

# Climate Change, Epidemics and Inequality\*

Belinda Archibong<sup>†</sup>  
Barnard College

Francis Annan  
University of California, Berkeley

August 20, 2022

## Abstract

What are the links between climate change, epidemics and socioeconomic inequality? While recent epidemics have focused attention on the effects of epidemics on economic outcomes, and a separate literature in climate science and environmental health has linked global environmental change to increased incidence of epidemics of infectious disease, there's relatively little work connecting these two literatures. We explore the links between climate change, epidemics and group-based inequality by first reviewing the scientific literature modeling the effects of global warming on epidemics of infectious disease. We highlight the ways in which climate variables like temperature, precipitation and wind speeds, and adaptive human behavior like migration may more easily facilitate the spread of infectious disease. We then examine the effects of climate-induced epidemics on gender inequality using evidence from the African meningitis belt. The results show that epidemics can worsen outcomes for groups in already relatively economically precarious circumstances, thereby widening group-based socioeconomic inequality. Effective policies to combat the negative effects of epidemics must be mindful not to increase existing group-based inequalities, and should focus on minimizing damage for members of the most marginalized groups.

*JEL classification:* I12, I14, I24, J16, J24, O12, O15, Q54

*Keywords:* Climate Change, Epidemic, Disease, Economic, Pandemic, Inequality

---

\*We are grateful to Carlos Perez, Madeleine Thomson, Nita Bharti, and World Health Organization (WHO) for the data on meningitis used in this study. Thanks to Mary Evans and anonymous referees for helpful comments and suggestions. Thanks to Shristi Bashista for excellent research assistance. Errors are our own.

<sup>†</sup>Corresponding author. Barnard College, Columbia University. 3009 Broadway, New York, NY 10027, USA. ba2207@columbia.edu.

# 1 Introduction

What are the links between climate change, epidemics and socioeconomic inequality? While recent epidemics have focused attention on the effects of epidemics on economic outcomes, and a separate literature in climate science and environmental health has linked global environmental change to increased incidence of epidemics of infectious disease, there's relatively little work connecting these two literatures. Recent evidence from the COVID-19 pandemic has highlighted the very unequal way the pandemic and past epidemics have affected individuals and groups, with the most recent COVID-19 pandemic referred to as the "great unequalizer" (Alsan, Chandra, and Simon, 2021). There is a robust literature on the negative consequences of increased group-based or intergroup inequality for human welfare, with increased inequality associated with a host of negative outcomes from conflict (Huber and Mayoral, 2019) to decreased welfare (Klasen, 2002). To the extent that models of environmental health have linked climate change and global warming to the increased risk of epidemics of infectious disease, we explore the links between climate change, epidemics and group-based, socioeconomic inequality in this paper.

We explore these links in three steps. First, we review the scientific literature modeling the connections between anthropogenic climate change and epidemics. The models point to the role of both direct effects, where climate change and associated global warming may cause epidemics through changes in climate variables like temperature, precipitation and wind speeds, and indirect effects, where adaptive behavior to these direct effects by human populations through strategies like migration may more easily facilitate the spread of disease. We provide examples of these modeled effects from airborne diseases like meningococcal meningitis and vector-borne diseases like malaria and dengue fever. Second, we examine the effects of these climate-induced epidemics on group-based inequality using new evidence from

recent epidemics in the African meningitis belt where meningitis epidemics are endemic<sup>1</sup>. We provide a simple conceptual framework highlighting how aggregate health shocks like epidemics can have differential effects on individual outcomes based on group membership. We then present evidence from the meningitis belt and use evidence from one country in the belt, Niger, and its 1986 meningitis epidemic to test predictions from the framework and examine the effects of the epidemic on gender inequality. The results show that epidemics can worsen outcomes for groups in already relatively economically precarious circumstances, like women around the world, thereby widening group-based, socioeconomic inequality.

Finally, we conclude with an exploration of the ways effective policies may be designed to mitigate the inequitable effects of climate-induced epidemics on group-based inequality, highlighting the role of fiscal responses like health aid, cash grants and targeted stimulus to groups and households, following evidence from a recent literature. We highlight that effective policies to combat the negative effects of epidemics must be mindful not to increase existing group-based inequalities, and should focus on minimizing damage for members of the most marginalized groups in societies.

## **2 Modeling the Links Between Climate Change and Epidemics**

The Intergovernmental Panel on Climate Change (IPCC) predicted an average increase in temperatures by 1.5 to 5.8 degrees celsius around the world over the 21st century, with predicted corresponding increases in extreme weather events including heat waves, floods and droughts (Wu et al., 2016; Carleton and Hsiang, 2016). A growing literature has linked these changes in climate to human health, and particularly the spread of infectious diseases (Epstein, 1999; Carleton and Hsiang, 2016; Wu et al., 2016; Tol, 2020). Particularly worrying is the spread of epidemics and pandemics of infectious diseases, where an epidemic is defined by the World Health Organization (WHO) as “the occurrence in a community or region of

---

<sup>1</sup>A disease outbreak is endemic when it is “consistently present but limited to a particular region” Source: CDC: <https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section11.html>

cases of an illness clearly in excess of normal expectancy”, and a pandemic is defined as exponential growth in the spread of infectious diseases cutting across international boundaries (WHO, 2020).

The links between climate change, and particularly, anthropogenic climate change caused by human activities, global warming, ecosystems and epidemics of infectious disease are quite complex, with feedbacks throughout the system as shown in the simplified schematic in Figure 1. Figure 1 also includes a definition of key terms associated with epidemics. Although the links between climate change and epidemics of infectious disease are complex, we can model the relationship broadly into pathways: (1) direct effects where climate change and associated global warming may cause epidemics through changes in climate variables like temperature, precipitation, and wind speeds and (2) indirect effects where adaptive behavior to these direct effects by human populations through strategies like migration may more easily facilitate the spread of disease.

## **2.1 Direct Effects: Temperature, Precipitation, Wind Speeds and Changing Environment**

Airborne and vector-borne infectious diseases are among the top categories expected to be most affected by global warming (Kurane, 2010; García-Pando et al., 2014). These include vector-borne diseases like malaria and dengue fever, which are linked to the expansion of infested areas of mosquitoes, which are the primary vector of transmission. The distribution of these vector mosquitoes has been linked to inter-annual variability in temperature, rainfall and precipitation in affected regions within Africa and Asia (Kurane, 2010; Carleton and Hsiang, 2016). Both malaria and dengue fever are endemic in many regions around the world, infecting an estimated 200 million and 50 million people globally every year (Carleton and Hsiang, 2016). Previous research has shown that temperature and the presence of open water, which is itself constrained by rainfall, are two key climatic factors that affect the

intensity of infection in regions where malaria and dengue are endemic (Zhou et al., 2004; Bhatt et al., 2013). Hence changes in temperature and rainfall predicted by climate change models may change both the severity and distribution of malaria and dengue epidemics around the world, with significant consequences for human health.

Similarly, for airborne infectious diseases like meningococcal meningitis, changes in climate are associated with changes in the severity and distribution of epidemics of the disease (García-Pando et al., 2014). Meningococcal meningitis is a disease that is endemic in sub-Saharan Africa (SSA), with an entire region of 23 countries from Senegal to Ethiopia, making up over 700 million individuals, termed the ‘meningitis belt’ due to frequent exposure to meningitis epidemics<sup>2</sup> (Archibong and Annan, 2020). The epidemic form of the disease is caused by the bacterium *Neisseria meningitidis* and is characterized by an infection of the meninges or the thin lining covering the brain and spinal cord. Infection, similarly to malaria and dengue fever, is associated with fevers, pain, reduced cognitive function, and in the worst cases, permanent disability and death (Archibong and Annan, 2020). While the epidemiology of the disease is complex, scientists have linked higher wind speeds and dust concentrations and lower humidity and temperatures that come with the onset of the dry season in sub-Saharan Africa with higher incidence of meningitis epidemics (Perez Garcia Pando et al., 2014; Sultan et al., 2005; Yaka et al., 2008). The disease hence has a strongly seasonal quality, with cases increasing during the dry harmattan season from October to March and declining with the onset of the rainy season in June. The disease is spread through contact with respiratory droplets or throat secretions from infected individuals, and one proposed mode of transmission has been that hot, dry northeasterly trade winds blowing from the Sahara through West Africa carry dust particles that irritate the inner linings of the noses of the region’s inhabitants, and hence increase the risk of meningitis infection during more intense dry seasons (Yaka et al., 2008). This pattern of transmission, particularly with airborne

---

<sup>2</sup>The meningitis belt is shown in Figure 3 in the Appendix.

diseases like meningitis make adaptive human responses to climate change, like migration that might increase population density, an important way that epidemic disease can spread in response to global warming.

## **2.2 Indirect Effects: Migration**

To what extent do adaptive human responses to climate change like migration increase the risk of epidemics of infectious disease? A recent literature has identified two countervailing effects of global warming on migration. First, increases in temperature associated with global warming may worsen economic conditions, particularly through their effects on decreasing crop yields that decrease incomes for, particularly, agricultural workers. This may then lead workers to either increase migration away from rural areas to more urban areas if they are not liquidity constrained and are able to access resources to move, or on the other hand, they may not move if they are unable to access resources to finance a move (Carleton and Hsiang, 2016; Cattaneo and Peri, 2016). While the evidence on the effects of climate change on migration is both sparse and mixed, recent evidence finds that in middle income economies, higher temperatures increased migration rates to urban areas and other countries (Cattaneo and Peri, 2016). As economies become wealthier and more countries achieve middle income status, one prediction is that we may see more migration to urban areas in response to climate pressures. Increased rural to urban migration and the associated higher population density has been linked to increased risk of infectious disease spread in existing epidemiological models (Archibong and Metcalf, 2021). Other works have linked high density, mass gatherings of people for cultural events like the Islamic Hajj to meningitis epidemics outbreaks in religious centers (Archibong, Annan, and Ekhaton-Mobayode, 2021). The combination of these empirical facts point to the potential role that migration, as an adaptive strategy to climate change, may play in further increasing the risks of epidemic disease spread.

## 3 The Effects of Epidemics on Inequality: Evidence From the Meningitis Belt

### 3.1 On Group-Based Inequality

Given the links between climate change and epidemics outlined in Section 2, how then might these climate-induced epidemics affect socioeconomic, and particularly group-based inequality? Group-based inequality in socioeconomic outcomes refers to disparities in social and economic outcomes along the lines of social group identity markers like race, ethnicity, gender, class, and other social identifiers. This inequality can be present within countries or across countries, and we focus on the case of within country group-based inequality here<sup>3</sup>. Previous research has shown that group-based inequality can be persistent, and has well-documented negative consequences for development outcomes (Archibong, 2018). How do these group-based inequalities originate and persist over time? A growing body of work in stratification economics has highlighted how formal and informal institutions within societies can shape differential outcomes across groups through public policy, and the inequitable application of social, economic and political power (Darity Jr, 2022; Chelwa, Hamilton, and Stewart, 2022; Archibong, 2018). These institutions can then maintain group-based inequality, further entrenching social hierarchies where members of some groups are more “subaltern” or marginalized relative to other groups (Darity Jr, 2022). This marginalization is reflected in lowered access to valuable goods like health, education, income, wealth and environmental quality, that makes members of these groups even more vulnerable to increased damage in the aftermath of health shocks like epidemics, in ways that are fundamentally inequitable.

A growing body of evidence shows that epidemics increase inequality by worsening

---

<sup>3</sup>There is a large literature that has examined the origins and drivers of between country group inequality, but a much sparser literature on intergroup inequality within countries, which motivates our study focus here (Corak, 2013).

outcomes among vulnerable or marginalized groups like women (Archibong and Annan, 2017, 2020; Bandiera et al., 2020) and Black-Americans in the United States (Alsan, Chandra, and Simon, 2021). To explore the channels through which epidemics can increase group-based inequality, we first present a simple framework in Section 3.2, then test predictions of the framework using evidence from meningitis epidemics in Section 3.3 and Section 3.4.

### 3.2 Conceptual Framework

Aggregate health shocks like epidemics can have differential effects on individual outcomes based on group membership like, for example, gender. Epidemics have both direct and indirect costs to individuals and households. Direct health costs come through costs associated with treatment of the illness itself which can have consequences for shifting in individual and household budget constraints or if diseases infect individuals differentially by group membership<sup>4</sup>. Indirect costs come through the opportunity cost of missed work or missed school and forgone income, along with the increased costs associated with taking care of sick household members. These costs can be particularly difficult to manage because, unlike idiosyncratic health shocks like illnesses in the household, epidemics will affect large numbers of people at the same time over a large geographic area, such that individuals cannot smooth consumption easily or manage the increase in individual and household costs, by simply borrowing from neighboring social networks (e.g. friends and family), especially in the absence of easy access to formal credit markets.

This may also lead households to attempt to smooth consumption by engaging in behaviors (e.g. marrying daughters off at earlier ages in environments where institutions of bride price exist that allow transfers of wealth from the groom’s family to the bride’s family upon marriage) that are detrimental in the medium to long run to members of already marginalized groups (like women, in the case of the bride-price example). This means that, to

---

<sup>4</sup>For example, women are primarily affected by gynecological illnesses like uterine cancer.



the extent that groups are co-located, epidemics will have vastly differential outcomes based on group membership- worsening outcomes for groups in already economically precarious circumstances, with relatively lower income, wealth, educational attainment and human capital outcomes more generally.

We test the predictions of this framework by examining the effects of epidemics on gender inequality and the educational outcomes of girls using new evidence from meningitis epidemics and the meningitis belt in Africa.

### 3.3 The Meningitis Belt

As discussed in Section 2, meningococcal meningitis is a disease that is endemic in sub-Saharan Africa. The World Health Organization (WHO) estimates that around 30,000 cases of the disease are reported each year, with case figures increasing significantly during epidemic years (Organization, 2018). Meningococcal meningitis can have high fatality rates, up to 50% if left untreated according to WHO estimates (Organization, 2018). Although vaccines have been introduced to counter the disease since the first recorded cases in 1909 for SSA, effectiveness of the vaccines has been limited due to the mutation and virulence tendencies of the bacterium (LaForce et al., 2009)<sup>5</sup>.

Young children and adolescents are particularly at risk of infection (Basta et al., 2018). Niger is one of the worst affected countries in the meningitis belt as more than 95% of the country’s population reside in the belt (Yaka et al., 2008). The country has experienced six epidemics since 1986, with the longest lag occurring between the 1986 and 1993 epidemics<sup>6</sup>

---

<sup>5</sup>The most recent vaccine MenAfriVac has been available in meningitis belt countries since 2010 and has been found to be effective against serogroup A, the strain of the bacterium most frequently associated with epidemics in the belt (Karachaliou et al., 2015). There has been a reduction in serogroup A cases in many countries since the introduction of the vaccine with the vaccine hailed as a success. Concerns have been raised about waning herd immunity over the next decade especially if the vaccine does not become part of routine childhood vaccinations; and an increase in serogroup C cases has been noted in other regions more recently prompting concerns about more epidemics from other serogroups of the bacterium (Karachaliou et al., 2015; Novak et al., 2019). There is currently no vaccine that prevents against all serogroups of *Neisseria meningitidis* (Novak et al., 2019).

<sup>6</sup>Though there is no subnational record of epidemics available prior to 1986, historical records suggest

(Archibong and Annan, 2017). The periodicity of epidemics for countries like Niger in the meningitis belt is around every 8 to 12 years (Yaka et al., 2008). In one of the most acute instances in the country’s recorded disease history, the 1986 epidemic registered over 15,000 reported cases and a case fatality rate of approximately 4% (Archibong and Annan, 2017). The difference in the case load of meningitis between epidemic and non-epidemic years is stark, with caseloads much higher during epidemic years. The size of Niger’s young population, with the median age remaining at 15 years for more than a decade, has historically placed a significant share of the country at risk during epidemics<sup>7</sup>. While there is no concrete evidence of a causal link between climate change and the severity of the 1986 epidemic, there are strong associations between climate change and fluctuations in the climate variables described in Section 2.1 and the severity of the 1986 epidemic (Archibong and Annan, 2020; García-Pando et al., 2014).

Documented data on health expenditure of countries in the meningitis belt show that households spend a significant portion of their incomes on direct and indirect costs stemming from meningitis epidemics (Colombini et al., 2009). In Burkina Faso, Niger’s neighbor in the meningitis belt, households spent some \$90 per meningitis case- 34% of per capita GDP- in direct medical and indirect costs from meningitis infections during the 2006-2007 epidemic (Colombini et al., 2009). In households affected by sequelae, costs rose to as high as \$154 per case. Costs were associated with direct medical expenses from spending on prescriptions and medicines<sup>8</sup> and indirect costs from loss of caregiver income (up to 9 days of lost work), loss of infected person income (up to 21 days of lost work) and missed school (12 days of missed school) (Colombini et al., 2009). Meningitis epidemics are a notable negative income shock to households in the belt. Using data from one of the largest meningitis epidemics in

---

that the most recent epidemic prior to 1986 occurred in 1979 in Niger (Yaka et al., 2008).

<sup>7</sup>Source: UNICEF statistics.

<sup>8</sup>Vaccines and treatment are technically free during epidemics, however information asymmetry among health care workers and shortages of medicines often raise the price of medication (Colombini et al., 2009).

Niger's history, the 1986 epidemic, we can assess the effects of the epidemic on gender gaps in education (Archibong and Annan, 2017).

### **3.4 Niger's 1986 Meningitis Epidemic and Gender Inequality**

The results on the effects of Niger's 1986 epidemic on gender gaps in education have been documented in previous research (Archibong and Annan, 2017). The findings show that sudden unexpected exposure to meningitis or meningitis shocks, increased the gender gap in educational attainment during the epidemic. The effect sizes are economically large with meningitis shocks during the epidemic year significantly decreasing years of education for girls relative to their male counterparts, by 0.7 years and 0.4 years for primary school (6-12 years old) and secondary school (13-20 years) aged girls respectively. The magnitude of the decrease corresponds to a 58% and 33% decrease in educational attainment for girls relative to the unconditional sample mean of 1.2 years of education (Archibong and Annan, 2017).

These results suggest that these epidemics disproportionately impact investment in girls' education potentially due to increases in the direct and opportunity costs of parental investment in girls' education during epidemic years. Epidemic years and higher than expected meningitis exposure might mean a contraction of the household budget due to lost wages and increased health costs associated with the epidemic. Direct costs associated with fees might be higher when the household budget constraint shifts inward. Opportunity costs might rise with girls' labor increasingly commanded to care for sick family members or act as substitute labor for sick family members during the epidemic years.

One way that parents might respond to rising costs is by marrying off female children to reduce consumption burdens and accrue income from bride price transfers from grooms' families to brides' families. This is particularly salient within a context like Niger which has the highest rates of early marriage in the world, with 75% of girls married before the age of eighteen (Archibong and Annan, 2020). While detailed data on marriage payments in the

form of bride price are not available, with per capita income at \$250 in 1986 by World Bank estimates<sup>9</sup>, the maximum bride price for a young never-married female child would amount to some 86% of the yearly average income during the 1986 epidemic year (Boye et al., 1991). These figures highlight the fact that bride price might present a significant income boost to households, especially poorer households, during periods of negative shocks.

To evaluate the plausibility of the bride-price/marriage channel, we examine the effects of meningitis shocks on early marriage during epidemic and non-epidemic years. We provide evidence of an increase in early marriage for women in highly affected meningitis shock districts following the epidemic, with results shown using cumulative hazard curves in Figure 2. As shown in Figure 2, women who were school going aged during the 1986 epidemic year were almost two times more likely to marry earlier, before the age of eighteen, in highly exposed meningitis shock districts than in less exposed areas. We do not observe the same trends during a non-epidemic year like 1990. The evidence from this research shows that epidemics can worsen outcomes for groups in already relatively economically precarious circumstances, like women around the world, widening group-based socioeconomic inequality.

#### **4 Concluding Remarks and Designing Effective Policies to Mitigate the Effects of Climate-Induced Epidemics on Inequality**

Climate change increases the likelihood that we will see an increase in more severe epidemics, like the 1986 meningitis epidemic in Niger, in the future. While the effects of climate-induced epidemics on group-based inequality, and particularly their role in worsening economic outcomes of already marginalized populations, are worrying, there are important policy responses around adaptation and mitigation that can be pursued. A recent literature has highlighted the importance of fiscal responses, health aid and stimulus in mitigating the negative effects of epidemics, and assisting households with consumption smoothing dur-

---

<sup>9</sup>In nominal prices.

ing epidemics (Archibong, Annan, and Ekhaton-Mobayode, 2021; Gyimah-Brempong, 2015). Particular in light of how historical institutions have entrenched group-based inequalities in ways that make members of marginalized groups more vulnerable to the negative consequences of epidemics, targeted policies, like targeted health aid and cash grants to members of marginalized groups during epidemics, can play an important role in mitigating these negative consequences and enhance societal welfare in the short to medium run.

As a further, more long-term policy, changes in institutions that may make members of marginalized groups more vulnerable during epidemics (like regulating bride price institutions that may disadvantage women or extending labor regulation protections to service sector workers like home health aides where Black women are more heavily represented in the US), are needed to reduce inequitable and unequal exposure to the negative effects of epidemics. Effective policies to combat the negative effects of epidemics must be mindful not to increase existing group-based inequalities, and should focus on minimizing damage for members of the most marginalized groups.

Further research needs to be done to evaluate the effectiveness of these policies, understand the role of migration and migratory pressures in response to climate change in increasing the risk of epidemics and think carefully about targeted prevention strategies that address the contribution of human activities to global warming and infectious disease spread. Without research-informed policy implementation, there is a real, present and growing risk of detrimental increases in socioeconomic inequality from climate-induced epidemics, with the according negative consequences for human welfare.

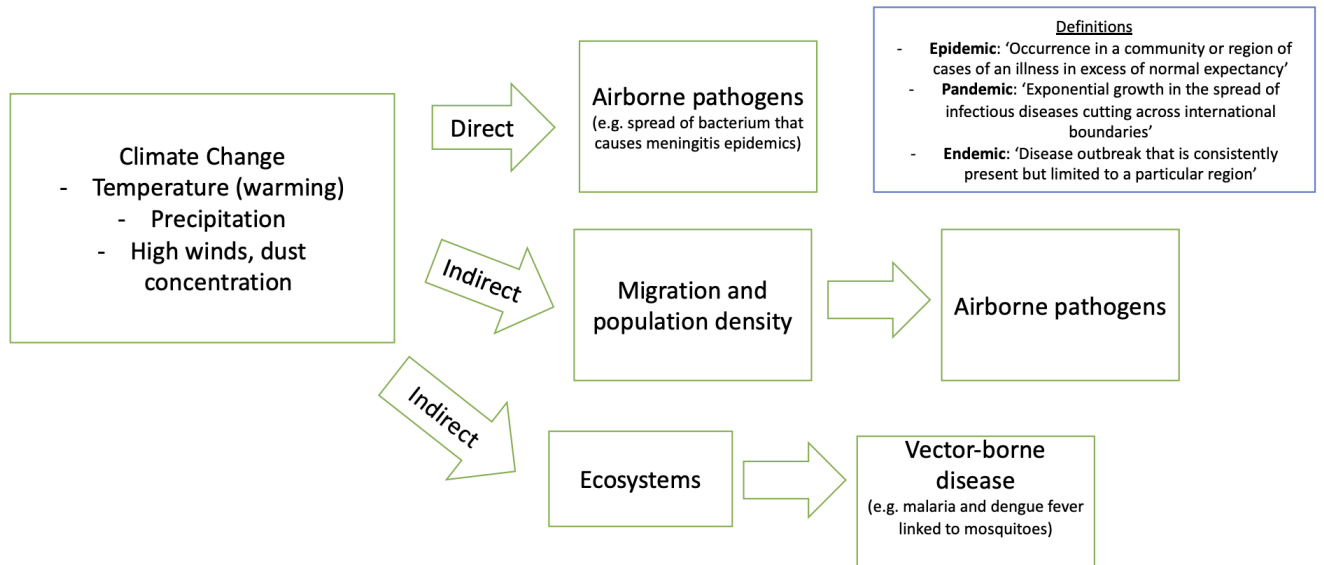


Figure 1: Modeling the links between climate change and epidemics

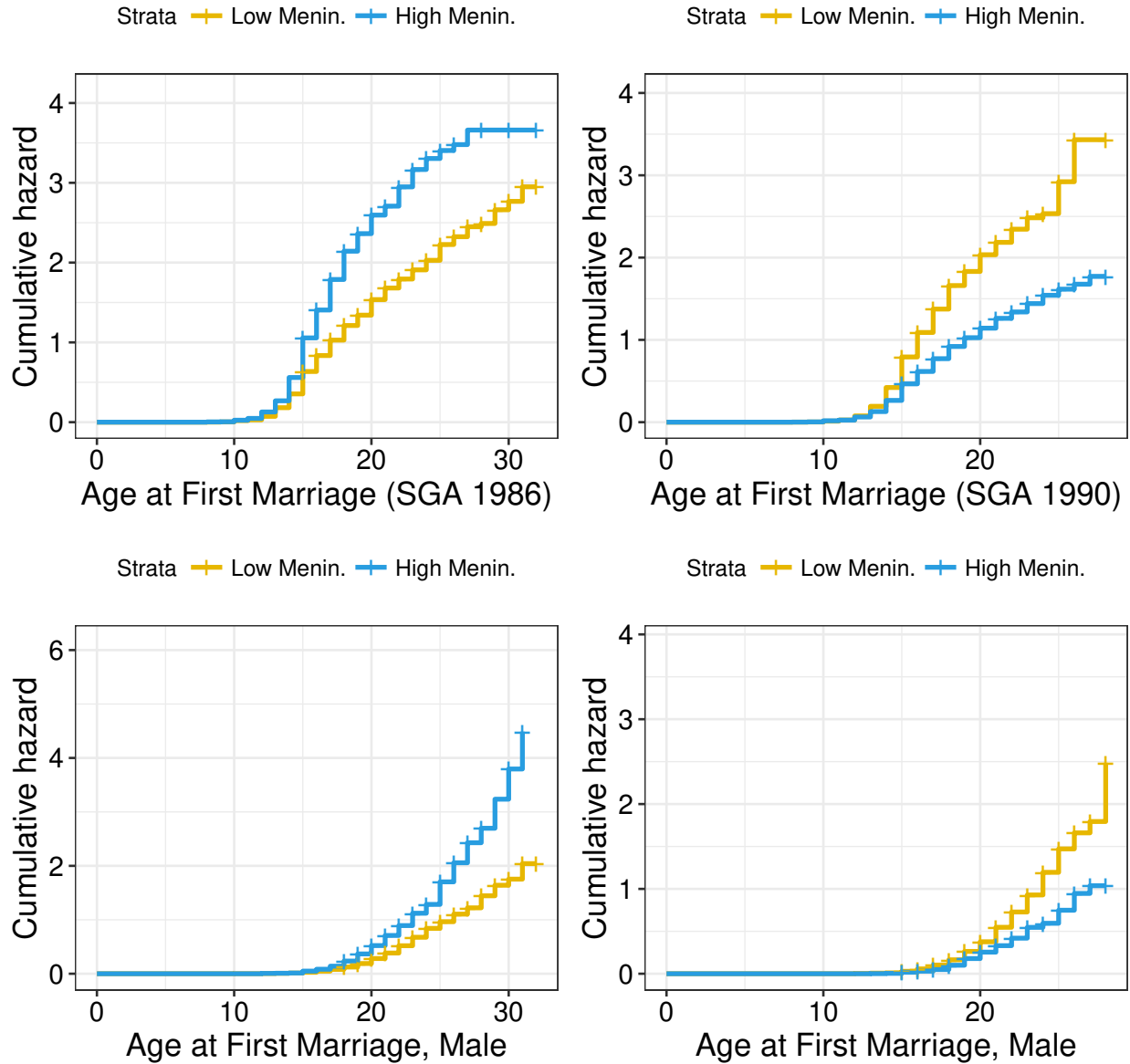


Figure 2: Age at first marriage cumulative hazard for school-going aged (SGA) populations in high meningitis areas ('High Menin.') in epidemic (1986) and non-epidemic (1990) years for female (top panel) and male (bottom panel) populations

## References

- Alsan, Marcella, Amitabh Chandra, and Kosali Simon. 2021. “The great unequalizer: initial health effects of COVID-19 in the United States.” *Journal of Economic Perspectives* 35 (3): 25–46.
- Archibong, Belinda. 2018. “Historical origins of persistent inequality in Nigeria.” *Oxford Development Studies* 46 (3): 325–347.
- Archibong, Belinda, and C Jessica E Metcalf. 2021. “Building toward useful SARS-CoV-2 models in Africa.” *Proceedings of the National Academy of Sciences* 118 (31).
- Archibong, Belinda, and Francis Annan. 2017. “Disease and Gender Gaps in Human Capital Investment: Evidence from Niger’s 1986 Meningitis Epidemic.” *American Economic Review, Papers and Proceedings* 107 (5): 530–35.
- Archibong, Belinda, and Francis Annan. 2020. “Climate Change, Disease and Gender Gaps in Human Capital Investment.” In *Women and Sustainable Human Development*. Springer pp. 15–35.
- Archibong, Belinda, Francis Annan, and Uche Ekhaton-Mobayode. 2021. “The Epidemic Effect: Epidemics, Institutions and Human Capital Development.” *CDEP-CGEG Working Paper No. 84* .
- Bandiera, Oriana, Niklas Buehren, Markus Goldstein, Imran Rasul, and Andrea Smurra. 2020. “Do school closures during an epidemic have persistent effects? Evidence from Sierra Leone in the time of Ebola.” *J-PAL working paper* .
- Basta, Nicole E, Abdoulaye Berthe, Mahamadou Keita, Uma Onwuchekwa, Boubou Tamboura, Awa Traore, Musa Hassan-King, Olivier Manigart, Maria Nascimento, James M



- Stuart et al. 2018. “Meningococcal carriage within households in the African meningitis belt: A longitudinal pilot study.” *Journal of Infection* 76 (2): 140–148.
- Bhatt, Samir, Peter W Gething, Oliver J Brady, Jane P Messina, Andrew W Farlow, Catherine L Moyes, John M Drake, John S Brownstein, Anne G Hoen, Osman Sankoh et al. 2013. “The global distribution and burden of dengue.” *Nature* 496 (7446): 504–507.
- Boye, Abd-el Kader, Kathleen Hill, Stephen Isaacs, and Deborah Gordis. 1991. “Marriage law and practice in the Sahel.” *Studies in Family Planning* 22 (6): 343–349.
- Carleton, Tamma A, and Solomon M Hsiang. 2016. “Social and economic impacts of climate.” *Science* 353 (6304): aad9837.
- Cattaneo, Cristina, and Giovanni Peri. 2016. “The migration response to increasing temperatures.” *Journal of development economics* 122: 127–146.
- Chelwa, Grieve, Darrick Hamilton, and James Stewart. 2022. “Stratification Economics: Core Constructs and Policy Implications.” *Journal of Economic Literature* 60 (2): 377–99.
- Colombini, Anaïs, Fernand Bationo, Sylvie Zongo, Fatoumata Ouattara, Ousmane Badolo, Philippe Jaillard, Emmanuel Seini, Bradford D Gessner, and Alfred Da Silva. 2009. “Costs for households and community perception of meningitis epidemics in Burkina Faso.” *Clinical Infectious Diseases* 49 (10): 1520–1525.
- Corak, Miles. 2013. “Income inequality, equality of opportunity, and intergenerational mobility.” *Journal of Economic Perspectives* 27 (3): 79–102.
- Darity Jr, William A. 2022. “Position and Possessions: Stratification Economics and Intergroup Inequality.” *Journal of Economic Literature* 60 (2): 400–426.
- Epstein, Paul R. 1999. “Climate and health.” *Science* 285 (5426): 347–348.

- García-Pando, Carlos Pérez, Madeleine C Thomson, Michelle C Stanton, Peter J Diggle, Thomas Hopson, Rajul Pandya, Ron L Miller, and Stéphane Hugonnet. 2014. “Meningitis and climate: from science to practice.” *Earth Perspectives* 1 (1): 14.
- Gyimah-Brempong, Kwabena. 2015. “Do African countries get health from health aid?” *Journal of African Development* 17 (2): 83–114.
- Huber, John D, and Laura Mayoral. 2019. “Group inequality and the severity of civil conflict.” *Journal of Economic Growth* 24 (1): 1–41.
- Karachaliou, Andromachi, Andrew JK Conlan, Marie-Pierre Preziosi, and Caroline L Trotter. 2015. “Modeling long-term vaccination strategies with MenAfriVac in the African meningitis belt.” *Clinical Infectious Diseases* 61 (suppl\_5): S594–S600.
- Klasen, Stephan. 2002. “Low schooling for girls, slower growth for all? Cross-country evidence on the effect of gender inequality in education on economic development.” *The World Bank Economic Review* 16 (3): 345–373.
- Kurane, Ichiro. 2010. “The effect of global warming on infectious diseases.” *Osong public health and research perspectives* 1 (1): 4–9.
- LaForce, F Marc, Neil Ravenscroft, Mamoudou Djingarey, and Simonetta Viviani. 2009. “Epidemic meningitis due to Group A Neisseria meningitidis in the African meningitis belt.” *Vaccine* 27: B13–B19.
- Novak, Ryan T, Olivier Ronveaux, André F Bitá, Honoré Flavien Aké, Fernanda C Lessa, Xin Wang, Ado M Bwaka, and LeAnne M Fox. 2019. “Future directions for meningitis surveillance and vaccine evaluation in the meningitis belt of sub-Saharan Africa.” *The Journal of infectious diseases* 220 (Supplement\_4): S279–S285.
- Organization, World Health. 2018. “Meningococcal meningitis. Fact sheet 2018.”

- Perez Garcia Pando, Carlos, Michelle C Stanton, Peter J Diggle, Sylwia Trzaska, Ron L Miller, Jan P Perlwitz, José M Baldasano, Emilio Cuevas, Pietro Ceccato, Pascal Yaka et al. 2014. “Soil dust aerosols and wind as predictors of seasonal meningitis incidence in Niger.” *Environmental Health Perspectives* .
- Sultan, Benjamin, Karima Labadi, Jean-François Guégan, and Serge Janicot. 2005. “Climate drives the meningitis epidemics onset in West Africa.” *PLoS medicine* 2 (1): e6.
- Tol, Richard SJ. 2020. “The economic impacts of climate change.” *Review of Environmental Economics and Policy* .
- WHO. 2020. “WHO Humanitarian Health Action, Definitions: emergencies.” <https://www.who.int/hac/about/definitions/en/>.
- Wu, Xiaoxu, Yongmei Lu, Sen Zhou, Lifan Chen, and Bing Xu. 2016. “Impact of climate change on human infectious diseases: Empirical evidence and human adaptation.” *Environment international* 86: 14–23.
- Yaka, Pascal, Benjamin Sultan, Hélène Broutin, Serge Janicot, Solenne Philippon, and Nicole Fourquet. 2008. “Relationships between climate and year-to-year variability in meningitis outbreaks: a case study in Burkina Faso and Niger.” *International Journal of Health Geographics* 7 (1): 34.
- Zhou, Guofa, Noboru Minakawa, Andrew K Githeko, and Guiyun Yan. 2004. “Association between climate variability and malaria epidemics in the East African highlands.” *Proceedings of the National Academy of Sciences* 101 (8): 2375–2380.

## A Appendix (For Online Publication)

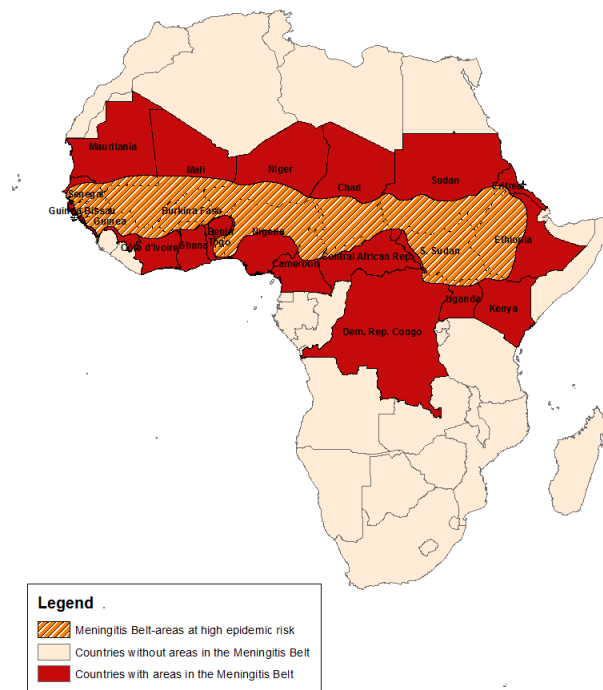


Figure 3: Areas with frequent epidemics of meningococcal meningitis (“Meningitis Belt”)