transmission, for example, and persist in or even increase their reliance on social behaviors that are trusted but unsafe, like burial practices with extensive physical contact. Potentially infected individuals may actively avoid local health systems and seek refuge among previously unaffected sub-populations, driving up the national rate of transmission. By contrast with the “no behavior change” counterfactual, these responses move society to the southwest of point 3 rather than towards point 4. Just as importantly, they flatten out the feasible frontier by limiting the public authorities to draconian policies that achieve only modest reductions in transmission.

Given the state of the health system, therefore, the best that social distancing policies can achieve is to find an appropriate balance along the short-run tradeoff between containment and economic activity. Even this task is not trivial: when information is highly imperfect and public-sector communication and enforcement capabilities are limited, the situation can produce either too little distancing and too rapid a spread of the epidemic, or too much distancing and a needless contraction in economic activity.

Health-system improvements, by contrast, shift the entire tradeoff between containment and economic activity. These interventions come in three main forms:

- Credible guidance about safe behavior
- Access to health supplies to reduce transmission
- Improvements in the diagnosis and isolation of infected individuals.

By contrast with social distancing, these initiatives ameliorate the tradeoff between containment and economic activity. From a point like 4, the introduction of safe burial practices, an initiative that combines all three dimensions of health-system improvement, reduces transmission for any given level of social distancing. If social distancing behaviors are unchanged, society moves to a point directly north of point 4, with sharply reduced transmission and no improvement in economic activity.

As illustrated in Figure 2, health-system improvements open up a range of potential new options, representing alternative combinations of reduced transmission and improved economic activity. Where society goes among these options depends on how public and private actors respond to the prospect of reduced transmission. Models of economic epidemiology note that healthy individuals will have an incentive to reduce their own distancing to some degree, because an improvement in the health system renders normal interactions slightly safer (Gersovitz and Hammer 2003). This response
would push society to the northeast of point 4 rather than directly above it, producing a smaller reduction in transmission but an improvement in economic activity. Public policy can facilitate this outcome, for example by loosening official restrictions; or push against it, by reinforcing restrictions in order to guarantee a sharp reduction in transmission.

Figure 2 emphasizes that a reduction in exit is one of the channels through which health-system improvements secure a more favorable menu of short-run outcomes. The same logic implies that non-coercive policy initiatives to reduce exit, whether by host governments or external partners, can play an important role in limiting the second-order consequences of an outbreak. WHO guidance on safe travel and transport behavior, and exhortations to third-party governments to avoid excessive border restrictions, are cases in point. Like health-system improvements, these shift the entire social distancing tradeoff favorably, opening up favorable new combinations of higher economic activity and reduced transmission.

External responders played a key role in the West African Ebola epidemic, most prominently in supporting health-system improvements but also in maintaining core government functions through budget support, supporting import capacity and exchange-rate stability through foreign-exchange inflows, and providing targeted humanitarian relief. The impact of health-system improvements is well captured in Figure 2, which emphasizes their dual impact in reducing transmission and restoring economic activity. But the overall inflow of external personnel and resources can also have a palpable effect on short-run outcomes. In the framework of Figure 2, these inflows operate as the opposite of exit. The local procurement component of external support directly reverses some portion of the decline in local economic activity, shifting the entire social distancing frontier to the right and opening up new combinations of reduced transmission and higher economic activity.

A final dimension of the behavioral response to a major outbreak is the suspension or reduction in public and private investment plans. Public investment falls as part of the fiscal response to falling revenues and rising health-related costs; private investment falls as non-resident stakeholders reassess the costs of operating in the domestic environment. These impacts can be large, because the costs associated with delaying an investment project are small relative to the short-term need for public-sector resources and the temporary increase in uncertainty about the returns to private investment. The associated reduction in current expenditure on domestic output (e.g., reduced construction activity) is already captured in Figure 1 as a component of exit. But reductions in investment also have an important intertemporal effect, by reducing future productive capacity relative to the no-Ebola baseline. Figure 2 is a snapshot in time, and therefore incorporates this effect only over time.

4.2 Applying and extending the framework

This analysis provides a framework for understanding some of the key public policy challenges of the West African Ebola epidemic and drawing out lessons applicable to similar situations.

- **Trustworthy communication is crucial to a successful response.** Private individuals will change behavior self-protectively in response to their beliefs about mechanisms of transmission. Accurate and accepted information about safe interaction is crucial in aligning private incentives with the imperatives of public health and ensuring that private distancing behavior reduces transmission.

- **Policy options deteriorate very sharply if a strategy of rapid diagnosis and contact tracing is infeasible.** The experience of second-round countries suggests that there is a window of opportunity for full containment early in an outbreak, even in a weak health system. Once this
opportunity is lost, exit accelerates and governments, communities and individuals are relegated to aggressive social distancing policies.

- **Health-system improvements are an immediate and continuous priority in managing an outbreak.** Interventions to improve the health system – broadly construed to include the activities of both private and public actors – are required to generate favorable shifts in the tradeoff between containment and economic activity.

- **The appropriate policy balance shifts away from distancing as health-system improvements gain traction over transmission.** In regulating social distancing, public policy has to strike a balance between containing the epidemic and stopping economic activity. The stronger the health system, the less need for social distancing.

- **The economic costs of an epidemic depend crucially on the strength of the health system.** Many crucial health-system improvements cannot be implemented rapidly. If an outbreak is not stopped early on, therefore, countries with weak health systems may suffer further health-system deterioration, generating highly adverse tradeoffs and implying a combination of large second-order impacts and slow containment.

One of the most striking features of the West African epidemic is the dramatic difference between the experiences of first-round and second-round countries. Guinea, Liberia and Sierra Leone together accounted for all cases at the time of the WHO’s declaration of a global public health emergency on August 7, 2014. These first-round countries had by definition missed any prospect of early containment. A year later their outbreaks were not yet stopped despite a massive response effort by local governments and external partners. By contrast, every outbreak that occurred in a second-round country was contained with small case totals and minor (if any) second-order effects.

Rapid containment in Spain and the United States was a testimonial at least in part to strong overall health systems. But outbreaks were also rapidly contained in Senegal, Nigeria, and Mali. The common denominator in the second-round cases was therefore not a robust health system but a situation of advance awareness, which facilitated a strategy of rapid diagnosis followed immediately by intensive contact tracing and safe isolation. The urgency of these protocols does not appear to have been fully understood by local governments in the first-round countries, or by their outside partners. Whether this was a simple failure of vigilance or a deeper limitation in the knowledge base around Ebola containment is not fully clear. The result, however, was that by the time the WHO declared the global health emergency the caseload was large enough that protocols that would have been highly effective at the earliest stages of the epidemic were no longer feasible.

The sharp practical distinction between first- and second-round outbreaks in the West African epidemic may alter how the costs of similar future epidemics are modeled. In its masterful early treatment of the economic costs of the Ebola outbreak, the World Bank (2014a) simulated the economic effects of regional viral contagion by assuming that the costs of outbreaks seeded into new countries would be proportional to the costs experienced by the original outbreak countries, adjusted for the level of development and the quality of the local health system in the country receiving the virus. In practice, the economic costs of second-round infections have been much smaller than suggested by these projections, as a result of the very rapid containment of these outbreaks; and these costs do not appear to have varied strongly with the level of development or quality of the local health system.

Our framework makes it clear that the size and duration of the secondary economic effects of an outbreak depend not only on how rapidly the outbreak is contained but also on how rapidly the
behavioral responses to the crisis are reversed. The analysis developed here suggests some of the considerations that shape the short- and long-term costs of a crisis:

- By contrast with armed conflict or natural disaster, the economic impacts of an infectious outbreak – provided social stability is maintained – do not include the outright destruction of physical capital. Many of the secondary impacts are therefore quickly reversible as the safety of normal activity is restored.

- Persistent secondary impacts can nonetheless operate, through a variety of channels. The degree to which household assets are depleted – including the human capital of children – will reflect the duration of the outbreak (and of school closings), the magnitude of secondary damage to incomes, the efficacy of humanitarian support to households experiencing food insecurity, and the speed with which normal primary health services are restored.

- The speed with which expatriates and outside investors restore economic operations will depend on how sharply and persistently their perceptions of health-related business costs and public-sector capabilities deteriorate as a result of the epidemic. Permanent improvements in the health system and the business environment may be required to restore the investment environment to its pre-outbreak track.

An important question on which there is essentially no evidence to date is whether there is a substantial difference, in terms of reversing exit behavior, between achieving a very low caseload and being officially virus-free. The question has a policy dimension because health-system improvements that generate large reductions in the transmission rate encourage a reduction in social distancing as public officials and private individuals respond to the safer environment. This response may be premature if getting all the way to zero infections would make a major contribution to reversing exit.

To close this section we return to the role of information as a policy instrument, through its impact on the perceived costs of economic interaction. We have emphasized the value of accurate and trusted information about health risks, a theme underscored by the WHO in its guidelines on communication during a public health crisis (WHO 2017). It is important, however, to acknowledge at least two complexities in this argument. First, our traders model emphasizes the private costs of economic interaction during an outbreak, rather than the social costs. Traders in our analysis maximize expected profits, accounting for risks to their own health and ignoring risks to the health of others. In this setting, credible information alone will not align the private and social incentives for reducing disease transmission, due to the adverse externalities associated with physical interaction. Privately-optimal behavior will generate too much economic activity and too much transmission. Does it then follow that some form of direct regulation of physical interaction (e.g., work furloughs or travel restrictions) is required to reach the appropriate balance of reduced activity and reduced transmission (e.g, a point along the frontier in Figure 2)?

Given the long-run costs of losing credibility, it is likely that there is some combination of credible information with direct regulation that is superior to a policy that overstates health risks in order to align private incentives with social costs in the short run. But the scope for effective regulation may also be easily overplayed, particularly if it creates resentments or incentivizes work-arounds (e.g., clandestine border crossings) that undermine the capacity of the public health system to identify and isolate infected individuals. In such a situation, direct regulations may generate a welfare-reducing southwest movement in Figure 2 – a reduction in economic activity and an increase rather than a decrease in disease transmission (Maharaj and Kleczkowski 2012). The deeper point here is that the task of internalizing externalities should in substantial part be allocated to the communication strategy.
Local authorities should play a key role in a campaign that appeals to the health of the community, the value of collective action, and the obligation to avoid putting the health of others at risk.

Second, public institutions may be under a very different kind of pressure to overstate the risks to public health, if the funding they need to respond adequately is allocated on a discretionary basis that is outside of their control (Clarke and Dercon 2016). In late September 2014, for example, the CDC published a set of estimates suggesting that Liberia and Sierra Leone alone could be the site of 1.4 million cumulative cases by early 2015 (Meltzer et al. 2014). This worst-case scenario was generated by a mathematical epidemiology model in which the reproductive rate of the virus was governed solely by the evolution of infections and deaths, with no role for the social-distancing responses and health-system improvements we have emphasized – and despite the fact that such responses were already underway. The scientific validation of a highly implausible scenario may have been intended to expand and accelerate the response of the U.S. Congress and other key funding sources to the crisis. But if the spirit of our analysis is correct, it may also have generated large economic losses within the EVD-affected countries, by sharply elevating perceptions of risk and encouraging excessive exit and social distancing. These losses may well have been excessive from a welfare point of view even if the CDC’s report influenced the size or speed of the foreign-assistance response from the US and other partners. More to the point, they would have been altogether unnecessary had the required resources been triggered automatically by a realistic assessment of the likely scale of the outbreak. Of further concern is the impact of the CDC’s overestimate – even its mid-range estimate was off by a factor of 10 – on the credibility of CDC pronouncements in future episodes. Clarke and Dercon (2016) take an actuarial approach to international disaster assistance and argue for increased use of stand-by mechanisms that are automatically triggered by non-politicized technical assessments.

5. Conclusions and an application to the ongoing DRC emergency

We have argued in this chapter that the first- and second-order impacts of an infectious outbreak are two sides of the same coin. Our unified account is simplistic in many ways, and there is a great deal more to be done, not just in understanding the short- and long-run economic impacts of the West African Ebola epidemic but in establishing how perceptions of health risk are formed and altered, and how they jointly affect economic behavior and disease transmission. We hope economists will collaborate with health professionals and social scientists who are familiar with many of these ideas, to develop this analysis further and improve the evidence base for future policy.

The world is now grappling with a second Ebola Public Health Emergency of International Concern, declared by the WHO on July 17, 2019 (WHO 2019a) and originating in an outbreak that began in April 2018 in an eastern area of the Democratic Republic of Congo (DRC). As of October 2019, the WHO reported 3,205 estimated cases and 2,142 deaths in DRC, and 4 cases and 3 deaths in Uganda. We close by noting two features that stand out in applying our framework to the ongoing situation on DRC.

First, the preventive medical options are now much more favorable than they were in West Africa in 2014-16. The experimental Merck rVSV-ZEBOV-GP Ebola vaccine has been shown to be extremely effective against Ebola infections and deaths based on a large-scale rollout by the

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15 The CDC multiplied all of its simulated case counts by 2.5 (implying an undercount by 60 percent), to reflect its assumption that for every recorded case 1.5 cases were missed and would continue to be missed. Scarpino et al. (2015) demonstrated that infections were highly clustered and therefore unlikely to be missed; Scarpino et al. estimated the proportion of under-counting at 17 percent.

16 The death on October 4, 2014 of an EVD-infected man who had traveled to Dallas, Texas from West Africa, and the infection by EVD of two of his attending health workers, may have done more to precipitate action in Congress.
Government of DRC and the WHO of a strategy that combines vaccination of health-care and front-line workers with so-called “ring vaccination” of all identifiable contacts and contacts-of-contacts of infected individuals. The Government of DRC has now approved the field evaluation of a second experimental vaccine in at-risk areas without active transmission (WHO 2019c).

The efficacy of the Merck vaccine and the feasibility of the ring strategy are first-order improvements in the health system, amounting to large outward shifts in the policy frontier in Figure 2. While our framework does not determine where society goes along the more favorable menu of outcomes, our trader analysis suggests that any broadly-perceived reduction in the risk of contact is likely to increase the frequency and/or intensity of interpersonal contacts, and thereby to undercut to some degree the reduction in transmission that would otherwise occur. On balance, therefore, availability of the vaccine seems extremely likely to reduce both the overall size of the epidemic and its economic costs; but in the absence of much broader coverage it is less likely to dramatically shorten its duration.

Second, our framework has not emphasized what may be the most important contributor to the scope and duration of the DRC’s crisis, which is the hostile security environment confronted by Ebola responders. Less acute security issues appear to have played a role in the West African episode, particularly in Guinea where there was persistent mistrust of safe burial teams and other Ebola responders particularly in rural areas (Wilkinson and Fairhead 2017). In DRC, the location of the outbreak within a zone of ongoing armed conflict undermines what is necessarily a logistically demanding public-health response, and may be generating population movements that heighten the risk of regional or international transmission. But violence also appears to have been targeted directly against responders, for reasons that include mistrust but remain various and unclear (Aizenman 2019).

In our framework, the result of a hostile security environment is to shift the policy frontier inwards, simultaneously prolonging the epidemic and reducing economic activity. In such cases the appropriate concept of health-system improvements includes a security strategy that protects responders while addressing the underlying drivers of mistrust and violence. Given the elevated risk of cross-border transmission, securing the safety of responders is a regional and even global collective good. This suggests that the appropriate locus of security cooperation may also be regional or global rather than national.

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17 As of September 23, 2019, 223,000 persons had received the rVSV-ZEBOV-GP vaccine.
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International Monetary Fund (2014) Liberia: Third Review Under the Extended Credit Facility Arrangement and Request for Waiver of Nonobservance of Performance Criterion and
Modification of Performance Criteria—Staff Report; and Press Release (Washington, DC: International Monetary Fund), July


http://www.worldbank.org/content/dam/Worldbank/document/Poverty%20documents/Socio-

World Health Organization *Ebola Situation Reports*, various issues
http://www.who.int/csr/disease/ebola/situation-reports/en/


Table 1 *Summary data on the three EVD-affected countries*

<table>
<thead>
<tr>
<th>Economic and Demographic Characteristics in 2013</th>
<th>Guinea</th>
<th>Liberia</th>
<th>Sierra Leone</th>
<th>Total</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP (billions of 2011 international dollars)</td>
<td>19.7</td>
<td>5.4</td>
<td>11.5</td>
<td>36.6</td>
<td>WDI</td>
</tr>
<tr>
<td>Population</td>
<td>10,893,000</td>
<td>4,248,000</td>
<td>6,864,000</td>
<td>22,005,000</td>
<td>GPP</td>
</tr>
<tr>
<td>GDP per capita (2011 international dollars)</td>
<td>1,813</td>
<td>1,282</td>
<td>1,669</td>
<td>1,665</td>
<td>WDI</td>
</tr>
<tr>
<td>Extreme poverty rate (%) (year varies*)</td>
<td>35.3</td>
<td>38.6</td>
<td>52.2</td>
<td>41.2</td>
<td>WDI</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Annual Disease Prevalence in 2013</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of malaria cases</td>
<td>4,230,272</td>
<td>890,474</td>
<td>2,705,514</td>
<td>7,826,259</td>
<td>GHO</td>
</tr>
<tr>
<td>Number of persons with HIV/AIDS</td>
<td>110,800</td>
<td>39,863</td>
<td>64,471</td>
<td>215,134</td>
<td>GHO</td>
</tr>
<tr>
<td>Number of non HIV-positive persons with tuberculosis</td>
<td>15,900</td>
<td>12,150</td>
<td>19,100</td>
<td>47,150</td>
<td>GHO</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Estimated Annual Mortality by Cause in 2013</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths of children under 5, all causes (2015)</td>
<td>42,500</td>
<td>11,500</td>
<td>34,200</td>
<td>88,200</td>
<td>GHE</td>
</tr>
<tr>
<td>Maternal deaths from childbirth (2015)</td>
<td>3,100</td>
<td>1,100</td>
<td>3,100</td>
<td>7,300</td>
<td>GHO</td>
</tr>
<tr>
<td>Deaths from communicable diseases (2015)</td>
<td>54,600</td>
<td>17,700</td>
<td>44,700</td>
<td>117,000</td>
<td>GHE</td>
</tr>
<tr>
<td>Deaths from malaria</td>
<td>8,985</td>
<td>2,167</td>
<td>17,922</td>
<td>29,074</td>
<td>GHO</td>
</tr>
<tr>
<td>Deaths from HIV/AIDS</td>
<td>4,211</td>
<td>2,149</td>
<td>2,419</td>
<td>8,779</td>
<td>GHO</td>
</tr>
<tr>
<td>Deaths from tuberculosis (non HIV-positive)</td>
<td>3,300</td>
<td>3,250</td>
<td>4,050</td>
<td>10,600</td>
<td>GHO</td>
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<table>
<thead>
<tr>
<th>EVD incidence, 2014 and 2015 (annual averages)</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Population</td>
<td>11,291,500</td>
<td>4,416,000</td>
<td>7,094,500</td>
<td>22,802,000</td>
<td>GPP</td>
</tr>
<tr>
<td>Number of EVD cases**</td>
<td>1,902</td>
<td>5,338</td>
<td>7,061</td>
<td>14,301</td>
<td>SRs</td>
</tr>
<tr>
<td>Deaths from EVD**</td>
<td>1,268</td>
<td>2,405</td>
<td>1,978</td>
<td>5,650</td>
<td>SRs</td>
</tr>
<tr>
<td>EVD cases per 1000 population</td>
<td>0.17</td>
<td>0.26</td>
<td>0.29</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Deaths from EVD per 1000 population</td>
<td>0.12</td>
<td>0.57</td>
<td>0.29</td>
<td>0.26</td>
<td></td>
</tr>
</tbody>
</table>

Sources (all online): World Bank World Development Indicators (WDI), UN Global Population Prospects 2019 (GPP); and World Health Organization: Global Health Observatory (GHO), West Africa Ebola Epidemic Situation Reports (SRs), and Global Health Estimates 2016 (GHE).

*Extreme poverty rate at $1.90 2011 international dollars per day. Consumption survey dates: Guinea 2012, Liberia 2014, Sierra Leone 2011.

**These 2014 and 2015 averages include the small number of estimated cases and deaths in Guinea from late 2013. From WHO Situation Reports, the total number of estimated cases and deaths, including 2016, were: Guinea 3,814 and 2,544, Liberia 10,678 and 4,810, Sierra Leone 14,124 and 3,956 (totals ss and tt).
Figure 1 Real GDP per capita, EVD-affected countries and other countries in SSA

Source: IMF, World Economic Outlook April 2014, October 2016 and April 2019. All series rescaled to 2013=100.
<table>
<thead>
<tr>
<th>Countries</th>
<th>n</th>
<th>WEO April 2019 data</th>
<th>WEO Oct 2016 vs Apr 2014</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>All SSA</td>
<td>44</td>
<td>2.36</td>
<td>1.25</td>
<td>-1.11</td>
<td>3.04</td>
<td>1.39</td>
</tr>
<tr>
<td>EVD countries</td>
<td>3</td>
<td>7.38</td>
<td>-4.15</td>
<td>-11.65</td>
<td>5.68</td>
<td>-5.14</td>
</tr>
<tr>
<td>Guinea</td>
<td>1</td>
<td>2.25</td>
<td>1.20</td>
<td>-1.05</td>
<td>2.15</td>
<td>-1.87</td>
</tr>
<tr>
<td>Liberia</td>
<td>1</td>
<td>5.69</td>
<td>-2.08</td>
<td>-7.77</td>
<td>4.99</td>
<td>-2.22</td>
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<tr>
<td>Other countries*</td>
<td>40</td>
<td>1.99</td>
<td>1.62</td>
<td>-0.34</td>
<td>2.84</td>
<td>1.87</td>
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<tr>
<td>Second-round</td>
<td>3</td>
<td>0.21</td>
<td>2.84</td>
<td>2.63</td>
<td>2.77</td>
<td>2.39</td>
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<tr>
<td>Contiguous</td>
<td>4</td>
<td>1.05</td>
<td>3.50</td>
<td>2.45</td>
<td>2.54</td>
<td>3.05</td>
</tr>
</tbody>
</table>

Source: IMF World Economic Outlook databases as indicated.

*The second-round countries are Mali, Nigeria, and Senegal. The contiguous countries are Senegal, Mali, Ghana and Niger.
<table>
<thead>
<tr>
<th>Comparison group</th>
<th>n</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>EVD 3</td>
<td>Guinea and Liberia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other countries</td>
<td>41</td>
<td></td>
<td>-11.31</td>
<td>-4.07</td>
<td>-9.85</td>
<td>-4.64</td>
<td>(p = 0.014)</td>
<td>(p = 0.036)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(p = 0.003)</td>
<td></td>
<td></td>
<td></td>
<td>(p = 0.000)</td>
<td></td>
</tr>
<tr>
<td>Other countries</td>
<td>41</td>
<td></td>
<td>-11.43</td>
<td>-4.74</td>
<td>-9.94</td>
<td>-5.14</td>
<td>(p = 0.007)</td>
<td></td>
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<tr>
<td>(control for TOT)</td>
<td></td>
<td></td>
<td>(p = 0.001)</td>
<td></td>
<td></td>
<td></td>
<td>(p = 0.028)</td>
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<tr>
<td>Second-round</td>
<td>3</td>
<td></td>
<td>-14.27</td>
<td>-7.04</td>
<td>-10.44</td>
<td>-5.24</td>
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<tr>
<td>Contiguous</td>
<td>4</td>
<td></td>
<td>-14.10</td>
<td>-6.86</td>
<td>-11.34</td>
<td>-6.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Calculated from Table 1. The top half of this table shows two regression specifications using a panel of 41 countries in SSA and the year 2013 and 2015. The first row is based on the regression \( g(it) = \beta_0 + \beta_1 \cdot \text{post13} + \beta_2 \cdot \text{evd3} + \beta_3 \cdot (\text{post13} \times \text{evd3}) + \epsilon(it) \) where \text{evd3} and \text{post13} are dummy variables for the EVD-affected countries and the years after 2013. In the time-difference regressions, \( g(it) \) is a 2-year backward moving average of growth from WEO 2019 (means for this variable are shown in columns [1] and [2] in Table 2a). In the forecast-error regressions, \( g(it) \) for \( t = 2013 \) and \( t = 2015 \) corresponds to the forecasted and actual values underlying columns [4] and [5] in Table 2a. The reported values of \( \beta_3 \) in this regression correspond exactly to the difference in time differences between the EVD3 and the other countries in Table 2a (for example, the -11.14 in column [6] corresponds to 11.95 – (-0.05) in column [4] of Table 2a). The second row reports the coefficient on the same interaction term, from a regression that includes 2-year moving averages of the income effect of the terms of trade. We do this in order to control for possibly differential movements in this variables between the EVD and non-EVD countries before and after 2013. The bottom half of the table simply reports additional raw differences in differences based on the data in Table 2a.
Figure 2 Exit, social distancing, health-system response, and economic activity

1: Pre-Ebola baseline
2: Direct loss of labor
3: Exit reduces economic activity
4: Social distancing reduces both transmission and activity
5: Health-system improvements generate superior options